

Index of NPL acoustics publications 1981 - 1990

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ABSTRACTS OF PUBLICATIONS 1981 - 1990

A case study of environmental noise evaluation

Acoustics Report Ac 96, 1980 (April)

R. F. Higginson and A. J. Rennie.*

The noise in the neighbourhood of a hovercraft ferry terminal has been measured and quantified using the equivalent continuous sound level, L_{eq} . A number of different sources of noise were present in the area concerned and the measurements were made for demonstration purposes. The main objective was to illustrate how individual components of a noise environment can be evaluated and to that end the magnitudes of individual noise events were determined by their single event exposure levels, L_{AX} . In addition, the intention was to show how the levels of the total noise can be determined from limited measurements of the components and how a noise prediction formula can be established.

National and international standardisation

Institute of Acoustics, Conference on Standardisation in Acoustics, 1980, Teddington. Preprints, 1-7.

D. W. Robinson.*

To appreciate the thrust of standards activity and the relationship between its several branches, it is useful to distinguish broadly between standard in the metrological sense (Eichmass, Ger.; etalon, Fr.) and standard in the sense of a specification (Norm, Ger.; norme, Fr.). Metrological standards activity is characterised by the hierarchical principle of traceability, normally from BIPM through national laboratories (eg NPL), thence via secondary standards held at lower levels which serve, in turn, to calibrate instruments at the point of end-use. The BIPM link is missing in the case of acoustics, possibly because the quantities of interest (sound pressure, sound power) are readily derived locally from established SI base units; also the secondary calibration chain is relatively thin in the UK, the British Calibration Service being inoperative in acoustics probably due to low demand compared with other technologies. On the other hand, in the field of acoustical specification standards, including vibration and ultrasonics, there has been 30 years of unbroken and expanding activity with an abundance of published standards on measuring instruments, acoustical test methods (especially noise emission) and applied scientific data (eg hearing thresholds).

(Also in published form,
Acoustics Bulletin, 1981, 6 (2), 4-7)
See item 272.

Dissemination of audiological standards

Institute of Acoustics, Conference on Standardisation in Acoustics, 1980, Teddington. Preprints, 37-39.

M. S. Shipton.

Diagnostic audiology makes use of a wide variety of tests and physical measurements. Tests such as tympanometry, speech audiometry and electric response audiometry are now carried out almost routinely but at present it is only in the area of conventional pure-tone threshold audiometry that accepted specifications and a system for traceable instrument calibration exist.

This system, recently developed for both air and bone conduction by the NPL in collaboration with the Department of Health and Social Security, is based on the use of secondary standards and reference devices which provide links to the appropriate national standards. The system evolved provides not only for the calibration of audiometers at the working level but also for the checking of dedicated test equipment used to maintain the working instrument in correct calibration. The principles of the tests carried out at NPL are described.

A study of the effects of fluctuation frequency on adverse reactions to noise

Acoustics Report Ac 97, 1980 (September)

H. C. Fuller and D. W. Robinson.*

As a result of theoretical considerations, it has been suggested that the fluctuation term in the formula for Noise Pollution Level should be weighted according to the frequency of the level fluctuations. In this modified form the term is down-weighted for level fluctuations which occur at high or low frequencies but is unchanged for intermediate frequencies.

This report describes an investigation into the effects of the frequency of level fluctuations on the adverse reaction generated by a noise stimulus. Test stimuli with levels varying by 10 dB and 20 dB with periods of between 6 and 600 seconds were used and the adverse reaction generated after 10 minutes was measured. The results were examined in relation to the noise ratings L_{NP} , L_{eq} , a measure of the rate of fluctuation of the level and the proposed modification of L_{NP} .

None of the four measures fully explains the results, but there is some evidence to support the modification of L_{NP} , suggesting that only level fluctuations at frequencies between 0.1 Hz and 0.01 Hz contribute to the general adverse reaction.

189. An objective experimental method for studying aversion to noise

Acoustics Report Ac 98, 1980 (October)

H. C. Fuller and D. W. Robinson.*

A novel method which avoids the need to rely on introspection and verbal descriptors in the experimental assessment of reaction to an aversive noise stimulus is presented, together with results of an experiment designed to test the method.

Subjects were given the option of reducing the impact of an unpleasant auditory stimulus consisting of irregular impulses by substituting a continuous white noise, which at higher levels would itself become aversive. The hypothesis was that at a particular level of the continuous noise, aversive reaction to the combined stimulus would reach a perceptible minimum. Objective measurement of this level would then give a non-verbal measure of a subject's aversion to the impulse stimulus; further, unpleasant noises could be ordered because higher continuous noise levels would be set in the presence of more aversive stimuli.

An experiment was conducted with three levels of impulse and it was found that the method could be used to differentiate successfully between the subject's reactions to these stimuli. Some subjects showed a marked reluctance to experiment with the available level control and there was an indication that the task used to normalise the subject's attention interfered with the experiment, but both difficulties could be overcome.

The method described may be a useful tool in the battery of experimental tests available for the study of aversive reaction to noise.

190. Uncertainties in realising the standard of sound pressure by the closed coupler reciprocity technique

Acoustics Report Ac 99, 1980 (December)

M. E. Delany* and E. N Bazley.*

Sources of uncertainty associated with realising the standard of sound pressure using one-inch laboratory standard microphones calibrated by the closed coupler reciprocity technique are discussed in detail. A measurement technique designed to achieve an acceptable level of uncertainty is described and the components of systematic and random uncertainties in the range 63 Hz to 12.5 kHz given. With suitable microphones the overall systematic uncertainty of calibration is estimated to be less than 0.025 dB at frequencies up to 1 kHz, increasing to 0.11 dB at 10 kHz.

See item 198.

The assessment of environmental noise

The Association of Consulting Scientists, Symposium on the Problems of Assessing Environmental Noise, 1981, Ealing. Preprints, Paper 1.

B. F. Berry

Environmental noise assessment involves two main aspects. The first is quantification or numerical description of noise which involves measurement of existing sources or prediction for future sources.

The second aspect is evaluation in which the actual or predicted value is compared with some criterion value which, depending on the circumstances, might for example be a legal limit planning guideline.

The problem is discussed from the viewpoint of research and standardisation. Recent NPL contributions to various aspects of the problem are described and some observations on future trends are made.

Thresholds of hearing by air-conduction and by bone-conduction under different masking conditions

Acoustics Report Ac 100, 1981 (June)

M. S. Shipton and D. W. Robinson.*

Air-conduction and bone-conduction thresholds were determined for 152 subjects in the age range 16 to 30 years. Bone-conduction tests were carried out using a B-71 vibrator applied to the left and right mastoid under three conditions at the contralateral ear: unoccluded, masked at 25 dB and at 40 dB sensation level.

For air-conduction audiometry and masking noise a TDH-39 earphone was used. By a systematic process of otological classification of the subjects, the bone-conduction threshold for "normal hearing" could be estimated with an uncertainty of less than 1 dB and interpolated for masking noise levels from zero to 40 dB sensation level. Results are expressed as alternating force levels in an artificial mastoid of current commercial design and also with respect to BS 2497 Part 4. Individual air-bone gaps are shown to be widely spread for an otologically normal group but distributions are normal and have a mean value close to zero.

See item 197.

193. An investigation of the status of bone-conduction audiometer calibration in the National Health Service

Acoustics Report Ac 101, 1981 (June)

G. R. Torr and L. S. Whittle.*

At the request of the Department of Health and Social Security, a survey has been carried out to assess the accuracy and uniformity achieved in the calibration of bone-conduction audiometers in NHS hospitals.

Ten hospital centres were asked to measure the acceleration output of an NPL-calibrated bone vibrator supplied as part of an audit kit. The artificial mastoid and associated measuring equipment at each centre were then brought to NPL, where the artificial mastoid was recalibrated, the measuring equipment checked, and the audit measurements verified.

The mean difference between the hospital measurements and the NPL calibration of the vibrator was of the order of 2 dB at all test frequencies. It was found that individual differences were substantially reduced by re-interpreting the hospital measurements using the up-to-date NPL determination of the sensitivities of the artificial mastoids and by correcting the measurements to a common temperature.

On the basis of the results, recommendations are made with the aim of improving the accuracy of calibration of bone-conduction audiometers.

194. An appraisal of methods for estimating effectiveness of hearing protectors

J. Sound Vib., 1981, 77 (1), 79 - 99.

G. J. Sutton* and D. W. Robinson.*

The protection afforded by a hearing protector to a wearer, defined here as the reduction in A-weighted sound pressure level at the ear, varies between wearers and between noises. "Effective protection" of a protector in a given noise, defined as the value reached by a specified majority of wearers, may be estimated by various methods according to the amount of information available on the noise. These methods comprised the octave-band and numerous "single-number" ratings which attempt, in differing degrees, to allow for wearer and noise-dependent variations. They are reviewed here together with their underlying assumptions. Attenuation data on individual wearers for seven protectors were used in conjunction with 100 noise spectra to test the validity of these assumptions and to calculate and compare the errors of each type of method. On the basis of these results it was concluded that the best single-number method, representing a practical compromise between accuracy and convenience, is one which generates a rating number to be subtracted from the C-weighted sound pressure level of the noise.

195. Audiometric zero for air conduction: A verification and critique of international standards

Audiol., 1981, 20, 409 - 431

D. W. Robinson,* M. S. Shipton and R. Hinchcliffe.**

The international standard of audiometric zero for normal hearing by air conduction was originally given only for laboratory reference earphones. Subsequently, it has been extended to cover earphones in general audiometric use. A new determination is described in which these derived standards are tested by comparison with the measured thresholds of hearing of 108 subjects in the age range 18-30 years. Particular attention is paid to the otological classification of subjects and its relation to the description of otological normality in the ISO standards. Suggestions for adjustment of the standards at certain frequencies are made.

See item 197.

196. Characteristics of a pvdf membrane hydrophone for use in the range 1-100 MHz

IEEE Trans. Son. Ultrason., 1982, SU-29 (1), 18-25.

D. R. Bacon.

The experimental determination of the frequency response, directionality, and electrical characteristics of membrane hydrophones is reported. These characteristics are interpreted in terms of theoretical models, based mainly on published values for the properties of polyvinylidene fluoride (pvdf). The frequency response was determined using both linear and nonlinear acoustic fields. The directionality is affected by the angular variation of piezoelectric sensitivity and also, for large angles of incidence, by Lamb wave propagation in the membrane. The hydrophones are shown to be useful experimental devices both for studying acoustic waves in the frequency range 1-100 MHz and for investigating the properties of pvdf. They are well-suited to the study of nonlinear ultrasonic fields, and those used in medicine and non-destructive testing.

197. A standard determination of paired air- and bone-conduction thresholds under different masking-noise conditions

Audiol., 1982, 21, 61-82

D. W. Robinson* and M. S. Shipton.

Air-conduction (ac) and bone-conduction (bc) thresholds were determined for 96 subjects in the age range 16-30 years. The bc tests were carried out using a B-71 vibrator applied to left and right mastoid under three conditions at the contralateral ear: unoccluded, masked at 25 dB and at 40 dB sensation level; ac audiometry and masking noise used a TDH-39 earphone. By a systematic process of otological classification of the subjects, the bc threshold for 'normal hearing' could be estimated with an uncertainty of less than 1 dB and interpolated for masking noise levels from zero to 40 dB sensation level. Results are expressed as alternating force levels in an artificial mastoid of current commercial design. Variance of the air-bone difference for individual ears is found to be less than the sum of ac and bc threshold variances calculated separately, implying strong air-bone correlation. Comparison is made with other recent studies using B-71 and KH-70-type vibrators, and average results are presented in the context of a proposed international standard for the normal threshold of hearing by bc.

See item 192.

198. Uncertainties in realising the standard of sound pressure by the closed-coupler reciprocity technique

Acoustics Report Ac 99, 1982 (Second edition, January)

M. E. Delany* and E. N. Bazley.*

Sources of uncertainty associated with realising the standard of sound pressure using one-inch laboratory standard microphones calibrated by the closed coupler reciprocity technique are discussed in detail. A measurement technique designed to achieve an acceptable level of uncertainty is described and the components of systematic and random uncertainties in the range 63 Hz to 12.5 kHz are given. With suitable microphones the overall systematic uncertainty of calibration is estimated to be less than 0.025 dB at frequencies up to 1 kHz, increasing to 0.11 dB at 10 kHz.

See item 202.

Pure tone thresholds of hearing

Brit. J. Audiol., 1982, 16, 71.

Abstract of lecture to British Society of Audiology, September 1981.

M. S. Shipton.

This lecture describes work undertaken on both air- and bone-conduction threshold values.

See items 192, 195 and 197.

The absolute calibration of hydrophones and their use in the measurement of the output from medical ultrasonic equipment

Institute of Acoustics Spring Conference, 1982, Guildford.
Proceedings, Paper B.2.1.

Livett,* R. C. Preston and D. R. Bacon.

The most widely used and convenient method of measuring the spatial and temporal characteristics of ultrasonic fields is by means of miniature hydrophones. These hydrophones are not absolute measurement devices and must be calibrated in terms of the voltage they produce for an applied acoustic pressure.

The two techniques for hydrophone calibration which are most commonly used are being studied at the NPL. One method of hydrophone calibration is to measure the total power from a transducer using a radiation pressure balance and compare this with a value for total power obtained by scanning the hydrophone over the ultrasonic field and integrating. In the two transducer reciprocity method, a transducer is first measured by self-reciprocity, and then the hydrophone to be calibrated is placed in the ultrasonic field and its output open-circuit voltage determined. In the first part of this paper, the sources of uncertainty in both techniques are indicated and some of the practical measurement problems are discussed.

The second part of the paper describes the use of hydrophones to determine the output from medical ultrasonic equipment. This equipment can be divided into three broad categories depending on its use: therapeutic, monitoring (Doppler) or diagnostic. In therapeutic equipment, the ultrasound is usually continuous and, as measurements of the intensity close to the transducer front surface are required, there are particular measurement difficulties. Several ultrasonic machines have been measured at the NPL, and the problems of using hydrophones to obtain reliable and accurate results are discussed.

See item 206.

The measurement of speech levels for audiometry

Institute of Acoustics Spring Conference, 1982, Guildford.
Proceedings, Paper D.3.5.

H. C. Fuller and L. S. Whittle.*

A computerised system for speech audiometry has been developed in which the words are stored in digital form and are reproduced at levels controlled by a programmed attenuator. This gives a much greater flexibility in the level and form of presentation than is practicable with a conventional system and makes it easier to examine the different criteria available for equalising the level of presentation of the words.

In a study to find the acoustic measure which corresponds best with the speech detection threshold, a wide range of weighting networks and meter response times was investigated. Detectability measured by a Bekesy technique with repeated word presentation, was correlated with the different objective measures. The meter response time was found to affect the correlations much less than the weighting network used, linear measures giving poor results. The highest correlations obtained with standard measuring equipment made use of the A-weighting and impulse hold settings. The improvement which could be obtained by using a non-standard weighting network matched to the response of the earphones was too marginal to be justified.

An investigation is now in progress to find the best measure relating to the speech reception threshold.

See item 210.

Uncertainties in realising the standard of sound pressure by the closed coupler technique

Metrologia, 1982, 18, 117-132.

M. E. Delany* and E. N. Bazley.*

Sources of uncertainty associated with realising the standard of sound pressure using one-inch laboratory-standard microphones calibrated by the closed-coupler reciprocity technique are discussed in detail. A measurement technique designed to achieve an acceptable level of uncertainty is described and the components of systematic and random uncertainties in the range 63 Hz to 12.5 kHz are given. With suitable microphones the overall systematic uncertainty of calibration is estimated to be less than 0.025 dB at frequencies up to 1 kHz, increasing to 0.11 dB at 10 kHz.

See item 198.

A method amenable to computer control, for the determination of U/i in the reciprocity calibration of condenser microphones

J. Sound Vib., 1982, 85 (1), 132-135.

G. R. Torr and D. R. Jarvis.

A computer-controlled system for the measurement of U/i has been developed, in which a modification of Koidan's method is used. Measurements are now made slightly faster than they were in the previous manually operated system but, most importantly, automation of the measurements has relieved the operator of a repetitive and fatiguing task. Measurements are made with high precision and, despite the fact that the modified version of Koidan's method relies additionally on the linearity of the two measurement channels in the system, the measurements are found to differ by less than 0.01 dB from measurements obtained manually by using the original method.

Nonlinear propagation and the characterisation of medical ultrasonic equipment

Ultrasound in Med. and Biol., 1982, 8, Supp. 1, p8.

Abstract of lecture to Fifth World Congress of Ultrasound in Medicine and Biology, 1982, Brighton.

D. R. Bacon.

The development of techniques for the characterisation of the acoustic output from medical ultrasonic equipment is important for both dosimetry and system performance assessment. The implications of nonlinear acoustical propagation for this characterisation have been investigated through measurements on fields from both medical and experimental laboratory equipment with piezoelectric hydrophones. Existing theory has been used to interpret the results and to determine measurement errors due to finite amplitude effects. The study demonstrates that if reliable measurements are to be made, the performance of the hydrophone and its signal measurement system must be taken into account. For instance, a hydrophone with limited bandwidth can cause errors of up to 40% in the measurement of intensity and this can occur even if no significant nonlinear attenuation has occurred. In addition, to specify the acoustic intensity precisely, it is necessary for the whole acoustic waveform to be characterised and not just the peak acoustic pressure.

The study reveals the importance of specifying precisely the parameters that have been measured and it is suggested that an extra parameter should be determined if the measurements are to be related realistically to patient dose.

PVDF membrane hydrophones - their performance and use

Ultrasound in Med. and Biol., 1982, 8, Supp. 1, p8.

Abstract of lecture to Fifth World Congress of Ultrasound in Medicine and Biology, 1982, Brighton.

Bacon, R. C. Preston and A. J. Livett.*

The piezoelectric hydrophone is one of the most versatile instruments for the measurement of the acoustic fields used in medical ultrasound, but to date the ideal hydrophone has not been developed. One possible design is the membrane hydrophone, and this paper reports the characteristics of the hydrophones of this type that have been developed during a contract between the Department of Industry and GEC-Marconi Ltd. A good hydrophone should have high sensitivity and signal-to-noise ratio, a broad, flat frequency response, good directional characteristics, temporally stable properties and introduce little acoustic perturbation. These aspects of hydrophone performance have been studied for the present devices, and will be discussed in the light of improvements that have been made. In particular, the directivities of hydrophones and the effect of acoustic reflections from the membrane have been studied and improvements in the immunity to RF pick-up have been achieved.

The devices have predictable performance characteristics, and are therefore well suited for use as secondary standards. They are also valuable as field devices for the characterisation of medical ultrasonic fields.

Absolute hydrophone calibration

Proceedings of Fifth World Congress of Ultrasound in Medicine and Biology, 1982, Brighton, 191-195.

A. J. Livett,* D. R. Bacon and R. C. Preston.

Ultrasonic hydrophones are the most widely used and convenient method of measuring the spatial and temporal behaviour of ultrasonic fields. These hydrophones are not absolute devices and the relation between the voltage they produce and the applied pressure in the ultrasonic field must be determined by calibration.

This paper describes the two techniques currently in use at the NPL for hydrophone calibration and discusses the sources of uncertainty and measurement problems in both the techniques. The two methods have been used to calibrate a membrane hydrophone, and the calibration figures obtained over a range of frequencies are compared.

See item 200.

207. A new method for ultrasonic hydrophone calibration

IEEE Ultrasonics Symposium, 1982, San Diego.
Proceedings, 2, 700-704.

D. R. Bacon.

A new method for the absolute calibration of hydrophones at ultrasonic frequencies is being developed which relies on predicting the effect of finite amplitude propagation in a transducer field. A mathematical model has been implemented which predicts both the extra attenuation of the fundamental component and the relative amplitude of the harmonic components. By making appropriate measurements in the field of a transducer it is thereby possible to calibrate a hydrophone absolutely at a number of frequencies.

The results obtained are self-consistent and in good agreement with the results of conventional methods. The method is well suited to calibration at ultrasonic frequencies because of the relative ease of production of appropriate high amplitude fields and the relative inaccuracy of existing techniques. Advantages of the technique are the capability of performing calibrations at several frequencies simultaneously and its insensitivity to transducer performance. The limitations of the technique and prospects for its improvement are also discussed.

208. The effect on the measurement of aircraft noise of reflections from the ground

Acoustics Report Ac 102, 1982 (December)

R. C. Payne.

Published data relating to the acoustic impedance of various ground surfaces have been used to estimate the influence of ground reflection on levels of aircraft noise measured at the conventional height of 1.2 m. It is shown that the effect on the perceived noise level can be determined by means of the pressure reflection coefficient at a frequency of 2 kHz, hence removing the requirement for information on acoustic impedance as a function of frequency.

A number of techniques for determining the reflection coefficient of ground surfaces at a single frequency have been evaluated and a practical procedure for in-situ measurements has been developed. Using this the reflection coefficients of a variety of ground surfaces have been measured and data are reported.

Annoyance due to railway noise and traffic noise: A further comparison

J Sound Vib., 1983, 88 (2), 275-281

B. F. Berry.

This letter is in response to a paper by Fields and Walker [J. Sound Vib., 1982, 81, 51-80] in which annoyance response due to railway noise obtained in the ISVR Rail Noise survey were compared with those due to road traffic noise in Langdon's Greater London survey of 1972 [J. Sound Vib., 1976 47, 243-263]. A social survey of annoyance due to road traffic noise not analysed by Fields and Walker is reanalysed and further comparisons made. The results indicate large differences between road traffic noise surveys and also suggest that railway noise sometimes incurs greater annoyance than road traffic noise.

Speech level standardisation in audiometry

11th International Congress on Acoustics, 1983, Paris. Contributed papers, 3, 205-208.

H. C. Fuller.

Using a computerised system for speech audiometry, the speech reception threshold has been correlated against a number of acoustic test measures. It is shown that, using standard measuring equipment, the use of A-weighting before the level measurement produced correlations better than 0.9.

See item 201.

211. Aircraft noise measurement using ground-plane microphones

11th International Congress on Acoustics, 1983, Paris. Contributed papers, 6, 97-100.

R. C. Payne.

Sound pressure levels from several ground-plane microphone configurations are compared with pressure-doubled levels derived from the standard 1.2 m microphone position.

Below 3.15 kHz reasonable estimates of the pressure-doubled spectrum are obtained but at higher frequencies interference and microphone directivity effects occur. The importance of these effects on the measurement of different aircraft types is discussed.

Intercomparison of sound pressure standards

11th International Congress on Acoustics, 1983, Paris. Contributed Papers, 6, 343-346.

M. E. Delany,* E. N. Bazley* and S. P. Dowson.

An intercomparison of the realisation of the standard of sound pressure over the audio frequency range has been undertaken among six European primary calibration laboratories under the auspices of the Community Bureau of Reference (BCR) of the EEC. NPL acted as central laboratory and calibrated ten 1-inch laboratory standard condenser microphones using a reciprocity technique based on IEC Standard 327:1971 but incorporating a number of significant improvements. Each participating laboratory received two of these for calibration over the range 125 Hz to 8 kHz and then returned them to the central laboratory for recalibration. The reported sensitivity levels differed by up to 0.1 dB at low and middle frequencies and by 0.15 dB at high frequencies; such discrepancies, although small, are nevertheless significant. Some progress has been made towards tracing the likely sources of error and subsequent work has indicated that maximum differences are now only about half as large as those reported initially. Many factors contribute to the overall uncertainty in the sensitivity level of a standard microphone and the most significant components will be considered in some detail.

See item 198.

L_{Aeq} and subjective reaction to different noise sources: A review of research

Internoise 83, 1983, Edinburgh. Proceedings, 2, 993-996.

B. F. Berry.

One important aspect of the problem of a unified measure of environmental noise is the question of whether, in general, subjective reaction to noise at a given value of L_{Aeq} is the same whatever the source of the noise. In this paper, published research results relating to this question are reviewed. The review is necessarily limited in scale and, in particular, attention has been focused on comparisons between major sources, ie road traffic, aircraft, railways and industrial/construction noise. What might be termed second-order comparisons, eg between different types of railway noise, have been excluded in order to reduce the review to manageable proportions. Nevertheless, it is hoped that this account of the current situation will indicate some of the difficulties associated with the question of "source-differences" and highlight areas requiring further study.

PVDF membrane hydrophone performance properties and their relevance to the measurement of the acoustic output of medical ultrasonic equipment

[. Phys.E: Sci. Instrum., 1983, 16, 786-796.

R. C. Preston, D. R. Bacon, A. J. Livett* and K. Rajendran.*

Three basic types of membrane hydrophone made from the piezoelectric polymer polyvinylidene fluoride (PVDF) are described. These have been developed as instruments for the characterisation of ultrasonic fields in the megahertz frequency range. Performance properties such as sensitivity, directional response, membrane reflection, linearity and signal-to-noise ratio are considered for various devices made from films of thicknesses between 0.006 mm and 0.080 mm and with active elements from 0.5 mm to 4 mm in diameter.

Noise-attenuating characteristics of TDH-39 earphones fitted with MX-41/AR ear cushions

J. Sound Vib., 1983, 91 (2), 315-317.

M. S. Shipton.

Criteria for permissible ambient noise levels during audiometric testing depend partly on the noise attenuating characteristics of the earphone and cushions used. Results of measurements of the attenuation characteristics of Telephonics TDH-39 earphones when fitted with MX-41/AR ear cushions, a combination widely used in industry, are described.

Finite amplitude distortion of the pulsed fields used in diagnostic ultrasound

Ultrasound in Med. & Biol., 1984, 10 (2), 189-195.

D. R. Bacon.

A simple theoretical model of the nonlinear propagation of pulsed focused beams is described. It enables the distortion of the peak cycle of the pulse to be calculated from a few experimentally-measured parameters. The model is discussed and justified for application to the fields generated by medical ultrasonic diagnostic equipment. It is particularly relevant for specifying the degree of distortion present, as might be required by future written standards for diagnostic equipment performance. Preliminary experimental verification of the model is reported.

217. Radiation pressure and its measurement

IEEE Ultrasonics Symposium, 1983, Atlanta.
Proceedings, 749-751.

A. J. Livett* and S. Leeman.**

Measurement of the acoustic force on a target is a much-favoured method for the calibration of medical ultrasonic transducers, even though the relationship between the measured quantity and the true field variables is still a matter for debate. In this paper, a simple theory is developed in which radiation pressure, ie the time-averaged force per unit area on the surface of a target, appears as a true field parameter. Proceeding from a definition for radiation pressure, which is compatible with almost all existing approaches to the subject, some long-standing discrepancies in published values are resolved.

The design of a practical, sensitive and accurate radiation pressure balance is fraught with problems. The concept of a perfectly-absorbing target is discussed, and some sources of systematic uncertainty in its use are pointed out. Some reflector target configurations are analysed, and a novel design for a sensitive system is described.

218. Medical ultrasonic standards at NPL

IEE Proceedings, 1984, 131, Part A, (4), 233-240.

R.C. Preston and A. J. Livett.*

Absolute measurement of the acoustic output of medical ultrasonic equipment in the megahertz frequency range is discussed, together with the methods developed at NPL for the determination of the total ultrasonic power using a radiation pressure balance and the measurement of spatial and temporal field quantities with miniature piezoelectric hydrophones. The principles of the radiation pressure balance and the absolute calibration of hydrophones, which form the basis of the NPL ultrasonic standards programme, are described. Finally, beam calibration systems, which have been specially developed for the rapid and quantitative evaluation of ultrasonic fields, are briefly discussed.

219. A comparison of displacement and pressure waveforms of a nonlinear ultrasonic field

J. Ultrasound in Med., 1984, 3 (9), p73.

Abstract of lecture presented to the 29th Annual Convention of the American Institute of Ultrasound in Medicine, Kansas.

D. R. Bacon.

The temporal and spatial properties of acoustic waves may be described using one of several field parameters. Examples are acoustic pressure, velocity, displacement or even temperature. Each parameter requires a different experimental method for its measurement, but they are all related through the characteristic equations of the medium. This paper reports a comparison of the waveforms obtained by using a membrane hydrophone to measure acoustic pressure and a laser interferometer to measure displacement in a wave distorted by nonlinear propagation and it is shown that the two measuring methods correspond well. The frequency and acoustic pressure used were typical of those encountered in biomedical ultrasound. Consequently, the interferometric method gives independent confirmation of the existence of nonlinear propagation at biomedical frequencies and intensities.

220. A new system for the rapid evaluation of ultrasonic output levels

J. Ultrasound in Med., 1984, 3, Supplement 9, p83.

Abstract of lecture presented to the 29th Annual Convention of the American Institute of Ultrasound in Medicine, Kansas.

R. C. Preston, G. E. M. Taylor,* A. J. Livett* and B. Zeqiri.

Based on a multi-element linear array membrane hydrophone, a new system for the rapid determination of the acoustical output of medical ultrasonic transducers has been developed. Through microprocessor control, the beam profile and the acoustic pressure temporal waveform can be presented in real time and stored for subsequent analysis. Referred to as BECA 2 (Beam Calibrator), the system is capable of determining all the relevant acoustical output parameters.

See item 225.

221. The observation of distorted waveforms: nonlinear propagation or hydrophone overload?

Ultrasound in Med. & Biol., 1984, 10 (5), 639-642.

D. R. Bacon.

This letter to the editor questions the conclusions of Kossoff and Carpenter (1984) that currently available wideband hydrophones give rise to significant overload distortion at intensities above 30 W cm^{-2} . The paper shows that waveform distortion can be attributed to nonlinear propagation in water.

222. Absolute calibration of hydrophones in the frequency range 0.5 MHz to 15 MHz

Institute of Acoustics, 1984, Bracknell. Proceedings, 6, part 5, 60-67, (Invited Paper).

R. C. Preston, A. J. Livett* and D. R. Bacon

The absolute calibration of piezoelectric hydrophones in the frequency range 0.5 MHz to 15 MHz is discussed, with the emphasis on the techniques which are routinely used and are under continual development at the NPL. Both reciprocity and planar scanning techniques are described, with particular reference to the sources of uncertainty. Results of comparisons between these two techniques are presented. Emphasis is placed on the calibration of membrane hydrophones although the techniques may be applied to other devices at the expense of reduced accuracy. The development of optical interferometry to measure absolutely the acoustic displacements in a high frequency field is described and preliminary results of calibrations of hydrophones are presented.

A theoretical appraisal of the use of ground-plane microphones for aircraft noise measurements

Acoustics Report Ac 103, 1984 (December)

R. C. Payne and G. F. Miller.**

The pattern of sound pressure across a plate (baffle) mounted in or over the ground surface, when exposed to the noise of an over-flying aircraft, is examined theoretically. In particular, the effects of diffraction due to the impedance mis-match between the baffle and the ground surface are studied. This has been done with a view to finding the optimum arrangement for a microphone on the ground to measure aircraft noise, particularly that emitted from light propeller aircraft. Ranges of a number of parameters are considered and a particular arrangement is recommended which gives a close approach to a measurement of a pressure-doubled sound spectrum.

The NPL hearing protector test rig

Institute of Acoustics Spring Conference, 1985, York.
Proceedings, 7, part 2, 245-249.

M. S. Shipton and J M. Mason.**

The attenuation of hearing protectors is measured subjectively in accordance with BS 5108:1983 using a threshold test method. The NPL test rig is based on the Norwegian Electronics 828 hearing protector test unit and is controlled by a BBC microcomputer. A suite of programs has been developed to allow easy use and calibration whilst ensuring that no aspect of the test is overlooked. Overall, the facility exceeds the sound field requirements called for in the standard. The software involved has been clearly annotated in distinct modules to ensure that future modifications, brought about by changed demands, can be readily incorporated.

The performance of the ultrasound beam calibrator BECA 2

Proceedings of the Fourth World Federation for Ultrasound in Medicine and Biology, 1985, Sydney, p537.

Preston, G. E. M. Taylor,* R. C. Thompson,* B. Zeqiri and A. J. Livett.*

Developed at the NPL for the rapid evaluation of the acoustic output of medical ultrasonic equipment, BECA 2 has been improved. The changes to the system are described and include new multi-element hydrophones, a larger test tank and an improved data acquisition system. As part of the performance evaluation of BECA 2, data are shown which compare the results of measurements of the acoustic output of a phased scanner operating in different output modes using conventional hydrophone measurement techniques with those obtained using BECA 2.

See item 220.

Current status of acoustic output standards for medical ultrasonic equipment

Brit. Med. Ultrasound Soc. Bulletin, 1985, 37, 4-5.

R. C. Preston.

The author reviews the current status of standards associated with either the measurement of acoustic output of medical ultrasonic equipment or the establishment of maximum output levels. National standards in Canada, Japan and USA and international standards produced by the International Electrotechnical Commission are covered.

An experimental appraisal of the use of ground-plane microphones for aircraft noise measurement

Acoustics Report Ac 104, 1985 (August)

R. C. Payne.

Sound pressure levels measured using several ground-plane microphone configurations are compared with pressure-doubled spectra derived from measurements using a conventional 1.2 m microphone location. Experimental data have been obtained under laboratory conditions and in the field using a stationary sound source producing either pure tone signals or shaped white noise. One particular arrangement, involving a half-inch condenser microphone inverted over a circular baffle, gave a close approximation to a pressure-doubled spectrum. Initial field trials made using over-flights of light propeller-driven aircraft measured at Denham Aerodrome have confirmed the validity of the arrangement.

A new primary standard for hydrophone calibrations

Institute of Physical Sciences in Medicine Report 47, 1986, 30-35.

Bacon, L. E. Drain,** B. C. Moss* and R. A. Smith*.

The acoustic output from medical ultrasonic equipment is commonly determined using miniature hydrophones, which are not absolute devices and must therefore be calibrated. At the NPL a calibration method has been developed which utilises laser interferometry. The particle displacement in an ultrasonic field is determined in terms of the wavelength of light, and the acoustic pressure derived from a knowledge of the acoustic impedance of the propagating medium. A hydrophone is then placed in the known field and calibrated by determining its output voltage. Compared with previous techniques the method offers increased accuracy and speed of calibration.

Calibrations have been performed in the frequency range 0.5 to 15 MHz and the estimated overall uncertainty in this range is between 2% and 6.3%.

Standardisation of acoustic output for diagnostic ultrasound equipment - present and future

Institute of Physical Sciences in Medicine Report 47, 1986, 55-59.

D. R. Bacon and R. C. Preston.

There are several national or international standards for the specification of the acoustic output parameters of medical diagnostic equipment, either under development or available in published form. The complexity and methods of approach of these standards differ widely and until recently there has been no international consensus concerning the method of characterising these ultrasonic fields. Progress is now being made, however, to obtain international agreement on the definitions of many of the relevant parameters so that measurements made in different countries may be compared.

In this paper these developments are described briefly. A large number of parameters have been defined, but the discussion is limited to those that are likely to be most significant for diagnostic ultrasound equipment.

Various issues that have still to be resolved within the UK are also discussed. Two such issues being acoustic output labelling and the possibility of establishing maximum output levels.

230. Tissue mimicking materials - a start towards their characterisation

Institute of Physical Sciences in Medicine Report 47, 1986, 85-93.

B. Zeqiri.

The development of materials whose acoustical properties closely resemble those of real tissue is attracting some interest in the field of medical ultrasonics. It is hoped that these tissue-mimicking materials will permit the evaluation of scanner performance by routine quality assurance tests. To be clinically useful, they must be characterised by a set of well-defined acoustical parameters (attenuation, velocity etc). To meet this requirement, the NPL has initiated a research programme to establish material characterisation techniques and this paper reports on the early stages.

A general-purpose measurement rig has been built. Its construction is described and the results of attenuation measurements on castor oil obtained using a through-transmission substitution technique are presented, and compared with those in the literature.

231. A survey of speech audiometry in the National Health Service

Acoustics Report Ac 105, 1985 (August)

H. C. Fuller and I. K. Moss.

This report gives the results of a study of the use of speech audiometry in the National Health Service (NHS). Visits were made to nine clinics in order to discuss with the audiologists the technique of speech audiometry and to observe how the tests were conducted. The information gained during these visits was used to construct a questionnaire which was then circulated to NHS hearing aid clinics throughout the UK. Topics which were covered by the questionnaire included the frequency of use of speech audiometry, the word lists, recordings, equipment and test procedures used, criticisms of the available test material and limitations on the use of speech audiometry.

Investigation of traffic noise at Mary Hare Grammar School, Newbury

Acoustics Report Ac 106, 1985 (September)

R. F. Higginson, A. L. Harris and A. J. Rennie.*

Measurements have been made of the noise from traffic on the A34 trunk road, where it passes the Mary Hare Grammar School for the Deaf, at Newbury. The measurements were made in octave frequency bands and used as the basis for predicting future noise from traffic on (a) the existing road, if it remains unaltered, and (b) a proposed new road system, incorporating a by-pass to the town of Newbury, which skirts the School grounds. The traffic noise levels are assessed with respect to the difficulty likely to be experienced by the pupils in understanding speech through their hearing aids. Recommendations are made for the erection of noise barriers alongside the proposed new road.

Evaluation of impulsive environmental noise: Laboratory studies of annoyance reactions

Internoise 85, 1985, Munich. Proceedings, 2, 921-924

B. F. Berry.

A series of related experiments is being conducted to investigate the dependence of annoyance on some basic physical parameters of impulsive noises. This paper describes two such experiments in which subjects, in a simulated living-room environment, made numerical category scale judgements on the annoyance of various noise exposures. These included recordings of real impulsive noises, eg pile driver noise, digitally synthesised impulsive noises and low variability road traffic noise.

The results confirm the need for an "impulse penalty" to be added to the measured L_{Aeq} of impulsive noise, and provide estimates of the magnitude of such a penalty. The method of classifying noises as impulsive or non-impulsive, used in EEC Directive 79/113 and elsewhere, which uses the "Impulse" time-weighting characteristic of IEC 651, is shown to be unsatisfactory.

234. Progress towards international standardisation of aircraft noise contour calculations

Internoise 85, 1985, Munich. Proceedings, 2, 1413-1415.

R. F. Higginson.

Uses of noise contours around airports are reviewed and the methods of production of the contours are summarised. Different countries use different data bases and computer models in the production of contours, giving rise to substantial differences in results. Progress made within the European Civil Aviation Conference, the Society of Automotive Engineers and the International Civil Aviation Organization towards standardisation of the data and methods of calculation is described.

Hearing protector standard measurements

Acoustics Bulletin, 1985, 10 (4), 4-6.

M. S. Shipton.

Measurement of the attenuation characteristics of hearing protectors helps to ensure that users are not exposed to excessive noise levels. Kitemarking of muffs ensures their efficiency when in use.

This article outlines, in general terms, the tests used to describe the performance ratings of protectors.

Pressure sensitivity calibration of 1-inch microphones by the reciprocity technique

BCR Information Report EUR 10167EN, 1985. Commission of the European Communities. ISBN 0 11 970572 9.

M. E. Delany* (Editor).

An intercomparison involving five other primary calibration laboratories within the EEC has been carried out with NPL acting as the Reporting Laboratory. Detailed results obtained from the calibration of ten Brüel & Kjær microphones Type 4160 using the closed-coupler reciprocity technique over the range 63 Hz to 12.5 kHz are presented. Pressure sensitivity levels measured prior to the despatch of two microphones to each of the participating countries are compared with those obtained following their return to NPL, whilst the mean value for each microphone is compared with that reported by the relevant Contributing Laboratory.

NAMAS, NATLAS, BCS and EEC

Acoustics Bulletin, 1986, 11 (1), 4-5.

M. E. Delany.

The role of NAMAS, the National Measurement Accreditation Service which brings together NATLAS and BCS under one organisation, and the eligibility of laboratories is described. Its relevance to acoustical testing laboratories has been increased by the implementation of EEC Directives on noise from construction plant and machinery, since measuring laboratories in the UK are required to be accredited by NATLAS, the National Testing Laboratory Accreditation Scheme. Moreover, calibrations of the equipment must be traceable to national standards via calibration laboratories accredited by BCS, the British Calibration Service. An inexpensive calibration procedure which nevertheless offers a high degree of assurance is described.

A comparison of the AIUM/NEMA, IEC and FDA (1980) definitions of various acoustic parameters for ultrasonic transducers

Ultrasound in Med. & Biol., 1985, 11 (6), 793-802.

A. J. Livett* and R. C. Preston.

Comparison is made between the values obtained for the acoustic output from different types of medical ultrasonic equipment when determined according to the definitions given in different documents. In particular, the AIUM/NEMA Safety Standard for Diagnostic Ultrasound Equipment, the FDA Diagnostic Ultrasound Reporting Guide (1980) and the proposed IEC Standard are compared for pulse-echo and Doppler equipment. Differences of up to 40% in the spatial-average, temporal-average and spatial-average intensities are shown to be a result of the different definitions of beam area and pulse duration.

239. Measurement and characterisation of the acoustical output of medical ultrasonic equipment - Part 1

Med. Biol. Eng. & Computing, 1986, 24 113-120

R. C. Preston.

A review of measurement techniques for the determination of the acoustic output of medical ultrasonic diagnostic, Doppler and therapeutic equipment is presented. A brief survey of a wide range of techniques is given followed by a discussion of acoustic output specification methods.

The NPL ultrasound measurement service and comments on the measurement and specification of the acoustic output of medical ultrasonic equipments.

Proceedings Ultrasonics International, 1985, 269-274

R. C. Preston.

The NPL provides an Ultrasonic Measurement Service whereby the acoustic output of medical ultrasonic equipment may be determined, the result being directly traceable to the National Measurement Standards. Many of the measurements are made using miniature hydrophones made from polyvinylidene fluoride with both the hydrophone and ultrasonic transducer mounted in a versatile beam-plotting facility. This facility is described together with the data acquisition system for recording and storing the measured signals. Some of the problems involved with the determination of pulse-average acoustical quantities are described together with illustrations of source uncertainty.

241 Measurement and characterisation of the acoustical output of medical ultrasonic equipment - Part 2

Med. & Biol. Eng. & Computing, 1986, 24, 225-234.

Preston.

A review of measurement techniques for the determination of the acoustic output of medical ultrasonic diagnostic, Doppler and therapeutic equipment is presented.

Two techniques widely used for measurements, the radiation pressure balance and the hydrophone, are considered in detail together with guidelines for good measurement practice. The review concludes with a discussion of a rapid assessment system, BECA2, which has been developed for the characterisation of ultrasonic transducers. Much of the emphasis is on techniques developed at NPL.

242. Intercomparison of measurements on ear protectors by subjective and objective test methods

BCR Information Report, EUR 10575 EN, 1986.
Commission of the European Communities. ISBN 92-825-6362-6.

M. S. Shipton.

An intercomparison involving five laboratories has been carried out, with NPL acting as the central coordinating laboratory. Detailed results of measurements made on five hearing protector types using both the objective and subjective methods are presented. Insertion loss measurements made prior to despatch of twenty muffs to each participating country are compared with those made following their return to NPL. Results of repeated attenuation measurements at NPL and in the participating laboratories are compared both against NPL values and against the mean values over all laboratories.

See items 252, 262, 268.

Nonlinear ultrasonic fields: Theory and experiment

Institute of Acoustics Spring Conference, 1986, Salford.
Proceedings, 8, part 2, 39-46.

Bacon.

The central problem in the theoretical modelling of nonlinear ultrasonic fields is the fact that the three processes of diffraction, nonlinear distortion and attenuation have to be accounted for simultaneously. One approach that has been employed successfully to overcome this difficulty is the use of a Gaussian beamshape to model the field. This method has the advantage that the problem can be analysed in terms of modes that both satisfy the diffraction conditions and propagate independently until the distortion becomes severe.

A general method of describing the propagation is given which accounts for the phase variation occurring within the near field zone and which can be used when the distortion is severe. The results of measurements in transducer fields, including those with a Gaussian shading function, are also presented.

244. The importance of the frequency response of a hydrophone when characterising medical ultrasonic fields

Institute of Acoustics Spring Conference, 1986, Salford.
Proceedings, 8, part 2, 119-128.

R. A. Smith.*

The increasing concern about the safety of diagnostic ultrasound is prompting interest in the acoustic output levels from medical ultrasonic equipment. The most widely used and convenient device for determining the spatial and temporal distribution of acoustic pressure within an ultrasonic field is the miniature piezoelectric hydrophone.

The sensitivity of these hydrophones changes with frequency and this variation must be determined before reliable measurements of waveforms can be made.

A new technique for the rapid intercomparison of hydrophones is being developed at NPL using the distorted waveforms produced by the nonlinear propagation of ultrasound in water. During the validation of this technique various types of probe and membrane hydrophones have been calibrated.

This paper describes the technique and presents some measured frequency responses. The relative merits of the different hydrophones in the light of these and other measurements are discussed with regard to their use for characterising medical ultrasonic fields.

245. Quality control in acoustic testing

Institute of Acoustics Spring Conference, 1986, Salford.
Proceedings, 8, part 3, 301-303.

R. F. Higginson.

A requirement of the recent series of European Economic Community Directives on noise emitted by construction site machines is for Governments of member states to appoint 'approved bodies' for the conduct of machinery type examinations. In the UK, a pre-condition for approval is that test houses should be accredited for the conduct of the noise measurements through the National Measurement Accreditation Service (NAMAS). By this means, the competence of the testing laboratories to carry out the measurement work to a high standard is recognised. Accreditation involves the implementation of quality control practices covering the equipment, facilities and staff engaged in the work. Through the furnishing of a Quality Control Manual and a process of formal assessment, a laboratory has to demonstrate that it has a suitable management organisation, including an individual with responsibility for quality control who has access to top management. Staff have to be technically qualified; suitable measuring equipment has to be available, the calibration of which is traceable to national standards of measurement; detailed records have to be kept of all work done; and test results have to be clearly presented. An accredited laboratory must be able to quantify the uncertainty associated with its test results. A number of the laboratories seeking accreditation for measurements according to the EEC Directives are keen to widen the scope of their accreditation to bring in a range of other acoustic test work.

246. A survey of local authority noise measurements

Institute of Acoustics Spring Conference, 1986, Salford.
Proceedings, 8, part 3, 308-309.

B. F. Berry.

In order to review the extent and accuracy of statutory noise measurements made by local authorities and to assess the need for changes in the regulations governing such measurements, a questionnaire was circulated to a sample of one-in-three of all authorities in the UK. This paper outlines the development and distribution of the questionnaire and describes the initial analysis and responses obtained.

See item 267.

UK national measurement standards for medical ultrasonics and their dissemination

Institute of Acoustics Spring Conference, 1986, Salford.
Proceedings 8, part 2, 95-102.

R. C. Preston.

Two primary standards in the field of ultrasonics are described; the radiation-pressure balance and the laser interferometer. These provide the basis for the UK national measurement standards for the determination of the acoustic output of medical ultrasonic equipment. The range of application accuracy achievable and the methods of dissemination of these standards are described.

248. Acoustics at the National Physical Laboratory

Acoustics Bulletin, 1986, 11 (2), 5-8.

M. E. Delany.*

NPL is a research establishment of the Department of Trade and Industry (DTI). Its main functions are to provide the metrological base for the United Kingdom and to pioneer research in key technological areas. Nearly 80% of the Acoustics Branch programme is funded by the Metrology and Standards Requirements Committee of the DTI, the balance being made up by special research investigations and customer services. The primary interests of the 25-strong Branch are basic acoustical metrology in air and water, the measurement and assessment of environmental noise, and the standardised assessment of speech technology devices.

Traceability for acoustical measurements: from primary standard to end user

The International Measurement Exhibition & Conference,
Test and Transducer, 1986, Wembley. Proceedings, 3, 143-151.

G. R. Torr.

With the development in the UK of the National Measurement Accreditation Service (NAMAS), Government is beginning to require that measurements made in support of statute shall be carried out by accredited organisations using instruments calibrated against national standards. This paper explains how NPL derives standards for the measurement of noise and how these standards are disseminated to NAMAS laboratories and other users. It also discusses some of the problems that are arising as the demand for different forms of traceability broadens, and how these demands are highlighting deficiencies in international and equivalent British Standards on acoustical instruments.

250. Ultrasonic field characterisation using the NPL beam calibrator

The International Measurement Exhibition & Conference,
Test and Transducer, 1986, Wembley. Proceedings, 3, 193-195.

R. C. Preston.

A new measurement system for the rapid determination of the acoustic output of medical ultrasonic equipment is described. It is based on a 21-element membrane hydrophone which is mounted in a versatile test tank and linked to a fast microprocessor data acquisition system. Acoustical output of ultrasonic transducers can be determined in a matter of a few seconds. Results of performance evaluation tests are given by comparison with measurements made using the NPL beam-plotting facility.

251. Measurement and characterisation of bio-medical ultrasonic fields: summary of the London meeting on ultrasound standards, 5 July 1985.

Ultrasound in Med. & Biol., 1986, 12 (9), 706-707.

R. C. Preston.

A report is given of the meeting of 5 July 1985 dealing with Ultrasound Standards. Proposals for the presentation of acoustical output information in scientific publications and for acoustic output labelling requirements for medical diagnostic ultrasonic equipment are given.

252. Hearing protector testing - an EEC inter-laboratory comparison

12th International Congress on Acoustics, 1986, Toronto.
Invited paper B9-3.

M. S. Shipton.

Under the auspices of the European Economic Community, a five-nation intercomparison has been carried out which compared measurements on a number of different types of hearing protector made by both the subjective and the objective test methods specified by the International Organization for Standardization. The intercomparison highlighted difficulties and shortcomings with the standards and showed differences in test results between the participating laboratories.

See items 242, 262, 268.

253. The performance of the NPL ultrasound beam calibrator:
Part 1 Physiotherapy transducers

Acoustics Report Ac 107, 1986 (September)

Preston and C. E. Mason.*

The performance of the NPL Ultrasound Beam Calibrator (BECA2) has been assessed for measurements of the acoustic output of physiotherapy transducers. Reflection from the polyvinylidene fluoride membrane hydrophone used to determine the sound field and lack of cylindrical symmetry of the beam emitted by physiotherapy transducers are considered, and guidelines are given for minimising their effect on the measurements. Sources of systematic and random uncertainty are considered and typical values for these quantities are given.

Comparison of subjective evaluations of impulsive noise with objective measurements of the loudness-time function given by a loudness meter

Internoise 86, 1986, Cambridge USA.
Proceedings, 821-824.

B. F. Berry and E. Zwicker.**

New versions of a loudness meter based on ISO 532 B, incorporating temporal effects in loudness, were demonstrated at Internoise 85 (Zwicker, Deuter and Peisl; Proceedings p.1119). For noises with relatively slow temporal variation in loudness, such as an aircraft overflight and a truck pass-by, Fastl (ibid, p.1403) presented data to show that both loudness and annoyance can be assessed by means of the maximum value of the running loudness-time function indicated by the loudness meter. But how do loudness and annoyance compare for noises with more rapid variations in loudness such as impulsive noises and how should the loudness-time function be interpreted for such noises? This paper addresses these questions, comparing trends already observed in laboratory experiments on annoyance reactions to a variety of noises (Berry, ibid, p.921) with objective loudness measurements on the same noises.

255. An overview of the AIUM/NEMA standard and the draft IEC standard for ultrasound exposure measurements

Ultrasound in Med. & Biol., 1986, 12 (9), 680-681.

R. C. Preston.

A comparison is made between the 1981 AIUM/NEMA Safety Standard for Diagnostic Ultrasonic Equipment and the draft IEC 29D Field Characterisation document. The various requirements of the two documents are given and the rationale behind the IEC draft presented.

256. The calibration of hydrophones for use in medical ultrasonic fields - a review

Acoustics Report Ac 108, 1986 (November)

R. A. Smith.*

A growing concern for the safety of patients exposed to medical ultrasound has highlighted the importance of the characterisation of medical ultrasound equipment in terms of absolute acoustical parameters. To meet this need, various types of miniature piezoelectric hydrophone have been produced to measure the temporal and spatial distribution of acoustic pressure in the ultrasound field. However, in order to measure absolute acoustic pressure, the receiving sensitivity of the hydrophone must be determined over a range of frequencies. This report reviews the many techniques available for calibrating hydrophones, giving details of the method, the validation and the accuracies achieved. The current state of each technique is described together with the results of comparisons between techniques and between laboratories. An important contribution to the international standardisation of some of the more established techniques has been the publication of certain standards, which are also reviewed.

Variation in glottal open and closed phases for speakers of English

Institute of Acoustics Autumn Conference, 1986, Windermere.
Proceedings, 8, part 7, 539-546.

P. Davies,** G. Lindsey,** H. C. Fuller and A Fourcin.**

The realisation of contrastive segmental targets is associated not only with supraglottal changes but also with structured variation in larynx activity; prosodic contrasts are also associated with qualitative variations in larynx activity in addition to basic fundamental frequency adjustments. One parameter of this laryngeal variation is the relative duration of the open and closed phases of the glottal cycle. The present work is founded on the analysis of this feature of speech and larynx activity in the speech of women for both normal and pathological production. Two types of speech material have been examined, namely, contrasts in vowel-consonant-vowel sequences and extended stretches of speech.

The improvement and evaluation of a laser interferometer for the absolute measurement of ultrasonic displacements in the frequency range up to 15 MHz

Acoustics Report Ac 109, 1986 (November)

D. R. Bacon.

This report describes the application of a laser interferometer to the absolute calibration of hydrophones in the frequency range 0.5 to 15 MHz. The interferometer, previously developed and improved at AERE Harwell, has now been assessed in terms of its performance characteristics. The optimum experimental arrangement and method of calibration has been defined and corrections for various effects which influence the measurement have been studied experimentally and theoretically. The reproducibility of the method is approximately 1% and the estimated systematic uncertainty ranges from 2.1% at 0.5 MHz to 6.3% at 15 MHz. A hydrophone has been calibrated using the interferometer and using two other methods, and the results are in agreement to within the estimated uncertainties.

Identical to item 265.

259. Audiometric earphone calibration using the IEC 303 Reference coupler: a cautionary note

British Journal of Audiol., 1987, 21, 75-77.

T. R. Sherwood and M. S. Shipton.

The diaphragm of a condenser microphone is exceedingly fragile and, in normal use, is covered by a protective grid. However, when the microphone is incorporated into the IEC 303 reference coupler for the calibration of audiometers or audiometric earphones, the Standard demands that the diaphragm be left exposed. Nevertheless, in order to avoid inadvertent mechanical damage, some users leave a protective grid on the microphone. The effects of two particular grids have been investigated and the magnitude of the resulting errors is indicated.

260. Flight effect on aircraft noise during the ground roll

Danish Acoustical Institute Report No. 138, 1987 (February)

R. F. Higginson, B. Plovsing** and C. Svane.**

Measurements of noise during the take-off ground roll of a large number of aircraft at Kastrup Airport, Copenhagen, are reported, the results of which have been analysed to show the effect of aircraft speed (the "flight" effect) on the source noise levels. Other noise measurements during the same phase of aircraft operations at Heathrow airport, London, and Roissy - Charles de Gaulle Airport, Paris, have also been analysed and compared with calculated noise levels determined according to the latest internationally-standardised method. Differences were found between the measured and calculated levels, which can be explained in part by the failure of the calculation method to take the flight effect into account. There are indications that the calculation method might also need to be modified in other ways in order to give an improved capability for prediction. Theoretical and experimental work by other investigators has been reviewed and found to give results in line with those reported here.

261. Acoustical admittance of cylindrical cavities

J. Sound Vib., 1987, 117, (2) 390-392.

D. R. Jarvis.

In calibrating microphones in closed cavities it is often necessary to know the acoustical admittance of the cavity. This admittance is affected by the conduction of heat from the gas to the walls of the cavity and the calculation of this effect depends on the impedance of the sound source. This paper points out an error in the current IEC standard for the reciprocity calibration of microphones where a wrong assumption is made about the impedance of the microphone which drives the cavity. Results are also presented to show how heat conduction affects the length modes in the cavity.

262. Hearing protector testing - an EEC interlaboratory comparison

Institute of Acoustics Spring Conference, 1987, Portsmouth.
Proceedings, 9, part 3, 201-206.

M. S. Shipton.

In the United Kingdom, both the subjective (ISO 4869:1981) and objective (ISO/DIS 6290) test methods are widely used. They play an essential part in kitemarking of earmuffs and the assessment of different hearing protectors for hearing conservation purposes. The errors involved in testing, particularly by the subjective method, are therefore of interest to all users.

In a five-nation intercomparison sponsored by the EEC Community Bureau of Reference, measurements on five different types of hearing protectors (four muffs and one plug), using both test methods have been compared. NPL acted as the central reporting laboratory, and this paper summarises the most significant results.

See items 242, 252, 268.

263. Noise levels from propeller-driven aircraft measured at ground level and at 1.2 m above the ground

Acoustics Report Ac 110, 1987 (March)

R. C. Payne.

During a series of aircraft flight tests using a British Aerospace HS748 and a Piper Navajo PA31, noise measurements were obtained using microphones close to the ground plane and at a height of 1.2 m. Substantial differences between measured A-weighted sound levels were observed. The differences were found to be dependent on ground cover, aircraft type and flight manoeuvre. The ground-plane microphones generally produced A-weighted levels which closely approximated to pressure-doubled values.

Two procedures for correcting A-weighted sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, have been examined. In one procedure the noise spectrum was assumed to be represented by a series of 1/3-octave bands, in the other by a number of pure tones or discrete narrow-bands of noise. Neither correction procedure was wholly successful.

Factors influencing measurements made using a microphone 1.2 m above the ground have been examined. It is concluded that, to avoid significant variations in measured A-weighted levels, noise measurements must be made using a ground-plane microphone.

See item 288.

264. Recommendations for organising the calibration of pure tone audiometers

Acoustics Report Ac 112, 1987 (July)

Collated by M. S. Shipton.

A three-tier strategy for maintaining correct calibration of audiometric test equipment is described. The first two tiers represent routine checking performed on the equipment in situ, and the third tier represents non-routine, 'on demand', repair at a central laboratory with a full re-calibration and a check to specification. These proposals were originally prepared by the now disbanded Advisory Committee on Audiological Equipment for the Department of Health and Social Security, but will be of interest to many users.

The improvement and evaluation of a laser interferometer for the absolute measurement of ultrasonic displacements in the frequency range up to 15 MHz

BCR Information Report, EUR 10910 EN, 1987. Commission of the European Communities.

D. R. Bacon.

This report describes the application of a laser interferometer to the absolute calibration of hydrophones in the frequency range 0.5 to 15 MHz. The interferometer, previously developed and improved at AERE Harwell, has now been assessed in terms of its performance characteristics. The optimum experimental arrangement and method of calibration has been defined and corrections for various effects which influence the measurement have been studied experimentally and theoretically. The reproducibility of the method is approximately 1% and the estimated systematic uncertainty ranges from 2.1% at 0.5 MHz to 6.3% at 15 MHz. A hydrophone has been calibrated using the interferometer and using two other methods, and the results are in agreement to within the estimated uncertainties.

See item 258.

The evaluation of impulsive noise

Acoustics Report Ac 111, 1987 (September)

B. F. Berry.

A series of related experiments has been conducted to investigate the dependence of annoyance on some basic physical parameters of impulsive noises. Subjects, in a simulated living-room environment, made numerical category scale judgements on the annoyance of various noise exposures. These included recordings of real impulsive noises, eg pile driver noise, digitally-synthesised impulsive noises and low-variability road traffic noise.

Using data from these experiments, the performance of a number of objective descriptors of impulsive noise has been compared. The method of classifying noises as impulsive or non-impulsive used in EEC Directive 79/113 and elsewhere, which uses the "Impulse" time-weighting characteristic of IEC 651, is shown to be unsatisfactory. The method developed in previous NPL work on helicopter noise and described in Acoustics Report Ac 93 is found to give the best fit between objective and subjective data.

267. A survey of the work of local authorities on noise

Acoustics Report Ac 113, 1987 (September)

B. F. Berry and K. Moss.

In order to review the extent and accuracy of statutory noise measurements made by local authorities and to assess the need for changes in the regulations governing such measurements, a questionnaire was circulated to a sample of one-in-three of all authorities in the UK. This report outlines the development and distribution of the questionnaire and describes the responses obtained.

It was found that 47% of authorities had a policy of regular recalibration of acoustical instruments, with the most common recalibration interval being one year. However none of these calibrations could be considered traceable to national standards.

Some possible changes to measurement regulations are discussed but the precise implications of any such changes will require further study.

See item 246.

268. Intercomparison of measurements on ear protectors by subjective and objective test methods (NPL Results)

Acoustics Report Ac 115, 1987 (September)

M. S. Shipton.

An intercomparison involving five laboratories was carried out under the auspices of the Community Bureau of Reference of the European Economic Community, with NPL acting as the central coordinating laboratory. The purpose of the intercomparison was to quantify and identify the origin of discrepancies involved in measuring the attenuation of five different types of hearing protector using both subjective and objective procedures. This report describes the test methods used at NPL and gives the detailed results obtained on both muffs and plugs for measurements carried out at NPL.

See items 242, 252, 262.

Speech variability in high performance rotary wing aircraft

European Conference on Speech Technology, 1987, Edinburgh.
 Proceedings, 2, p78.
 (Abstract only).

M. R. Taylor*, C. Leeks,** D. R. Tincello,** A. J. Fourcin,**
 D. J. Miller** and I. Bickerton.**

Next generation high performance rotary wing aircraft are likely to employ Direct Voice Input (DVI) as a means of cockpit equipment control. If DVI systems are to provide benefits which justify the overheads of added weight, size and cost, they must be capable of robust recognition performance throughout the aircraft's full flight envelope.

As avionic equipment selection often takes place some years ahead of prototype aircraft roll-out, it is essential that speech data-bases are available which contain characteristics thought to be typical of speech spoken within these vibrant, high noise platforms. To this end Smiths Industries has made some initial speech recordings from speakers within a high performance helicopter. Details of these recordings, together with their initial analysis, are presented within this paper.

The final section of the paper describes the methodology and instrumentation used for recording a larger corpus of speech data under controlled vertical vibration conditions.

Assessment of speech technology in a multi-lingual aerospace environment

International Speech Tech' 87, 1987, London.
 Proceedings, 1, part 1, 244-249.

Taylor*.

This paper discusses the importance of speech technology assessment in multi-lingual civil and military aerospace environments. Although the applications described are specific to aerospace, the problems posed apply equally to other high technology areas. A European initiative aimed at developing multi-lingual speech assessment procedures has recently been supported by the EEC ESPRIT organisation. The countries and organisations involved in the project title "Multi-Lingual Speech Input-Output Assessment Methodology and Standardisation" are identified within the paper.

271. Nonlinear propagation in the focused fields used in medical ultrasound

XI International Symposium, Problems of nonlinear acoustics, 1987, USSR. Proceedings, 1, 149-153.

D. R. Bacon.

Nonlinear propagation is significant in the fields produced by medical ultrasonic equipment because it complicates the measurement of acoustic output and makes it difficult to predict the exposure levels for patients. When determining the output of medical equipment, the response of the hydrophone to the acoustic shock front gives rise to ringing in the measured waveform, which can lead to errors of up to 40% in the determination of peak pressure.

To predict the amount of distortion present both in water and in tissue a computer algorithm has been developed. The results show that conventional methods of predicting in-situ exposure can be in error by as much as 80% and this paper suggests possible ways of improving these predictions.

Standardisation in Acoustics

Institute of Acoustics, Acoustics Index 1987-88, 4.0.1.-4.0.4.

M. E. Delany*

Based on an earlier paper by D. W. Robinson this article outlines the traceability chain from a primary standard of great accuracy to successively lower grade standards with increasing uncertainty. The international organisations are reviewed and the stages in the preparation of an international standard are outlined.

See item 186.

The use of the NPL ultrasound beam calibrator to characterise scanners generating duplicate or multiple-focus scan lines

Sixth Congress of the European Federation of Societies for Ultrasound in Medicine and Biology, 1987. Proceedings, p325.

R. C. Preston.

The use of the NPL Ultrasound Beam Calibrator to measure the acoustic output of real-time ultrasonic scanners operating in multiple-focused and duplicate scan line mode is described. The results of measurements made on a linear array transducer are given and demonstrate the unique capability of the Beam Calibrator.

The dissemination of ultrasonic hydrophone calibration standards in the United Kingdom

Sixth Congress of European Federation of Societies for Ultrasound in Medicine and Biology, 1987. Proceedings, p329.

R. A. Smith.*

To meet the UK requirements for traceable acoustic output measurements of medical ultrasonic equipment, the NPL employs polyvinylidene fluoride membrane hydrophones as secondary standards. A primary standard laser interferometer is utilised to provide absolute calibrations of these standard hydrophones, which are then used to calibrate hydrophones for customers by employing intercomparison techniques. The end-of-cable open-circuit sensitivity and the complex impedance of the hydrophone are provided in 1 MHz intervals over the frequency range 1 to 15 MHz. From these values it is possible to derive the end-of-cable sensitivity when using a load of known impedance.

Both the absolute calibration and the intercomparison techniques need to be validated by comparison with other techniques. This paper compares some of the intercomparison techniques which are often used for the dissemination of standards.

Physics in medical ultrasound

Ultrasonics, 1987, 25, 303-304.

D. R. Bacon.

This is a report of a conference held by the Institute of Physical Sciences in Medicine. The scientific sessions included the interaction of ultrasound with tissue, Doppler ultrasound, acoustic output measurement and new techniques. There was also a poster session and a commercial exhibition. In all 21 papers were presented and will be published in the conference proceedings.

276. Noise levels from a jet-engined aircraft measured at ground level and at 1.2 m above the ground

Acoustics Report Ac 114, 1988 (January)

R. C. Payne.

During a series of aircraft flight tests using a British Aerospace HS125-700, noise measurements were obtained using microphones close to the ground plane and at a height of 1.2 m. Substantial differences from ground level to 1.2 m were observed, in measurements of perceived noise level and effective perceived noise level. The differences were found to be dependent on ground cover and flight manoeuvre. The ground-plane microphones generally produced noise levels which closely approximated to pressure-doubled values.

A procedure for correcting 1/3-octave band sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, has been examined. The procedure was successful when used in adjustments of perceived noise levels but, because of inaccurate estimates of duration corrections, was found to be less suitable in the case of effective perceived noise level, especially for aircraft in approach to landing.

It is concluded that, to avoid significant variations in measured noise levels, measurements should be made using a ground-plane microphone.

277. Pressure waveforms generated by a Dornier extra-corporeal shock wave lithotripter

Ultrasound in Med. & Biol., 1987, 13 (2), 651-657.

A. J. Coleman,** I. E. Saunders,** R. C. Preston and D. R. Bacon.

Pressure waveforms in the acoustic field generated by a Dornier (HM3) shock-wave lithotripter have been measured using a bilaminar shielded PVDF membrane hydrophone in water. Using these waveforms, values of the peak-positive and peak-negative pressure at various positions in the field have been estimated. At the focus, peak-positive is 38.6 MPa (standard deviation = 9.0 MPa) and peak-negative is 10.1 MPa (standard deviation = 1.0 MPa) at 20 kV discharge potential and an electrode separation in the range 1.3 to 2.4 mm. The peak-positive pressure is found to fall to 50% (-6 dB level) at about 60 mm either side of the focus on the major axis of the reflector and on a 10 mm radius circle around the focus in the focal plane. A shot-to-shot variation of $\pm 25\%$ in peak-positive is attributed to the inherent variability of the electrical discharge which may result in changes in the exact position and strength of the acoustic field. The results reported are considered to be more accurate than those of previous measurements due to the relatively flat frequency response of this type of hydrophone.

278. The accuracy of the electrostatic actuator method of determining the frequency response of condenser microphones

J. Sound Vib., 1988, 123 (1), 63-70.

D. R. Jarvis.

Measurements have been made of the difference between the frequency response of a condenser microphone as determined by the electrostatic actuator method, and the true response as determined by the closed coupler reciprocity method. Results are given for Brüel & Kjær microphones type 4144, 4145 and 4134 and the manufacturer's actuators. Methods of reducing the difference, and the effect on the difference of a perforation in the diaphragm, have been investigated. A procedure is suggested for ensuring the validity of actuator calibrations at low frequencies.

279. The effect of irregularity and intermittency on the judged annoyance of impulsive noise

Institute of Acoustics Spring Conference, 1988, Cambridge.
Proceedings, 10, part 2, 447-454.

B. F. Berry and I. K. Crittenden.

Two experiments have been conducted to investigate the effects of irregularity and intermittency on the annoyance ratings of impulsive noise. Numerical category scale adjustments on the annoyance of various noise exposures were made by subjects in a simulated living-room environment. Recordings of digitally-synthesised impulsive noises and of low-variability traffic noise were used for the noise exposures.

In one experiment the impulsive noise was presented continuously during the exposure period with either a regular repetition rate or an irregular rate. In a separate experiment an impulsive noise of regular rate was presented either continuously or in intermittent bursts, whilst keeping the value of L_{Aeq} constant.

This paper describes the two experiments and assesses the significance of the data obtained. A comparison is made to certain aspects of earlier investigation into other parameters of impulsive noise which are the subject of NPL Report Ac 111 - The Evaluation of Impulsive Noise.

See item 266.

280. Calibration of medical ultrasonic equipment: procedures and accuracy assessment

IEEE Trans. on Ultrason., Ferroelectrics & Freq. Control, 1988, 35 (2), 110-121.

R. C. Preston, D. R. Bacon and R. A. Smith.*

A beam-plotting facility has been developed at the NPL to provide a reference measurement system for determining the acoustic output of medical ultrasonic equipment. It consists of two coordinate-positioning systems controlled by stepping motors and a minicomputer. One system is used for holding and manipulating an ultrasonic transducer and the other for a hydrophone. A membrane hydrophone made from polyvinylidene fluoride of 9 μm thickness with an active element of 0.5 mm diameter is used for most measurements. The hydrophone is connected to an amplifier and digitiser, also controlled by the minicomputer, and the whole system has a measurement bandwidth of 75 MHz (-3 dB). A detailed description of this system is given together with a full assessment of measurement uncertainties and the methods used to correct for the effects of nonlinear distortion and spatial averaging.

281 The NPL ultrasound beam calibrator

IEEE Trans. Ultrason., Ferroelectrics & Freq. Control, 1988, 35 (2), 122-139.

R. C. Preston.

The NPL ultrasound beam calibrator has been developed to provide a measurement system for rapidly determining the acoustic output of medical ultrasonic equipment. It consists of a multi-element membrane hydrophone made from polyvinylidene fluoride which is mounted in a versatile test-tank and linked to a fast data acquisition and presentation system. Acoustic output parameters of both simple medical ultrasonic systems and complex automatic scanners operating in imaging modes can be determined in a straightforward manner. Designed as a comprehensive measurement system, with the calibration traceable to national standards and the software configured to conform with written standards, it provides a convenient and rapid method of determining the acoustic output for both manufacturers and users of medical ultrasonic equipment. The computer operating system is described, followed by an analysis of the postprocessing calculations which are applied to the acquired waveform data for the determination of acoustical parameters. Finally, a full assessment of the sources of uncertainty in the measurements is given, together with a comparison of results obtained using a reference measurement system.

282. Primary calibration of ultrasonic hydrophones using optical interferometry

IEEE Trans. on Ultrason., Ferroelectrics & Freq. Control, 1988, 35 (2), 152-161.

D. R. Bacon.

A primary calibration method for ultrasonic hydrophones has been developed which uses a Michelson interferometer to determine the particle displacement in an ultrasonic field. The acoustic pressure is derived from this measurement and used to determine the free-field sensitivity of a hydrophone in the frequency range 0.5-15 MHz. The random uncertainty of the method is typically 1%, whereas the systematic uncertainty varies from 2.3 to 6.6% over the frequency range. To obtain this accuracy, the performance of the system has been carefully examined and appropriate correction factors derived. The greatest difficulty in the method lies in determining the frequency response of the optical detection system, and two different approaches have been used to measure this response. Several acoustical effects have also been studied and the calibration procedure modified to take account of them. The calibration results are in agreement with those of other methods and with the theoretically predicted frequency response of a hydrophone. The method has been used to determine the temporal stability of a hydrophone over a period of two years.

283. Interlaboratory comparison of hydrophone calibrations

IEEE Trans. on Ultrason., Ferroelectrics & Freq. Control, 1988, 35 (2), 206-213.

R. C. Preston, D. R. Bacon, S. C. Corbett,** G. R. Harris,**
P. A. Lewin,** J. A. McGregor,** W. D. O'Brien** and T. L. Szabo.**

The results of an interlaboratory comparison of hydrophone calibration techniques in the frequency range 1-10 MHz are reported. Two membrane hydrophones were circulated to six laboratories, and each laboratory determined the end-of-cable loaded sensitivities using their normal calibration methods; these included optical interferometry, planar scanning, reciprocity combined with time-delay spectrometry, and suspended-sphere radiometry. After converting the results to end-of-cable open-circuit sensitivities, in most cases agreement between the various values was within $\pm 10\%$ at all frequencies.

284. Small area membrane hydrophones

IEEE Ultrasonics Symposium, 1987, Proceedings, 761-764.

H. R. Gallantree** and R. A. Smith.*

Ultrasonic hydrophones are used for the measurement of medical ultrasonic fields, which vary widely in their characteristics. To meet these requirements, a range of PVDF membrane hydrophones has been developed with active element diameters of 0.5 mm and above. However, hydrophones with improved spatial resolution are needed for some applications such as highly-focused high-frequency fields. It is necessary for such devices to have a signal-to-noise ratio at least comparable with current hydrophones. Various methods of improving the signal-to-noise ratio of membrane hydrophones are discussed and some preliminary performance characteristics are presented for experimental hydrophones with active element diameters of 0.2 mm.

285. A fundamental criticism of hydrophone-in-water exposure measurement

Ultrasound in Med. & Biol., 1988, 14 (4), 305-307.

F. A. Duck** and D. R. Bacon.

At present medical ultrasonic equipment is calibrated in a water tank, but the important parameters that determine the safety and performance are those which apply to propagation in tissue. If these in-situ values are required, a simple correction is often applied to the water values to take account of the increased attenuation of tissue. This letter analyses the reliability of such a procedure by determining the output of a scanner in a water tank and also when applied to a sample of bovine liver. It is shown that the field in tissue cannot be predicted using a simple attenuation correction because nonlinear propagation effects occur in water, giving rise to extra losses. It is concluded that alternative approaches to exposure measurement should be reviewed as a matter of some urgency.

CEC joint project on impulse noise: physical quantification methods

The 5th International Congress on Noise as a Public Health Problem, 1988, Stockholm. Proceedings, 1-6.

B. F. Berry and R. Bisping.**

In this phase of a joint project, funded under the Fourth Environment Programme (1986-1990), the National Physical Laboratory and the Institut für Medizinische Psychologie (IMP, University of Düsseldorf) have been studying the problem of physical quantification methods in order to derive optimum objective rating.

Two separate but complimentary lines of investigation have been followed. At IMP the emphasis has been on the frequency domain and the application of autoregressive spectrum analysis, whilst at NPL a number of methods of analysing temporal variations in the A-weighted sound pressure level have been evaluated.

This paper describes the analysis methods, illustrating their applications to a variety of impulsive noises and presents the results of comparisons between subjective ratings and the physical analysis.

Measurement and prediction of the noise of the Harrier V/STOL aircraft

Internoise 88, 1988, Avignon, France. Proceedings, 1203-1206.

B. F. Berry, A. L. Harris, R. C. Payne, N. E. Milton and R. J. Weston.**

A series of flight trials was conducted at the Royal Naval Air Station, Yeovilton, using a Sea Harrier (FRS Mk 1). In the first part of the trials the aircraft operated in hover mode, performing a number of vertical take-offs, landings and turns. In the second part, nine level fly-bys were made with the aircraft using a range of engine settings, nozzle angles and speeds, representative of conditions used in normal airfield operations.

Digital recordings were made of the noise during all events, using microphones at the conventional 1.2 metre height, and ground-plane microphones. In addition video-tracking techniques developed at NPL were used to obtain position and speed information on the aircraft.

This paper describes the trials, measurement and analysis techniques and shows how the source noise data are derived for incorporation into a noise exposure prediction model.

288. Factors affecting the uncertainty of measurements of noise levels from propeller-driven aircraft

Internoise 88, 1988, Avignon, France.
Proceedings, 1227-1230.

R. C. Payne.

During a series of aircraft flight tests using a British Aerospace HS748 and a Piper Navajo PA31, noise measurements were obtained using microphones close to the ground plane and at a height of 1.2 m. Substantial differences between measured A-weighted sound levels were observed. The differences were found to be dependent on ground cover, aircraft type and flight manoeuvre. The ground-plane microphones generally produced A-weighted levels which closely approximated the pressure-doubled values.

Two procedures for correcting A-weighted sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, have been examined. In one procedure the noise spectrum was assumed to be represented by a series of 1/3-octave bands, in the other by a number of pure tones or discrete narrow-bands of noise. Neither correction procedure was wholly successful.

Several factors that influence noise measurements made 1.2 m above the ground have been examined. It is concluded that, to avoid significant variations in measured A-weighted levels, noise measurements must be made using a ground-plane microphone.

See item 263.

289. Sound isolation of a commercial free-field chamber

Applied Acoustics, 1988, 25 (1), 11-15.

S. P. Dowson.

This paper gives an indication of the sound isolation that can be achieved in a single-walled free-field chamber based on one of the panel systems commonly used to construct noise enclosures in factories. Isolation exceeding 40 dB at frequencies of 200 Hz and above has been measured in a chamber lined with 0.4 m long absorbent wedges and having a free volume of $2.2 \times 2.2 \times 2.6$ m between the wedge tips.

290. Pressure sensitivity calibration of half-inch microphones by the reciprocity method - contractor's report on the 1982-87 EEC intercomparison

BCR Information Report, EUR 11751 EN, 1988. Commission of the European Communities.

G. R. Torr and D. R. Jarvis.

Primary pressure calibrations of Brüel & Kjær half-inch microphone types 4134M and 4134 at five EEC standards laboratories have been compared. The intercomparison was radially organised with NPL (UK) as the pilot laboratory and including also DTH (Denmark), INM and LNE (France), and PTB (F R Germany). At frequencies up to 10 kHz, the sensitivity levels determined by the laboratories spanned 0.14 dB and 0.2 dB for the microphone types 4134M and 4134 respectively. At 20 kHz, NPL reported results between 0.2 and 0.3 dB higher than the other laboratories. Normalising the results to common values of microphone total effective volume and acoustic impedance reduced the discrepancies at low frequencies considerably, but left the high frequency results almost unchanged. Residual discrepancies may possibly be related to differences in the measurement of the electrical transfer impedance of the coupled microphones.

291. The significance of nonlinear propagation in determining ultrasonic exposure

Physics in Medical Ultrasound II, IPSM Report 57, 1988, 70-78.

D. R. Bacon.

The importance of nonlinear propagation in medical ultrasound is being increasingly recognised, particularly its effect on the measurement of the output of diagnostic equipment. Most published work has concentrated on the effects that occur when performing measurements in water: only recently have the effects that may occur in tissue been studied, and these are still not fully understood. Since calibration measurements on medical equipment are currently performed in water, it is important to consider the relationship of the field measured in water to the corresponding field in tissue. The results can be used to determine in situ ultrasound exposure levels both in therapeutic and diagnostic applications. This is relevant to the recent discussions about the safety of diagnostic ultrasound, particularly in foetal examination, which recognised the need for more work to determine exposure levels and the conditions that could give rise to hazard. At present there is no agreed basis for calculating in situ exposure, the most common method being to apply a correction to the water-borne measurements to take account of the differing attenuation coefficients of water and tissue. Such a method assumes that the propagation in both media is linear and does not allow for nonlinear effects. This paper demonstrates that this assumption is not valid in general and shows how nonlinear propagation can be taken into account when determining exposure.

292. A comparison of the frequency response of membrane and needle probe PVDF hydrophones

Physics in Medical Ultrasound II, IPSM Report 57, 1988, 79-86.

S. P. Robinson.

There is an increasing need for hydrophones to make accurate measurements of the acoustic output of medical ultrasound equipment. The pulsed fields used by this equipment contain many frequency components, so it is necessary to calibrate the hydrophones over a broad frequency range. It is particularly important to measure the response at small frequency intervals (eg. 0.1 MHz) because some hydrophones have sharp resonances in their response which would otherwise be undetected.

An absolute hydrophone calibration technique based on laser interferometry has been used to measure the sensitivity of a polyvinylidene fluoride (pvdf) membrane hydrophone at small frequency intervals over the range 1 to 15 MHz. The results are compared to the predicted flat response for a membrane hydrophone. PVDF needle probe hydrophones have been shown to possess fluctuations in response over the frequency range 1 to 3 MHz. Such a hydrophone has also been calibrated using the above method and the results compared to those obtained for the membrane hydrophone. The implications of this work for the measurement of the acoustic fields of medical ultrasonic equipment are discussed.

293. A national intercomparison of hydrophone calibration methods

NPL Acoustics Report Ac 116, 1988 (June).

S. P. Robinson, R. C. Preston and D. R. Bacon.

This document is the final synthesis report for a national intercomparison of hydrophone calibration methods organised by the National Physical Laboratory (NPL). The intercomparison was conducted by circulating to participating establishments three types of hydrophone for operation in the frequency range 250 Hz to 500 kHz. Each of the ten participants carried out measurements to determine the open-circuit voltage sensitivity of the hydrophones; monitoring of the stability of the hydrophones between participant stages was carried out by NPL.

The results for each participant are presented along with an overall comparison and assessment of the results. In almost every case, the maximum difference between the participants' results and the grand means of all the results exceeded the uncertainties (95% confidence level) for that particular participant. Maximum differences were frequently greater than 1 dB and sometimes greater than 3 dB. Clearly, the estimates of uncertainty were in many cases too optimistic. It should be of some concern to those interested in reliable calibration results that only one participant was capable of producing a set of results which were consistent with overall uncertainties of 1 dB (95% confidence level).

294. Progress in NAMAS accreditation of acoustical testing laboratories

Proc. Inst. Acoust., Windermere, 1988, 10(8), 233-237.

R. F. Higginson.

Quality control practices have come to be applied formally in recent years in the field of acoustical test work, through the auspices of the National Measurement Accreditation Service (NAMAS). In brief, these practices comprise the following:

- a) Definition of a clear management structure, including provision for quality control;
- b) Employment of suitably-qualified staff;
- c) Availability of the required test facilities;
- d) Calibration of measuring equipment traceable to national standards;
- e) Production of documented test procedures;
- f) Keeping of adequate records of test items and results;
- g) Determination of the uncertainty of test results;
- h) Provision of adequate security covering test items and results.

A total of ten organisations have now been accredited to conduct acoustical tests to various specified procedures. The spur for many of these organisations to apply for this form of recognition has been the introduction of legislation to enforce EEC Directives to limit the noise emission of different kinds of machinery, the legislation requiring the appointment of "approved bodies" to undertake the necessary testing. Companies have, however, taken the opportunity to include other types of test within the scope of their accreditation, including building acoustics, traffic and industrial noise measurements. The implications of the assessment and accreditation process for the applicant organisation will be described in this paper and possible future needs for accreditation will be reviewed.

295. Recent changes in audiometric Standards

British Journal of Audiology, 1989, 23, 261-263.

M. S. Shipton.

A number of new British Standards have been published which affect users of audiometers and audiometric calibration equipment. These are identical to their international counterparts, giving us agreed values for thresholds of hearing by both air and bone conduction. This article draws attention to the important changes that have taken place and looks forward to likely future changes.

Field parameter measurements using a large-aperture hydrophone

Proc. Ultrasonics International 89, 1989, 989-994.

B. Zeqiri.

The acoustic properties of a pvdf membrane hydrophone of active element diameter 30 mm have been investigated. Waveforms recorded on the acoustic axis of a 10 mm diameter broadband transducer are compared with those obtained using a 1 mm active element membrane hydrophone, the smaller hydrophone being used as a reference, 'point'-like, receiver. The comparison is also carried out in the frequency domain. The observed diffractive structure is discussed and measurements of the axial dependence of the hydrophone voltage for the larger device are shown to be consistent with theoretical predictions.

Prediction of *in-situ* exposure to ultrasound: an improved method

Ultrasound in Medicine and Biology, 1989, 15, 355-361.

D. R. Bacon.

The acoustic output of medical ultrasonic equipment is usually measured in water but to determine the safety (or performance) of a machine it is necessary to know the *in-situ* acoustic pressure levels inside a patient. At present, when estimates of these levels are made, a linear propagation model is used although in practice the propagation is nonlinear. This paper shows that such a model can lead to large errors (80% or more in pressure) and in particular that *in situ* predictions of the peak-negative acoustic pressure are too low. To describe the field in water and in tissue it is necessary to take account of diffraction, attenuation, and dispersion as well as nonlinear propagation. It is difficult to use acoustic output levels in water to predict *in-situ* values because the amplitude in water approaches a limit, an effect known as saturation. Nevertheless, a method of making such predictions is presented in this paper and is validated by comparison with experiment. The method is relatively time-consuming to implement and has not yet been applied to pulsed fields, so there is a need for more complete and simpler methods.

298. Comparison of two theoretical models for predicting non-linear propagation in medical ultrasound fields

Phys. Med. Biol., 1989, 34, 1633-1643.

D. R. Bacon and A. C. Baker*.

Non-linear propagation models are required to predict the fields from medical ultrasonic equipment, particularly diagnostic devices and lithotripters. This need arises because of the requirement to know the safety and effectiveness of these instruments. Several theoretical models have been developed to take account of non-linear propagation as well as diffraction, focusing and attenuation, but little work has been done to validate them. This paper compares two theoretical models with each other and with measurements in the field of a 3.5 MHz focused transducer. One model uses an approximation based on modelling the beam profile with a Gaussian function, whereas the other utilises a full three-dimensional finite difference method, using a uniform transducer excitation function. Comparisons are made in the time and frequency domain at the focus for four different source levels and in general the results agree to within about 10%. However, an important conclusion is that the finite amplitude field of a real transducer may differ significantly from that of an ideal piston source, particularly for the weakly focused beams used in diagnostic ultrasound.

299. A reference liquid for ultrasonic attenuation

Ultrasonics, 1989, 27, 314-315.

B. Zeqiri.

Dow Corning 710 silicone fluid has been investigated to establish its suitability as a reference liquid for ultrasonic attenuation. Measurements made in the megahertz frequency range with overall uncertainties of 4-5% at a confidence level of 95% are compared with previous values given in the literature. The results of studies made to assess the long-term stability of the fluid are also presented.

300. Measurement of enhanced heating due to ultrasound absorption in the presence of nonlinear propagation

Proc. 1989 IEEE Ultrasonics Symposium, 1989, 1057-1060.

D. R. Bacon and E. L. Carstensen**.

An important biophysical effect concerning the safety of diagnostic ultrasound is the heating caused by absorption of ultrasonic energy in tissue. This paper shows that nonlinear propagation can increase this ultrasonic heating. The experimental arrangement incorporates a fluid path followed by a sample of tissue-mimicking gel, which models the scanning of a foetus through the full bladder. The measurements were made using a constant spatial-peak temporal-average intensity of 1 W/cm^2 but the temporal-peak intensity was varied by altering the pulsing regime. Up to a threefold increase in the temperature rise of the gel was observed, with the maximum rise being about 2°C . This increased heating correlates well with the amount of nonlinear distortion present in the incident wave, as characterised by the shock parameter. At low amplitudes the results are compared with theoretical calculations. The experimental results are used to estimate the temperature rise that may be produced by diagnostic equipment when the acoustic path in the patient is composed mainly of fluid.

301. A radiation force technique for determining ultrasonic attenuation

Phys. Med. Biol., 1989, 34, 1653-1666.

B. Zeqiri and D. R. Jones*.

The NPL primary standard radiation pressure balance has been modified to enable phase-insensitive through-transmission measurements of attenuation to be made. The accuracy of the basic technique has been assessed by careful measurements on Dow Corning 710 silicone fluid contained in NPL liquid reference cells of various thickness. Several important sources of measurement uncertainty have been identified and studies to assess their significance are described. Interfacial reflections occurring at the two cell membranes result in transmission loss, multiple reflections and, most importantly, standing waves set up between the sample and transducer. Water currents generated in the reference ultrasonic beam, caused by convection and acoustic streaming, may lead to overestimates of the attenuation coefficient of up to 4%. The most important source of uncertainty is a temperature rise which occurs during the measurement and is a consequence of the absorbed power. This effect, which may lead to underestimates in the attenuation coefficient of up to 20%, has been verified by a combination of thermocouple measurements and calculations performed using available theory, both of which are presented. The implications for attenuation measurements in general are discussed.

302. NPL's Ultrasound Beam Calibrator

Electronics and Wireless World, 1989, 95, 892-897.

R. C. Preston, D. Williams** and R. M. Rodriguez**.

The NPL Ultrasound Beam Calibrator has been developed to meet the needs for a measurement system capable of providing a rapid method of measuring the acoustic output of medical ultrasonic equipment. This paper describes the various aspects of the system from the concepts involved in the measurement process through to the electronics used to achieve the fast data acquisition and finally the software used to control the acquisition and data presentation.

303. Are hydrophones of diameter 0.5 mm small enough to characterise diagnostic ultrasound equipment?

Phys. Med. Biol., 1989, 34, 1593-1607.

R. A. Smith.*

A basic requirement for making measurements of medical ultrasonic fields using small sensors is that the sensor should be smaller than the ultrasonic wavelength. Until recently, the smallest commercially-available PVDF membrane hydrophone sensor had a diameter of 0.5 mm, which is larger than the wavelength in water for frequencies above 3 MHz. Thus many measurements have been made with hydrophones which are strictly too large. In this situation, averaging of the acoustic pressure over the active element can cause an underestimate of the spatial-peak acoustic pressure level. In the past, this error was estimated using theoretical models of the beam profile. However, these models make basic assumptions about both the ultrasonic field and the directional response of the hydrophone - assumptions which may not be valid in all diagnostic ultrasonic fields. GEC-Marconi membrane hydrophones with diameters as small as 0.1 mm have now been used to check these theories for diagnostic fields. This paper shows that the error resulting from the use of too large a hydrophone can be up to three times that predicted by current theories. Possible new correction methods are discussed for use in some situations. In other cases the errors can only be reduced by using these new hydrophones, particularly when the acoustic waveform is distorted by nonlinear propagation.

A comparison of national standards of sound pressure

Metrologia, 1989, 26, 253-256.

Torr and D. R. Jarvis.

The International Electrotechnical Commission is currently revising its specification for the method of realising the standard of sound pressure. To provide information on the consistency of present standards worldwide, an intercomparison was organised in which sixteen national standards laboratories each sent a pair of one-inch microphones to the NPL for calibration. This paper presents the results of the intercomparison which show that there is broad agreement between laboratories within the uncertainties claimed.

305. The use of short-term L_{Aeq} in the assessment of impulsive noise

Proc. Inst. of Acoustics, 1989, Vol. II, (9), 309-317.

B. F. Berry, A. D. Wallis** and A. Rozwadowski**.

This paper describes the concept of short-term L_{Aeq} , outlines instrumentation techniques necessary to take the basic time-period down to as low as 5 milliseconds, and explains how these techniques have been applied in a special instrument developed by Cirrus Research plc for NPL. The paper then goes on to describe how the instrument together with special software written to analyse the L_{Aeq} time-series, have been used in the development of special objective measures of impulsiveness such as the "Increment" descriptor.

306. Using short L_{eq} in the measurement and rating of impulsive noise

Proc. Inter-Noise 89, 1989, 951-954.

A. D. Wallis** and B. F. Berry.

This paper describes part of the European Community Joint Project on Impulse Noise which has two parts. Three laboratories, in the UK (ISVR), Italy (IDAC) and Germany (MIU) have been conducting listening tests under a common protocol on the subjective rating of the impulsivity and annoyance of a wide range of noises. Two other laboratories in the UK and Germany have been studying the problem of physical quantification methods in order to derive an optimum objective rating. This paper describes the methods and techniques used by NPL in the UK and presents results of comparisons between the subjective ratings and physical analyses. A new instrument for use in such analyses is introduced.

307. New techniques for the measurement and rating of impulsive noise

Proc. 8th FASE Symposium on Environmental Acoustics, 1989, 291-294.

B. F. Berry and A. D. Wallis**.

The Joint Project on Impulse Noise, funded by the CEC under the Fourth Environment Programme (1986-90) has two related parts. Three laboratories - the Institute of Sound and Vibration Research, University of Southampton (ISVR), the Medical Institute for Environmental Hygiene, University of Düsseldorf (MIU) and the Institute of Acoustics (IDAC) in Rome - have been conducting listening tests under a common protocol on the subjective rating of impulsivity and annoyance of a wide range of noises.

NPL and the Institute for Medical Psychology, University of Düsseldorf have been studying the problem of physical quantification methods in order to derive an optimum objective rating. This paper describes the methods and techniques used by NPL and presents results of comparisons between the subjective ratings and physical analyses. New instrumentation for use in such analyses is introduced.

Recent advances in the measurement and rating of impulsive noise

Proc. 13th International Congress on Acoustics, 1989, Vol. 3, 147-150.

B. F. Berry

The Joint Project on Impulse Noise, funded by the Environment Programme (1986-90) has two related parts. Three laboratories - the Institute of Sound and Vibration Research, University of Southampton (ISVR), the Medical Institute for Environmental Hygiene, University of Düsseldorf (MIU) and the Institute of Acoustics (IDAC) in Rome - have been conducting listening tests under a common protocol on the subjective rating of impulsivity and annoyance of a wide range of noises.

NPL and the Institute for Medical Psychology (IMP), University of Düsseldorf have been studying the problem of physical quantification methods in order to derive an optimum objective rating. This paper describes the methods and techniques used by NPL and presents results of comparisons between the subjective ratings and physical analyses. New instrumentation for use in such analyses is introduced. A separate paper is to be presented on the related work at IMP by Bisping.

The evaluation of small area membrane hydrophones

NPL Report RSA(EXT)0002, 1989 (April)

R. A. Smith

This report contains some of the results obtained from a project funded by the Bureau Communautaire de Reference (BCR) of the CEC which was undertaken jointly by GEC-Marconi and NPL. The aim of the project was to develop and evaluate the performance of small area hydrophones produced by GEC-Marconi with particular attention to their suitability for characterising medical diagnostic ultrasonic fields. NPL was responsible for the evaluation of the acoustical performances of the devices. Both frequency and directional responses were measured up to 30 MHz and compared with theoretical models. The hydrophones had active diameters of 0.2 mm and 0.1 mm when determined from the directional responses. Finally, the hydrophones were used to characterise the fields from three medical diagnostic transducers and the results compared with those using membrane hydrophones with larger active elements. In one case, a 0.5 mm diameter hydrophone measured only 25% of the true pressure as a result of spatial averaging over the active element. In the same field the 0.1 mm diameter hydrophone measured over 87% of the true pressure.

Review of current IEC activities in acoustic output standardisation of medical equipment

Ultrasound in Medicine and Biology, 1989, 15, (Suppl. 1), 101-103.

R. C. Preston.

A brief survey is given of the work of Technical Committee 87: Ultrasonics of the International Electrotechnical Commission (IEC) relevant to measurement of the acoustic output of medical ultrasonic equipment. Particular emphasis is placed on the generation of standards related to safety of medical ultrasonics or standards related to the calibration of ultrasonic field measuring devices.

Noise levels from a VSTOL aircraft measured at ground level and at 1.2 m above the ground

NPL Report RSA(EXT)0009, 1989 (October)

R. C. Payne

During a series of aircraft flight tests using a British Aerospace Sea Harrier (FRS Mk1) noise measurements were obtained using microphones close to the ground plane and at a height of 1.2 m. Substantial differences from ground level to 1.2 m were observed, in measurements of perceived noise level and effective perceived noise level. The differences were found to be dependent on ground cover and flight manoeuvre, and in addition, for a microphone located 1.2 m above a grass surface a dependence on precise microphone positioning was observed. The ground-plane microphones generally produced noise levels which closely approximated to pressure-doubled values.

A comparison of the Harrier noise data with the data obtained for a Panavia Tornado and a McDonnell Douglas Phantom indicates that the variation in the departure from pressure-doubled levels is dependent on the aircraft noise spectrum. This results in a greater dependence on aircraft manoeuvre than on aircraft type.

A procedure for correcting $\frac{1}{3}$ -octave band sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, has been examined. The procedure was successful when used to adjust noise levels measured using a microphone located over a runway surface but not when considering data obtained over a grass surface. This is a result of difficulties involved in assessing ground impedance and a precise microphone height when considering a natural grass covered surface.

It is concluded that, to avoid significant variations in measured noise levels, measurements should be made using a ground-plane microphone arrangement.

312. Speech databases for UK speech technology research: A survey of resources and future needs

NPL Report RSA(EXT)0010, 1989 (October)

M. J. Goldsmith

A National Archive of Speech Databases is being established at the NPL, consisting of pre-existing and newly developed speech material. The archive will act as a library and information service for UK speech technology researchers. To survey the needs and resources of the UK speech research community, two questionnaires were designed and circulated to academic, industrial and government organisations with interests in this field.

Responses to the questionnaire on resources have been used to compile a detailed list of existing databases. Many existing databases are potentially useful, but suffer in general from a lack of annotation or from not being computer-readable. Information on speakers and recording details is also meagre.

From the survey of needs, it is concluded that there is strong interest in a National Archive, and particularly in the availability of well recorded speech in quiet conditions in British English (preferably in a range of accents). There is interest in a wide range of types of speech, available on a range of media including Betamax standard video cassette tapes. Background information on the speakers is required.

Eight databases are now held in the National Archive, together with information on sixteen more. Further expansion is planned.

313. Effects of low frequency whole-body sinusoidal vibration on speech

Proc. Inst. of Acoustics, 1989, Vol. II (5), 151-158.

M. R. Taylor*.

Fixed wing aircraft have fairly broad band vibration characteristics concentrated below 10 Hz, whilst rotary-wing aircraft have discrete often intense vibration frequencies between 15-25 Hz. Unfortunately major body resonances affecting speech production also occur within these frequency ranges.

Research results published by Nixon, and Nixon and Sommer have shown whole-body sinusoidal vertical (Gz) vibration at 6, 8 and 10 Hz, can contribute to a reduction in speech intelligibility. Low frequency whole-body sinusoidal vibration has also been observed by Leeks to cause a reduction in automatic speech recognition accuracy, particularly when speakers are subjected to 10 Hz or 20 Hz Gz vibration at acceleration levels of 0.25g (rms).

This paper describes data acquisition and analysis experiments designed to contribute towards the understanding of speech variability as a function of whole-body Gz sinusoidal vibration.

Evaluation of a model for the prediction of temperature rise in tissue due to the absorption of ultrasound

NPL Report RSA(EXT)0013, 1990 (July)

G. R. Doré

Results are given of an evaluation of the NCRP model for the prediction of temperature rise in tissue due to the absorption of ultrasound. Starting from a standard configuration in which a transducer has a diameter of 2 cm, a radius of curvature of 10 cm and an operating frequency of 3 MHz radiating into soft tissue, a series of graphs are presented giving the variation in temperature rise when transducer and tissue parameters are varied one at a time.

The behaviour of the equations describing the beam width is closely examined and an anomaly is highlighted for the case of tightly focused beams. A variation on these equations is described and, in addition, a Gaussian field distribution has been considered.

An attempt to predict enhanced heating from nonlinear propagation has been made using a model in which the ultrasound travels through a water path before entering the tissue. Harmonic pressures and widths are related by $1/n$ and $1/\sqrt{n}$ factors respectively and give enhancements of up to 1.4.

Comparisons have been made between observed and calculated temperature rises and the calculated temperature rises are observed to be 50% lower. However, a number of factors are suggested which might explain this discrepancy.

Hydrophone calibration using nonlinear propagation

IEEE Guide for Medical Ultrasound Field Parameter Measurements, 1990,
IEEE Std 790-1989, Section 1.4.4.

D. R. Bacon.

This section of the standard describes a procedure for calibrating hydrophones utilising nonlinear propagation. Measurements with an uncalibrated hydrophone are used to infer the acoustic pressure in the field. Calculations of nonlinear propagation are then used to evaluate the amplitudes of all the harmonic components that are generated in the medium. Having characterised the acoustic field, the response of the hydrophone can be determined from the measurement of its output spectrum. A simple method of calculating the results is given; more sophisticated methods for obtaining the results are described in references to the literature. Brief details are given of the accuracy of the technique, the equipment required and how to obtain the results.

316. Hydrophone calibration by substitution in a sawtooth wave

IEEE Guide for Medical Ultrasound Field Parameter Measurements, 1990,
IEEE Std 790-1989, Section 1.4.5.

D. R. Bacon.

This section of the standard describes a method for calibrating an unknown hydrophone by comparing its response with that of a known, calibrated device. The acoustic field used in this measurement has a sawtooth shape, due to nonlinear propagation and so contains many harmonic frequency components. Brief details of the equipment, the procedure and the applicability of the method are given.

317. NPL Ultrasound Beam Calibrator - BECA2

IEEE Guide for Medical Ultrasound Field Parameter Measurements, 1990,
IEEE Std 790-1989, Section 1.5.3.

R. C. Preston.

A description of the important performance properties of the NPL Ultrasound Beam Calibrator is given. Simple procedures for its use in determining the acoustical output of medical diagnostic ultrasonic equipment are described.

318. Tethered float wattmeter

IEEE Guide for Medical Ultrasound Field Parameter Measurements, 1990,
IEEE Std 790-1989, Section 2.12.

R. C. Preston.

The tethered float radiometer is a device for measuring the total output power of ultrasonic therapeutic equipment. The basic technical performance of the tethered flow wattmeter are described together with simple procedures for its use.

A database of normative speech recordings

Proc. Inst. of Acoustics, 1990, Vol. 12, (1), 1-6.

H. C. Fuller, A. J. Fourcin**, M. J. Goldsmith, M. Keene** and W. J. Barry**.

As part of an Alvey-funded collaborative project, a small speech database has been recorded in which the choice of speakers, the language material, the speech production tasks and the acoustic conditions have been very carefully defined and controlled. Digital recordings of the speech and larynx signals were made simultaneously and as a first step analyses of the larynx signal have been carried out.

Stability of average laryngeal frequency in speech

Proc. Inst. of Acoustics, 1990, Vol. 12, (1), 7-15.

W. J. Barry**, M. J. Goldsmith, A. J. Fourcin** and H. C. Fuller.

This paper presents results from an in-depth study of the laryngeal patterns in speech of four speakers, and investigates the question of stability in a number of ways. Firstly it looks at average frequency data for varying stretches of speech from 10-15 seconds up to two minutes. There is evidence from the literature that two minutes of continuous speech are sufficient to characterise a speaker, and this has been clinical practice in the UK for more than a decade. However, there are also indications that systematic longer term fluctuations exist. Consequently a series of longer recordings were made at different times of one day in order to check for a systematic shift in voice pitch during the day. Also, a number of different types of speech tasks were set in order to examine the stability of average voice frequency over tasks. Finally, the relationship between the 'stability' of the two-minute period and 15-minute period was examined.

323. Increased heating by diagnostic ultrasound due to nonlinear propagation

J. Acoust. Soc. Am., 1990, 88, 26-34.

D. R. Bacon and E. L. Carstensen**.

The heating of tissues by the absorption of ultrasound is an important safety consideration in the use of diagnostic ultrasound. This paper shows that models of ultrasonic heating for this situation need to take account of nonlinear propagation. Measurements were made of the temperature rise in a sample of tissue-mimicking gel, caused by the application of 3.6 MHz focused ultrasonic beams for 3 min. The propagation path to the focus was in water, to mimic the situation where the fetus is scanned through the full bladder. The effect of nonlinear propagation was seen by changing the pressure amplitude of the pulse, while altering the pulsing regime to preserve a constant spatial-peak temporal-average intensity of 1 W cm^{-2} . When nonlinear distortion was present, an enhancement in the temperature rise was observed, which correlated with the value of the shock parameter. The enhancement ratio was typically up to a factor of 3, and the maximum temperature rise observed was 2°C . This enhanced heating was seen both at the surface of the tissue-mimicking gel and after propagation through 23 mm of the material. Under conditions of nonlinear propagation, the maximum heating usually occurs in the prefocal region, rather than at the focus.

321. Standards for hydrophone calibration in the UK

Proc. Inst. of Acoustics, 1990, Vol. 12, (1), 199-207.

S. P. Robinson, R. C. Preston and G. R. Doré.

In the past, there have been no UK national measurement standards for the calibration of hydrophones at frequencies below 500 kHz. Three years ago, under pressure from industry, the National Physical Laboratory (NPL) started to assess requirements for standards in this field. Initially, to investigate current capabilities within the UK, NPL organised a 'round-robin' intercomparison involving a total of ten participants, in which three common types of measuring hydrophone were circulated for calibration in the frequency range 250 Hz to 500 kHz. The results and conclusions from the intercomparison are described in the first part of this paper. A spread in the results of 3-4 dB was obtained with the majority of participants unable to calibrate the hydrophones to an accuracy commensurate with their estimated uncertainties.

As a result of these findings, NPL is planning to establish a UK primary standards facility for the calibration of hydrophones, leading to the launch of a new calibration service. Initially, this will be based on free-field reciprocity calibration in the frequency range 10-500 kHz. However, other methods will also be investigated, especially for calibrations at frequencies outside this range. A description is given of NPL's current activity and future plans in this area.

322. Effects of whole-body vibration on speech

Proc. Inst. of Acoustics, 1990, Vol. 12, (2), 577-581.

M. J. Goldsmith and M. R. Taylor*.

It is fairly well established that one major effect of physical and/or emotional stress on speech is an increase in pitch, and one of the chief components of physical stress in aircraft is vibration, and in particular, vibration at frequencies below 25 Hz. This fact has gradually been quantified, most recently by Taylor, who has studied the effects of different vibrations induced in pilots on a three-axis vibrating rig on human speech. He found that the vibration frequency which produced the strongest effects was 9 Hz. The present paper investigates in more detail the effects on the speech signal at this frequency, by statistical analysis of the larynx signal.

Measurement standards, testing and quality assurance for the control of noise at work

Proc. I. Mech. E., 1990, Engineering a Quieter Europe, 119-122.

R. F. Higginson.

The EC Directive and proposed UK legislation on protection from exposure to noise at work recognise that noise above certain levels constitutes a potential safety and health hazard. The legislation will require measurements to be made of noise in workplaces, to determine whether the defined hazardous levels are being exceeded. Long-term strategies for control of noise will need additionally to include the testing of machinery and equipment against individual noise limits. Extensive use of noise measurements will therefore follow from the new legislation and they must give reliable results.

This paper will review the present British and international standard specifications for noise measurements, and also the current activities of the standards organisations aimed at revising, up-dating and extending the range of published standards. Of course, the use of standard measurement procedures does not of itself guarantee reliable results. It is vital that properly calibrated equipment is used, and the present facilities within the UK which are able to provide acoustical calibrations traceable to national standards will be described. It is also important to ensure that the procedures are applied correctly by competent personnel working to a defined plan. The author will argue that this is best ensured by arranging for the testing to be undertaken within a Quality Assurance regime. Means of putting this into effect across a very wide variety of workplace environments and organisations will be suggested.

Military aircraft noise prediction and measurement

Proc. Inst. of Acoustics, 1990, Vol. 12, Part 12, 19-26.

B. F. Berry and A. L. Harris.

For a number of years the National Physical Laboratory has been developing AIRNOISE, a mathematical model for computing military aircraft noise contours. The model is used by the Royal Air Force Institute of Community and Occupational Medicine (RAF ICOM) to determine eligibility for compensation for noise nuisance. Details of the criteria applied by the Ministry of Defence (MoD) and the background to them have been described by Boardman, and by Weston and Berry. This paper describes the AIRNOISE model including the extension of its capabilities to include the Harrier V/STOL aircraft in vectored thrust mode. It then goes on to discuss recent work on noise from low-altitude, high-speed operations and to outline the directions in which future developments are likely to take the work.

326. The measurement of the frequency response of a photodiode and amplifier using an opto-mechanical frequency response calibrator

Meas. Sci. Technol., 1990, 1, 1184-1187.

S. P. Robinson, D. R. Bacon and B. C. Moss**.

A description is given of the measurement of the frequency response of two avalanche photodiodes and their associated amplifier over the frequency range 1 kHz to 25 MHz by an opto-mechanical frequency response calibrator. The photodiodes are part of a laser interferometer which is used in the calibration of ultrasonic hydrophones. The accuracy of the calibrator has been estimated to be better than 3% for measurements made at frequencies below 20 MHz.

327. Overview of absorption of finite amplitude, focused ultrasound

Frontiers of Nonlinear Acoustics: Proceeding of 12th International Symposium on Nonlinear Acoustics, 125-130.

D. Dalecki**, E. L. Cartensen**, K. J. Parker** and D. R. Bacon.

Predictions of the absorption of focused finite amplitude waves based on weak shock theory have been tested experimentally. Under appropriate conditions, the absorption of finite amplitude ultrasound is determined largely by source amplitude, field geometry and the nonlinear properties of the medium and is only weakly dependent upon the small signal absorption coefficient of the material. To emphasise nonlinear absorption, focused sound fields were used and measurements of heating were made in agar which has a very small linear absorption coefficient.

328. Nonlinear acoustics in ultrasound calibration and standards

Frontiers of Nonlinear Acoustics: Proceedings of 12th International Symposium on Nonlinear Acoustics, 3-19.

D. R. Bacon.

Many diagnostic and therapeutic applications of ultrasound in medicine use amplitudes that are high enough for nonlinear distortion of the wave to occur. This gives rise to difficulties in the formulation of acoustic output and labelling standards, such as predicting the exposure to patients and the likely degree of tissue heating or cavitation activity. It is, however, possible to exploit nonlinear propagation in measurements of diagnostic equipment by using it in the calibration of the measuring device. A working hydrophone can be calibrated against a reference using a distorted field containing many frequency components. A harmonically rich field may also be used to obtain rapid, multi-frequency, measurements of the directivity and spatial resolution of these devices. Finally, a hydrophone can be calibrated in absolute terms by measuring the field amplitudes and comparing them with theoretical predictions. Such a technique can be carried out in a quasi continuous-wave field or a pulsed field. For calibrations using a pulsed field it has been possible to obtain agreement with the NPL primary standard interferometer in the frequency range 10 to 20 MHz and with theoretical predictions of the hydrophone response up to 100 MHz. A similar technique can be applied to measure the nonlinearity coefficient (B/A) of a material.

Measurement uncertainties in the determination of noise emission

Proc. Inter-Noise 90, 1990, 625-628.

R. F. Higginson.

No significance can be attached to a measurement of any quantity unless its accuracy is known. Such information is especially important when the purpose of determining the quantity is to decide whether a product is acceptable to a purchaser or even whether it conforms with legal requirements. Quantities related to noise emission of a source are the sound power level, determined from measurements of either sound pressure or sound intensity, and the sound pressure level at a defined position. No matter which is chosen, the result is derived from a complex process and can be affected to a significant degree by the acoustical environment, the measuring equipment and the operating conditions of the source. Accuracy in this context is difficult to define and for practical purposes it is more useful to estimate the measurement uncertainty, that is the range within which the true value is estimated to lie, at a given confidence level. The more closely defined are the surroundings, the instrumentation and the operating conditions, the smaller is the measurement uncertainty, but the greater, possibly, is the cost involved. Any noise emission labelled value should be interpreted in conjunction with the measurement uncertainty and, when compared with a performance specification, a suitable margin ought to be included. Every test code should include a clear statement of the associated measurement uncertainty, so that a user can make a choice on economic grounds. This paper describes the efforts being made to devise an adequate statement for this purpose in the course of current revisions and drafting of the basic international standards for determination of noise emission.

Noise from military airfields in the United Kingdom

Proc. Inter-Noise 90, 1990, 413-416.

R. J. Weston** and B. F. Berry.

This paper describes the background to MoD policy on noise compensation near military airfields and summarises the development and capabilities of the NPL mathematical model AIRNOISE, which is used for predicting noise contours. Problems of noise from low-altitude operations and helicopter operations are also briefly addressed.

331. An examination of the relationship between vehicle noise measures and perceived noisiness

Proc. Inter-Noise 90, 1990, 1141-1144.

G. Watts**, N. Godfrey** and B. F. Berry.

In a number of countries including the UK the noise emitted by road vehicles is controlled by vehicle type approval noise tests which set limit values for various vehicle classes. These limit values are specified in terms of the maximum permissible weighted sound pressure level achieved during full acceleration under specified conditions. The specification has used the maximum A weighted sound pressure level for many years now, but as more stringent requirements are stipulated there is an increasing need to ensure that there are commensurate improvements in the perceived noisiness of these vehicles. It is possible that there are other physical scales of noise that are better correlated to people's perception of noisiness and should therefore be considered as measures to test noise emission.

This paper describes a jury experiment where subjects were instructed to rate the noisiness of a range of vehicles as they were driven past a measurement site under different operating conditions. The experiment aimed to extend the original tests held about 30 years ago which led to the use of the dB(A) scale for vehicle noise. In the present trials, listeners were positioned both inside a listening room and in the open air, whereas in the original trials ratings were only made in the open air. A variety of noise measures were examined including A, B and C weighted levels and measures of loudness based on the Zwicker method of computation. The vehicles performed a variety of operations; passes at steady speed, acceleration from rest and from low speed, and steady tick over.

The initial analysis of this study involved the measurement of A and C weighted sound levels only and that has been reported elsewhere. This further analysis concentrated on loudness descriptors and B weighted levels and comparisons with the former measures.

332. A multiple-frequency hydrophone calibration technique

J. Acoust. Soc. Am., 1990, 87, 2231-2243.

R. A. Smith* and D. R. Bacon.

A method is described for comparing the sensitivity of two hydrophones over the frequency range 1-15 MHz. This technique forms the basis for the dissemination of national ultrasonic standards in the UK over this frequency range. A reference hydrophone is placed in an ultrasonic field and then the device being calibrated is substituted and the two output voltages are compared. This substitution method utilises a broadband ultrasonic field produced by nonlinear propagation. This it is possible to cover the whole frequency range with a single measurement on each hydrophone. The overall uncertainty in the intercomparison of two hydrophones increases from $\pm 4.2\%$ at 1 MHz to $\pm 8.2\%$ at 15 MHz (95% confidence level). The method has been compared with discrete-frequency substitution, time-delay spectrometry, and absolute calibrations using the National Physical Laboratory (NPL) Primary Standard Laser Interferometer. Various designs and sizes of hydrophones were compared, and agreement was within the combined random uncertainties for all the comparisons.

INDEX

- absorption 54, 61, 65, 67
 actuator 43
 air-conduction 4, 7
 aircraft . . 12-14, 18, 19, 23, 31, 34, 36, 39,
 42, 47, 48, 59, 60, 64, 66
 AIUM 24, 32
 annoyance 13, 22, 31, 37, 43, 57, 58
 audiological 2, 36
 audiology 2, 8, 51
 audiometer 5
 audiometry 2, 4, 7, 9, 13, 21
 Bacon . . 6, 8, 10-12, 15, 17, 18, 20, 26, 33,
 37, 40-42, 44-46, 49, 50,
 52-54, 61, 62, 65, 67, 68, 71
 Bazley 3, 7, 9, 14
 BCR 5, 14, 23, 26, 37, 49, 58
 BCS 24
 beam calibrator . . 17, 19, 30, 31, 40, 44, 55,
 62
 Berry . . 4, 13, 14, 22, 28, 31, 37, 38, 43, 47,
 56-58, 66, 69, 70
 bone-conduction 4, 5, 7, 8
 calibration . . 1-3, 5, 7-12, 14, 16, 18, 20, 23,
 24, 28, 32, 33, 34-37, 41,
 44, 45, 49-51, 56, 59, 61,
 62, 64, 67, 68, 71
 characterisation . . 10, 11, 15, 21, 24, 25, 30,
 32
 Crittenden 43
 Delany 3, 7, 9, 14, 23, 24, 29, 40
 Doré 61, 64
 Dowson 14, 48
 earphone 4, 7, 15, 34
 earphones 6, 9, 15, 34
 environment . . 1, 22, 37, 39, 43, 47, 57, 58,
 69
 environmental 1, 4, 14, 22, 29, 57, 58
 exposure . . 1, 32, 40, 43, 46, 47, 49, 52, 66,
 68
 FDA 24
 Fuller 2, 3, 9, 13, 21, 33, 63
 Goldsmith 60, 63, 64
 ground-plane . . 13, 18, 19, 36, 42, 47, 48,
 59
 Harris 22, 45, 47, 66
 hearing . . 1, 4-8, 18, 21-23, 26, 30, 35, 38,
 51
 hearing protectors 5, 18, 23, 35
 heating 54, 61, 65, 67, 68
 Higginson 1, 22, 23, 28, 34, 51, 66, 69
 hovercraft 1
 hydrophone . . . 6, 8, 10-12, 15, 17, 19, 20,
 25, 27, 30-33, 37, 40, 41,
 42, 44-46, 50, 52, 55, 58,
 61, 62, 64, 68, 71
 IEC 14, 22, 24, 32, 34, 35, 37, 59
 impulsive 22, 31, 37, 43, 47, 56-58
 impulsive noise 22, 31, 37, 43, 56-58
 intensity 8, 10, 54, 65, 69
 intercomparison . . 14, 23, 26, 27, 30, 35,
 38, 41, 49, 50, 56, 64, 71
 ISO 6, 31, 35
 Jarvis 10, 35, 43, 49, 56
 laser interferometer . . 17, 29, 33, 37, 41,
 67, 71
 lithotripter 42
 Livett 8, 11, 15-19, 24
 local authority 28
 loudness 31, 70
 masking 4, 7
 mastoid 4, 5, 7
 medical ultrasonic equipment . . 8, 10, 15,
 16, 19, 20, 24, 25, 27, 29,
 30, 40, 41, 44, 46, 50, 52,
 53, 55, 59
 microphone . . 13, 14, 18, 19, 23, 34-36, 42,
 43, 48, 49, 59
 Moss 20, 21, 38, 67
 NAMAS 24, 28, 29, 51
 NATLAS 24
 noise . . 1-5, 7, 11-15, 18, 19, 22-24, 28, 29,
 31, 34, 36, 37-39, 42, 43,
 46-48, 51, 56-59, 66, 69, 70
 nonlinear . . 6, 10, 15, 17, 26, 27, 40, 44, 46,
 49, 52, 54, 55, 61, 62, 65,
 67, 68, 71
 nonlinear propagation . . 10, 15, 17, 27, 40,
 46, 49, 52, 54, 55, 61, 62,
 65, 68, 71
 Payne . . 12, 13, 18, 19, 36, 42, 47, 48, 59
 Preston . . 8, 11, 15-20, 24, 25, 29-32, 40, 42,
 44, 45, 50, 55, 59, 62, 64
 protectors 5, 18, 23, 26, 35, 38
 quality 21, 28, 51, 66
 radiation pressure 8, 16, 25, 54
 railway 13, 14
 Rajendran 15
 reciprocity . . 3, 7-10, 14, 18, 23, 35, 43, 45,
 49, 64
 Rennie 1, 22
 Robinson 1-7, 40, 50, 64, 67
 Sherwood 34

Shipton . 1, 3, 2, 4, 6-8, 15, 18, 23, 26, 30,
34-36, 38, 51
Smith . . 20, 27, 32, 41, 44, 46, 55, 58, 71
sound isolation 48
speech . 2, 9, 13, 21, 22, 29, 33, 39, 60, 63,
64
standard . . 1, 3, 6, 7, 9, 13, 14, 18, 20, 23,
24, 28, 29, 32, 34, 35,
40-42, 54, 56, 60-62, 66, 68,
71
standardisation 1, 2, 4, 13, 20, 23, 32, 39,
40, 59
standards . . 1, 2, 6, 11, 14-16, 19, 20, 24,
25, 28-30, 32, 38, 40, 41,
44, 49, 51, 56, 59, 64, 66,
68, 69, 71
Sutton 5
Taylor 17, 19, 39, 60, 64
tethered float 62
thresholds 1, 4, 6-8, 51
tissue . 21, 40, 41, 46, 49, 52, 54, 61, 65, 68
Torr 5, 10, 29, 49, 56
traffic 13, 14, 22, 37, 43, 51
ultrasonic attenuation 53, 54
vibration 1, 39, 57, 58, 60, 64
vibrator 4, 5, 7
Whittle 5, 9
Zeqiri 17, 19, 21, 52-54

1. The first part of the paper is devoted to a general discussion of the problem of the existence of solutions of the system of equations

$$\frac{dx}{dt} = A(x)u, \quad \frac{dy}{dt} = B(x)y,$$

 where $A(x)$ and $B(x)$ are matrices depending on x , and u is a vector function. It is shown that under certain conditions the system has a solution in the form of a power series in x .
 2. In the second part, the problem of the stability of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are stable.
 3. In the third part, the problem of the asymptotic behavior of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system tend to zero as $t \rightarrow \infty$.
 4. In the fourth part, the problem of the periodicity of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are periodic.
 5. In the fifth part, the problem of the bifurcation of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system bifurcate at the origin.
 6. In the sixth part, the problem of the global behavior of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are globally stable.
 7. In the seventh part, the problem of the global asymptotic behavior of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are globally asymptotically stable.
 8. In the eighth part, the problem of the global periodicity of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are globally periodic.
 9. In the ninth part, the problem of the global bifurcation of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system globally bifurcate at the origin.
 10. In the tenth part, the problem of the global stability of the solutions of the system is considered. It is shown that if the matrix $B(x)$ is negative definite, then the solutions of the system are globally stable.