

NOISE AND STANDARDIZATION, FOCUSING ON MACHINERY AND WORKPLACE DOMAINS

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ABSTRACT

European standardization has boomed over the 15 past years due to the implementation of the “*new approach*” European regulatory scheme that links European directives to European standards. This has had major consequences in the field of machinery noise as a key aspect of product safety. A huge “*machinery programme*” has been set up by CEN comprising:

- standards covering horizontal aspects of safety such as noise, applicable to all machinery,
- standards specific to families of machinery (dealing with all aspects of safety in particular noise), including methods for measuring noise emission (noise test codes).

One privileged way for a machine manufacturer to get presumption of conformity to noise requirements of the Machinery Directive (98/37/EC) is to apply the provisions on noise of the relevant machine-specific standard. This is now possible for many families of machines.

One original aspect of the European “new approach” is the “CEN consultants” quality control system. Under a financial support of the European Commission, CEN consultants, including consultants for noise, check the quality of standards at key stages of the drafting.

Machine-specific standards are prepared by product Technical Committees in CEN (and sometimes at the international level (ISO)). Basic standards on noise are prepared in ISO Technical Committee 43 “*Acoustics*” /Sub-Committee 1 “*Noise*” as a continued policy of CEN Technical Committee 211 “*Acoustics*”. Basic standards on noise emission measurement comprise:

- a series of standards on the determination of the emission sound pressure level at the operator position of machines,
- a double series of methods (one based on measured sound pressure levels and the other on sound intensity levels) for the determination of the sound power level of sound sources.

Other key standards in the machinery noise field deal with the design of low-noise machinery, the declaration of noise emission value and the comparison of noise emission values.

Through this complete set of standards, a fruitful policy of machinery noise control, based on the comparison of noise emission data, is enforced at European and international levels. The stress put on noise emission by machines reflects the primary importance of noise control at the source.

Other aspects of the control of noise at the workplace have also been subject to detailed standardization in ISO. Key standards are those dealing with:

- the design of low-noise workplaces and workplace acoustics,
- the design and acoustical performance of source enclosures, screens, cabins for the personnel, silencers,
- the measurement of exposure to noise in the work environment.

Key issues and challenges for the future are the on-going and long-term revisions of the basic standards on noise emission measurement, the measurement uncertainty issue, the use of noise emission data (provided in noise declarations made by manufacturers) for the purpose of comparing machinery on the market, globalization and the maintenance of the present collection of standards.

1. INTRODUCTION

In the field of noise at the workplace, in spite of national regulations on noise at work in force for many years, lots of people are still getting hearing losses due to machinery noise in Europe. In order to progress, there was a need for a policy enforcing noise reduction at source at the design stage and allowing market forces to encourage less noisy machinery being put on the market. This was made possible in Europe through a specific European regulation.

In parallel to the strong action on noise reduction at source at the design stage, a standardization programme developed at the European and international levels on workplace noise in particular on designing low-noise workplaces, designing means to reduce noise on the propagation path and measuring their effectiveness.

Figure 1 illustrates the essential role of standards in the current strategy for reducing noise in industry.

This paper is by no means meant to be exhaustive. Only essential aspects of standardization in the field of industrial noise are presented.

2. MACHINERY NOISE – REDUCTION AT THE SOURCE AT THE DESIGN STAGE

2.1. The “New Approach”

A major decision taken in 1985 by the European Economical Community (EEC, now the European Union, EU) is the removal of technical barriers to trade. This was achieved by adopting a series of directives which would “*approximate the laws of Member States*”. The series of directives became known as “*new approach*” directives. These directives define legislative harmonisation in specific sectors, e.g. machinery, where barriers to trade exist due to divergent national regulations and/or technical methods e.g. for assessing hazards due to the use of a particular product. The basic principle is that the directives are written as a series of simple legal requirements (so-called “*Essential Safety Requirements*” – ESR) and leave to standards the provision of means of reaching the objectives. In the field of machinery, the overall objective is the free circulation of machinery with a high level of quality regarding health and safety.

In this context, standards harmonised under a new approach directive, although their use remains voluntary, are a legal continuation of the regulation. The use of a harmonised standard is one way to get presumption of conformity to the related new approach directive.

2.2. The Machinery Directive

A major new approach directive is Directive 89/392/EC (first published in 1989, subsequently amended and renumbered in 1998 as 98/37/EC), so-called “*Machinery Directive*” [1].

Three types of standards, so-called type A, type B and type C standards, are elaborated to accompany this directive. Type A is for standards covering basic safety concepts, type B standards covering horizontal issues (e.g. noise emission measurement in general) applicable to a large number of machinery and type C standards concerning safety aspects (including hazards due to noise emission) of single types of machinery.

2.3. The requirements on noise of the Machinery Directive

Noise is a common source of hazards for machinery. The Machinery Directive addresses specifically the noise issue through two ESRs. The first one, known as ESR 1.5.8, is about the design and manufacturing of machinery with reduced noise emission :

“*Machinery must be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source*”.

The second ESR, known as ESR 1.7.4 f), is about the provision by manufacturers of machinery of information on noise emission, so-called “*noise declaration*”:

“...*The technical documentation describing the machinery must give information regarding the airborne noise emissions...The instructions must give the following information concerning airborne noise emission by the machinery...:*

- *equivalent continuous A-weighted sound pressure level at workstations, where this exceeds 70 dB(A)...*
- *peak C-weighted instantaneous sound pressure value at workstations when this exceeds 63 Pa...*
- *sound power level emitted by the machinery where the equivalent continuous A-weighted sound pressure level at workstation exceeds 85 dB(A).”*

The ESR goes on with provisions on what to do in the case of very large machinery and machinery that have no defined workstation(s). It also specifies that “*the manufacturers must indicate the operating conditions of the machinery during measurement and what methods have been used for the measurement.*”

Clearly, the directive requires noise reduction at the design stage and the yielding of noise emission values (always in terms of emission sound pressure levels at workstation(s), and sound power level only when the other quantity exceeds the threshold of 85 dB(A)). The intention is to allow potential buyers to compare machinery on the market on the basis of their noise emissions.

2.4. The machinery standardization programme

The European Committee for Standardisation (CEN) and CENELEC for the electrical counterpart are in charge, in close co-operation with the European Commission (EC) and the European Free Trade Association (EFTA), of producing European Standards (EN) that support the new approach directives. Under the Machinery Directive, CEN is handling a so-called “*machinery programme*”. This programme started around 1988 with the acceptance of Mandates from the EC and EFTA that define the criteria for standards to achieve the status of being ‘*mandated*’. Early November 2003, 472 standards were ratified, 179 were under approval and 53 under development.

The preparation of drafts is carried out in CEN Technical Committees (TC), each of them composed of several Working Groups (WG). 5 TCs elaborate type B standards (TC 114 for machinery safety in general, including safety components, TC 122 for ergonomics, TC 211 for acoustics, TC 231 for vibrations, TC 169 for lighting). 46 TCs, each of them being specialised in a particular family of machinery (e.g. woodworking machinery, construction equipment, printing and paper machinery, tannery machinery, textile machinery etc.), elaborate type C standards for specific families of machinery. Since most machinery emit noise significantly, most standards prepared by these TCs give (or should give) provisions on noise to back the ESRs on noise of the Machinery Directive.

2.5. The articulation between type B and type C standards

Because type B standards apply to a large number of different products, they constitute key stones to which type C standards may make a normative reference. For example, a type C standard on the safety of meat mixers will make reference to one or several type B standards for the measurement of noise emission. There is no obligation for type C standards to make a normative reference to type B standards but it is clear that type B standards are privileged reference documents. TCs are encouraged to make use of type B standards as much as possible. Type B standards are actually used through their reference in type C standards.

2.6. The structure of standardization in the field of acoustics

Standardization is, at least for Europeans, a three-layer cake with a national layer (the member bodies e.g. BS in the U.K., DIN in Germany, AFNOR in France, DS in Denmark etc.), a European layer i.e. CEN (Comité Européen de Normalisation) and its electrical counterpart CENELEC, and an international layer (ISO, IEC). The standardization programme in acoustics is mostly managed by Danish Standards who have been holding for many years the secretariat of the ISO technical

committee on acoustics (ISO TC 43 and its sub-committee 1 “Noise”) and, since its creation in 1990, that of the European technical committee on acoustics (CEN TC 211).

The constant policy has been to develop basic standards in acoustics at the international level (ISO). This policy proved itself effective; all type B standards (see § 2.7) on noise emission are ISO and European (EN) standards. The situation is quite different regarding noise from products. Indeed, product standards are prepared in specific Technical Committees under the pressure of economics and competition between industrial partners and standardization is presently carried out mostly at the European level, with a clear tendency to move to ISO (see § 2.12.4).

2.7. Type B standards on noise emission from machinery

CEN TC 211 is in particular responsible for the preparation of the type B standards to be harmonised under the Machinery Directive. The first resolution taken by TC 211 was that type B standards that are needed for European purposes should be prepared at the ISO level whenever ISO agree to carry out the work. All work items of European interest have therefore systematically been first submitted to ISO and so far ISO have accepted them. As a result, an intense activity developed, in particular through WG 28 of ISO TC 43/SC 1. The consequence is that all type B standards on noise emission from machinery but one (EN 1746 [2], see 2.8) are actually EN ISO standards.

In order to back the ESRs on noise of the Machinery Directive, type B standards were needed on:

- the design of low-noise machinery. No standard was available on this topic. EN ISO 11688-1:1998 and -2: 2000 (published as Technical Reports in ISO) were elaborated [3]. These standards give only recommendations to machinery designers but they are now recognised as a new type of very useful documents.
- the determination of A-weighted emission sound pressure levels at the workstation(s). No international, regional or national standard was available and a fully new series of standards, the EN ISO 11200 series [4 to 9], was prepared. It comprises six standards with EN ISO 11200:1995 [4] as an introduction to the series serving as an aid to the choice of the most appropriate standard(s) in a given practical situation.
- the determination of the sound power level of machinery. The ISO 3740 (pressure methods) [10 to 17] and ISO 9614 (intensity methods) [18] series did exist, with many counterparts as national standards. The European incentive triggered the revision of the whole ISO 3740 series. Two new methods were added i.e. EN ISO 3743-1:1995 (comparison method in hard-walled rooms) [12] and EN ISO 3747:2000 (comparison method in situ) [17]. The reverberation room standards were combined into one single EN ISO 3741:2000 [11]. EN ISO 3745 [15] was the last one to be revised due to its limited industrial use. The frame standard EN ISO 3740 [10] introduces both EN ISO 3740 and EN ISO 9614 series and serves as an aid to the choice of the most appropriate standard(s) in a given practical situation.
- the declaration (and, consequently, the verification) of noise emission values. ISO 4871 did exist. It was thoroughly revised; EN ISO 4871 was published in 1996 [19]. It is the most controversial standard in the field of industrial noise because it addresses the highly sensitive and political issue of the information to be provided by manufacturers of machines to users.
- the evaluation of noise emission data in view of the comparison of noise emissions from similar machinery put on the market by different manufacturers. No standard existed to allow fair comparison of noise emission data. EN ISO 11689, where the concept of noise control performance is introduced, was published in 1996 [20].

2.8. Noise in type C standards

A type C standard deals in principle with all hazards that are identified through an appropriate risk assessment as being significant for the specific family of machinery that it covers. Whenever noise is a significant hazard, and it often is, the relevant type C standard must deal with noise.

Recommendations for the drafting of noise clauses of type C standards are given in EN 1746 [2]. This standard is actually a policy document. It tells what aspects of noise emission should be covered in a type C standard so that the use of the type C standard can give presumption of conformity to the Machinery Directive. The recommended structure and contents for the noise clauses are the following:

a) in the clause on “*safety requirements and measures*”, there should be three sub-clauses on noise:

- one called “*noise reduction at source at the design stage*” with a list of the main noise sources present and of the noise control measures currently available to reduce noise at source, with reference to the type B standards EN ISO 11688 [8];

- one called “*noise reduction using protective measures*”, dealing with enclosures, screens, silencers etc. with reference to existing standards on the design and on the determination of the acoustical performance of these protective measures (see paragraph 3);

- one called “*reduction by information*” giving recommendations to be made by the manufacturer to the user for reducing noise further whenever it is known that, for the machinery concerned, the current technical know-how is insufficient to reduce noise at the design stage further. These include additional enclosures or screens, limited daily duration of operation and wearing of personal hearing protectors.

b) in the clause “*verification of safety requirements or measures*”, there should be a clause “*verification of noise emission*” giving the reference to the noise test code specific to the machinery concerned (see next paragraph) that shall be used for determining noise emission values. Whenever enough quantitative and comparable data on noise emission is available for the machinery that is currently on the market, indicative values for the family of machinery concerned may be given for information in the type C standard.

c) in the clause “*instructions for use*”, the requirement to provide quantitative information on noise emission, in conformity with the ESR of the Machinery Directive, as obtained using the relevant noise test code when one exists, plus possible recommendations to the user should be given.

2.9. Noise test codes

The need for noise test codes was recognised a long time ago and quite a few such codes were available at ISO and at a few national levels when the Machinery Directive was published. The legal European requirement to measure and declare noise emission with the aim to compare noise emissions of different machinery from different manufacturers in different Member States of the European Union put out a real challenge. It was quickly admitted that the requirements of existing noise test codes were not precise enough and that, for a given family of machinery, one single noise test code should be in force over the entire EU. EN ISO 12001 was then prepared [21]. It gives the rules for the drafting of a noise test code, leaving to CEN or ISO/TCs in charge of type C standards the responsibility to prepare noise test codes. It is now accepted that each Working Group of each CEN/TC elaborating type C standards should prepare a noise test code for its family of machinery as long as noise is a significant hazard for the machinery concerned.

A noise test code is either a separate standard or a normative annex to a type C standard. Some are published (EN or ISO or EN ISO), some are still in preparation (prEN). They cover a large variety of machine families such as **pumps** (EN 12639:2000, presently being exported to the ISO level); **printing, paper making and paper converting machinery** (EN 13023:2003); **agricultural machinery** (EN 1553:1999 as frame noise test code for this wide family of machines); **forestry machinery** (wood chippers, prEN 13525); **garden equipment** (integrally powered shredders/chippers, EN 13683:2003; pedestrian controlled lawn aerators and scarifiers, prEN 13684; hand-held integrally powered hedge trimmers, EN 774:1996/Amendment 3; electrically powered walk-behind and hand-held lawn trimmers, EN 786:1996/Amendment 1:2001; powered lawn-mowers, EN 836:1997/Amendment 2:2001); **mobile cranes** (prEN 13000); **industrial trucks** (EN 12053:2001); some families of **construction equipment** (e.g. core drilling machines, EN 12348:2000; masonry and stone cutting-off machines, EN 12418:2000; floor sawing machines, EN 13862:2001; hydraulic hammers, prEN 13778); some families of **food processing machinery** (e.g. food processors and blenders, EN 12852:2001; rotating bowl cutters, EN 12855:2003; salad dryers, prEN 13621; mincing machines, EN 12331:2003; fixed deck oven loaders, prEN 13591; circular saw machines, EN 12267:2003); some **rubber and plastics machinery** (e.g. blade granulators, strand pelletisers,

shredders, EN 12012-1:2000, -2 and -3:2001); **footwear and leather goods manufacturing machines** (EN 12545:2000); **industrial thermo-processing machinery** (EN 1547:2001); **foundry machinery** (EN 1265:1999); **fastening driving tools** (EN 12549:1999); **textile machinery** (EN ISO 9902:2001 in seven parts); **non-electrical hand-held tools** (EN ISO 15744:2002), **compressors** (EN ISO 2151:2004), **earth-moving machinery** (revision of ISO 6393 to 6396 in progress), **chain saws and brush-cutters** (prEN ISO 12868 to replace ISO 9207:1995 and ISO 10884:1995), **aircraft ground support equipment** (prEN 1995-4) etc.

2.10. The so-called “*Outdoor Directive*”

The Machinery Directive is not the only one dealing with machinery noise. European directive 2000/14/EC on the “*noise emission in the environment by equipment for use outdoors*” [22,23] aims at the protection of the environment from excessive noise being emitted by 57 families of equipment used outdoors such as earth-moving machinery, road-breakers, paver-finishers, compaction machines, chain saws, lawn-mowers, mobile and power cranes, mobile waste containers, compressors, truck mixers etc. As opposed to the Machinery Directive, the Outdoor Directive considers only the A-weighted sound power level, fixes noise emission limit values for 23 machinery families and specifies the measurement method to be used by making or not reference to existing standardized noise test codes. The Outdoor Directive does not require explicitly that noise be reduced at the design stage but it requires manufacturers to affix on the machine the guaranteed value of the A-weighted sound power level. Even more than the Machinery Directive, it relies on market forces to ensure that less noisy machines are progressively put on the market.

2.11. The “*CEN consultants*” quality control system

The “*New Approach*” has given standardization a strength that it did not have before. The basis for standardization is the consensus between the stakeholders. Experts with varied and sometimes opposite views on a given issue gather around a table and try to come to a consensus. The standard is the direct reflection of this consensus. How is then the quality of standards ensured? Until 1994 when a quality control system was introduced at the European level, the technical quality of standards was never assessed. In November 1998, three independent experts, so-called “*CEN consultants for noise*”, in charge of checking the quality of the noise content of European standards prepared under the Machinery Directive, started to work for CEN under a sponsorship of the European Commission. The reason why the decision was made by the EC and EFTA to start employing consultants for noise is that it was widely recognised that the quality of the noise contents of machinery safety standards was quite poor with regard to hazards due to emissions in general and noise in particular. The reason is that the expertise of WG members elaborating type C standards is mostly in the field of mechanical and electrical safety. The challenge CEN consultants for noise face is to introduce in product safety standards high quality technical requirements on noise while keeping within what is judged as economically acceptable by manufacturers. In most machinery fields, the know-how of manufacturers in both low-noise design and noise emission measurement is low and only too few of them are prepared to make the technical and economical efforts necessary to increase their know-how significantly. A consequence is that the level of quality of the noise contents of product safety standards and of noise test codes may vary from one family of machinery to the other.

The main tasks of CEN consultants for noise are:

- to assess drafts formally at the CEN Enquiry stage (DIS stage in ISO) and at the CEN Formal Vote stage (FDIS stage in ISO). A draft cannot proceed to Formal Vote until an agreement has been reached between the Working Group and the CEN consultants concerned.
- to assist Working Groups at the earliest possible drafting stage (in order to avoid negative assessments of drafts and delays at later stages).

2.12. Some key issues and challenges for the future

2.12.1. On-going and planned revisions of type B standards on noise emission measurement

A short-term revision of the whole EN ISO 3740 [10 to 17] and 11200 [4 to 9] series has just started [24,25]. It is expected that new versions of all standards in the EN ISO 3740 series will be ready by 2006. No fundamental changes will be introduced. Revision is based on existing knowledge and focusses on:

- harmonizing the series regarding terminology and definitions,
- adding provisions for measuring the sound energy levels for sources which emit sound of short duration,
- introducing a correction for meteorological conditions,
- introducing more provisions regarding measurement uncertainty in the spirit of the *“Guide to the expression of uncertainty in measurement”*, so-called GUM [26] (see also paragraph 2.12.2).

A long-term revision is planned with the intention to:

- make the series more user-friendly by reducing the number of standards (users complain that there are too many basic standards; they get lost in this jungle).
- completely change the manner to deal with accuracy grades by introducing, if this is demonstrated to be feasible, a *“floating system”* with an *“à la carte”* menu leading from a set of values of measurement parameters to a pre-chosen value of the uncertainty (so tailoring the measurement effort to the desired accuracy),
- make each method in complete agreement with the GUM [27].

This long-term revision will be based on research which is at present being planned [24,25,27].

2.12.2. Evaluating measurement uncertainty and using it for noise declaration purposes

A basic aspect of acoustical metrology is the uncertainty associated to measured values of noise emission. Basic standards offer maximum values for the standard-deviation of reproducibility for A-weighted quantities. Experts preparing a noise test code are welcome to introduce values of uncertainty specific to the particular machinery family they are considering. Unfortunately due to the current lack of noise emission data available at manufacturers, specific values of the uncertainty cannot be derived and agreed. Consequently, maximum values offered by the basic standards are chosen, which lead to high values of uncertainty. A consequence is that some experts from industry are extremely reluctant to accept that reference is made in the noise test code to the relevant basic standard i.e. EN ISO 4871 [19].

At both ISO and CEN levels, the GUM [24] is presently enforced. According to this Guide, any measurement method should be accompanied by an uncertainty budget i.e. a list of sources of uncertainty with an uncertainty value attributed to each source. The present series of basic standards for determining noise emission from machinery do not follow this approach. This is the main reason why a full revision of these standards is planned [27].

Under the Machinery Directive, it is agreed that the noise declaration should be a dual-number declaration as defined in EN ISO 4871 [19] i.e. separate indication of the measured noise emission value and of the value of the associated uncertainty. However, due to marketing aspects, not all experts accept this rule and dealing in sufficient details with noise declaration in the noise test code is a most difficult task.

For machines that are covered by the Outdoor Directive, the situation is particularly critical because the guaranteed value (that has to include measurement and production uncertainties) is then a higher figure and limit values of noise emission prescribed by that directive may be exceeded. In the present context of highly competitive markets, this puts hard pressure on manufacturers.

2.12.3. Use of comparative noise emission values

The use by all manufacturers of a given family of machines of a unique method (the noise test code relevant to the family concerned) for determining the noise emission values ensures that noise emission values are comparable. They can then be put together on one single graph; the so-obtained cloud of values tells what the state of the art is regarding the noise emission of a family of machines. Knowing the state of the art is the key to assess the “*lowest possible*” noise emission than can be achieved for a given family. Such a scheme has been used and is still used for comparing noise emissions from house-hold appliances. Unfortunately, manufacturers of industrial machines are not ready yet to make use of this possibility. Health and safety organizations are currently carrying out pilot actions to show that this is feasible and encourage manufacturers to join in [28,29].

2.12.4. Globalization

The present globalization of markets puts pressure on standardization to go international. More and more European standards are actually prepared at the ISO level under the so-called “*Vienna agreement*”. Regarding type B standards on noise emission, there is no problem as European standards have been made from the start at the ISO level. Going international is therefore feasible regarding noise. However, regarding type C standards in general, it is another story as these are product standards tailored to fulfil a European regulation. Attempts are presently made to invent a “*new approach*” scheme at the international level.

3. NOISE REDUCTION IN THE WORKPLACE

In parallel to the “*new approach*” and in the wake of it, classical standardization has developed in the other fields of industrial noise. European standards have been prepared that are not harmonized as they are not associated to any European regulation. Main other issues now covered by standards are:

- the design of low-noise workplaces (EN ISO 11690 part 1 to 3 [30]). Part 3 deals with the key issue of prediction of noise levels in workshops.
- the design of means to reduce noise during its propagation and the measurement of their acoustical performance. These include enclosures (EN ISO 15667 [31], EN ISO 11546 [32]), cabins for the personnel (EN ISO 15667 [31], EN ISO 11957 [33]), screens (EN ISO 11821 [34]) and silencers (EN ISO 14163 [35], EN ISO 11691 [36] and EN ISO 11820 [37]).
- the characterisation of workplace acoustics using spatial sound decay curves (EN ISO 14257 [38]).

Measurement of exposure to noise in the workplace is so far a subject for national standardization only as it does not concern products but persons. There is however an ISO standard (ISO 9612 [39]) on this topic that has been rejected some years ago as a European standard mainly because each member state of the EU wanted to keep its own national standard. When the present revision of ISO 9612 is carried through, it will be interesting to see, in the context of the new “*noise at work*” directive 2003/10/EC [40], whether the European policy will change (some national authorities seem today more in favour of a single measurement method being used throughout the EU on the ground that, although workshops do not move from one country to another, employees do).

Personal hearing protectors have also been the subject of intensive standardization.

4. CONCLUSION

A tremendous work has been accomplished in the past twenty years to develop a comprehensive set of EN and ISO standards to cover the full spectrum of industrial noise, from machines to personal hearing protection. The programme of standardization work that was started at the European level under the pressure of European regulation on machinery safety has been particularly gigantic as there was a need to deal with noise for each of the hundreds of machine families concerned. The challenges are many. Continuous interest and involvement from noise experts and all parties concerned by

industrial noise abatement will be required in order to maintain the present collection of standards through regular revisions.

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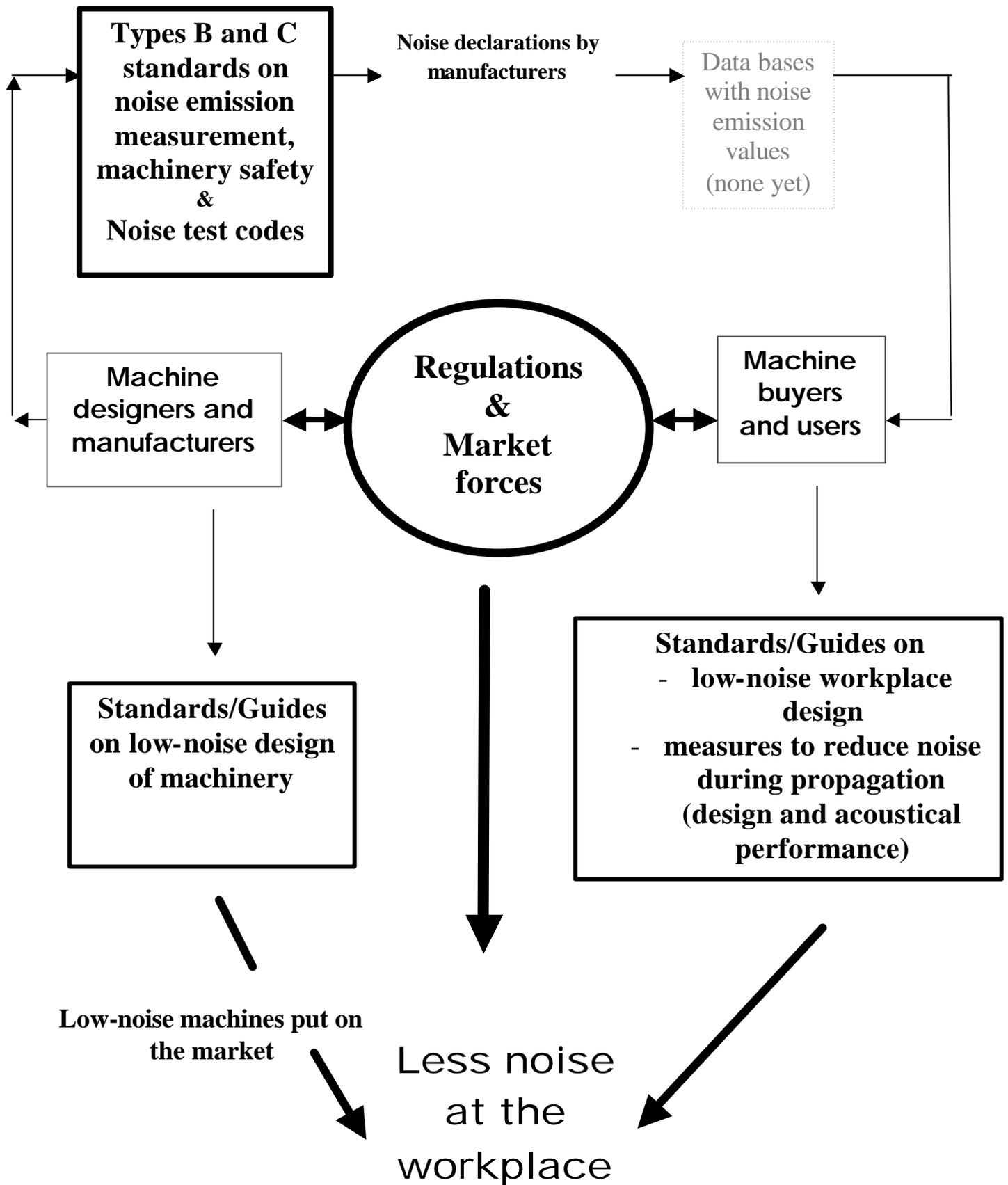


Fig. 1 Standards as key tools of the global strategy for noise abatement in industry