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PREPRINTS

STANDARDISATION IN ACOUSTICS

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8th OCTOBER 1980

NATIONAL PHYSICAL LABORATORY
TEDDINGTON, MIDDLESEX

INSTITUTE OF ACOUSTICS

INSTITUTE OF ACOUSTICS

A One-Day Meeting

STANDARDISATION IN ACOUSTICS

NATIONAL PHYSICAL LABORATORY

8TH OCTOBER 1980

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PROGRAMME

0930	REGISTRATION	
1000	OPENING OF THE MEETING by DR. P.J. CAMPION, Deputy Director, National Physical Laboratory	
	INTRODUCTORY LECTURE	
1005	National and International Standardisation DR. D.W. ROBINSON, National Physical Laboratory, Teddington	pg. 1
	NOISE MEASUREMENT STANDARDS	
1045	Instrumentation Standards for Noise Measurement DR. W.V. RICHINGS, Dawe Instruments Limited, London	pg. 9
1150	Standards in Aircraft Noise Measurement MR. L.R. BENTLEY, Rolls Royce Limited, Derby	pg. 19
1225	Measuring the Noise Emission of Industrial Machinery MR. K.J. MARSH, Engineering Department, British Petroleum Co. Ltd., London	pg. 25
1300	LUNCH	
	AUDIOLOGICAL STANDARDS	
1400	Electroacoustical Standards in Audiology MR. M.C. MARTIN, OBE, Royal National Institute for the Deaf, London	pg. 31
1430	Standards in Occupational Noise and Hearing Conservation DR. D. ELSE, Safety and Hygiene Group, Aston University, Birmingham	pg. 35
1455	Dissemination of Audiological Standards MR. M.S. SHIPTON, National Physical Laboratory, Teddington	pg. 37
1515	TEA	
	MEDICAL ULTRASONICS STANDARDS	
1535	The Need for Standards in Medical Ultrasonics DR. G.R. ter HAAR, Institute of Cancer Research, Sutton	pg. 41
1610	Development of Measurement Standards and Techniques MRS. A. LIVETT, National Physical Laboratory, Teddington	pg. 47
1640	Practical Techniques and Present Status in Hospitals DR. R.C. CHIVERS, University of Surrey, Guildford	pg. 53
1700	CLOSE OF MEETING	

NATIONAL AND INTERNATIONAL STANDARDIZATION

D.W. ROBINSON
NATIONAL PHYSICAL LABORATORY

WHAT IS A STANDARD?

English dictionaries give twenty or more meanings of this remarkable word. Leaving out some of the more recondite and the botanical, here are a few which come within hailing distance of today's proceedings:

- a flag or banner
- a class
- a level of excellence required, aimed at, or possible
- a criterion
- an established or accepted model
- a basis of measurement
- an exemplar or substance chosen to be, or afford, a unit.

No single one of these fits all ten occurrences of the word "standard" in the programme of this meeting. In USA there are two well-known institutions named for standards, the National Bureau of Standards (NBS) and the Americal National Standards Institute (ANSI), which nicely exemplify the conceptual distinction between the two sorts of standards - metrological and specification - which principally concern us. These two types are complementary although they lead to different sorts of activity.

Broadly, standardization in metrology means the realization of physical units and quantities, and the system whereby these material representations are propagated down a traceability chain from a unique exemplar of great accuracy at the apex, through successively lower levels with ever-increasing replicas and correspondingly decreasing accuracy (or increasing uncertainty as we are nowadays encouraged to say). At the international level, the Comité International des Poids et Mesures (CIPM) with its laboratory at Sèvres (BIPM) is at the head of this chain; national standardizing laboratories, of which NPL is one, stand at the apex of the respective national pyramids, and below them various forms of dissemination and calibration service operate to provide standards of measurement for the end users in manufacturing industry, health services, environmental protection and so on. This pyramid shown greatly simplified in Fig. 1 (left) operates, at the top, in a purely scientific climate whilst technological and engineering emphasis dominates at the base. The recommendations of the 18 members of the CIPM on SI units, such as the value of the metre and ampere, are generally accepted by states which are signatories of the Metre Convention of 1875; the pyramid operates on the basis of mutual acceptance without important political or economic distortions but in a financial straitjacket.

Paralleling this is the other metrological pyramid shown at centre, in which the driving force is not science or engineering but legislation on weights and measures for trade and consumer protection. The International Organization for Legal Metrology (OIML) at the apex is composed of the representatives of member Governments and the standards it produces are usually in the form of model laws. OIML has a long history, but its activities have, as yet, barely touched on acoustics so we can conveniently leave OIML aside.

In contrast to these metrological activities, the pyramid for specification standards (Fig. 1, right) exists primarily to prevent barriers to trade, and also to establish voluntary norms where proliferation would be in nobody's interest, in the fields of applied science and technology. Specification standards at the international level are produced mainly by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) through a vast network of technical committees. Although the two bodies are separate they share a common address in Geneva, and IEC works in practice as the electrical division of ISO. The members of ISO are the national standardizing institutions, and of IEC the National Electrotechnical Committees. In UK, the British Standards Institution (BSI) fills both roles but this unity is not the case everywhere. ISO and IEC standards are voluntary although member bodies who vote in favour of them are pledged to adopt them. If there is a conflict with national requirements they are not supposed to vote in favour. Obviously this provides opportunities, in an imperfect world, for pre-emption, backsliding, using the standards as instruments of national commercial policy, and other scientifically "impure" acts. This is most marked in the case of instrument specifications, where the commercial interests are greatest, and also for some standards dealing with methods of measurement of products, but happily almost absent in the case of applied scientific data. Despite the limitations a great deal has been accomplished (over 5000 standards, 80-odd in the acoustical sphere) which must gratify any but a perfectionist. It is worth adding that these standards sometimes permit, within them, different standards (using the word in the sense of "levels") of measurement accuracy, manufacturing tolerances etc. What they expressly do not do is to incorporate standards (using the word in yet another sense, to mean "criteria") which imply or assert limit values; this would undermine the system fatally.

As mentioned, Fig. 1 is greatly simplified. There are cross-links at various levels, for example between NPL and its sister institutions abroad. There are a number of regional organizations (EEC, NATO etc) that operate supranationally but not fully internationally. There are fully international organizations that produce specification standards in particular technologies, for example ICAO in civil aviation and CCITT in telecommunications. Furthermore there is no sharp dividing line between the fields of metrological standards (étalons) and specification standards (normes); an example is the realization of the sound pressure unit. This is clearly metrology but it happens to be done through the medium of a series of IEC specification standards detailing the calibration of condenser microphones by reciprocity.

ACOUSTICAL STANDARDS

The important physical quantities in acoustics are sound pressure and, to a lesser extent, sound power. The respective units, pascal and watt, are derived units in the SI system and, although their realizations in the frequency range of acoustics differ in form from that of the pascal as a static pressure and of the watt in its electrical manifestation, it might be supposed that they would feature in the work programme of BIPM. This, however is not the case probably due to resource limitations and competing demands on the Sèvres laboratory. Furthermore, the UK traceability chain for acoustical measurement standards is less organized than the diagram suggests. The British Calibration Service (BCS), for example, does not cover any part of the acoustical field (vibration excepted); potential test laboratories have apparently judged the profitability insufficient in relation to the costs of BCS approval. Pressure from the ultimate customer for guaranteed acoustical performance of products (eg noise emission) has not built up to the extent that it has in other countries, notably USA and West Germany, or in other technologies such as radiological protection. NPL therefore has to provide acoustical calibration services through non-BCS channels or direct to users. There is also some leakage due to the large fraction of imported acoustical instruments in UK, calibration traceability of which sometimes by-passes the orthodox UK chain. We at NPL cannot regard this situation as satisfactory from a national viewpoint.

In contrast to the above, specification standards both nationally and internationally present a lively picture with a long and active history of UK participation. The rest of this lecture will be devoted to an outline of this activity.

PROCESS OF INTERNATIONAL STANDARDIZATION

The forerunner of ISO, a body called the International Federation of the National Standardizing Associations (ISA for short), convened the first acoustical standards convention in June 1937 in Paris. This meeting did accomplish, among other things, the definition of the *phon* substantially as it is today, but the committee (TC43) had hardly got off the ground before the outbreak of war. Acoustical activity resumed in 1953 with the re-establishment of Technical Committee 43 (Acoustics) under auspices of the newly-formed ISO, and of Technical Committee 29 (Electroacoustics) of IEC. Their first meetings were held in 1953 in London and The Hague respectively. The founding fathers were sharply divided over the wisdom of having two technical committees (TC) instead of one, but the constitutions of ISO and IEC made it logical and the arrangement was endorsed by the ISO General Council and the IEC Committee of Action. Progress was assured by the pragmatic solutions of joint Steering Committee and coordinated meeting schedules. Save for a temporary and unsuccessful break in the latter, now repaired, both arrangements have survived. The respective domains of interest, though theoretically split along non-electrical versus electro-technical lines, in practice divide neatly along a related axis: ISO TC43 deals with acoustical data, principles and measurement procedures, IEC with instruments. There are few exceptions to this.

The time scale of production of standards is often criticized by the technical public and sometimes, with greater justification, by those directly involved. It must be remembered that standards cannot be imposed but can only represent a consensus reached after rounds of draft-writing, commenting and voting. Furthermore, it is rarely possible to plunge straight into the writing phase. If a project is started at a stage of technical development early enough to forestall proliferation, it often has to begin with 2 or 3 years of coordinated research work, exchange measurements or evaluation of prototype devices by members of the appointed Working Group (WG) (Fig 2); on the other hand if it is initiated too late, time is lost at the later stages in compromises and unscrambling national standards which diverge and harden in the meantime. At best, the course of events follows the plan in Fig 3.

A new project may either be started on the initiative of a member body (provided it receives majority support under the ISO or IEC balloting directives) or on request of another ISO or IEC technical committee or of an international body in official liaison. The latter is well illustrated by ICAO's request to ISO to standardize a method of measuring and describing aircraft noise heard on the ground. To do this TC43 in turn requested IEC TC29 to prepare a standard specification for the relevant instrumentation. The usual (dare I say "standard"!) procedure is to set up a Working Group of experts drawn from the principal interested countries. They serve in a personal capacity, not as national delegates, nor as emissaries of the member bodies. They have to keep in mind, of course, that the fruits of their labours must pass the test of acceptance by the member bodies, including their own, BSI in our case.

The secretariat of a TC circulates a WG proposal as soon as it judges - or is advised - that a sufficient technical consensus exists. The proposal is circulated to all member bodies for comment (or, under accelerated procedure, for voting as well but this is appropriate only in cases where agreement is thought highly likely). ISO has two types of member body: "P" (participating) who can vote and "O" (observing) who can comment but not vote. TC43 has 26 "P"- and 15 "O"- members. IEC does not have this distinction; there are 15 national electrotechnical committees in TC29. The comment document is called a Draft Proposal (DP) in ISO parlance, a Secretariat document in IEC. Assisted by the WG, the secretariat next prepares a revised version which is usually placed on the agenda of the next plenary meeting of the TC. With luck the meeting will approve the document with only minor changes and it then goes to the ISO Central Secretariat (or IEC Central Office) for issue as a draft standard for voting. At this stage it is called a DIS (Draft International Standard) or a Central Office "Six Months' Rule" document in ISO and IEC parlance respectively. The time limit for voting is 6 months and in principle this is a yes/no ballot with opportunity for editorial but not technical comments. If the requisite number of votes is favourable the document goes to a permanent editing committee and thence to the ISO General Council or IEC Committee of Action for approval to publish. More often than not, a document has to be recycled at one stage or another due to objections from one or more member bodies. Not infrequently, such delays snowball because the technical state of art does not stand still.

Once the standard is published it is expected that national standards should be issued, or old ones amended, in line with it. By a recent change of ISO rules, their standards come up for automatic review every 5 years - a ridiculously short time for some types of document eg. the data standards of psychoacoustics. This has greatly increased the already substantial volume of second-generation work, which in any case brings new dimensions of difficulty into the proceedings. First-generation standards will have been followed by contingent national standards and sometimes legislation which tend, in their nature, to be resistant to amendment. This is why, for example, the first ISO document on motor vehicle noise emission measurement (R362) was completed from start to finish in the period 1959 to 1964, whereas its revision begun in 1971 is still at the voting stage in 1980 with dubious prospects of agreement. Another feature causing problems in the second generation work is awareness that specifications of measurement uncertainty are wanting or deficient in many of the earlier productions. Whilst certainly necessary on good metrological principles, these features prove quite difficult to implement in a consistent (standard!) manner.

ACOUSTICAL SPECIFICATION STANDARDS

In 1953, TC43 had a single project, namely musical pitch, as important as it is simple to state: A = 440 Hz. Between then and 1967 (the next cardinal date) this was followed by 14 more standards on topics as diverse as threshold of hearing, loudness, sound insulation and absorption, motor vehicle and aircraft noise, preferred measuring frequencies etc. During the same period, IEC produced standards on hearing aid performance, sound level meters, audiometers, band-pass filters, and the testing and calibration of therapeutic ultrasonic generators. A sub-committee (SC 29A) also issued several standards in the commercially important field of sound recording; in the mid-sixties SC 29A was "promoted" to become an independent TC (TC60).

TC43 and TC29 were reconstructed in 1967, due to increasing specialization of the work, and sub-committees were added. The bulk of TC43 work was delegated to SC1 (Noise), this being by far the larger share, and to SC2 (Building Acoustics). The parent committee retained responsibility for audiometry, thresholds of hearing etc. Since 1967, the noise work of 43 SC1 has proliferated, with 20 standards published and 35 more in the pipeline. They range from the general to the particular and cover all sorts of machines; there are also standards on hearing protector tests, noise as a hearing damage risk and as an environmental pollutant, sonic boom measurement etc. Due to a 1974 resolution of the ISO General Council, TC43 is responsible for all noise emission standards whether originating within TC43 or other ISO committees, which contributes heavily to its work load. IEC TC29 continued, after the reconstruction, with the residual functions of hearing aid and vocabulary standards but delegated the bulk of its programme to three subcommittees. SC 29B (Audio engineering) operates in the rapidly-changing fields of sound systems and hi-fi and holds the record for output measured in pages of print. SC 29C (Measuring devices) has issued 12 standards in as many years on things as diverse as audiometers, artificial ears and mastoids, sound level meters, pressure and free-field calibration of condenser microphones (referred to earlier), and equipment for measuring aircraft noise; in the pipeline are, among other things, important documents on personal sound exposure meters and integrating sound level meters. SC 29D (Ultrasonics) is smaller than the others but likely to develop; it has produced a specification for a standard hydrophone (up to 100 kHz) and the calibration of hydrophones (1 Hz to 1 MHz); in the pipeline are standards for ultrasonic cleaning and medical diagnostic equipment, surgical and dental apparatus, underwater echo-sounding devices, and hydrophone calibration up to 15 MHz.

NPL PARTICIPATION IN INTERNATIONAL STANDARDIZING ACTIVITY

The technical work of ISO and IEC depends in large measure on the voluntary input of research data from laboratories in the participating countries. A complete listing of the contributions of NPL to the acoustics work would not be appropriate here, but mention of some examples of standards which owe their existence wholly or largely to this work carried out at NPL in the last 3 decades may be of interest.

An early example was ISO R226 - the equal-loudness contours - standardized exactly as published by Dadson and me in 1956. Research on the relation between the *phon* and *sone* scales of loudness, and on the loudness of diffuse sound fields went into the making of ISO 131 and ISO 454. We also participated in the "round robin" comparisons that produced respectively the method of measuring reverberation absorption coefficient of materials (R354), and the normal threshold of hearing (or audiometric zero) in ISO 389. With the Motor Industry Research Association we did the original experiments that decided the scale of noise measurement for motor vehicles (R362).

Later we became involved in occupational hearing loss and the associated measure of noise exposure (A-weighted daily noise immission) which is found in ISO 1999; also with the measurement of sonic boom given in ISO 2249, and with other aspects of aircraft noise measurement (atmospheric attenuation, the scale of effective perceived noise level, characteristics of microphones and analysers etc) which have been incorporated in the evolving series of ISO and IEC documents (R507, R1761, ISO 3891, IEC 537, IEC 561) on this subject.

Considerable effort has been devoted in the last few years to the standards (already mentioned) which in effect comprise a realization of the unit of sound pressure. This work, which mainly involved other national standardizing laboratories besides NPL, was coordinated in a WG of SC29C and some continuations of it are still proceeding. Also, at this time, we are acting as the lead laboratory in microphone calibration exchanges at regional level, in this case under the applied metrology programme of the EEC.

In the audiological sphere, both the artificial ear and the artificial mastoid specified in IEC standards 318 and 373 originated here with the prototype instruments developed by Delany, Whittle and me in the '60's; and coming up to recent times we have provided major input to current ISO work on the threshold of hearing by bone conduction and on the age effect in hearing. Finally it is topical to mention the imminent publication of ISO 4869 describing the real-ear method for determining the acoustical attenuation of ear protectors on lines similar to those devised at NPL.

Bearing in mind that the NPL Acoustics Unit is just one among many of the research groups - albeit one with a long record - which contribute to the work of international standardization, the sum total of knowledge and expertise available to the committees can be seen to be wide in scope and large in volume. We therefore greatly welcome an opportunity, such as is provided by this meeting, to lift the lid on this activity and help to promote an understanding of its aims and accomplishments.

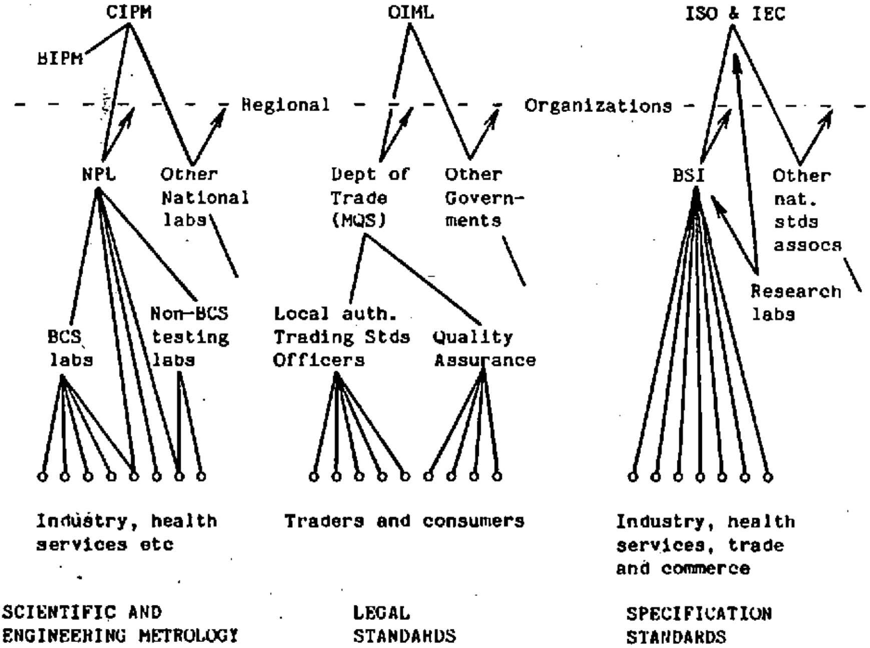

Fig.1 Three branches of Standards activity, simplified

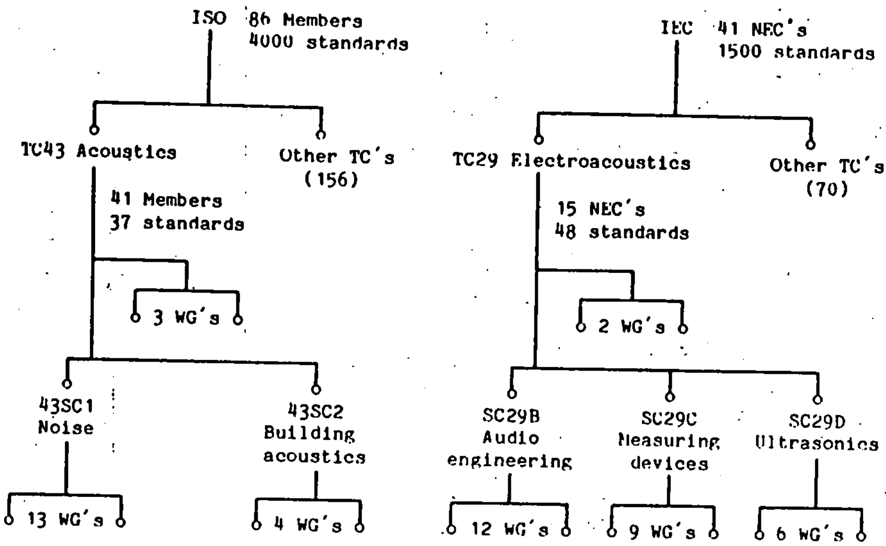

Fig.2 Structure of international acoustical standardizing organizations

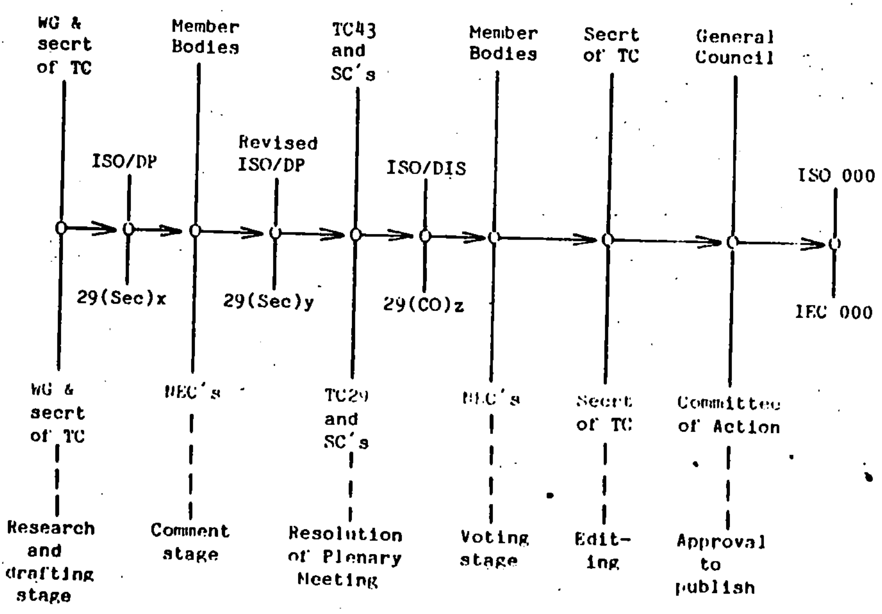

Fig.3 Stages in preparation of an International Standard (upper and lower parts correspond to ISO and IEC terminology respectively)