Acoustics Bulletin

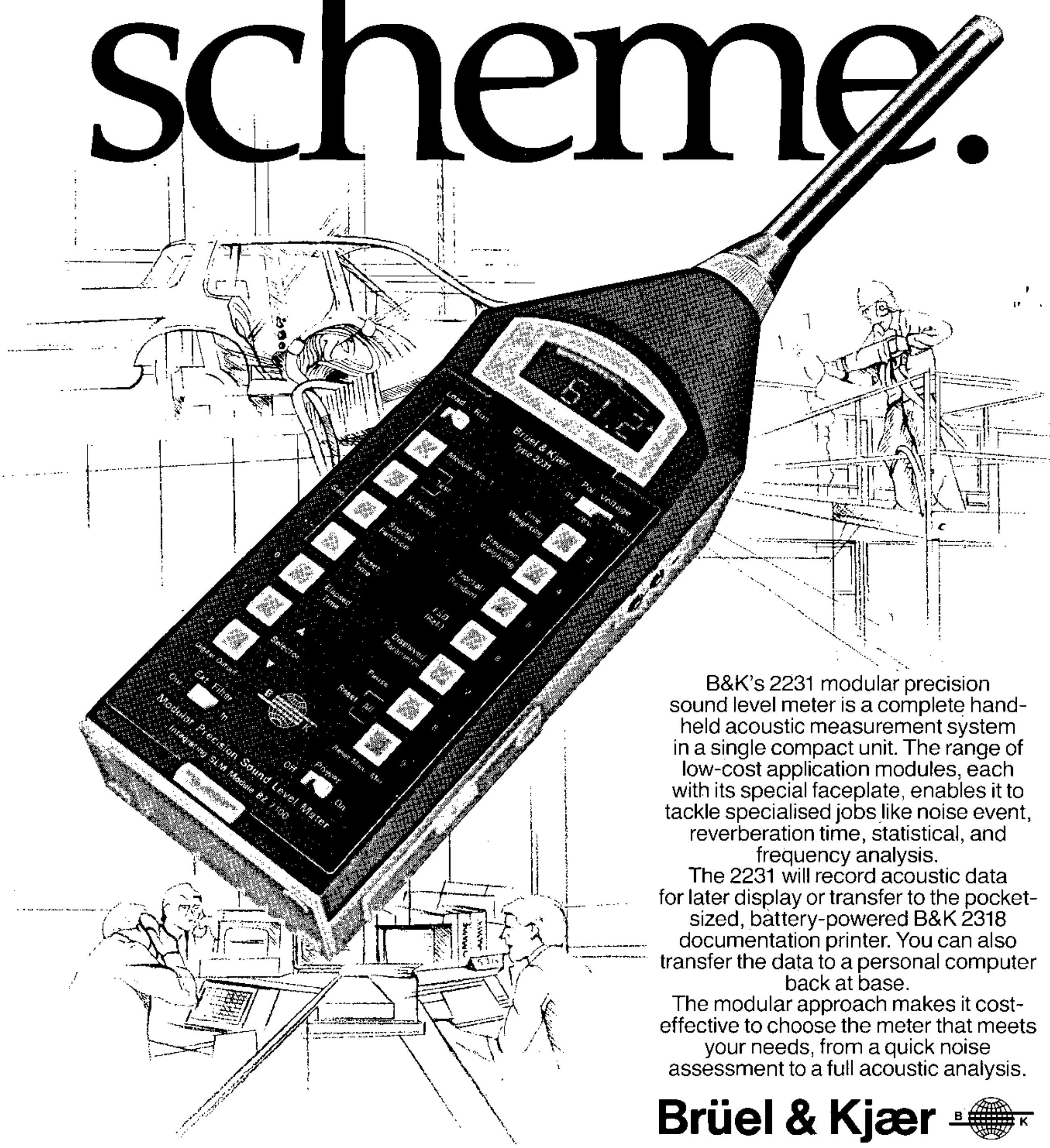
January 1988 Volume 13 Number 1

Special Feature

VEHICLE NOISE CONTROL

INSTITUTE OF ACOUSTICS

A sound scheme.



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The Institute of Acoustics was formed in 1974 by the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is now the largest organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand and since the beginning of 1977 it is a fully professional Institute.

The Institute has representation in practically all the major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental acoustics, architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

Sponsor Members

Editors' note Will readers please note that the list of Sponsors appearing in the October 1987 issue was printed incorrectly. An erratum slip was distributed in November but the editors would like to record here their apologies to the companies whose names were omitted.

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President's Letter

Dear Fellow Member,

One of the recent innovations in the IOA calendar has been the annual conference on Reproduced Sound held at Windermere in November. The idea of such a meeting (organized in collaboration with five Societies and Associations involved in sound recording and reproduction) was conceived by Roy Lawrence, whose hard work and the goodwill and appreciation of all parties concerned has turned these conferences into annual successes. I am informed that the one held this year conformed to past performance.

I thought I would highlight this particular point both to record my appreciation of Roy's hard work on behalf of the Institute and to underline the extent to which the functioning of the IOA depends upon the commitment of some individuals.

I believe that the health of any organization (such as ours) must depend, in the long run, on the participation of its membership at all levels of its operation.

May I take this opportunity of wishing you all contentment and fulfilment in the New Year.

Yours sincerely,

Orhan Berktay

The Institute in Edinburgh, 1979 to 1988

It is now nearly nine years since the Institute of Acoustics moved its Headquarters from London to Edinburgh. As a large proportion of the membership have joined in that time, readers may be interested to know something of the background to the move and to reflect upon some of the changes that have taken place in this time.

The Institute of Acoustics started life in 1974 through an amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society which was primarily designed to facilitate the organization of the 8th International Congress on Acoustics in London in June of that year. The Institute was formerly run from an office within, and with staff and facilities subsidized by, the Institute of Physics. The service charges levied by the Institute of Physics progressively rose over a period of a few years towards an economic figure and that fact in combination with the decision not to raise membership fees in step with the current levels of inflation created a considerable financial problem in the summer of 1979. Council took the decision that the Institute could no longer afford a presence in Belgrave Square and invited proposals from interested groups or individuals to provide a full secretarial office service.

The decision

Honorary Officers visited several interested groups throughout the UK and after due consideration accepted a proposal from myself backed by a generous offer of support facilities from Heriot-Watt University. The proposal was that, with a background of a degree in Business Administration and a postgraduate degree in Acoustics, I should form a management company called Cathy Mackenzie Management Services and take on all aspects of the organization of the Institute. The management company would employ such staff as was necessary from time to time, thus freeing the Institute of the usual statutory obligations in respect of employment legislation. To cover this activity, CMMS is voted a total fee by Council each year based on University Administrative Scales and I think it is fair to say that this arrangement has proved a broadly satisfactory one all round.

As a combined result of the hard work of Dr H G Leventhall who was the Hon. Treasurer at that time, the generous rental terms which covered a number of additional facilities offered by the Heriot-Watt University administration and the readiness of many Institute members to agree to a retrospective increase in membership fees, the immediate financial problems were overcome.

One of my first actions upon setting up the Institute office was to collect together Institute activities which had hitherto been handled in ad hoc arrangements at various other centres within the UK. These included meetings organization, the sale of publications and the administration of the Institute Diploma that had been set up in 1977. It has not, however included the publication of *Acoustics Bulletin*, which has been and still is under the care of an Editor, who is paid a fee for each edition.

Three phases

Looking back over the nine years that the Institute has been run from the Edinburgh office, I am aware that many changes have taken place in both substance and style in the Institute's way of life and that amidst these changes three overlapping phases of development can be discerned. The first was the initial period mentioned above during which the Institute's immediate financial situation stabilized. The second stage was an expansion of existing activities which coincided with a steady increase in membership from the 700s in 1978 to approximately 1500 in 1987. The Institute became a professional society during that time and in terms of its numerical strength, benefited from the manpower and training implications of such measures as the Control of Pollution Act 1974 and the Noise Insulation Regulations.

The third phase has been characterized by a reaching outwards to establish contact with other individuals and organizations involved in some way with acoustics. The annual *Reproduced Sound* Conference in November in Windermere is of importance here as it brings together more delegates from outside the Institute, such as television sound engineers, public address engineers, electronic music enthusiasts and so forth, than from within. The part the Institute is playing in forming the Noise Council as a successor to the Noise Advisory Council, in collaboration with the Institution of Environmental Health Officers, the Royal Environmental Health Institute of Scotland and the Institution of Occupational Safety and Health, is another example.

During the last nine years there has been a gradual but significant change in the pattern of attendance at conferences organized by the Institute. The number of delegates attending the Annual Spring Conferences reached a peak at Cambridge in 1978 and since then the number of members attending in relation to the size of the membership has tended to fall. This is probably a reflection of economic pressures.

The visible face of the Institute's lifestyle is carried by its various publications such as conference notices, statutory notices, meetings handbooks and the like. During the last nine years a more or less uniform house-style has emerged with a characteristic coloured band being frequently used to identify notices from the Institute. The Institute's literature is mostly printed in Liverpool with the benefit of both lower costs and short lead times.

The Institute's Diploma has shown a steady growth, confounding predictions based on an assumed backlog of potential students. A Distance Learning scheme has also been developed in collaboration with Heriot-Watt University.

Other developments

Among other developments that have occurred during the past nine years, I would highlight the hosting of *Internoise '83* at Edinburgh, which attracted nearly 700 delegates making it one of the largest in that series. Additionally there has been the acceptance of the Institute Code of Conduct and the establishment of the Proceedings of the Institute of Acoustics in its current referenced form. The publication earlier this year of the first issue of *Acoustics Index,* a general reference manual on all matters acoustical, was a major event and especially so for an Institute of this size. The negotiations with companies and individuals as potential advertisers in the *Index* highlighted the fact that the Institute is not yet widely known among many involved with the subject. This suggests that more work may have to be done to extend the Institute's influence on national noise policy, for example.

The affairs of the Institute are of course regulated by the Honorary Officers and Council, mainly through its Standing Committees. On a day-to-day basis, however, there can be no doubt that the responsibility for the good conduct of the Institute's affairs lies with me and in some ways this is no little burden. In common with the experience of many other learned societies of similar size to the Institute, the financial health of the Institute is an ever present matter for concern. When the office moved to Edinburgh the total cash flow that year was in the region of £7,000 whilst in 1986 it was £190,000. A large contributor to the Institute's income account has been the revenue derived from conferences and meetings and this is essentially haphazard in nature and the seemingly erratic nature of the Institute's year-end results can be traced in the main to that fact. For example, in 1983 the Institute benefited from the fees of delegates attending *Internoise '83* and in 1984 from the sale of a considerable number of copies of the *Internoise '83* proceedings. In 1986 there was a considerable surplus from an exceptional year as far as meetings were concerned; the two Windermere conferences, *Reproduced Sound 2* and *Speech Research,* were especially profitable in that respect. And the last lines on the Institute's balance sheets mirror this pattern perfectly. As a consequence it is no easy matter to advise the Hon. Treasurer on setting membership and meetings fees at a level that is acceptable to the Institute and to individual members.

The good organization of the Institute relies heavily, of course, on the voluntary efforts of many members of Council, of its Standing Committees and of the Group and Branch Committees. For this reason it is clearly important to maintain a good flow of members willing to serve on these bodies. This is doubly so because, for perfectly understandable reasons, members of these committees may find their circumstances change so they are unable to maintain their initial level of active commitment.

The future

For the future, I look forward to *FASE '88*, to be held in Edinburgh during the Festival, not only as an obvious source of helpful revenue but also so that we may again demonstrate our willingness to play a part in the affairs of acoustics at an international level.

From the point of view of its organizational development, it is my view that the Institute is now approaching a satisfactory steady state placing the emphasis on consolidation and extending the influence of the Institute to cover some of the many involved with acoustics who are presently outside its membership.

Cathy Mackenzie

Autumn Conference on Industrial Noise

held at the Hydro Hotel, Windermere, 26-29 November 1987

The Conference, organized by the Industrial Noise Group, attracted some 120 delegates and 40 accompanying guests, and was a great success, largely due to the efforts of Roy Lawrence and of Bob Peters, the Programme Committee chairman. High standards of technical papers and of presentation were achieved over the three days, yet the informal 'weekend' atmosphere for which the Hydro is renowned was also maintained.

The Conference was run as two parallel sessions, covering virtually all aspects of industrial noise. Particularly notable presentations were given by Dr Adye Pye on 'Structural cochlear changes after noise exposure', Professor Taylor on 'Hand–arm vibration' and the three guest speakers H Dawson, A J N Lee and M F Russell.

The two Workshop discussions on the subjects of 'Sound power' and 'BS 4142 and its revision' were very well attended and provided opportunity for some quite vigorous debate! The BS 4142 discussion was carefully positioned by the programme committee to be held just before lunch – probably as well, since it might otherwise be continuing now!

In view of the success of the Conference and the focus on Industrial Noise being generated by the legislation, there are proposals to run a similar event in 1989. This constitutes advance warning to all potential authors!

S C Bennett

Outdoor Sound Propagation

The Abstracts of this meeting were published in the October issue of Acoustics Bulletin

Rather unusually, British presenters were outnumbered two to one at the Institute meeting on Outdoor Sound Propagation held in London on 14 September 1987. Furthermore, on this occasion, the curious mixture of science and practice that is the hallmark of most Institute meetings was biased very much towards science. Mr Bines of SRL and Mr Nierop from a Dutch engineering firm were the minority representatives of the practical and pragmatic with their respective contributions on *EEC certification of lawnmowers and Sound propagation from industrial sources in built up areas.* It seems that the problem of variation in ground absorption from grassy site to grassy site has not been overcome entirely by restricting measurements to an artificial surface since the specification of that surface's absorption coefficient versus frequency is not sufficiently tight. Less accuracy is required in assessing the noise impact of an industrial site and Mr Nierop described an empirical method for allowing for attenuation due to screening and scattering by houses.

I would guess that another unusual feature of this meeting was the fact that those who attended were treated to two videos. The first, forming part of a talk by Johann Wempen of the University of Oldenburg (West Germany), demonstrated the formation of the excess attenuation spectrum in his synchronization-based measurement technique. The second, presented as the final part of a fascinating talk by Dennis Thomson, Professor of Meteorology at Pennsylvania State University, demonstrated the capabilities of a prediction scheme based on ray-tracing and on input knowledge of sound velocity–height profiles every two minutes during a 24-hour period. It showed time-dependent sound propagation over a low frequency (63 Hz) source over a range of 25 km and the shifting patterns of localized enhancement.

The meeting provided clear evidence of the considerable strides that have been made in the study and understanding of outdoor sound propagation since the last Institute meeting on the subject seven years ago. Papers by Yasushi Miki, Johann Wempen and Cramond and Don outlined recent advances in techniques of measuring ground impedance which is an important parameter in the assessment of ground effect. The large contrast between propagation over snow and over other ground surfaces was highlighted in a joint paper by authors from the Open University and the Keeweenaw Research Center of Michigan Technical University. The methods presented for measuring ground impedance may well have wider application in acoustics. The usefulness of the Boundary Integral Equation method as a numerical technique for dealing with propagation over mixed impedances or barriers was portrayed by Simon Chandler-Wilde (now at Lanchester Polytechnic, Coventry) in a joint paper with David Hothersall of the

Continued on p. 7

Continued from p. 5

University of Salford, where this work was carried out.

Another feature of the progress made in the last seven years is the wide recognition of the importance of meteorological effects even at short ranges (less than 50 m). These effects were the subject of four of the eleven papers presented at the meeting, including that of Professor Thomson, who, as a meteorologist, and with a background in vertical acoustic sounding of the atmosphere, acts as a messiah for his subject. Less stringent requirements for meteorological information were specified by Huisman, Martens and van Asseldonk and Walkden and West in their ray-tracing prediction schemes. The latter offered rigorous theory, used profiles available from the meteorological office, ignored ground effects and did not present comparison of resulting predictions with acoustic measurements. The former pair used less rigorous theory with their own measured temperature profiles and were able to show some accord with predictions including ground effect. By the way, the paper by the Dutch authors differed in several respects from their abstract. Three months is a long time in both research and politics.

An interesting deviation was found by Cramond and Don between corrected creeping wave theory and measurement of impulses within the shadow region caused by positive sound velocity gradients. Measurements near the ground surface give much higher levels than predicted. The possibility of additional sound paths rather than those modelled as a result of air-ground interaction occasioned subsequent discussion.

From comments received, it seems that the meeting, although specialist, must be judged a success overall. If so, this success is due, in part, to the helpfulness of Cathy Mackenzie and Roy Lawrence, who were both involved in sorting out various problems with video replay facilities on the day. Furthermore, in the organizer's eyes, the success will be in spite of continued widespread use of ground impedance models other than those published by the organizer.

Keith Attenborough

3rd Conference on Reproduced Sound Windermere, 5-8 November, 1987

The third in this series of annual November conferences was a 'resounding' success both technically and socially. This conference is unique in the IOA calendar in that it attracts professionals from a wide range of fields who normally would not attend IOA events. This means a lot of extra work and Dr Roy Lawrence, ably supported by Cathie Mackenzie and her staff, deserves our congratulations. One of the highlights was the performance of the BBC team. Dick Mills of the BBC Radiophonic Workshop (he composes the sounds for *Dr Who*) gave away some of the secrets of the trade, Malcolm Johnson, Assistant Head of BBC TV sound, told us of developments in stereo sound broadcasting for TV, and Anthony Askew, Serious Music Producer, BBC Transcription Service, gave us an historical survey of stereophonic sound: astonishing how long ago the stereo effect was first demonstrated (19th century). Other subjects ranged over a wide field: digital techniques including digital audio tape (DAT), entertainment noise control, room and studio acoustics, loudspeaker developments and performance acoustics in British theatres. The excellent social arrangements at the Hydro hotel began with a firework display on the 5th and ended with the ever popular (and ever wet) cruise on Lake Windermere. Roll on *Reproduced Sound 4*.

John W Tyler

Report of the Chief Examiner

The table of results shows some changes this year, most probably arising from changes in the Examiners of specialist modules. The total number of passes, however, hardly changed at 471. The Law and Administration Module had a higher failure rate than others though the average marks and standard deviations of the marks do not stand out particularly. The Transportation Noise module had a notably higher overall mean mark but the pass rate remained near normal. It is worrying that the number of candidates for the Measurement and Instrumentation module was so low.

A minor experiment was made in the General Module where an open-ended question was tried to allow candidates to spread themselves and reveal their understanding of basic concepts. The question slightly disconcerted the markers but ended up having the highest average mark of all the eight on the paper. By far the most unpopular question, and also the one with the lowest average mark, was a basic one on the properties of waves, pointing to a need for stronger teaching in this area of fundamental physical acoustics.

IOA Diploma Examination 1987

The following candidates are to be congratulated on qualifying for the award of the Diploma in Acoustics and Noise Control.

Bristol Polytechnic

A R Brassington
L H Burt
M V Hodges
W K James
N H Land
P Rodwell

Colchester Institute

Mrs K L Cattle
S Ferenczi
D W Harper
G Howat
B G Hunt
Miss H Jackson
A Lockwood
I R Lones-Greaves
J C Rainer
N A Robbins
M G Sims
K Steele
A F Weaver

Cornwall College

P G Ford
S J Garlick
Ms C Joslin
M C Walton

Derbyshire College of Higher Education

T C Charlesworth
A C Gillies
S J Holmes
D J Howes
A M Jones
L J Knowles
R Mecia
W G Miller
C J Shipman
M E Wainwright

Heriot-Watt University

D M R Johnston
B F Nelson
T Y Smith
M A Stewart
S A Williamson

Leeds Polytechnic

S Ashton
D R Blyth
Ms A M Bulner
P J Mears
M Powell

IOA Diploma Summary 1987

	General Module			Architectural Acoustics			Noise Control Engineering			Transportation Noise			Vibration Control			Law and Administration			Instrumentation and Measurement			Totals	Pass	Projects
	M	P	F	M	P	F	M	P	F	M	P	F	M	P	F	M	P	F	M	P	F	M + P + F → T	%	Complete
A	1	20	5	4	23	0	5	9	4	4	6	0	1	5	0	2	11	4	—	—	—	17 74 13 → 104	87.5	24
B	0	10	3	2	10	1	0	1	0	1	11	2	—	—	—	—	—	—	—	—	—	3 32 6 → 41	85.4	8
C	0	0	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0 0 1 → 1	0	—
D	0	8	1	1	4	1	—	—	—	0	1	0	0	0	1	1	2	2	—	—	—	3 15 5 → 23	78.3	3
E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0 0 0 → —	—	5
F	0	11	0	1	0	0	1	8	2	—	—	—	—	—	—	2	7	1	—	—	—	4 26 3 → 33	90.9	8
G	7	14	0	4	5	1	1	5	0	2	10	0	1	2	0	0	9	7	0	3	0	15 48 8 → 71	88.7	14
H	3	12	4	1	2	0	0	1	1	11	12	2	—	—	—	3	7	7	—	—	—	18 34 14 → 66	78.8	13
J	6	7	1	—	—	—	1	14	0	—	—	—	1	5	0	2	6	2	—	—	—	10 32 3 → 45	93.3	15
K	0	6	0	0	1	0	0	2	0	0	4	0	0	1	0	0	4	0	—	—	—	0 18 0 → 18	100	6
L	0	0	1	2	2	1	0	1	0	—	—	—	1	3	0	—	—	—	—	—	—	3 6 2 → 11	81.8	—
P	5	10	5	3	6	1	1	3	1	—	—	—	2	10	2	2	5	2	—	—	—	13 34 11 → 58	81.0	14
Totals	22	98	21	18	53	5	9	44	8	18	44	4	6	26	3	12	51	25	0	3	0	86 319 66 → 471	86.0	—
Module Pass %	85.1			93.4			86.9			93.9			91.4			71.6			100			86.0		

Key to Diploma Centres:

A North East Surrey College of Technology
B Liverpool Polytechnic
C Newcastle Polytechnic
D Cornwall College of Further and Higher Education
E Leeds Polytechnic
F Bristol Polytechnic
G Tottenham College of Technology
H Derby Lonsdale College of Higher Education
J Colchester Institute of Higher Education
K Heriot-Watt University
L North Staffordshire Polytechnic
P Sheffield Polytechnic

Liverpool Polytechnic

N P Birchenough	S J Haigh	A Mavroidis
R T F Dennison	M R Kay	D J Young
K Earnshaw		

North East Surrey College of Technology

J L Batchelor	K J Hatcher	P J Payne
F C Blyth	Miss T A Hewinson	J H Pierce
S Coulter	C A Horton	Mrs S J Prince
Miss E Davis	Mrs D G Langdown	R M L Southwood
J M Fletcher	D Ledger	R D Turner
Miss A E Francis	A S Mitchell	M A Williams
Ms J L Gilby	R Parker-Harding	R J Woodcock
L T Glass		

Sheffield City Polytechnic

Ms L Acheson	P Milner	Miss C Stenthorpe
Mrs D J Adamson	Miss N K Moore	Mrs J Szlamp
N Chaplin	C R Oliver	P Woodward
Miss K Gidman	P J Simpson	

Tottenham College

D Carter	S P Grice	Mr S Stenson
R Downham	Miss C E Hughes	D Waters
R J Gallop	Mrs R M Owen	A L Watts
Ms C J Greaves		

Congratulations also go to the candidates listed below for obtaining passes in additional Specialist Modules in 1987.

Colchester Institute

J Reeve	M J Smith	A G Tull

Cornwall College

S J Garlick

Derbyshire College

T C Charlesworth	S J Holmes	L Poultney
N Cooper	I C Keagle	L Smith
E Davies		

Liverpool Polytechnic

Miss E A Woloschin	C J Yates

North East Surrey College of Technology

Miss J C Bailey	D J Durrant	M Pledger
S Blake	J H Hamilton	J M Prince
A C Conrad	K Harpur	J R Pyke
L Cronin	S D Hedley	R Woodcock
D S Cunningham		

North Staffordshire Polytechnic

D Brassington	A Montgomery	C J Pritchard
Miss L A Brookman		

Sheffield City Polytechnic

P Clayton	A Rupkus

Tottenham College

P T Bassett	C Grimwood	R I Osborough
N Forster		

NEW ELECTIONS

The following elections to corporate and non-corporate membership of the IOA have recently been approved by Council.

FIOA

J Engelbrecht	R Shack
R K Moore	M Tatham

MIOA

M P Alston	P J Hubbard
S Arnott	L V Murray
P R Atkins	P S Nagra
P Chisnall	J Nicol
W C Frame	P F O'Halloran
P Henson	C Tsang
T Hor	

Associate

S D Andrews	C J Jackson (D)
A C Ashby (D)	M F Johnson
D M Bexon	J M McDonald
K D Blake	W G Miller (D)
D I Bott	R A Murray
J N B Carpenter (D)	P F J Naylor (D)
G Cuffley (D)	B J Robinson
T Curd (D)	A K Sharif
K A Carruthers	M G Sims
J C Donovan (D)	R M L Southwood (D)
R J Gallop (D)	S M Summers
A A Gibson (D)	D J Waters (D)
J Grayling (D)	D S Wright
T A Hewinson (D)	

Student

M K Ling	R Lyons

ISVR Short Course 1988

The annual Short Course on Engine Noise and Vibration Control 22-24 March 1988. Information from ISVR Conference Secretary, The University, Southampton SO9 5NH. Tel. 559122 Ext. 2310.

Technical Articles

The editorial board would welcome offers of technical articles on Acoustics and related subjects likely to be of general interest. Please contact the Editor, John Tyler, at Pooh Corner, Chalkhouse Green, Reading RG4 9AG.

Contributions and information for the April issue of *Acoustics Bulletin* should reach the Executive Editor, Marjorie Winterbottom, at 14 Witney Road, Long Hanborough, Oxon OX7 2BJ, no later than 22 February, 1988.

Proceedings of the Institute of Acoustics – Abstracts

Underwater Communication and Position Fixing

International two-day conference organized by the Underwater Acoustics Group, at The University of East Anglia, Norwich, 17-18 December, 1987 (Conference Chairman, Professor Rodney Coates)

Electric, magnetic and acoustic noise generated underwater during offshore piling operations

R M Dunbar
Heriot-Watt University, Edinburgh

The paper describes original research in connection with underwater cable-less transmission of data in the presence of an offshore structure. A requirement exists for such transmission during piling operations and an experiment was carried out to measure electric, magnetic and acoustic noise generated during the recent installation of a North Sea platform, to obtain baseline data on noise spectra for the design of through-water communication links.

Short range multipath rejection in a bounded channel using a vertical line array

P Walmsley and S A S Jones
Thorn EMI, Woking

Multipath interference in a shallow water channel from surface and bottom reflections is a well known problem which taxes the transducer and system designer in applications such as underwater communications, navigation, position fixing and ranging. Particularly for long range situations a number of elegant solutions such as angle of arrival diversity and time delay triangulation statistics have been considered; less attention has been paid to short to medium range situations.

Since many of the solutions to the rejection of multipath interference rely on accurate knowledge of the bottom type, the work to be described considers the extent to which simple directionality in the receiver can be used to reject surface and bottom reflections. Using the model of a range independent channel with a perfectly reflecting surface and bottom both ray and mode analysis are used to predict the output from a vertical hydrophone array as range from the source varies. Considerations of element spacing and shading are addressed.

Experiments are then described in which a scale model is used in an acoustic test tank with a spherical projector and vertical receiving array. Experimental and theoretical results are compared and conclusions drawn as to the accuracy of the model, the degree of improvement over a single point receiver and the limits in range over which the technique is useful.

Finally the practical implementation of a full scale array is described using an array of PVDF hydrophones and comparison is made in terms of cost and capability with ceramic material.

High speed digital data transmission in an underwater channel

A Falahati, S C Bateman and B Woodward
The University of Technology, Loughborough

Based on understanding of all propagation effects present in an underwater communication channel, the research is involved with the development of a channel model for computer simulation.

The model is concerned with baseband serial binary (Multi-level QAM) transmission of high speed digital data in the presence of volume, surface and bottom scatterers in the sea. It employs Rayleigh multi-path fading simulation, i.e. taking into consideration changes in amplitude and phase of the received acoustic signal that may vary with time.

Both the transmitting and the receiving transducers can be stationary or mobile; i.e. the Doppler phenomenon is included. The effects of noise and attenuation, which include absorption and reflection, are also inserted in the model.

When the impulse response of the channel which encompasses all signal distortion effects is known, then the detection processes can be implemented. These include all practical forms of serial modems in which appropriate receiver functions are simulated. Such functions include a sampler, adaptive near maximum-likelihood detector, receiver filtering, channel estimator, carrier phase tracking, timing synchronization, automatic gain control and finally an echo cancellor.

Surface-generated noise in shallow water: a model

D M F Chapman
Institute of Sound and Vibration Research, University of Southampton (A B Wood Memorial Lecture)

In many underwater acoustic applications such as sonar, communications, and position fixing, we often combine signals from an array of hydrophones to form a receiving beam that can be steered in various directions. As well as providing information on the source direction, beamforming enhances the signal-to-noise ratio by excluding some of the background noise. To determine overall system performance in such cases, we must consider the noise directionality as well as the noise level. This paper deals specifically with a model of ambient noise due to sources at the ocean surface in a shallow water environment, with particular emphasis on noise directionality.

Although there are diverse sources of ocean ambient noise, there always exists that component due to the action of wind, waves, and precipitation at the ocean surface. Indeed, under the right conditions, this component may predominate. As these sources are distributed more-or-less uniformly, and as the acoustic propagation conditions usually (but not always) are independent of bearing, we find that the azimuthal dependence of the surface-generated noise field is weak. However, the intensity of the noise arriving at a receiver may depend strongly upon the angle of elevation above or below the horizontal plane. We call this functional dependence of received noise intensity upon angle of elevation the vertical noise directionality, for short.

In shallow water (i.e. on continental shelves, or in channels and harbours) the presence of an acoustically reflecting seabed allows noise from surface sources to arrive at a submerged receiver along a multitude of paths that reflect from the seabed and the sea surface any number of times. Noise arriving from a particular direction may have originated from several independent surface patches. In summing up all these contributions to determine the directionality of the noise field, the acoustic properties of the seabed become important. Since the reflectivity varies with grazing angle and changes from one seabed type to another, both the noise level and directionality will be sensitive to the seabed type.

The shallow water noise model to be presented in this paper will be based on several simplifying assumptions. We will assume that the sources themselves are uniformly distributed at the surface, that they are independent, and that their radiation pattern is arbitrary. For this simple model, we will assume that the ocean is a non-absorbing, isospeed, layer of constant depth, so that acoustic rays are straight lines and acoustic intensity spreads spherically from point sources. The seabed reflectivity will be based on the plane-wave reflection coefficient at a plane boundary between a homogeneous fluid and a homogeneous, lossy, elastic solid. These elements combine to provide a noise directionality function whose form is quite sensitive to seabed type.

Furthermore, we will see how vertical noise directionality (which is difficult to measure) transforms into noise coherence between vertically-separated hydrophones (which is easier to measure). We will then apply the model to interpret experimental data collected from two shallow water sites having quite different seabeds.

Identification of reverberation autoregressive model and predictor based on hydroacoustic signal envelope

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This paper concerns the identification problem of autoregressive (AR) modelling of reverberations, i.e. a special kind of interference caused by multipath scattering or undesirable multiple reflections occurring in underwater communication and location. Our research refers to particular situations when only the signal envelope is at disposal. The reverberation process property is that its features are varying slowly. It results in possibility of prediction which in turn allows to advance the intelligibility and reliability of underwater communication and the performance of location and target recognition as well. The AR model identification is equivalent to optimal prediction error filter (PEF) synthesis. Here, we intend it for reverberation rejection/suppression. On the PEF basis, zero-forcing equalizer for received signal enhancement is obtained.

The concept of phase recovery is deduced from the idea of Hilbert's so called minimum-phase demodulate as complex representation of narrowband signal. The minimum-phase demodulate is unique among all analytic signals of the same bandwidth and identical envelope shape. The properties of such a demodulate are: (i) fastest increase of energy density spectrum integral, (ii) univocal envelope-phase relationships, (iii) improvement ability of numerical ill-conditioning caused by oversampling.

The paper organization is as follows. First, phase recovery method referring to the complex minimum sampling rate representation of narrow-band signal is advanced. Second, on the basis of minimum-phase demodulate, digital filter parameters, namely prediction and reflection coefficients of both: transversal and lattice structures are estimated. Next, the discussion of mastering AR parameters by covariance matrix approach aimed to nonstationarity is given. Later on, prediction coefficients obtained are exploited to estimate high-resolution (maximum entropy) power density spectrum of reverberations, while reflection coefficients are treated as distinguished features of typical kinds of reverberations. Finally, both PEF structures are used to set the up-mentioned equalizer which effects in deconvolution of useful signal and reverberation.

Counteraction of multipath interference by a combination of beamsteering and adaptive equalization

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Adaptive equalization and adaptive beamforming/beamsteering are different approaches to reduce intersymbol interference in hydroacoustic communication. These techniques offer complementary properties with respect to tracking requirements, complexity and performance. In this paper simulation results are presented which show that even with transducer beamwidths less than 5° multipath interference may become severe in a number of practical situations. These simulations are performed with a ray tracing channel model where sound refraction, surface waves and bottom reflections are included. The transducer is implemented with fixed orientation and specified beamwidth and sidelobe attenuation.

The same simulation experiment is then repeated when including an adaptive FIR-equalizer controlled by the stochastic gradient lattice algorithm. The result is a reduction in the bit error rate from ca. 25% without equalization to about 10^{-4} with equalization and signal to noise ratio equal to 30 dB.

This experiment demonstrates performance improvement when applying an adaptive equalizer to the fixed point to point transmission.

Further simulations are performed to determine the tracking capability of the equalizer algorithm with respect to receiver/transmitter movement (ROV application). These simulations are based on a simpler channel model with a small number (3-5) of ray paths.

By combining the different simulation results, limits of the system's ability to operate in realistic situations are obtained.

Underwater acoustic communications: a review and bibliography

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This paper provides a brief review of the published literature on the subject of underwater acoustic communication. It is divided into four broad areas of consideration: Review and Fundamental Papers; The Channel; Engineering Aspects of Underwater Communications and Specific Communication Systems. In the first of these sections significant pruning of the available material was conducted and only the formative and in-depth reviews retained, together with some of the fundamental keynote papers. The acoustic channel is covered in some depth with reference made to papers describing channel models of varying complexity, the information theoretic aspects of underwater communication, measured channel characteristics, noise corruption and also anti-multipath strategies. In considering the engineering of the communication system, papers are referenced on error rate, coding for underwater transmission, system synchronization and timing. Finally, a large section is devoted to papers describing specific communication systems for a wide range of applications (112 references).

A reliable underwater acoustic data link employing an adaptive receiving array

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One of the main problems encountered when trying to produce a reliable underwater acoustic data link is that of multipath reflections from the sea surface and seabed. These reflections restrict the data rate and reduce the reliability of the link. The most common method of overcoming the multipath problem is to use transmitting and receiving transducers with very narrow beamwidths. However, this solution makes alignment of the beampatterns critical, and any mis-alignment or motion of the transmitter or receiver may destroy the acoustic link completely.

In this paper a reliable underwater acoustic data link is described which employs an adaptive receiving array. The purpose of the array is to provide automatic mainlobe tracking of the transmitter and to suppress directional multipaths and interferences. This adaptive array solves the problem of beampattern mis-alignment and also provides a certain degree of beampattern nulling to further suppress directional multipaths and interferences.

The adaptive receiving array requires some prior knowledge of the desired incoming signal in order to distinguish it from the multipath reflections. This is provided by using a PN coded DOSK modulation scheme, where the PN coding is known at both the transmitter and receiver. This PN coding is then used at the receiver to derive a reference signal for the adaptive array.

The performance of this, a direct sequence spread spectrum modulation scheme system, was assessed using a swimming pool as a test tank. The test results are reviewed in this paper and have demonstrated the system's feasibility.

PATSY: the pulsed acoustic telemetry system

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PATSY is an acoustic telemetry system, operating at a transmit frequency of 3.5 kHz, designed to facilitate data transmission from deep ocean sea-floor penetrators after embedment in some tens of metres of sediment. The paper outlines the basic design considerations via standard sonar equation calculations. The chosen system architecture, embodying pulse interval modulation, is then described. The control microcomputer, programmed in FORTH, is discussed and some test results, showing accelerometer response on impact, are presented.

FINMAP: A diver-carried, underwater navigation, mapping and data acquisition system

P J Hanna and R D Peden
Deakin University, Australia

FINMAP, an acronym for Fisheries Navigation and Mapping by Acoustical Positioning, is a diver-carried underwater computer system being developed at Deakin University. The FINMAP computer, together with a wrist-mounted encapsulated display and keyboard, is interfaced to a sonar navigation and mapping system. Data can be input through the keyboard and via a variety of sensors monitoring for example, salinity, temperature and electronic identification tags. The FINMAP system is described and its use in underwater surveillance and monitoring is discussed.

Diver navigation and sea bed surveying equipment

R L Mansfield, B K Gazey and B V Smith
University of Birmingham

The equipment described in this paper is a real time, self contained, battery operated, personal diver navigation system. In addition to functioning as a ship guidance system for use in difficult waters it also offers modes for deep or shallow water sea bed surveying with consequent applications in mapping archaeological sites, oil rig sites, harbours, sea shores and estuaries. In operation a hand held interrogator unit enables a free swimming diver to obtain precise positional information relative to two transponder base stations deployed on the sea floor. Depth and positional information relative to these fixed base stations are stored at regular intervals in the diver held interrogator unit under micro computer control. Range is measured in terms of the time of flight of a short duration sound pulse from the activated transponder. Depth is measured using the pulse echo principle. This allows specified sites on the sea bed to be surveyed enabling depth contour lines to be mapped. If required, both battery operated base stations can be left in position, in an automatic shutdown mode, for later navigational use. The equipment has a range of 800 metres and is able to overcome the severe multi-path effects which corrupt conventional coding systems in shallow water. Results from the operating system are in good agreement with theoretical predictions and confirm the feasibility of the method.

UPOS, a hydroacoustic positioning system for high precision and large dynamics

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UPOS is a hydroacoustical system for three-dimensional, real-time position fixing of submerged objects. It was originally designed for positioning and precise tracking of moving models in a research tank, the maximum range approaching 100 metres. Some of the most important design criteria were positioning of free running objects, sub-mm resolution, mm-range precision, high sampling rates (10 Hz), configuring flexibility, modular construction and to a maximum degree self-calibrating.

To allow these rigid specifications to be met, UPOS utilizes long proven, conventional techniques along with new technology. The hardware is built around a VME multiprocessor system although the concept is essentially totally independent of processor or bus structure. The complex handling of a maximum of 96 detections is secured by using modern FIFO components. PALs with up to 1800 gates are used wherever the constrainment of circuit complexity and space limitations dictate it.

The unique modular construction and design simplicity of UPOS invites to any configuration of number of hydrophones and frequency or time multiplexing within the frequency range of several octaves. A majority of these features are software controlled.

The mathematical processing of acoustical data comprises three main parts; calibration of system, synchronizing the system timebase and real time positioning.

The UPOS system has greatly benefited from the participants' experience with satellite navigation software, real-time processing and hydro-acoustical systems.

Accuracy prediction for distributed tracking systems

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Predicting the performance of a tracking system over the likely range of operating conditions is critical to system design. Simulating the different combinations of numbers and placement of receivers, velocity variations, and the positions of objects can be time-consuming, and give an incomplete picture nevertheless. New methods of approaching this problem are under development, and show promise of dramatically reducing the time needed to build up a performance profile. These methods are outlines and their application to simple arrangements of receivers is demonstrated.

Seismic streamer tracking: past, present and future

C H Rodbourne and R J Sharp
DBE Technology Group PLC, Aldershot

A review paper providing an overview of history, market requirements, previous system implementations, current work by DBE, possible future trends and applications.

Amplitude modulated continuous emission acoustic ranging technique

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University of Liverpool
L E Virr
ARE Experimental Diving Unit

A simple technique for providing accurate range measurements by observing phase differences between transmitted and reflected acoustic signals is described. A carrier at a chosen frequency is transmitted continuously and is envelope amplitude modulated sequentially at frequencies which enable successively more accurate range estimation by phase shift measurements at the modulating frequencies, after demodulation of the received signal. The most accurate range measurements are made using the unmodulated carrier itself. In one system described, originally developed for in-air range measurements for welding applications, chosen carrier and modulating frequencies were 40 kHz, 400 kHz and 4 kHz respectively, modulator switching and measurements being under microprocessor control.

Various design aspects are discussed, in particular the factors governing choice of carrier and modulating frequencies.

Potential subsea applications are discussed and the results of trials to date presented.

The predicted performance of an underwater navigation system based on a correlation log

P Atkins and B V Smith
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This paper describes some of the performance parameters of a correlation log suitable for use on an underwater vehicle. The correlation log may be used as the primary velocity reference of a dead reckoning navigation system.

The performance of a correlation log is primarily determined by the geometry of the transducer. The dimensions of the projector will determine the spatial correlation distance of the backscattered acoustic field. The dimensions of the receiver elements may well modify the effective correlation distance of the system. For example, a small receiver will result in the output of the system being the same as the correlation distance of the field whereas a large receiver will result in the effective correlation distance being that of the dimensions of the receiver.

A set of design guide-lines will be presented for a correlation log operating at a nominal frequency of 150 kHz with a maximum operating range of 200 m. These guide-lines include the required distance of travel between independent velocity estimates with respect to the receiver and transducer geometries. As an example, the case of a low-cost, two-axis temporal correlation log will be presented.

The results obtained during field trials of a simple integrated navigation system will be compared with the predicted performance of the device.

An experimental acoustic temporal correlation log for ship navigation

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Acoustic Doppler logs have generally replaced traditional speed logs onboard merchant ships, but their operation is far from ideal. Consequently, increasing interest has been shown in the acoustic correlation log which promises to overcome some of the deficiencies of the Doppler log. Advantages include bottom tracking the velocity to a greater depth than a Doppler log and much simpler transmitting and receiving array design.

The transducer arrangement is similar to the conventional echo sounder, where the pulses are transmitted vertically downwards. It is possible to operate the log in pulsed mode to great depths.

In shallow water a CW mode can be engaged, which permits a correlation log to be implemented easily at low cost and is ideal for navigation in shallow coastal waters, rivers and estuaries. It is this mode which is primarily under investigation and the subject of this paper. The paper describes work undertaken at LUT in implementing a CW correlation log in a water tank for the velocity measurement of a tracked platform.

Vehicle Noise Control

Road vehicle noise is not, by itself, an identifiable branch of acoustics, it is more of an offshoot whereby acoustical theory and techniques are applied to influence and direct the course of vehicle development. It is an important topic which has grown in stature since the early seventies when it was realized that the course of future development in this sector would be strongly influenced by the growing concern over the quality of the environment.

Of all the noise sources of concern, vehicle and traffic noise is, by far, the most pervasive. It affects us all to varying degrees and, by quite substantial numbers of the population, it is regarded as a serious form of disturbance. For example, recent estimates provided by OECD suggest that some 90 million people in OECD countries are exposed to noise levels from traffic which are judged by most authorities to be unacceptably high. Other transport sources such as aircraft produce intense noise levels on occasions but the effects are generally limited to the immediate vicinity of airports and the number of people seriously affected is, consequently, significantly less than from road traffic. In a similar vein, the Wilson Report published in 1963[1] concluded that 'In London road traffic is, at the present time, the predominant source of annoyance and no other single source is of comparable importance'. It is clear that the problem of London's traffic so graphically described over 20 years ago is as relevant today and is broadly true of other major cities throughout the world.

Research on vehicle noise and its control has proceeded at a great pace since the publication of the Wilson Report and while some of the benefits of this research are obvious in the vehicles that are operating in service today, it is, perhaps, the introduction of new legislation by the member countries of EEC which will begin to take effect in the next few years, that most strongly signals the technological developments that have taken place.

The papers that individual authors have so kindly provided for this special edition are intended merely to give a flavour of the various issues involved and are by no means a state-of-the-art presentation.

Paper 1 gives a brief review of the important steps that have been taken to reduce vehicle noise by regulation. The success of this new legislation depends, to a large extent, on the ability of the engineer to redesign vehicles so that less noise is generated without sacrificing other desirable aspects of performance. Unfortunately the sources of vehicle noise are both numerous and complex. The power unit is often the principal offender but this is not just a simple 'black box' whose noise can be controlled by covers or shields; it is a highly sophisticated piece of machinery which radiates noise by several mechanisms, each of which requires specialist treatment. Paper 2 of this special edition examines some aspects of power train noise control on cars.

As the vehicle moves over the road surface, the interaction between the tyres and the road texture produces noise which increases as the speed of the vehicle increases. This source of noise rapidly overtakes the power unit noise so that at motorway speeds, the noise that is generated is dominated by the contribution from tyre/surface interaction. This is the subject covered by paper 3 of this series.

Finally, papers 4 and 5 are concerned with the role of both Government and Industry in bringing about the changes needed to produce quieter vehicles. The successful introduction of more stringent legislation requires a joint approach by both private and public sector organizations to provide funding support, to bring together appropriate expertise and to co-ordinate development projects. As the noise levels are lowered a better understanding of the methods of testing vehicles will also be required if future legislation is to be effective in improving the quality of the noise environment in the vicinity of our roads.

Paul Nelson
Transport and Road Research Laboratory

Reference

1. Wilson, A. *Noise (Final Report)*, Her Majesty's Stationery Office, London (1963).

Vehicle Noise Legislation in the United Kingdom

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Department of Transport, Vehicle Standards and Engineering Division

Introduction

Much of present day policy on traffic noise stems from the report of the Wilson Committee on noise in 1963.[1] This made a number of recommendations concerning traffic noise.

The control of vehicle noise by measurement was introduced into the UK by a Construction and Use Regulation made in 1968. This set levels which were considered to be achievable at the time and prevented any further increases in noise from new designs of vehicle.

Developments in the 1970s

In 1971, the then Minister of Transport announced plans to develop a heavy articulated lorry with a drive past noise level of around 80 dB(A),* to demonstrate its feasibility and commercial viability. This became known as the Quiet Heavy Vehicle.[2] At the same time, the Minister proposed a limit of 84 dB(A) for all but the largest vehicles; however, legislation never came into effect because in 1973 we entered the European Community and had to accept the less stringent limits of EC Directive 70/157/EEC, applicable to cars, commercial vehicles and buses.

An amending directive, 77/212/EEC, initiated by the UK in 1977, broadly introduced the package of limits which the UK had intended to apply in 1974 and was applied in the UK from 1 April 1983.

Directive 78/1015/EEC introduced noise limits for motorcycles and was applied in the UK to new machines from 1982. The limits are shown in Table 1.

Noise test procedures

There is a need to adjust procedures from time to time to ensure that changes in vehicle technology continue to meet environmental needs. Directive 81/334/EEC improved the procedure for cars, lorries and buses to reflect the increased number of gears commonly used. Cars with 5-speed gearboxes had to be quietened by a further 2 to 3 dB(A) and many heavy lorries by up to 3 dB(A) even though the limit values were unchanged.

The fairly recent development of more powerful motorcycles and motorcycles with high revving engines has raised questions about the test procedure in Directive 78/1015/EEC. Changes to the UN/ECE test procedure now require motorcycles with a cylinder capacity exceeding 175 cm^3 and more than 5 gears to be tested in both second and third gear rather than just third gear alone which was the previous condition. This change to the test procedure was introduced to ensure that motorcycles with more than 4 gear ratios produce sufficient power during the test to demonstrate their noise potential.

The latest developments

In adopting Directive 77/212/EEC, the Council of Ministers agreed the following declaration:

> efforts should be made to achieve a noise level of around 80 dB(A) for all

Table 1 Noise Limits

Limits in dB(A) and dates of application to first vehicle registrations

Vehicle category	Limits		
Cars	*Before 1/10/83*	*After 1/10/83*	*After 1/10/89*
	84	80	$77^{c, d}$
Goods Vehicles	*Before 1/10/83*	*After 1/10/83*	*After 1/10/90*
<2 Tonnes	85	81	$78^{b, c}$
2 – 3.5 Tonnes			$79^{b, c, d}$
>3.5 Tonnes			
< 75 kW		86	$81^{a, d}$
75 – 100 kW	89	88	$83^{a, d}$
> 150 kW (200 hp)			$84^{a, d}$
Buses	*Before 1/10/83*	*After 1/10/83*	*After 1/10/89*
9 – 12 seats			
<2 Tonnes		81	$78^{b, c}$
2 – 3.5 Tonnes			$79^{b, c, d}$
>3.5 Tonnes	84		
<150 kW		82	80^{d}
150 kW – 200 hp			83^{d}
>200 hp		85	
>12 seats			
>2 Tonnes		81	$78^{b, c, d}$
2 – 3.5 Tonnes			$79^{b, c, d}$
>3.5 Tonnes	89		
– < 150 kW		82	80^{d}
– 150 kW – 200 hp			83^{d}
– < 200 hp		85	
Motorcycles	*Before 1/10/90*	*After 1/10/90*	*After 1/10/95*
< 80 cc	78	77	75
80 – 125 cc	80	79	77^{e}
125 – 175 cc	83		
175 – 350 cc	85		
350 – 500 cc	83	82	80
>500 cc	84		
Mopeds	*Before 1/10/83*	*After 1/10/83*	
	77	73	
Agricultural Tractors	*Before 1/10/83*	*After 1/10/83*	
<90 hp	89	89	
>90 hp		92	

Notes

a. Application of the limits deferred by one year.
b. For vehicles equipped with diesel engines, application of the limits deferred by one year.
c. For vehicles equipped with direct injection diesel engines the limit is increased by 1 dB(A).
d. For vehicles designed for off road use with a maximum permissible mass exceeding two tonnes the limit is increased by 1 dB(A) if their engine power is less than 150 kW and by 2 dB(A) if their engine power is equal to or greater than 150 kW.
e. Application of the limit deferred until the end of 1996.

*The method used to test the noise emission from vehicles is described later in a paper by McKinlay.

categories of vehicles by 1985. The levels decided upon will have to take into account what is technically and economically feasible at the time. Moreover, they will have to be established sufficiently early to give manufacturers an adequate transition period in which to improve their products.

In 1981, the commission set up a working party with representatives of all member states and the Motor Industry to examine the scope for further reductions. The study took account of costs for vehicle manufacturers and operators, effects upon fuel consumption and maintenance and the environmental benefits which would result from lower noise limits.

The working party made their report in 1982[3] and in June 1984 the Council agreed the amending directive 84/424/EEC.[4] The limits imposed are detailed in the final column of Table 1. These limits will result in considerable reductions in overall traffic noise – around 3 dB(A) at the 10% lorry to car mix ratio, when fully implemented and will more than offset increases in the number of road vehicles in the next few years. Agreement was also reached for a further review of the provisions of the Directive by 31 December 1990.

To ensure that the truck industry can produce vehicles and components capable of meeting the new limits and future requirements, a joint project between government and industry has been set up to carry out the necessary research and development. This project is known as QHV90 and a brief description is given in the article by J W Tyler.

Motorcycles

Agreement was reached in 1986, within the European Community, for two stages of reduced noise limits for all categories of motorcycle. They are laid down in directive 87/56/EEC. A summary of the limits is shown in Table I and it can be seen that a limit of 80 dB(A) will be achieved by stage II. Although the environmental benefits to be derived from quieter motorcycles are less easily estimated, it is obvious that the benefits will be substantial and should go a long way to improve the situation.

The noise of motorcycles, as manufactured, is not the only problem in reducing motorcycle noise. There has been a market in this country for inadequate exhaust systems and some are modified by their owners, resulting in the problem of individual motorcycles exceeding their construction limits and being used illegally on the roads causing enforcement problems. The Department has sought the co-operation of manufacturers and users organizations in tackling this problem. This has led to the preparation of a British Standard for replacement motorcycle exhaust systems BSAU 193: 1983.[5] Legislation has now been made to require new machines to be fitted with silencers which meet this standard.

Maintenance and enforcement

Inspection of exhaust systems for defects is, in the Department's view, a more effective method of enforcement than the pursuit of in use noise tests to replicate directly the noise emission observed at type approval. Studies have shown that noise does not increase markedly until a substantial failure occurs and a visual examination quickly reveals the fault. Also, in 1987, Robert Adley MP was successful in piloting a bill through Parliament which gave the Secretary of State powers to make Regulations to restrict the sale of inadequate motorcycle silencers. Legislation is being prepared to bring these powers into effect.

Noise enforcement in use may become more of a problem when 'quiet' vehicles come into service. This is because many of these vehicles will be fitted with engine shielding which may be removed, causing an increase in noise. The potential for in-service problems will be minimized if vehicles are quietened by methods other than the use of palliative shielding. Other methods such as quietening the components at source may have advantages in terms of weight reduction and ease of maintenance.

Conclusions

The new Directives will bring substantial reductions in the noise of cars, lorries, buses and motorcycles when fully implemented. They are practical limits which can be met with existing technology, and should ensure that increases in vehicle traffic are offset.

The views expressed in this paper are those of the author and do not necessarily reflect those of the Department of Transport.

References

1. *Final Report of the Committee on the Problem of Noise*, July 1963, Cmnd 2056.
2. J W Tyler, *TRRL Quiet Vehicle Programme.* Quiet Heavy Vehicle (QHV) project, TRRL Supplementary Report SR 521.
3. *Report of the Ad-hoc Group Evolution of Regulations – Global Approach (ERGA)*, Noise Commission of the European Communities III/540/82-Rev 2 EN (unpublished).
4. *Proposal for a Council Directive amending 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles,* O J No C200/5, 27 July 1983.
5. British Standard BS AU 193: 1983. *Specification for Replacement Motorcycle and Moped Exhaust Systems.*

Powertrain Design for Low Noise Refinement

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This paper is an abridged version of an article which first appeared in *Chartered Mechanical Engineer*, July/August 1987

This article examines powertrain noise. The word powertrain is used deliberately to include both engine and transmission as, in the case where engine and transmission are close coupled, transmission noise can sometimes be as important as the engine itself. The objective is not to review the familiar ground of noise control, so ably covered by the multitude of papers on the subject, but to examine some of the more novel aspects of noise and look more to the future regarding noise control measures.

Concern about powertrain noise is nothing new but as legislative pressures continue to increase in many areas[1,2] and the customer becomes more demanding and selective so the manufacturer has had to take a hard, and in many cases a fresh look at noise.

Since some of the earliest engines, the basic engine structure has changed little as far as the noise engineer is concerned. The conventional engine concept of a cylinder head fixed rigidly to a lightly damped open, cast, bell-like, structure onto which are bolted highly resonant covers and components has been the norm for many decades. Production cost, lack of appreciation of noise control and industry conservatism generally tended to constrain radical development beyond this concept. In recent years, however, the question of noise generating sources and the response of structures has received much more attention, especially in Japan. Now we are beginning to see attempts at stiffening structures, choosing highly damped materials and avoiding high mechanical and combustion excitation at source. There is enormous diversity in the industry, with some companies still in the dark ages of noise control, whilst others lead the world in highly advanced refined and sophisticated power units. The latter companies are now turning more to examine the *quality* of sound made by their engines rather than simply reducing noise levels. Perhaps 'simply' is not a good choice of word as reducing measured levels on a dB(A) basis (for example) is difficult enough let alone trying to make engines sound more acceptable. However, perhaps this now gives the manufacturer an option – if he can produce a better sounding engine which is not necessarily much quieter but nevertheless acceptable to the consumer this could give him the competitive edge. Customer perception of noise quality is highly complex and will be discussed later.

Powertrain noise, like any other design aspect, must be considered at the very earliest stages of concept design along with performance, fuel consumption, weight, cost and the multitude of other factors the designer must balance. Building hardware ignorant of noise control and then having to rectify expensive mistakes during the development phases is a poor philosophy and not one for the 1990s. Progressive designers today rely heavily on analytical and predictive techniques combined with practical experience to optimize the design at the earliest possible stage.

Designing for low noise

Figure 1 shows a concept of practical low noise automotive spark ignition engines. The key features for low noise and good refinement are indicated. High on the priority list must be a good structure design. Good in this context means rigid, lightweight, with ample ribbing and preferably with some form of bottom end stiffening. A 'bedplate' (sometimes known as a ladder frame) is shown in this hypothetical example. An actual example, in this case a PSA TU series engine, is shown in Figure 2. One means of characterizing the block response characteristics is to measure the structure attenuation to a given internal excitation (usually combustion). Typical curves are shown in Figure 3 for five spark ignition engines. The benefits of a bedplate are clearly shown for engine A compared with the similar size and configuration engine B with a conventional skirtless block and separate main bearing caps. Engine A is the only bedplate engine shown in this figure.

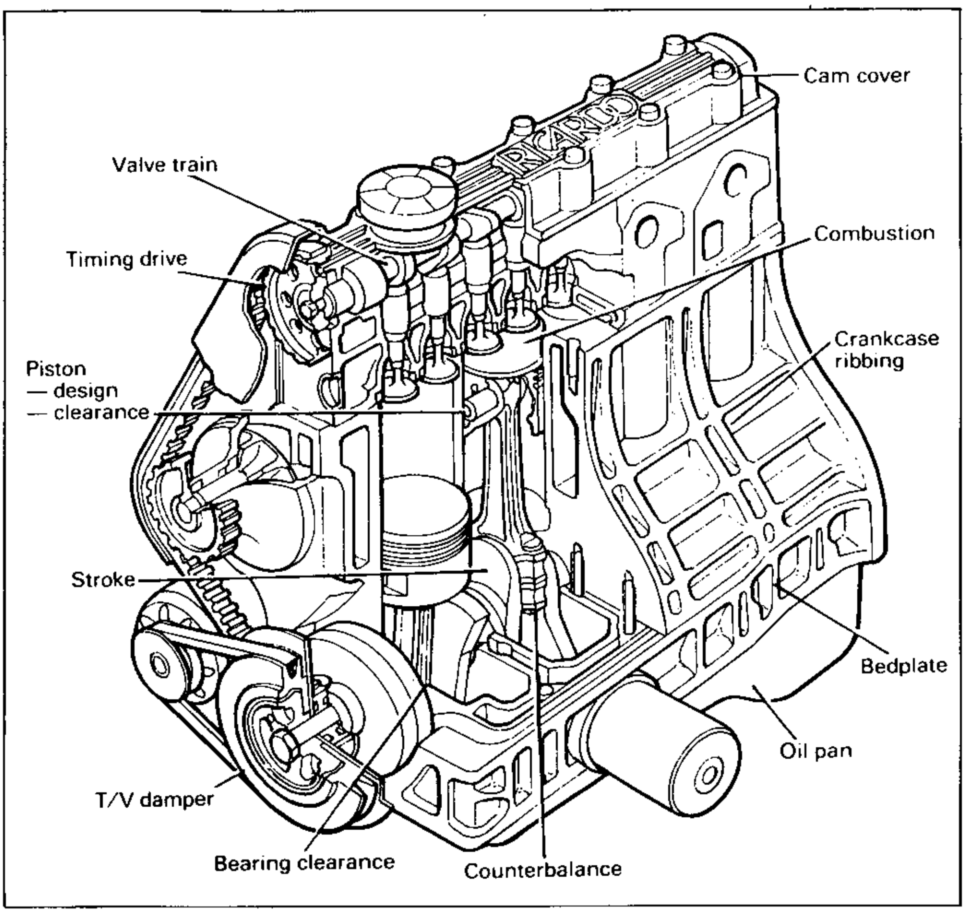

Fig. 1. A conceptual low noise automotive spark ignition engine. The key features are shown; attention must also be given to inlet and exhaust manifolds

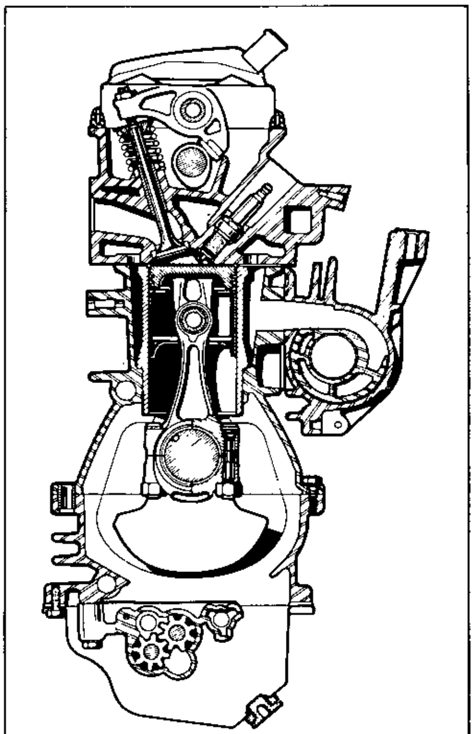

Fig. 2. An actual example of a bedplate engine – the new PSA (Peugeot/Citroën/ Talbot Group) TU series spark ignition engine

Other important structural components include the sump (often the most important single component noise source), cam cover and front timing drive cover. Cast aluminium should be

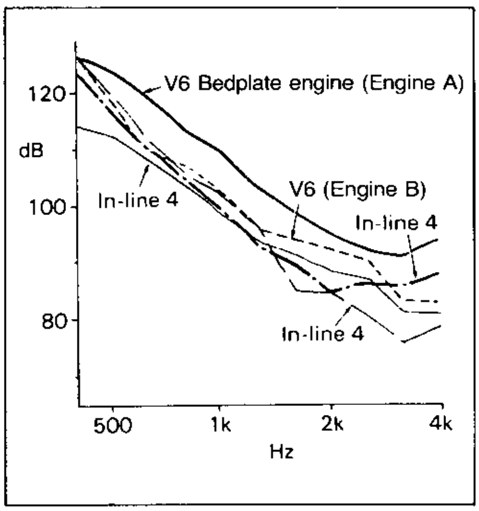

Fig. 3. Structural attenuation, defined as combustion excitation less combustion noise, for various spark ignition engines. The top curve is the only bedplate engine; the other four are of conventional structure. The other V6 engine is of similar size and configuration with a conventional skirtless block and separate main bearing caps

avoided for these components, despite its obvious production advantages and cosmetic potential. The use of damped laminated steel is preferable for low noise, unless a great deal of care has gone into the ribbing of an aluminium cover. Isolation is also increasing in popularity, even in one case on heavy duty diesel engine sumps. Care must be taken in isolating covers, however, as the system damping can change dramatically with isolation, needing additional damping treatment. It is not uncommon for an untreated isolated cover to be noisier than when it was rigidly bolted.

Ideally, the sources of excitation should, of course, be addressed first but the noise control engineer is often limited by what the performance, economy and emissions and production cost constraints will permit. On spark ignition engines a compromise between rapid rates of combustion at light load, low speed conditions and slower combustion rates at wide open throttle must be achieved. This is not easy and usually involves tailoring the swirl rate to throttle opening (e.g. by using a supplementary air port or modulating between ports on a 4-valve engine). For the light duty diesel engine, combustion excitation control at idle is of key importance, especially for passenger car applications – great improvements are being achieved with IDI (indirect injection) engines but the small high speed DI (direct injection) still falls short of total acceptability in the car application. More work is needed in this area, investigating optimum chamber geometry and fuel injection equipment matching, injection rate shaping and so called 'split-injection', where a small charge of fuel is injected into the combustion chamber prior to the main charge in order to stage the ignition process and smooth the resulting pressure rise in the cylinders.

Mechanical noise associated with the valve train and piston in particular must be carefully considered. Minor changes to cam profile and ramp can have dramatic effects on perceived and measured noise. Piston design is not just a question of achieving the correct profile and clearance. Phenomena such as 'stick-slip' have been identified, first published by Beardmore[3] and very recently by Werner[4]. Stick-slip, the sudden and significant force change on the piston at TDC and BDC as the friction mode changes from dynamic to static, can in some cases make a spark-ignition engine sound like a diesel at idle.

Mention must also be made in this section of the importance of accessory noise, especially the alternator. Only now are we beginning to see better alternator fan designs but the exposed and crudely formed steel air stirrer on the front of modern alternators is an all too common sight. A better arrangement is to enclose the fan at the rear and design the fan properly. Removal of a conventional steel fan can reduce alternator source noise by as much as 6 dB. Finally the transmission deserves mention and has been neglected somewhat in the quest for lower noise powertrains. This is especially so in the USA where some automatic transmissions tested at Ricardo have been shown to actually cause *engine* noise increases of up to 3 dB. Blaming the engine for a noisy powertrain therefore, is not always valid. Two-thirds of the total noise can be due to the combined noise of the transmission and accessories.

Good design for low noise and refinement means attention to detail. It means examining *all* components likely to influence noise, not just a quick, cheap palliative on a third order of importance single cover. It is by attending to this detail that a refined powertrain is produced. It is true that refinement is not achieved for nothing; someone has to pay somewhere along the line but it may be cheaper to examine carefully why the powertrain is noisy at source rather than have to bear the cost of relatively expensive palliatives. Some examples of what is meant by 'attention to detail' are given in Table 1.

Refinement and noise quality

If there is one single noise related subject which is receiving more and more attention currently it is 'noise quality'. This means how the engine sound is perceived and judged by the ear. It does not necessarily mean the engine must be quiet, although it is desirable to have both low noise and a 'good' sound. It is not just the field of passenger car engines which is receiving attention either. There is even interest at legislation level to possibly incorporate in the future a 'quality index' in a drive-by test which would apply to all vehicles.

Some of the earliest work published on subjective noise was carried out by Lord Rayleigh in 1890. More recently research has been carried out by automobile companies and independent consultants[5–7]. These studies have generally shown that several factors are important, notably rates of cylinder pressure rise during combustion, amplitude modulated waveforms generated either by cylinder to cylinder variation or by the presence of three or more harmonics of approximately equal magnitude occurring within the ear's frequency resolution bandwidth.

Whilst many of the techniques used derive from fundamental acoustics and psycho acoustics Ricardo has been examining whether subjective noise can be analysed related strictly to the engine, and more precisely to the engine cycle. Here, time domain analysis is used to examine how the noise energy changes over an engine cycle (and how it varies from cycle to cycle). This so-called 'cumulative energy integral' technique is illustrated in Figure 4 for a four-cylinder engine. The curve shows how the release of noise energy changes on a cumulative basis over a cycle. In the example shown there are distinct discontinuities at points X and Y. It is discontinuities such as these that can produce subjectively unpleasant noise. One of the main reasons for such large discontinuities can be combustion differences from cylinder to cylinder (curve A). Even distribution is essential for good refinement (curve B shows the result of an improvement to cylinder 4).

Table 1 Engine refinement: attention to detail

Examine *all* components likely to influence NVH*, including accessories and transmission
Constrain tolerance on all bearing clearances and keep clearances and tolerances *to minimum*
Optimize piston profile and clearance for best compromise between slap and 'stick-slip'
Select *materials* carefully for optimum NVH performance; particular care needed with large cast aluminium covers and sumps
Provide optimum *stiffening* in critical areas. Avoid redundant material
Ensure adequate crankshaft stiffness – use damper to minimize torsional vibration
Minimize *reciprocating mass* – counterbalance appropriately
Ensure *repeatable spark initiation, and combustion,* cylinder to cylinder and cycle to cycle
Control tolerances on masses of moving components to maintain *dynamic balance*
Minimize *combustion* rates of pressure rise and Pmax
Fine-tune end result on running engine (the best current analyses are all linear – the engine is not)

*Noise, vibration, harshness

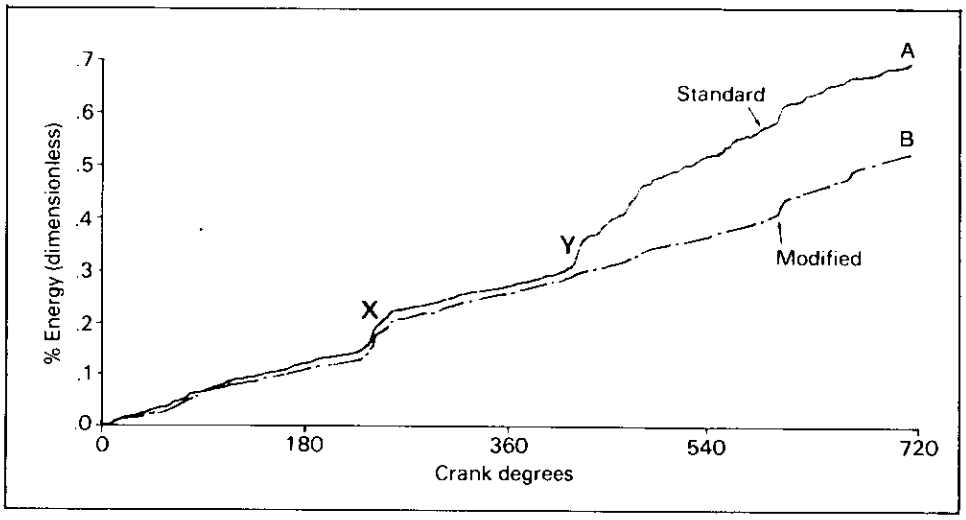

Fig. 4. Cumulative 'A' weighted noise energy over the engine cycle for a four-cylinder engine

A more acceptable plot would be a smooth curve from beginning to end of the cycle. This technique not only shows the position in the cycle where a problem is occurring but also quantifies the energy release at that point. This provides an instant visual appreciation of what is essentially perceived as a complex subjective perception. Such work in this area is continuing with the most recent published paper by Maeda et al.[7] Here a meter has been devised to assess engine noise quality based on three key parameters, loudness, impulsiveness and frequency characteristics. This may be simplistic but it is a start in trying to unravel the complexities of human judgement of sound. This will be more important in the future as the more progressive companies aim to provide the customer with the 'right' sound balance. Defining 'right' is the problem. Achieving it on the engine is the challenge.

The future

The future holds more reliable, quicker and cheaper analytical techniques for the noise engineer. Dynamic finite element analysis, a daunting and questionable approach for engines ten years ago, is almost accepted as routine today and will continue to improve, enabling the designer to predict engine noise reliably at the earliest possible design stage.

In parallel with analytical techniques, improvements in materials are seen as another major progression. Damped laminated steels are commonplace now. Plastic components are still relatively rare but also offer advantages of high damping and low weight (at a price). Innovations such as ICI's NIMS (New Inorganic Materials) offer exciting prospects for the designer. Such materials, consisting mainly of ordinary cement and a small proportion of bonding polymer, have excellent low noise properties and above all, are extremely cheap.[8] Tests at Ricardo have shown prototype NIMS engine cam cover noise reductions of 5–7 dB compared with conventional stamped steel (Figure 5). Such advanced materials are not without problems, however, and a suitably high temperature limit has yet to be achieved with NIMS. This problem is at present being examined but given time and development effort is expected to be overcome.

This article will finish as it was started, by reminding the reader that noise is just another factor to consider, but in today's world it certainly must be considered and not left as an afterthought, or worse still, ignored until the problem is horribly revealed on the development test bed. The word 'optimization' is never more applicable than to engine design for low noise, as low noise requirements often conflict directly with engine speed, performance, fuel economy, cost and engine weight. Optimization is now and will continue to be of critical importance in order to provide the customer with what he wants. Remember that whereas he may not be able to detect a few per cent difference in gaseous emissions or kilowatts of power he is equipped with two of nature's most sensitive detectors that will pick out the most subtle and, to him, irritating sounds. The contemporary designer must meet this challenge by 'getting it right' from square one.

References

1. Morrison, Road vehicle noise emission legislation, in *Handbook of Transportation Noise Control*, ed. P Nelson, Butterworths, 1987.

2. Engine noise regulations force design compromise, *Mobile Plant Design and Components*, September/October, 1986.

3. Beardmore, *Piston Stick-Slip Noise Generation Mechanism*, SAE 820753.

4. Werner, *Control of Piston Stick-Slip Noise in a 4 Cylinder Gasoline Engine*, SAE 870991.

5. Andrews, Anderton, Baker, *The Analysis and Mechanism of Engine Crank Rumble*, IMechE, C136/79.

6. Tsuge, Kanamaru, Kido, Masuda, *A Study of Noise in Vehicle Passenger Compartments During Acceleration*, SAE 850965.

7. Maeda, Maekawa, Nomura, *Development of an Engine Noise Evaluation Meter*, SAE 870965.

8. Love, *New Cement Based Materials for Engine Construction*, ASME Conference Paper, Oakbrook, 7 October 1987.

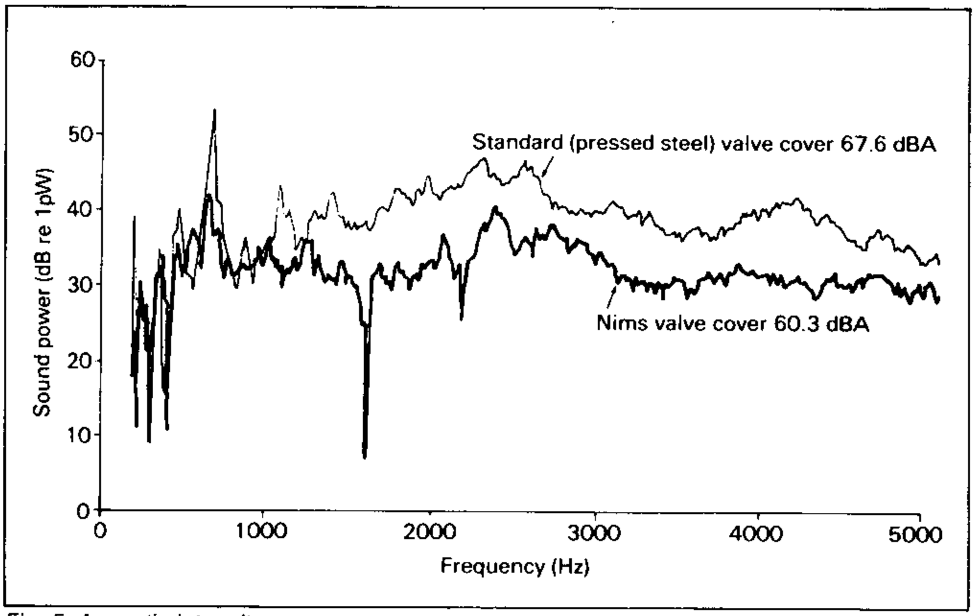

Fig. 5. Acoustic intensity measurements on standard and NIMS (new inorganic materials) valve covers at 16 rev/s (idle), 'A' weighted

Tyre Design and Noise Control

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Tyre Research Department, SP Tyres UK Ltd

Ultimately tyre/road interaction noise sets the lower limit as to how far the technically feasible noise reductions of vehicles are worth applying. Therefore there is a need to gain a deeper understanding of this noise source with a view to its reduction.

An approach to this work can be considered to comprise four main parts.

1. Measure and analyse tyre/surface noise on a drum in the laboratory.
2. Measure and analyse vehicle coasting noise on the road.
3. Develop a mathematical model in the computer in order to predict results.
4. Obtain as close a correspondence as possible between the above different parts of the work, and apply the knowledge gained to produce quieter tyre/road interfaces, bearing in mind other tyre/road properties.

Other factors which must be optimized are wet grip, irregular wear, endurance, stone trapping and chunking. These are fairly easily overcome on car tyres, but more skill and research is needed to obtain optimization on truck tyres.

This article concentrates on the measurement and analysis techniques that have been developed to cover parts 1 and 2 of the above schedule.

Replica road surfaces

Replicas of actual road surfaces have been made as resin shells which fit on a 1.7 m diameter drum. Examples of the replica surfaces are shown in Figure 1. The shells have outer layers with silicon carbide filler for high polishing resistance and inner layers of resin with glass fibre.[1] The replica surface has been tested for its resistance to polishing[2] and gives similar properties to those provided by granite chippings. The thermal conductivity of the resin material is also close to that of the road and gives fairly typical tyre temperatures following tyre warm up. The accuracy of the microtexture has been shown by photomicrographs using the scanning electron microscope. Replica surfaces have also been made for fitment to a truck tyre dynamometer.

Indoor testing of truck tyres on replica surfaces

For the indoor testing of truck tyres on replica surfaces two microphones are positioned, one each side of the tyre, at a distance of 0.1 m above the ground plane, 0.4 m from the undeflected tyre sidewall and 0.4 m behind the vertical axle plane. This is the position recommended by Sandberg[3] and by the ECE. Sound absorbing screens are used in the vicinity of the test area. Three types of tyre were tested: blank tread, steer axle (ribbed), drive axle (ribs and blocks) 18 mm depth, and drive axle (all blocks) 21 mm depth.

Five surfaces were used.

1. Smooth steel
2. Gussasphalt
3. Delugrip road surfacing material
4. Open textured macadam
5. Motorway hot rolled asphalt BS594

The noise level results are shown in Figure 2.[4] This figure shows two distinct effects of the road surface on the tyre/surface interaction noise.

(i) The noise excitation due to macrotexture of the surface.

This is evident when there is very little tread pattern effect, that is in the case of the blank tread.

(ii) The break-up of the tread pattern excited noise.

Up to a point the greater and more pointed the macrotexture the less the tread is in contact with the surface. Following from this the break-up is greater and the noise excited by the tread pattern will be less. This is shown more strongly with the deeper drive axle patterns where the effect of the break-up dominates over the macrotexture excitation effect.

A fairly reasonable correlation between indoor drum tests with replica surfaces and outdoor pass-by noise tests was shown by Plotkin.[5]

Separation of the two component parts of tyre/road interaction – excited tyre noise

More detailed analysis may be carried out. The decomposition of tyre/road noise into tyre periodic noise and road excited periodic noise was shown by Pope[6] on a Safety Walk surface. With a replica road surface on a drum, a

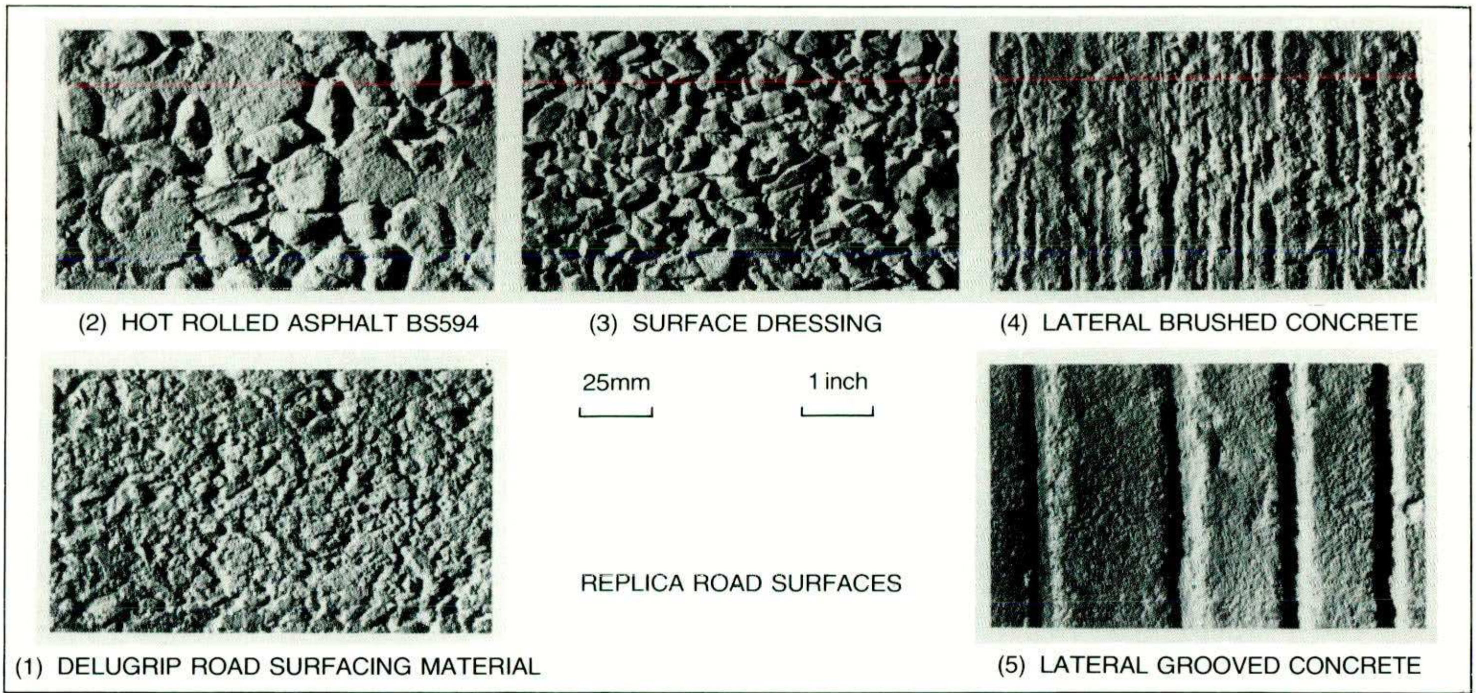

Fig. 1. Surface replicas available for use as shells on tyre testing drum

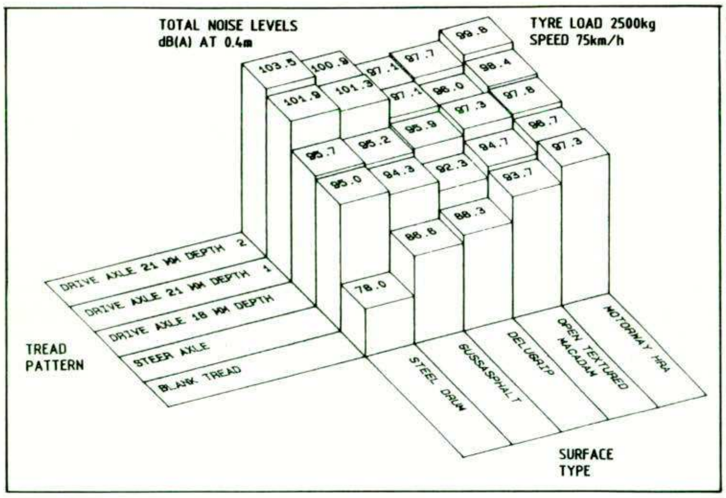

Fig. 2. Indoor testing of tread pattern/drum surface interaction excited total tyre noise on simulated road surface for various tyre/surface combinations

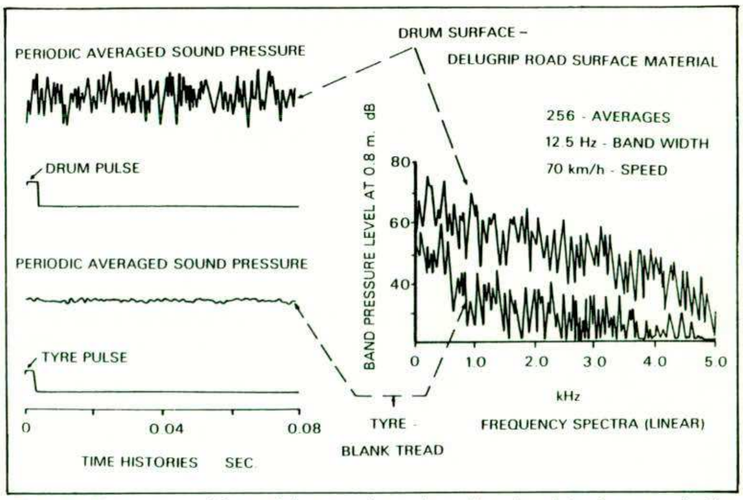

Fig. 3. Decomposition of the total tyre/road noise into tyre periodic noise and drum surface periodic noise with a plain tread tyre and the Delugrip replica surface

similar analysis can be carried out for actual worn road surfaces.

A real time spectrum analyser was used, triggered by a pulse from the drum to take in the sound wave for 0.08 seconds. This is repeated for each revolution of the drum and the sound waves averaged until the 256th average is reached. In order to correct for any small drifts in speed, for example 0.1 km/h, the signal from a 144 pulse per revolution source on the drum shaft was multiplied with the tracking adapter (phase locked) to provide the timing control for the real time analyser. Nicolet equipment was used for this.

As can be seen on the left-hand side of Figure 3 the plain treaded tyre periodic noise obtained with the triggering pulse, once per revolution of the tyre assembly, is very small; the replica surface noise is substantially non-periodic with respect to the tyre pulse and will therefore average away leaving tyre periodic noise. On the right-hand side of the figure the respective constituent spectra are shown.

Hence, by applying the foregoing technique, the total noise from the tyres due to tread pattern/surface interaction can be separated into (a) the tread pattern-excited noise from the tyre and (b) the surface-excited periodic noise from the tyre. The levels for the former are shown in Figure 4.

The blank tread excited noise is very quiet on all surfaces.

In the case of the patterned tyres there is a substantial decrease in the tread pattern-excited noise as the tyres move to surfaces with greater macrotexture.

The other part of the synchronous noise is the drum surface periodic noise as shown in Figure 5. The smooth steel drum excites less noise than any other surface. There is an increase for the patterned tyres on this surface, but comparison of these levels with the total noise figures in Figure 2 shows that both of these levels are below the discriminating power obtainable with 256 averages; that is, more than 23 dB(A) below the total noise figures.[7] Increasing noise excitation is shown with surfaces having increased macrotexture.

Subtraction of the tyre periodic noise from the road periodic noise gives the levels in Figure 6. On the motorway surface road-excited noise either exceeds or is within 1 dB(A) of tread pattern-excited noise.

Transport and Road Research Laboratory tests

Figure 7[8] summarizes the main dB(A) results published in the Transport and Road Research Laboratory UK quiet truck project work.[9] It shows the coasting noise levels in dB(A), fast response, at the standard distance of 7.5 m (25 ft) (the European Standard) from the centre line of the vehicle for a laden truck 13,200 kg (29,000 lb) travelling at 100 km/h (62 mph).

Here there are three dry surfaces: polished smooth concrete, coarse quartzite, and motorway surfaces; and three types of tyre pattern: blank tread, ribbed pattern and tractive pattern, on the 10.00–20 cross-ply tyres. A blank tread is one of full tread thickness without a tread pattern.

The polished smooth concrete surface

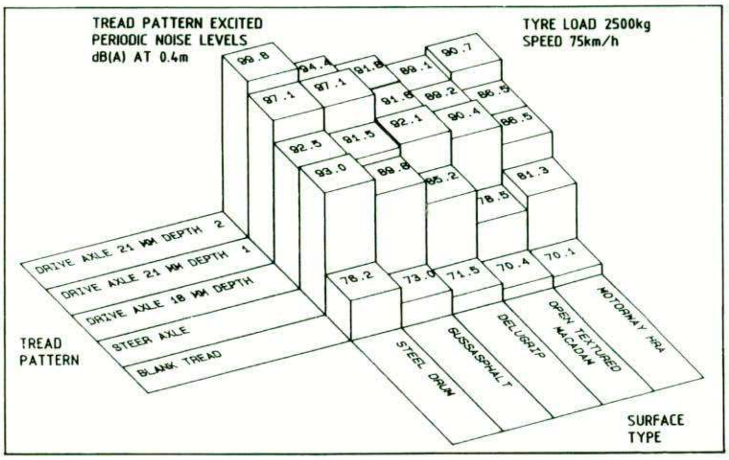

Fig. 4. Tread pattern excited noise from tyre due to tread pattern/drum surface interaction

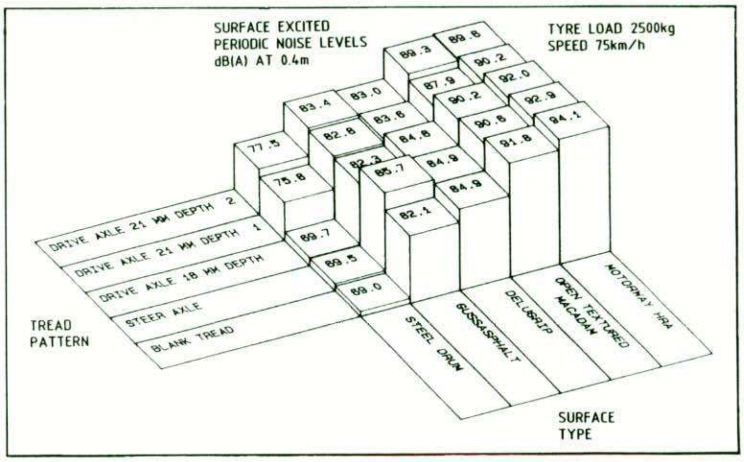

Fig. 5. Drum surface excited periodic noise from tyre due to drum surface/tread pattern interaction

shows a much greater contrast in tread pattern road noise than the surfaces with the greater macrotexture – this is the large-scale texture of the road surface for water drainage. In the latter cases, ribbed tyres are 1–2 dB(A) noisier than smooth tyres and traction tyres are 3 dB(A) noisier than the ribbed tyres. Thus the total effect of any major pattern feature is of the order of 3 dB(A).

This figure again shows two distinct effects of the road surface on the tyre/road noise.

Firstly, the excitation effect – the greater the macrotexture the more the tyre is excited and the greater the noise emitted, unless the frequency is high enough to be outside the sensitive region for the tyre. This is seen in the blank tyre results which get noisier as the macrotexture increases. There is no tread pattern effect in this case.

Secondly, the break-up of the tread pattern effect: up to a point, the greater the macrotexture the less the tread is in contact with the road. For deep road surface textures, the tyre will tend to contact just the tops of the stones. When this happens, the greater is the break-up of tread pattern related noise, and the noise from this source will be reduced as a result. This is shown in the traction pattern results where because of the transverse lug tread pattern (no centre rib) the effect of break-up dominates over the excitation effect and the tyre gets quieter as the macrotexture gets greater.

The coarse quartzite surface is 3–4 dB(A) quieter than the motorway surface for all tread patterns.

The effect of high hysteresis tread rubber was also measured, and as compared with natural tread rubber the average differences were less than 1–1.5 dB(A).

Other factors influencing tyre surface noise are discussed below.

Sectional width – automobile tyres
A 145 section tyre was 2.5 dB(A) quieter than the 185 section on both smooth asphalt and motorway HRA BS594 surfaces, at constant loads, 13 inch tyre, pass-by results.[8]

Aspect ratio – automobile tyres
An 80 series tyre was 0.7 dB(A) quieter than a 60 series tyre on smooth asphalt and 1.2 dB(A) quieter on BS594 HRA motorway surface. This compares with the findings of Hillquist and Carpenter[10] that 78 series tyres are 2 dB(A) quieter than 60 series.

Tyre diameter and wheels
In drum tests with block pattern tyres, of the same section and tread width, 10 inch tyres were 1.2 dB(A) noisier than 13 inch tyres and a light alloy wheel was 1.5 dB(A) quieter than a steel wheel.

Tyre construction – radial-ply and cross-ply car tyres
A tyre of each construction was tested on the drum, both having basically the same winter tyre block pattern and the same tread width. The noise levels from the three microphone positions were averaged. The radial tyre was 0.7 dB(A) quieter than the cross-ply. It is known that in the case of the radial-ply tyres there is less tread shuffle or micromovement on the road.

Tread compounds
The tread compound effect was also tested in the dry; the high hysteresis serrated rib rubber tyres were 0.9 dB(A) quieter on smooth asphalt and 1.7 dB(A) quieter on BS594 motorway.

Speed
The truck tyre tests previously discussed show an average 10 dB(A) increase with doubling of speed. This corresponds to 33 dB(A) per decade and 3 dB(A) per 25% increase in speed. The car test results show an average of 9.5 dB(A) increase with doubling of speed. In all the results previously discussed the differences in noise level have been fairly consistent over the speed range.

Load and inflation pressure – cross-ply truck tyres
Flanagan[11] reported that if the load is kept in the 75% to 100% range of the maximum rated load, and the scheduled pressure used, the sound level does not change appreciably. The NBS[12] showed that increasing the load per tyre from 0.69 to 2.01 Mg (1530 to 4430 lb) on cross-bar tyres gave a greater sound level increase, 6–8 dB(A), than on rib tyres, 1–3 dB(A). The USA Rubber Manufacturers Association[13] showed that at constant load an increase of 103 kPa (or 15 psi) gave a decrease in noise of 0.5 dB(A).

Tyres per vehicle
Doubling the load and number of wheels raises the sound level by approximately 2 dB(A) as shown by Tetlow.[14]

Tread profile – cross-ply cross-bar truck tyres
Tetlow also showed that tyres wore to a greater tread radius than in the new state. This gave a 6 dB(A) noise increase. Grinding the tyre to the original smaller tread radius reduced the noise to the original value for the new tyres.

Tyre wear – cross-ply truck tyres
Seldom does a tyre grow quieter at any speed as it wears out. The increase in noise level from new to half-worn treads is typically 2.5 dB(A) for ribbed patterns and 4.2 dB(A) for cross-bar patterns. The noise level then decreases as the fully worn state is approached, unless the tread pattern is such that pockets of air can be trapped at advanced stages of wear – Flanagan.[11] Irregular wear tends to occur on truck tyres, especially when the wear due to

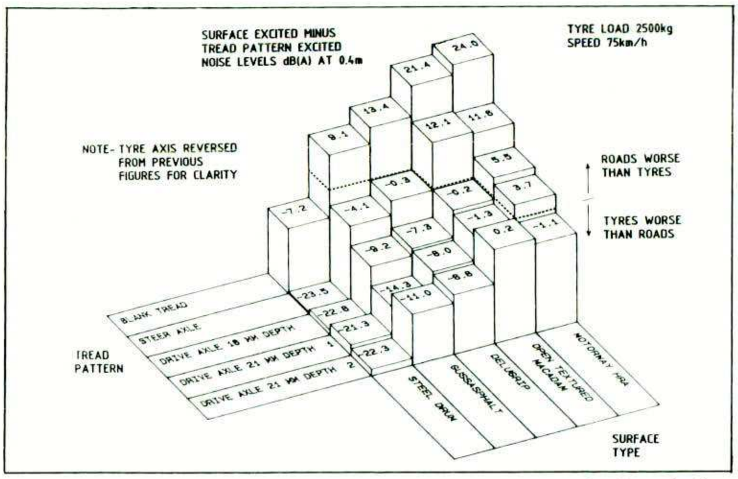

Fig. 6. Drum surface excited minus tread pattern excited periodic noise from tyre due to drum surface/tread pattern interaction

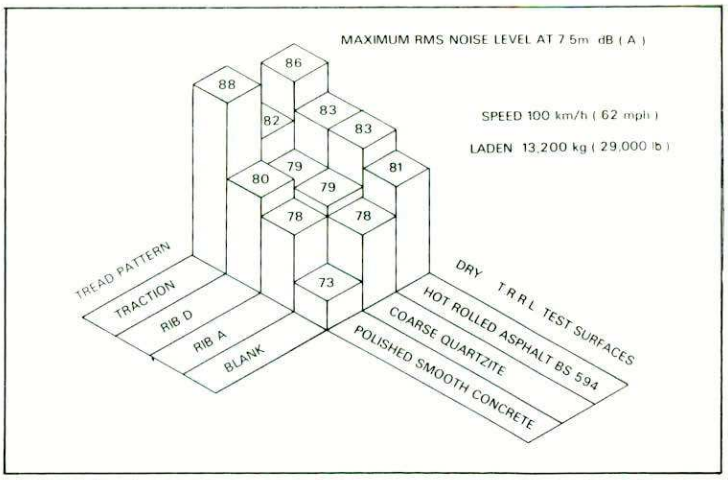

Fig. 7. Truck coasting noise for various tyre/road combinations

lightly laden motorway running predominates in the duty cycle. This is fairly rare in the UK because of the limited unbroken motorway mileages. Some examples of this type of wear can increase noise.

Temperature
Temperature causes no significant change in noise level when drum testing both rib and cross-bar cross-ply truck tyres between −4°C and 50°C, according to Tetlow.[14] However, in the case of nylon car tyres which have flatted, that is, parked overnight in the cold immediately after a high speed run, the flats should be run out before testing commences – NBS.[12]

Time-ageing
Over a period of two years rubber will slightly harden and the noise can increase by 1–2 dB(A), according to Favre and Pachiaudi.[15]

Tread pattern – variable pitch
For the last 45–50 years car tyres have had variable pitch segments in the tread pattern. Although this may not alter the overall sound level, it does break up any dominant frequencies. Empirically determined sequences have worked well over the years and now can be further refined by analysing the harmonics from the pattern sequence with a fast Fourier transform in the computer, and then optimizing the sequence. This is regularly used for new tyre patterns. The procedure is similar to that described by Varterasian.[16] Aural impressions of the tones were discussed by Zoeppritz.[17] Variable pitch segments are being applied to truck tyre traction patterns; Thurman.[18]

Conclusions
Indoor tests on simulated surfaces which have been carefully manufactured as true replicas of actual road surfaces give a fair correlation with pass-by testing of truck tyres. They have the advantage that rapid controlled tests can be made under laboratory conditions.

The separation of periodic tyre noise and periodic road noise shows the nature of tyre/road interaction, and indicates that the design of tread patterns and road surfaces need attention.

It is felt that there will be no 'quiet truck' without 'quiet road surfaces' and an improvement in truck tyre design, particularly relating to drive axle patterns.

Acknowledgements
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References
1. Walker, J C and Williams, A R, The improvement of noise and traction due to road/tyre interaction. *International Tyre Noise Conference*, Stockholm, 1979, pp. 261-271.

2. *Methods for Sampling and Testing of Mineral Aggregates, Sands and Fillers*, British Standards Institute, BS 812, 1973.

3. Sandberg, U and Ejsmont, J A, Development of three methods for measurement of tyre/road noise emission: coast-by, trailer and laboratory drum. *Noise Control Engineering Journal*, November–December 1986, pp. 68-88.

4. Williams, A R, Tyre to road interaction, harmony or conflict, ASTM Tyre Society Meeting, April 1987.

5. Stusnick, E and Plotkin, K J, *Evaluation of a Simulated Road Texture for the Testing of Tire/Road Noise*, EPA report no. 550/9-82-332, US Environmental Protection Agency, Arlington, VA USA, 1982.

6. Pope, J and Reynolds, *Basic Studies of Automobile Tyre Noise*, Report TNS1, Stanford University Mechanical Engineering Department, May 1978.

7. Walker J C, Noise Generated at the Tyre/Road Interface, PhD Thesis, University of Aston in Birmingham, 1981.

8. Walker, J C and Major, D J, Noise generated at the tyre-road interface, Paper 10, *Stress Vibration and Noise Analysis in Vehicles*, Applied Science Publishers Limited, 1975.

9. Underwood, M C P, *A Preliminary Investigation – into Lorry Tyre Noise*, Transport and Road Research Laboratory Report LR601, 1973.

10. Hillquist, R K and Carpenter, P C, A basic study of automobile tire noise, *J. Sound Vib.*, February 1974.

11. Flanagan, W, Recent studies give unified picture of tire noise, *Automotive Engineering*, 80 (4), April 1972.

12. Leasure, W A Jnr, Corley, D M, Flynn, D R, and Forrer, J S, *Truck Tire Noise I: Peak A Weighted Sound Levels due to Truck Tires*, National Bureau of Standards Department of Transportation Report, OST-ONA-71-9, 1970, and Addendum Report OST-TST-72-1, 1972.

13. Rubber Manufacturers Association. *Truck Tire Noise*, Presentation of the Office of Noise Abatement and Control of the Environmental Protection Agency Hearing, Washington DC, November 12, and Appendix, 1971.

14. Tetlow, D, Truck tire noise, *J. Sound Vib.*, 17–23 August, 1971.

15. Favre, B and Pachiaudi, G, *Tyre Noise, Theoretical and Experimental Aspects*, Internal Report by Research Institute of Transport, Arcueil, (private communication), 1974.

16. Varterasian, J H, *Quieting Noise Mathematically – Its Application to Snow Tires*, SAE 690520, 1969.

17. Zoeppritz H P, Possibilities and limitations of reducing tyre rolling noise, *A.T.Z.* 74 (1), 13-16 (MIRA Translation No. 37/72), January, 1972.

18. Thurman, G R, Characteristics of truck tire sound, *Truck Tire Noise*, SP 373, SAE Publication, 1972.

UK Government Quiet Vehicle Projects (TRRL QHV and QHV90)

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This paper starts by outlining the steps taken by the UK Government to demonstrate the technical and economic feasibility of reducing noise from heavy goods vehicles. The results from this work contributed, via the Armitage Inquiry[1] and the Government White Paper *Lorries, People and the Environment* (December 1981), to the decision by the European Community to require vehicles to be quieter by the end of the decade (EEC Directive 84/424, September 1984). Finally a brief description is given of the QHV90 Project which was a direct outcome of the White Paper and the anticipated EEC Directive.

For the class of vehicle concerned in this paper, 7.5 to 38 tonnes gross vehicle weight, the external noise levels required to be achieved by 1989/90 range from 81–84 dB(A) compared to the present requirement of 86–88 dB(A). Fuller details of the new vehicle noise legislation are given in the article by D. Tricker.

The TRRL QHV
The Quiet Heavy Vehicle Project (QHV) (2–4) was initiated by the Transport and Road Research Laboratory (TRRL) in 1971 following a report by an independent working group set up by the Minister for Transport to examine and review existing research into traffic noise and to recommend further research.[5] The Report recommended that research and development were needed to build a heavy articulated lorry aiming at a sound level at least 10 dB(A) below the then current levels, to dem-

onstrate the feasibility and commercial viability of such a lorry. This led to a target noise level of 80 db(A) being adopted.

The principal objective of the TRRL QHV Project was to enable British manufacturers of engines and vehicles to produce demonstration quiet diesel engine heavy articulated vehicle tractors, one at the weight and power conforming to the then current regulations, i.e. 32.5 tonnes gross vehicle weight and 158 kW (212 bhp) and the other capable of working up to 44.8 tonnes and with an engine power of some 262 kW (350 bhp).

Research prototypes of these vehicles were built by Leyland Vehicles (now Leyland DAF) and Foden Ltd (now Foden Trucks) together with Rolls-Royce Motors Ltd (Diesel Division) (now Perkins Engines Group Ltd) respectively, and achieved drive-by levels of 79.5 dB(A) and 83.5 dB(A) under the BS 3425:1966 test procedure. The Foden vehicle ended up somewhat lighter at 38/40 tonnes as this appeared to be the way maximum weight legislation appeared to be going at the time; in the event this was the legislative weight limit agreed upon in the latest regulations.

The research on the vehicle components was carried out by the Motor Industry Research Association (MIRA), exhaust and cooling system and the prototype research vehicles; National Engineering Laboratory (NEL), cooling system; Institute of Sound and Vibration Research (ISVR), quieter engines; and TRRL who carried out work on tyre/road surface noise. For work on the exhaust system design MIRA used the computer-based silencer design methods being developed at ISVR. The manufacturers co-operated closely with ISVR, MIRA and TRRL during the research phase and provided specialized facilities and advice to ensure that the outcome would be economically viable in production. This industrial involvement assisted a smooth transition from the research phase to the development phase involving the construction of the final demonstration vehicle.

As an example of the kind of results obtained during this research, Figure 1 shows the reduction in noise level over the frequency spectrum achieved by ISVR with the Rolls-Royce engine. A broad band of noise reduction was achieved above 500 Hz at rated power with a maximum of 12 dB(A) at 2.5 kHz. This was achieved by design changes which included a restructured cylinder block and crankcase, a decoupled sump, laminated close fitting damped panels attached to the block and a quieter fuel injection pump. Similar success with the design of the exhaust and cooling systems enabled MIRA to achieve a noise reduction of nearly 10 dB(A) with the prototype, compared with the original Foden vehicle.

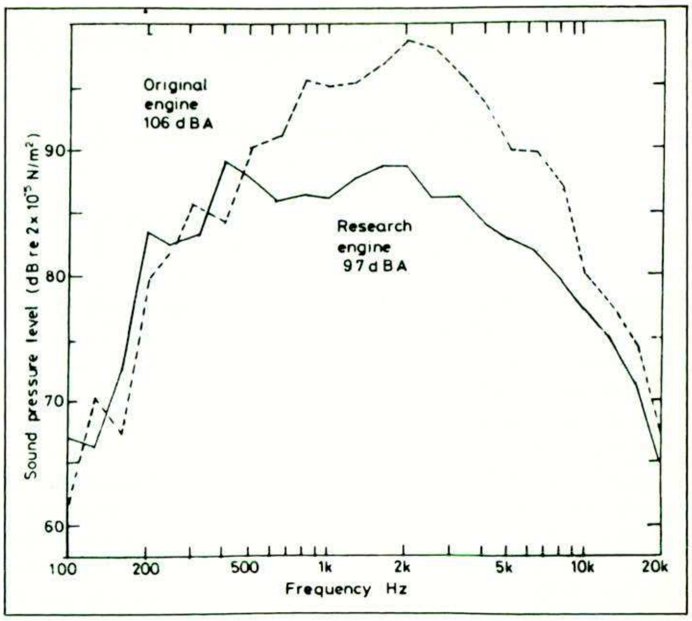


Fig. 1. Comparison of spectra of standard and research engines at rated conditions

Based on this research prototype, Foden/Rolls-Royce developed a demonstration vehicle built to production standards and achieving a drive-by noise level of 81/82 dB(A) when tested to BS 3425:1966. The maximum C weighted noise level recorded was 87 dB(C), a reduction of 8 dB(C) compared with the unmodified vehicle. Figure 2 compares the spectra of the QHV and a standard Foden vehicle of the time. Noise inside the cab was reduced to 72 dB(A).

The demonstration vehicle was put into service with a haulage contractor and, between November 1979 and October 1981, covered 118,000 km and carried 11,000 tonnes of payload in normal service.[6] The vehicle performed well during this test and apart from some temporary problems with the exhaust system there was no deterioration in the performance of the noise reduction measures in the vehicle. The increased capital cost of the QHV was estimated at 7.5% while the increase in total maintenance and servicing costs during the trials amounted to about 1.5%. This represented less than 0.2% of the total operating costs of the vehicle.

The significance of the QHV demonstration vehicle was to show that the technology existed to build a maximum weight goods vehicle to produce less than 82 dB(A) without excessive penalties on capital or operating costs.

The QHV90 Project

After the TRRL QHV had demonstrated the feasibility of a maximum weight vehicle emitting less than 82 dB(A), the Armitage Inquiry into Lorries, People and the Environment[1] recommended: 'The Government should adopt as explicit aims of policy that an EEC Directive should be agreed requiring lorries to be manufactured to a

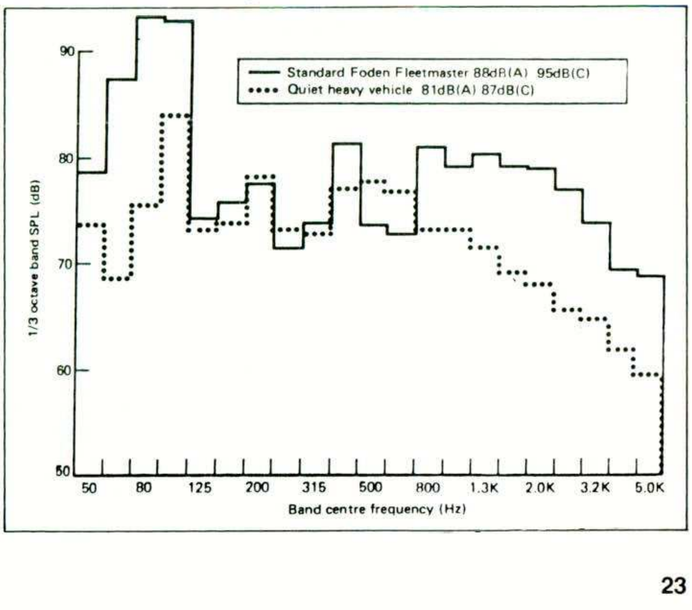


Fig. 2. Comparison of one-third octave band spectra for QHV and Foden Fleetmaster during standard test condition 81/334/EEC. (The spectra were obtained by sampling the total drive by noise in each case and displaying the maximum levels in each one-third octave band.)

maximum noise level of 80 dB(A) and that the new limit should be introduced as soon as practicable in the light of discussions with manufacturers and operators, and not later than 1990.' The Government then published in December 1981, a White Paper, *Lorries, People and the Environment* in which it stated as its target 'progressively to reduce the perceived noise from new heavy lorries coming on to the road to less than half the 1981 level, so that by 1990 they would be no noisier than 1981 model new cars . . . The Government will therefore set in hand a collaborative programme of research, involving vehicle and engine manufacturers . . . The new programme is intended to lead to the development of a "production" quiet heavy vehicle for the 1990s – the QHV90.'

The QHV90 Project[7] started in 1982 with discussions with manufacturers to select the vehicles and engines which would represent the products they would be marketing in the 1990s. Since the QHV90 Project is intended to assist the whole of the British commercial vehicle industry to meet the new noise limits, and to reduce the noise as perceived by the public, the project is much broader than the original QHV. Thus the programme includes the quietening of some maximum weight vehicles, some medium weight vehicles, engines to cover almost the complete range of goods vehicles, and research on the components that contribute to overall vehicle noise.

The vehicle manufacturers involved include ERF, Foden Trucks, IVECO Ford and Leyland DAF, while quieter engines are being developed by Cummins Engines, Ford Motor Co, Perkins Engines and Leyland DAF. In addition to the work being carried out by the manufacturers, research on specific aspects of vehicle noise is being done by the Motor Industry Research Association (MIRA), Loughborough University of Technology, and the British Hydromechanics Research Association (BHRA) (exhaust and air inlet noise); Institute of Sound and Vibration Research (ISVR) (reduction of noise from engine covers and the design of engine enclosures); and MIRA (computer model for vehicle noise prediction).

The QHV90 programme is being funded half by Government and half by industry. The Government funding comes about equally from the Department of Transport (DTp) and the Department of Trade and Industry (DTI) and the project is overseen by a steering committee of officials from the two Departments which is itself serviced by an Advisory Group of senior representatives from the manufacturing industry, since the overall programme is primarily to benefit the industry. The project will cost up to £10 million over a period of six years.

The QHV90 Project is just over halfway completed at the time of writing (August 1987) and although a great deal of successful work has been done, commercial confidentiality precludes any detailed discussion of results at this stage. However, it can be stated that all but one of the engine programmes have been completed and have achieved their noise targets. The vehicle manufacturers, who started their development programmes using standard, unquietened engines, are now using the quietened versions to determine the final amount of shielding and enclosure required to meet the new EEC noise limit. They are also engaged on considerable further development of other vehicle systems such as cooling, engine installation and cab design, in order to produce commercially viable production prototype vehicles.

QHV90 is a successful collaborative programme of research and development between Government and industry which includes research on the noise from heavy goods vehicles and the development and testing of prototypes of quiet vehicles, engines and systems components. As a result of this work and its own in-house research British industry will be enabled to build vehicles that will meet the more rigorous noise limits that will be in force by 1989/90.

Acknowledgements

The work described in this article forms part of the programme of the Transport and Road Research Laboratory and the article is published by permission of the Director. The author would like to thank all those in industry and research organizations who are contributing to the QHV90 programme.

References

1. Armitage, A. (Chairman), *Report of the Inquiry into Lorries, People and the Environment.* London, HMSO, 1980.
2. Tyler, J. W., *TRRL Quiet Vehicle Programme Quiet Heavy Vehicle (QHV) Project.* Department of the Environment/ Department of Transport, TRRL Report SR 521, Transport and Road Research Laboratory, 1979.
3. Tyler, J. W., The TRRL quiet heavy vehicle project, *Proc. Instn Mech. Eng, 193,* 179.
4. Tyler, J. W. and Collins, J. F. (Fodens Ltd, now Fodens Trucks), *TRRL Quiet Heavy Vehicle Project: development of Foden/Rolls-Royce demonstration vehicle.* Department of the Environment/ Department of Transport, TRRL Report LR 1067, 1983.
5. The Working Group on Research into Road Traffic Noise. *A review of road traffic noise.* Department of the Environment RRL Report LR 357, Crowthorne, 1970.
6. Nelson, P. M. and Underwood, M. C. P., *Operational Performance of the TRRL Quiet Heavy Vehicle.* Department of the Environment/Department of Transport, TRRL Report SR746, 1982.
7. Mitchell, C. G. B., Quiet Heavy Vehicles for 1990: the QHV90 Programme. Michigan, SAE Conference, Paper 850984, 1985.

The Challenge Facing the Vehicle Manufacturer

W McKinlay

Leyland DAF

Since the introduction of noise legislation to commercial vehicles, changes in the test methods and noise limits have resulted in the requirement for reduction in the overall noise levels of the vehicle. Figure 1 illustrates the reductions that have occurred in the noise limits through these changes (see also the article by D Tricker). The limits have been plotted on a relative sound power basis to highlight the reductions that have been made. Also shown is the noise limit that will be introduced as specified in EEC Directive 84/424, during 1988/89.

Meeting the new levels whilst maintaining cost competitiveness and efficiency of the product, presents the commercial vehicle manufacturers with a major challenge. The general solution to most noise problems is to shield the offending noise source from the observer. In the vehicle situation this involves engine encapsulation and enclosures mounted on the vehicle, similar to that documented in the British Leyland Patent Specification 1555466, the so called 'Easter Egg' concept. Although this concept is relatively simple to engineer, the major drawbacks are an increase in vehicle weight and cost, service access problems, introduction of cooling performance complications and, in the longer term, service refitting complexity.

A more effective and attractive solu-

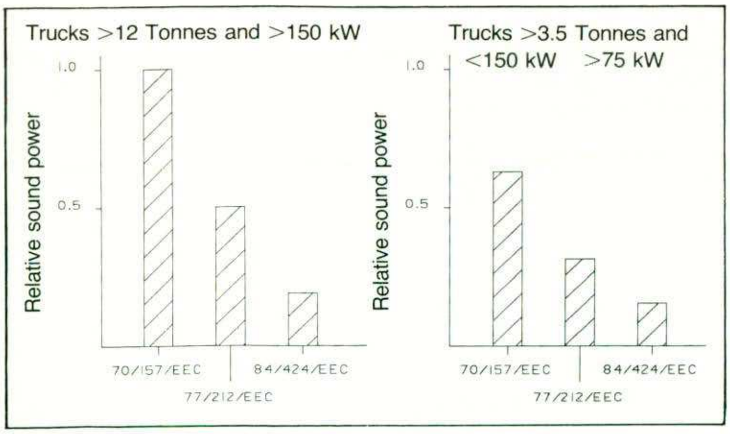


Fig. 1 Effects of noise legislation on noise levels

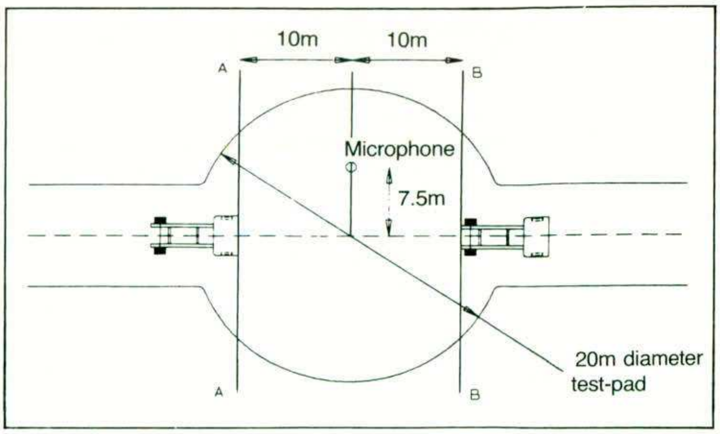


Fig. 2 External noise test area

tion to the product designer is to reduce the contributions of the individual noise sources. Such a solution, if technically feasible, would be more appropriate to the high volume Light Truck market as this is a particularly weight- and cost-sensitive market.

This latter approach to noise reduction requires a detailed understanding of the individual noise sources and requires comprehensive research and development programmes to identify the characteristics of the major noise sources such as the engine, exhaust, air intake, cooling system, axles and tyres. Advanced test technology is also required to validate noise reduction solutions.

The test procedure to ensure compliance with the legislation is defined by the EEC directive and requires a full throttle acceleration of the vehicle over the 20 metre test zone, a schematic of which is shown in Figure 2. The vehicle approaches the test start line A—A at a pre-determined speed and when the front of the vehicle crosses the line A—A, the driver applies full throttle and this is maintained until the rear of the vehicle exits the test zone.

The peak noise when the vehicle is within the zone is measured at the microphone position 7.5 metres from the vehicle centre line and at a height of 1.2 metres. The procedure is repeated for the opposite side of the vehicle and over a range of test gears and the test result is taken as the highest noise level recorded with 1dB(A) subtracted to account for measurement inaccuracies.

In the legislative test a single figure of sound pressure level is recorded. This single figure, however, is not sufficient to enable the development engineer to understand the contribution of the noise sources. It is therefore necessary to collect other vehicle parameters such as vehicle position in relation to the microphone, vehicle speed and engine speed simultaneously with the noise measurement. Telemetry is required to provide these data from the moving vehicle.

Unravelling the contributions from the major sources of the moving vehicle is further complicated due to the following:

1. Acoustic constructive and destructive interference caused by the moving sources.
2. Accelerating and therefore changing signatures of the noise sources.
3. The Doppler frequency shifting effect.
4. Effects of track surface reflectivity and absorptivity.

A comprehensive system for enhanced noise analysis using the pass-by test has been developed by Leyland DAF to provide an accurate and repeatable test procedure and acquire vehicle related parameters. Figure 3 shows a block diagram of the vehicle control system, telemetry and noise instrumentation that are in use for noise development purposes.

The control system for maintaining the vehicle approach speed comprises an actuator operating on the throttle pedal. Fuel is controlled by a solenoid which is activated when the front of the vehicle crosses the A—A line of the test zone. A further control aborts the test if the vehicle is off centre by more than + 0.3 metres. The telemetry system installed on the vehicle transmits the vehicle parameters engine speed, vehicle speed. Figure 4 shows a typical presentation of the results and indicates the vehicle speed, engine speed, distance in relation to the peak level of noise.

The analogue noise signal recorded on magnetic tape during the pass-by is processed using digital Fourier Analysis techniques to derive spectra in contiguous frames of 0.05 seconds duration.

Using the vehicle speed and distance information the noise spectra are adjusted to compensate changes in frequency ensuing from Doppler effects.

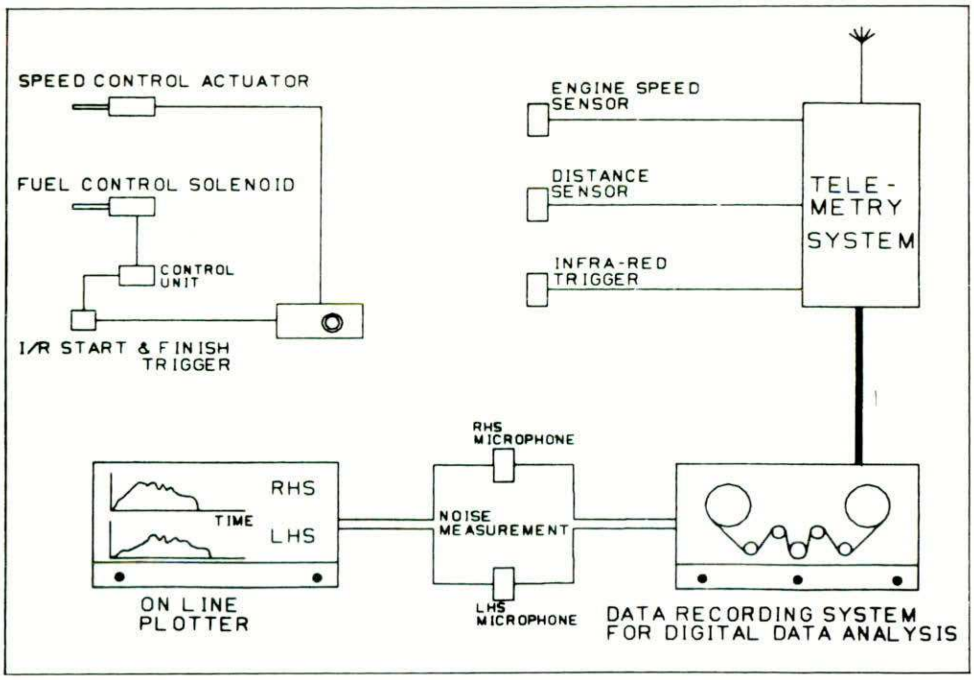


Fig. 3 Block diagram of vehicle control and noise data collection system

Waterfall plots as shown in Figure 5 identify resonance or speed related frequency components.

Conventional cladding and shielding methods, used in conjunction with the enhanced noise pass-by test and analysis enable contribution of the individual noise sources to be assessed.

Figure 6 shows typical current levels for the noise sources on the vehicle together with design target levels.

This illustrates the magnitude of the challenge that faces the commercial vehicle manufacturer in meeting the noise legislation of the 1990s without the use of chassis shields or engine enclosures. Much practical work remains to be done to achieve the design target levels without major impact to cost, vehicle weight and performance.

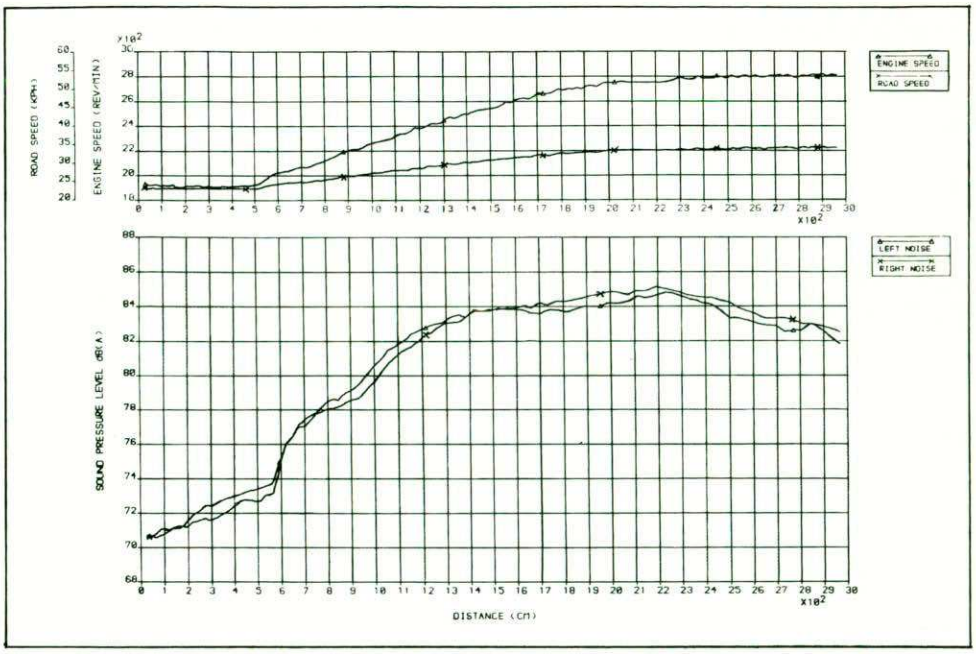


Fig. 4. Typical vehicle noise versus distance profile obtained using enhanced noise pass-by test and analysis methods

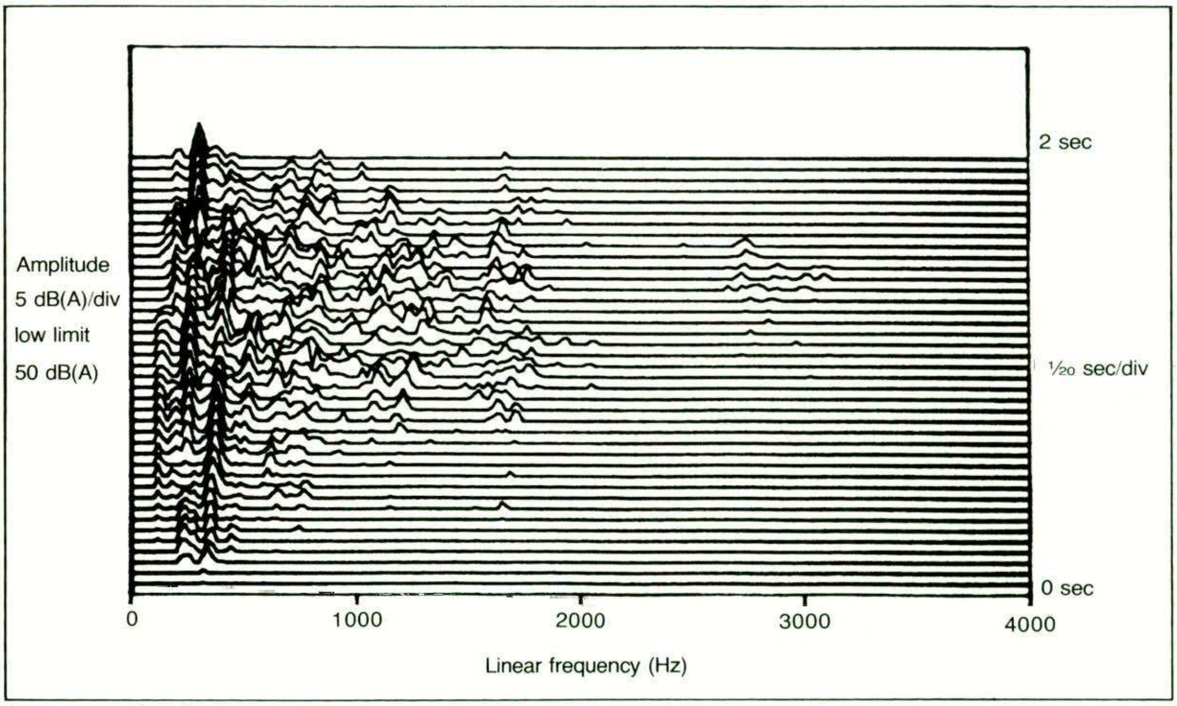


Fig. 5. Waterfall plot indicating noise level versus frequency for contiguous time intervals during pass-by test

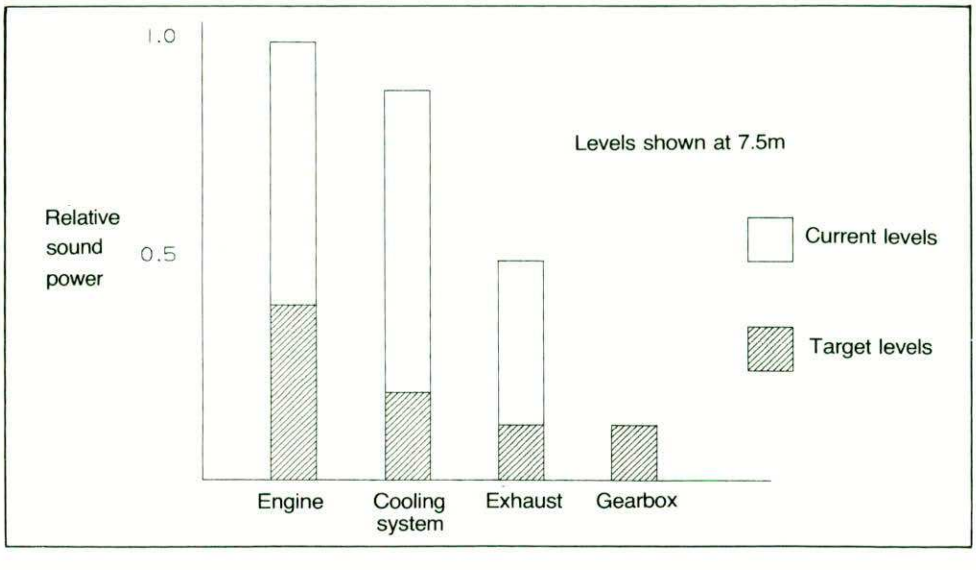


Fig. 6. Noise source targets to meet 84/424/EEC

BRANCH AND GROUP NEWS

London Branch

On 21 October 1987 the London Branch held its first Annual General Meeting which, as expected, was short and concise consisting of reports by the officers followed by the unopposed election of the London Branch Committee. The evening continued with one of the regular monthly evening meetings, on *Computer Based Data Acquisition Systems,* presented by Dudley Wallis of Cirrus Research Ltd. The basis of his talk was an assessment of the differences between an in-box processing system and a system which collects and stores raw data for processing later. One of the main advantages of a raw data collection system is that the information, having been stored, is available for later analysis as many times and in as many ways as may be required, whereas for an in-box processing system the required parameters must be decided first and no changes can be made after the event. Conversely an in-box processing system will give instant results on site whereas the raw data collection system requires further analysis by a separate computer. Other advantages of a computer-based system were pointed out by Dudley such as the computer in-built real time clock or the extensive help facilities available on screen at the touch of a button. By careful programming it is also possible to ensure that the measurement is set up and carried out in a proper step-by-step way, by use of a series of prompts on the screen which must be answered before passing to the next step. Dudley then explained how he whiles away the dark evenings at home by using a telephone link to watch aircraft noise levels in Western Australia. There followed a short discussion period after which the meeting was closed, to be re-opened a short time later for further discussion, in more convivial surroundings.

Paul Freeborn

North East Branch

On 12 June 1987 the Branch held a Social Evening which took the form of an evening meal held at the Ravensworth Arms, Newcastle upon Tyne. Eighteen people attended and enjoyed both the fellowship and an excellent meal in pleasant surroundings.

In order to broaden the range of topics for meetings covering members' interests and backgrounds, the committee agreed to hold more joint meetings with other locally-based professional institutions.

The first of these, held jointly with The Institute of Environmental Health Officers, took place on 7 October 1987 at County Hall, Durham. The overall title of this afternoon meeting was 'Noise Control at Mineral Extraction Sites', and approximately forty people attended to listen to two speakers, namely Mr W Walton who spoke on 'Legislative/Administrative Development' and Mr I Diggory, who discussed 'Noise Prediction and Monitoring'. Both of these talks were very well received, time only being the limiting factor for post-talk discussion.

A joint meeting with the IERE and IEE was held on 3 November, in which Mr P A Conway of Leeds Polytechnic gave a fascinating talk and demonstration entitled 'Digital Sound Synthesis'. This was given at Newcastle Polytechnic to a packed auditorium. Mr Conway described the history and development of the electronic synthesizer, illustrating the various sounds and effects of his own Yamaha Synthesizer as he presented his talk. People from all disciplines were thoroughly entertained by Mr Conway's talk, coming away with at least a basic understanding of what is involved in designing and playing a synthesizer.

On 16 March 1988 a joint meeting is planned with the IERE and IMechE on 'Vibration Aspects of Condition Monitoring'. This appears to be an area in which a lot of interest is being shown at the moment and it is hoped that more members will come along and learn and contribute to the meeting's success.

Please note that Mike Sullivan has taken over the post of Secretary from Mr R Bainbridge.

Mike Sullivan

North West Branch

Evening visit to the CEGB Regional Control Centre

In October the Branch met at the CEGB Regional Control Centre in Bramhall, Cheshire. This centre not only controls the North West Supergrid but is also the Management Centre for Telecommunications in the Electrical Supply Industry. The main electrical supply control room is the nerve centre for the distribution of electricity from the power station to our homes. The walls of the control room are made up of mosaic maps of the electrical system which show the routes from the power stations to local sub-stations; any faults in the system are indicated by lights. The main requirement is to be able to keep the delicate balance between supply and demand. This means being able to deal quickly with sudden demands, as in the case of an interval during a good film on the television when many kettles are switched on. It is also essential to compensate for loss of supply caused by natural phenomena like last year's gales and thunderstorms around London, or faults in the system. The control room is now largely computer controlled; this has resulted in a more efficient use of the system, and also allows remote switching at many of the sub-stations.

The Telecommunications Manage-

Continued overleaf

Letter from the Vice-President Groups and Branches

I started my letter in the last *Bulletin* by referring to the good number of reports from Groups and Branches that the previous edition had carried. I start this one by expressing my amazement at the fact that Group and Branch news covered three pages in the last edition. Secretaries please keep up the good work so that your colleagues can read about all they have missed (some extremely interesting speakers it appears!) and perhaps make a note to attend the next meeting. Details of many meetings are given in the *Bulletin* but the latest information can always be obtained by telephoning Head Office. Group and Branch Officers responsible for meetings should keep Cathy Mackenzie informed of any programme changes so that she can maintain an efficient service to members.

Congratulations to the Speech Group on the launch of their newsletter 'Speakeasy' which includes amongst the notices, jobs and reports a cartoon entitled 'The Graphic Equalizer'. With desk top publishing advancing at such a speed perhaps other groups will follow suit.

Further discussions have taken place on the matter of Group and Branch finances and the Institute Treasurer is currently working on a scheme which it is hoped will overcome the difficulties that treasurers have experienced in operating their accounts. I hope to be able to call a Group and Branch representatives meeting in the near future to discuss this.

Geoff Kerry

ment Control Room is of similar design. It consists of a computer-controlled digital network that gives communication between all sectors of the industry. In addition to normal telephone conversations the network also carries data. There is high system reliability in that both British Telecom and Mercury are used together with the CEGB's own microwave network, thus ensuring a low probability of total failure.

Following the tour we had discussions over light refreshments, and Mike Ankers thanked our hosts on behalf of the Branch.

Chris Waites

Scottish Branch

A small but select band of Scottish branch members visited the Department of Otolaryngology of Edinburgh Royal Infirmary on 12 November 1987. The meeting was addressed by Dr Alastair Kerr, Consultant Surgeon, and Dr Robin Barr-Hamilton, Audiological Scientist.

Dr Kerr reviewed the physiology of the ear and illustrated his talk with a number of slides. He discussed the question of conductive and sensorineural deafness and outlined the progress that had been made in the treatment of conductive deafness. Our members were most impressed at the intricacy of the surgery required and the high success rates quoted. Dr Kerr's remarks on sensorineural deafness led to lively discussion in the meeting on problems of impulsive noise, tinnitus and industrial audiometric screening.

Dr Barr-Hamilton then took over and discussed various forms of audiometric testing including the use of cortical audiograms. A variety of different hearing aids were reviewed and our members were impressed by the progress made in this field. Dr Barr-Hamilton's address also brought about discussion on a number of points including cochlear echo and its possible use in diagnostic audiometry.

After some very welcome coffee, Dr Kerr and Dr Barr-Hamilton conducted the visiting party round the audiometric testing facility which serves the Lothian area. We were shown a modern form of the ear-trumpet, which was surprisingly effective, as well as a standard hearing aid switched to its electromagnetic loop circuitry. Our members were very impressed by the testing facilities and the sound-proof rooms of what was clearly a very professional and hard-working audiological unit.

All Scottish branch members are reminded that there will be a technical meeting and a visit to the new facilities at the Department of Building, Heriot-Watt University, Riccarton on Wednesday 17 February 1988. The AGM will also be held on that date immediately after the visit.

W J Laurie

South West Branch

The Branch, in association with the SW Branch of the Association of Environmental Health Officers, and Cornwall College of Further Education, embarked on its most ambitious project, an International Seminar planned for June as a contribution to the European Year of the Environment. Despite circulating some 3000 leaflets locally and via the two Institutes, the Seminar had to be cancelled when two weeks before the event only seven people had registered their interest.

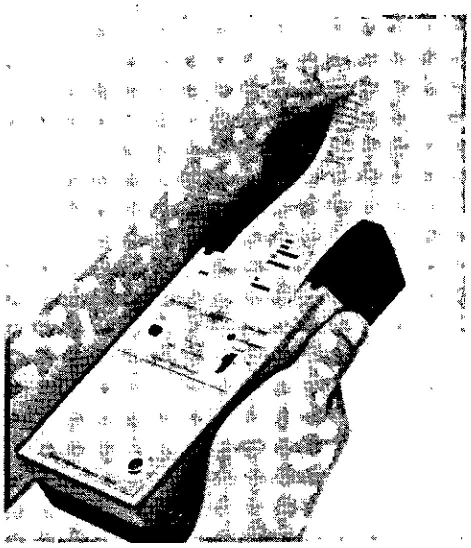
It has long been realized that the SW Branch activities have been on a precarious footing and faced with this latest setback the time has come for change.

R T F Vanstone

New Products

Submissions for inclusion in this section should be sent direct to J W Sargent, Building Research Establishment, Garston, Watford WD2 7JR.

Graphic Documentation Printer B&K Type 2318



The B&K Type 2318 graphic documentation printer is a small lightweight battery operated printer for graphic and alphanumeric printouts and is particularly suitable as an accessory for the B&K 2231 modular precision sound level meter.

When used with the 2231, all information necessary for the accurate analysis of the measurement data (e.g. band width, range, weighting factor and the type of module in use) is recorded on the printout and space is available for the operator to add any other relevant information. The presentation of data can be in the form of fully annotated graphs, tables or multi-component bar charts.

Phase meter B&K Type 2977
The Type 2977 phase meter has a 4-digit display of phase angle in degrees or radians and of frequency in Hertz. The frequency range is from 2 Hz to 200 kHz. The resolution is 0.1° or 1/1000 radian. There is an adjustable delay from 1 microsecond to 163.8 milliseconds and a DC output for recording.

Accelerometers for severe environments
Details of two new Delta Shear accelerometers for use in severe environments have been released by Bruel & Kjær (UK) Ltd.

The Type 8315 is suitable for use at 250° C, has a frequency range from 0.1 to 8100 Hz and weighs 102 grams.

The 8317 is certified as intrinsically safe for explosive areas (Class EEx 11C T6/T5/T4), has a built-in line drive amplifier, a frequency range from 0.2 to 7500 Hz and weighs 112 grams.

Further details from Bruel & Kjær (UK) Ltd., 92 Uxbridge Road, Harrow, Middlesex HA3 6BZ Tel: 01-954 2366.

Octave analyser Type CRL 2.37A
The CRL 2.37A is intended both as a precision sound level meter and as a fully integrated octave analyser. It is a fully graded convertible unit which accepts all the Cirrus range of microphones, vibration inputs and artificial ears directly or via a gooseneck or extension cable. Thus all grades of IEC 651 are available to the user up to and including Grade 1. The instrument has a range from 20 to 154 dB. Ten octave bands are included to cover the whole of the acoustic frequency bands (31.5 Hz to 16 kHz) and the filter performance meets or exceeds the requirements of IEC 225. The filters can be 'switched-in' instead of 'A', 'C' or flat frequency weighting or in series with the weighting. Impulse, Fast and Slow response speeds are available and the maximum level at each response speed can be read with the 'maximum rms' circuit. The meter is scaled 0 to +34 dB for sound and 1 to 50 for vibration. An interface option allows the CRL 2.37A to be used with a computer, to plot spectra or noise data.

Noise dosemeter M–8B
The Quest M–8B noise dosemeter available from Cirrus Research measures noise exposure in accordance with ISO R 1999. It is a lightweight rugged pocket-sized instrument with a microphone which is clipped on to the shirt collar where it receives the same dose as the user. The unit is completely selfcontained with LED digital display. A rapid count rate permits accurate short-term exposure measurements and rapid and accurate calibration. The memory unit retains exposure data even when the instrument is switched off and a protected 'reset' prevents the accidental erasure of data.

Data logging sound level meter CRL 2.36
The CRL 2.36 is a unique sound level meter which takes and stores a series of integrated data elements, called 'short L_{eq}' elements. Each element is a true representation of the actual energy occurring during the 1/8th of a second being integrated. The CRL 2.36 stores 114,000 sets of these data in its internal memory. It is capable of measuring over a 150 dB range to a resolution of 0.1 dB.

The unit can be turned off and any time later the data transferred to an IBM-compatible computer for storage on disk. The computer can be used to calculate from the data statistical indices, or the noise level of single events or of a given period of time. The source of noise can be coded while the CRL 2.36 is acquiring data.

Details on the above products can be obtained from Cirrus Research Ltd., Acoustic House, Bridlington Road, Hunmanby, North Yorkshire YO1 0PH Tel: 0723 891655.

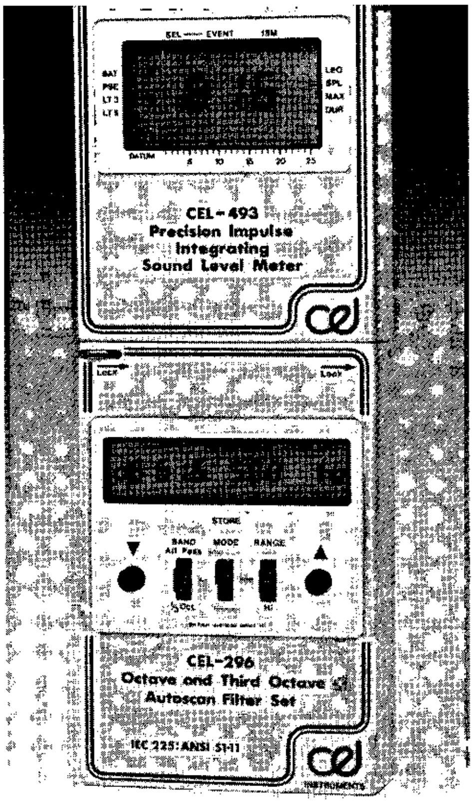
Battery powered two-channel FFT analysers
The AD-3524 and 3525 two-channel FFT analysers are fully portable battery-powered instruments which offer every major advanced digital function as standard. Standard functions include acoustic intensity, cepstrum, Hilbert transform, curve fit, open and close loop, octave and one-third octave as well as the traditional two-channel FFT analysis package. The units are either 20 or 100 kHz with 14-bit resolution. Real-time rates are as high as 5 kHz and can select up to 8192 points for the FFT calculation.

Details from Hakuto International UK Ltd., 33-35 Eleanor Cross Road, Waltham Cross, Herts EN8 7LF Tel: 0992 769090.

Portable dual channel FFT analyser type CF-350
The CF-350 has been designed as a field portable twin channel FFT analyser and weighs only 13 kg. It is approximately the size of a general purpose oscilloscope. Despite its small size it is fitted with a 512 k byte RAM and a 1 M byte floppy disk drive for data storage. Real time zoom plus waterfall display, signal

averaging, extensive triggering and post processing functions are all provided as standard features.

Autoscanning frequency filter set CEL-296



The CEL-296 autoscanning third octave band filter set is a plug-in accessory for use with CEL hand-held sound level meters. In addition to the coverage of the normal audio bandwidth in both octave band and third octave band resolution, the filter set has an extended low frequency analysis range down to 5 Hz enabling it to be used for vibration as well as acoustic analysis.

When used as a conventional filter set it is compatible with the CEL-160 graphic recorder permitting automatic hard-copy of 36 one-third octave bands from 6.3 Hz to 20 kHz. The CEL-296 has been designed to be compatible with the CEL low power serial interface which enables it to be used with the CEL-493 and CEL-275B precision integrating sound level meters and with the CEL-238 secondary processor.

Further details from Lucas CEL Instruments Ltd., 35/37 Bury Mead Road, Hitchin, Herts SG5 1RT Tel: 0462 422411.

Low cost noise indicators

Pulsar Instruments announce the Model 208 series of noise indicators which use ten LEDs to display the noise level in 2 dB steps in place of a conventional meter. The Model 208 covers the range 70-120 dBA and is intended for use in the workplace. The Model 208L reads down to 50 dB(A) and is ideal for checking environmental noise levels. Model 208F has a flat response and covers the range 70-120 dBLin making it suitable for setting up loudspeaker and disco systems. The 208 models are made in the UK under licence from Quest Electronics and sell at around £100.

Further details from Pulsar Instruments, Bridlington Road Industrial Estate, Hunmanby, North Yorkshire YO14 0PH. Tel: 0723 891662.

New data sheet for CEL–275 sound level meter

Lucas CEL Instruments Ltd have published a data sheet describing the CEL–275 Precision Integrating Sound Level Meter. This is the latest addition to the CEL programme of instruments designed as 'system sound level meters'.

The brochure graphically illustrates the L_{eq} measurement principle which is a requirement for all industrial and environmental noise measurements, whilst a detailed specification will enable the professional acoustician to verify the instrument's compliance with both IEC 651 and IEC 804 standards for sound measurement instruments.

NON-INSTITUTE MEETINGS

1988	
23-24 February	*Sound Eighty-Eight,* organized by the Secretariat of the Sound and Communications Industries Federation, at Heathrow Penta Hotel, London Heathrow Airport. Exhibits, Seminars and the official launch of the Federation and its new journal.
1-3 March	*Urban Noise and Territorial Administration:* 3-day International Meeting, organized by the City of Modena, Italy. Contact: Prof. P Zaniol, PMP Settore Fisico Ambientale, USL n. 16, Via del Pozzo 71, 41100 Modena, Italy.
1-4 March	84th Audio Engineering Society Convention, Paris, France. Contact: H A O Wilms, Exh. Director, Zevenbunderslaan 142/9, B-1190 Brussels, Belgium.
7-10 March	DAGA '88, Braunschweig, FGR.
22-25 March	OPTICS/ECOOSA '88 (in conjunction with Electro-optics and Laser Exhibition). Metropole Hotel/NEC, Birmingham.
28-30 March	16th Annual Congress of the Associazione Italiana Acoustica, Milan. Information: Congress Studio, Via Cappuccio 19, 20123, Milano.
29-30 March	*Colour Information Technology and Visual Displays,* Second International Conference organized by the Institution of Electronic and Radio Engineers. Venue: The University of Surrey, Guildford. Contact: The Conference Secretariat, Institution of Electronic and Radio Engineers, 99 Gower Street, London WC1E 6AZ. Tel: 01-388 3071.
9-10 April	*Physics in Medical Ultrasound.* Contact: Dr K Martin, Regional Medical Physics Dept, Newcastle General Hospital, Newcastle upon Tyne NE4 6BE.
11-14 April	ICASSP '88, USA. *International Conference on Acoustics: Speech and Signal Processing.* Information: A E Rosenberg, Room 2D-58, Murray Hill, New York, NY 07974.
26-27 April	*Stress Analysis and the Micro – '88.* Brunel University, Uxbridge, Middx.
4-5 May	Schalltechnik '88, Baden Baden, FGR. Information: Dipl. Ing. S Jud, VDI, Graf-Recke-Strasse 84, D-4000 Düsseldorf 1.
4-7 May	9th Conference on Acoustics, Budapest, Hungary. Inf: Optical, Acoustical and Film Technical Society, Fö u.68, H-1027 Budapest.
11-13 May	15th AICB Congress – *Noise Abatement,* Balatonfüred, Hungary. Secretariat: c/o Scientific Society for Transport, Kossuth tér 6/8, H-1055 Budapest.
16-20 May	Mtg. of Acoustical Society of America, Seattle, Washington. Details: Murray Strasberg, Acoustical Society of America, 500 Sunnyside Blvd, Woodbury, NY 11797.
5-9 June	19th International Congress of Audiology, Jerusalem, Israel: *Early Detection, Identification and Management of Deaf Infants.* For information contact: Secretariat, 19th International Congress of Audiology, PO Box 50006. Tel Aviv 61500.
6-10 June	XXXII Etan Conference, Neum, Yugoslavia. Contact: Prof. P Pravica, Electrotechnical Faculty, Bulevar Revolucije 73, YU-11000 Belgrade.
15-17 June	*NAM-88, Nordic Acoustical Meeting,* organized by the Acoustical Society of Finland and the Tampere University of Technology. Contact: Jukka Linjama, Acoustical Society of Finland, Metallimiehenkuja 8, SF-02159, Espoo, Finland.
20-22 June	*NOISE-CON 88, National Conference on Noise Control Engineering,* on Purdue University campus, together with exhibition; theme: Noise Control Design: Methods and Practice. Contact: Conference Secretary, Ray W Herrick Laboratories, Purdue University, West Lafayette, IN 47907, USA.
5-7 July	*Sixth British Conference on the Teaching of Vibration and Noise.* Contact: Mr P Round, Short Course Support Unit, Sheffield City Polytechnic, 43 Broomgrove Road, Sheffield S10 2NA.
18-29 July	*Acoustic Data Processing,* Royal Military College of Canada, Kingston, Ontario.
21-25 August	*NOISE '88, 5th International Congress on Noise as a Public Health Problem.* Abstracts by January 15, short papers before May 1, 1988. Contact: Conference Secretariat, Noise '88, c/o Reso Congress Service, S-113 92 Stockholm, Sweden.
21-27 August	I.U.R.A.M. Congress, Grenoble, France.
30 August – 1 September	*Inter-Noise '88, 17th International Conference on Noise Control Engineering,* Avignon, France. Theme: The Sources of Noise. Contact: Secretariat, Inter-Noise '88, BP 23, F 60302 Senlis Cedex, France.
5-7 September	*Noise Control '88,* Krakow, Poland. Information: Doc R Panuszka, General Secretary, *Noise Control '88,* Institute of Mechanics and Vibroacoustics AGH, Al. Mickiewicza 30, 30-059 Krakow, Poland.
5-8 September	*Healthy Buildings '88.* CIB Conference organized by the Swedish Council for Building Research in collaboration with the National Institute of Environmental Medicine, with the co-sponsorship of the World Health Organization. Information from: The Swedish Council for Building Research, S:t Gorangsgatan 66, S-112 33 Stockholm, Sweden.
3-5 October	I.E.E.E. Ultrasonics Symposium, USA. Details: W D O'Brien Jnr, University of Illinois, Bioacoustics Research Lab., Urbana, Illinois IL 61801.

Information relating to meetings of possible interest to readers should be with the Editor at the address on page 1 no later than four months before the date of the meeting.

Book Review

Nonlinear Underwater Acoustics

B K Novikov, O V Rudenko and V I Timoshenko, translated by Robert T Beyer Published for the Acoustical Society of America by the American Institute of Physics, New York, 1987, 272 pp, paperback, $25.00.

A necessary trick for the reviewer is to show the linear above-water reader that this is not really a treatise on nonlinear underwater acoustics, but actually a handbook for one of the most fascinating devices developed in the last couple of decades – the parametric source array. In such an array the medium plays an active role in the formation of the beam pattern.

Chapter 1 introduces the simplest form, with a small primary transmitter generating pump waves of high frequency and high intensity. The pump signal is biharmonic with neighbouring frequencies f_1 and f_2. The nonlinear processes in the medium generate waves at several other frequencies, including the difference frequency (f_1-f_2). For a collimated pump signal we virtually have an endfire source array at this secondary or difference frequency, radiating a pencil beam. Attenuation is high at the pump frequencies and this has two effects: first the pump signal is unimportant at moderate ranges, and second the difference-frequency source array tapers and so produces a very clean beam uncluttered by side lobes. But the main piece of magic is to produce a surprisingly narrow beam at the secondary frequency, given the smallness of the transmitter.

Later chapters spell out the theory, with various methods of calculation. One of these accounts for the progressive changes in the propagating wave profile according to Khokhlov's ideas, leading to the KZK equation. There are many different regimes of operation of the parametric radiator, and it can be necessary to allow for diffraction, dissipation, dispersion, focusing, and the particular effects of very high intensity.

The latter half of the book deals with more practical matters, such as construction and testing. Thus there are tabulations of the specifications for many Russian parametric devices. We are quoted a range of primary frequencies from 20 kHz to 5 MHz, with maximum source level 226 dB re 1 micropascal referred to 1 metre. Secondary frequencies run from 100 Hz to 500 kHz, with maximum source level 186 dB. After admiring the wide spread of possible values we may go on to realize that whatever other merits the parametric source may have it is not a high-efficiency device, and does not achieve really high levels at the difference frequency.

Although the idea of the parametric source is beautiful there has been some feeling in the past that it is one of those ideas without too many obvious applications. It is therefore interesting to read that 'measurement broadband parametric radiators are as necessary for underwater sound laboratories as standard signal generators are in radio engineering', an assertion partly based on the wide range of difference frequencies possible from a single device. Applications discussed here include information transmission and active sonar, the latter covering fathometers and fish finding.

Napoleon took much plunder in Moscow, and apparently found it necessary to hide his trophies in Semlevskii Lake. There have been many search expeditions, but echo-sounding is usually hindered by the sludgy gaseous sediments. However, parametric sonar can penetrate into the mud, and the echograms are there to prove it. This appears partly due to the narrowness of beam, and partly to some of the pump wave interaction actually taking place in the gaseous sludge – where there is a greater nonlinearity in the medium.

The book also includes extensive treatment of the nonlinear parametric acoustic receiver or PARRAY, in which a high-frequency pump wave is modulated by the low-frequency signal that it is desired to detect. In addition it covers opto-acoustic sources, where the energy absorbed from an electromagnetic source, such as a laser, causes a local expansion and a radiation of sound. And perforce it does have a certain amount of nonlinear acoustics generally.

The authors keep a reasonable balance between the contributions from Russia and from the West, though for the specialist much of the interest will lie in having a compact account of the work in the USSR. Thus there are some 90 citations from Russia and a similar number from the West, to be compared with an annual publication rate of over 250 in 1977! Proper recognition is given to Peter Westervelt's priority for the idea, to Orhan Berktay's pioneering studies, and to the first experimental verification by Bellin and Beyer. Incidentally Bob Beyer is not only the present translator but also the author of a general book on nonlinear acoustics.

The present production is very well done, with a format similar to that of the ASA reprint series. Your reviewer is an enthusiast for the merits of the book, though it is admitted the subject is not his subject and he is not well-placed to catch mistakes. The non-specialist should be encouraged to dip into it. For example, the above-water reader might note, and even set out to rectify, the smallness of the effort on parametric arrays in air, which parallels the case for sonar itself. This position is despite Westervelt's original idea having come from a casual observation in air! The specialist, the worker in related fields, and the librarian should be encouraged to buy – and this is made easier by the modest price.

David Weston

TECHNICAL LITERATURE RECEIVED

Guidelines to the design of quieter hydraulic fluid power systems

The BFPA Guidelines to the Design of Quieter Hydraulic Fluid Power Systems have recently been re-issued. The Guidelines were last updated in 1977; since then the Department of Industry has funded a £1.3 million research programme aimed at producing practical solutions to the problems of noise in fluid power systems. This edition of the Guidelines makes full use of the information generated by the research programme and also draws on data from the fluid power and other relevant industries. In addition, some previously unpublished data are included on overall system noise estimating.

Topics covered are: *The basis of noise from fluid power systems; the effect on the human observer; principles for design of quieter systems; enclosures and cladding.*

In each section the reader is taken through a description of the particular noise problem, is shown the results of recent work and is given suggestions for avoiding or curing the problem in practical cases.

Copies can be obtained from BFPA Ltd, Artillery House (4th Floor), Artillery Row, Westminster, London W1P 1RT at £8.00 per copy (inclusive of postage). A free-of-charge copy of AHEM/P5, *Guidelines to Contamination Control in Hydraulic Fluid Power Systems*, may be obtained on request.

Institute of Acoustics

Meetings

3 February	M	European Year of the Environment, *Noise to the Year 2000*, IOA/IEH Meeting	Birmingham
17 February	LB/M	Noise and Vibration Control on Construction Sites (one-day Seminar)	County Hall, London
24 February	SB	Modern Developments in Noise Control Equipment (and AGM) 1.30 p.m.	Guildhall, Portsmouth
March	SB	Practical Acoustical Applications in Property Conversions	Guildhall, Portsmouth
1 March	PAG	Digital Signal Processing and Display Techniques for Ultrasonics	London
16 March	LB	Noise Control by the Airfields Environment Federation Trust	County Hall, London
5-8 April	M	Spring Conference – **Acoustics '88**	Cambridge
20 April	LB	Low Frequency Noise	County Hall, London
27 April	SB	Inaudibility in the Assessment of Noise Nuisance	To be decided
28 April	SB	Condition Monitoring	University of Southampton
18 May	LB	Visit to British Aerospace	Hatfield
25 May	SB	Building Services Noise	N E Surrey College of Technology
15 June	LB	The Problem of Marine Vibration	County Hall, London
22-26 August	M	7th FASE Symposium: **Speech '88**	Edinburgh

Key

M = Meetings Committee Programme
BAG = Building Acoustics Group
ING = Industrial Noise Group
MAG = Musical Acoustics Group
PAG = Physical Acoustics Group
SG = Speech Group
UAG = Underwater Acoustics Group
LB = London Branch

EMB = East Midlands Branch
NEB = North East Branch
NWB = North West Branch
SB = Southern Branch
ScB = Scottish Branch
SWB = South West Branch
YHB = Yorkshire and Humberside Branch

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