TECHNICAL REPORT

ISO TR 11688-1

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Acoustics — Recommended practice for the design of low-noise machinery and equipment —

Part 1:
Planning

Acoustique — Pratique recommandée pour la conception de machines et d'équipements à bruit réduit —

Partie 1: Planification

TECHNICAL ISO

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the Internation Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11688-1, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 11688 consists of the following parts, under the general title *Acoustics — Recommended practice for the design of low-noise machinery and equipment*:

— *Part 1: Planning*
[Technical Report]

— *Part 2: Introduction into physics of low-noise design*

Introduction

This International Technical Report provides a guideline for the design of low-noise machinery. Most of the existing International Technical Reports prepared in ISO/TC 43/SC 1 specify methods for the measurement and/or evaluation of noise. The final objective of this International Technical Report, however, will be noise control in existing machinery and noise control at the design stage.

It is important that non-acoustic engineers are engaged in noise control practice. It is of great importance for these engineers to have a basic knowledge of noise generation and propagation characteristics and to understand the basic principles of noise control measures. Hence, this International Technical Report also serves as an introduction into acoustical terms, and as a basis to the acquisition of further knowledge in noise control.

It is strongly required to support the dissemination of the design rules given here through standardisation.

Such considerations have led to the preparation of International Technical Reports in the area of noise control.

Acoustics — Recommended practice for the design of low-noise machinery and equipment —

Part 1:
Planning

1 Scope

This International Technical Report is an aid to understanding the basic concepts of noise control in machinery and equipment.

The recommended practice presented here is intended to assist the designer at any design stage to control the noise of the final product. Methodical development of products was chosen as a basis for the structure of this document (see Clause 4).

The list of design rules given in this International Technical Report is not exhaustive. Other technical measures for reducing noise at the design stage may be used if their efficacy is identical or higher.

To solve problems going beyond the scope of this International Technical Report, the designer can refer to the bibliography in Annex D, which presents the general state of acoustic handbooks at the time of publication. Furthermore, reference is made to the numerous technical publications dealing with acoustical problems.

2 References

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 3746:—[1)], *Acoustics — Determination of sound power levels of noise sources — Survey method employing an enveloping measurement surface over a reflecting plane.*

ISO 4871:—[1)], *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

ISO 9611:—[1)], *Acoustics — Characterization of sources of structure-borne sound with respect to the airborne sound radiation of connected structures — Measurement of velocity at the contact points of machinery when resiliently mounted.*

ISO 9614-1:1994, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points.*

ISO 9614-2:—[1)], *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning.*

1) To be published.

ISO 11200:—[1], *Acoustics — Noise emitted by machinery and equipment — Guidelines for the use of basic standards for the determination of emission sound pressure levels at the work station and at other specified positions.*

ISO 11689:—[1], *Acoustics — Systematic collection and comparison of noise-emission data for machinery and equipment.*

3 Definitions

For the purpose of this International Technical Report the following definitions apply:

3.1 *Airborne, liquid-borne and structure-borne noise:* Sound propagating through air, a liquid or a solid structure, respectively.

3.2 *Active noise components:* Components of machinery, which generate noise. In many cases these are the power converting devices generating mechanical work from power resources, such as electrical, mechanical or magnetic energy, hydraulic pressure, internal forces, or friction. Other noise "components" may be regions with non-steady flow and contact surfaces between moving parts.

3.3 *Passive noise components:* Components which transmit noise generated by the active components; they do not contain noise sources but can be dominating radiators of noise. Typical passive components are structural parts and covering panels of machinery.

3.4 *Periodic noise:* A noise event which is periodically repeated. Typical sources of periodic noise are gear wheels and piston machines. It is characteristic for periodic noise that it exhibits a line spectrum.

3.5 *Tonal noise:* Noise which is dominated by one or several clearly distinguishable tone(s).

3.6 *Broad band noise:* Noise generated by either single shocks, i.e. short duration pressure pulses or impacts, or by turbulence in an air or fluid flow. The characteristics of broad band noise are that the frequency analysis shows a continuous spectrum over a large frequency range.

3.7 *Force excitation:* The excitation force is independent of the properties of the excited structure; an example of this is the effect of a light and flexible source on a relatively stiff and heavy structure.

3.8 *Velocity excitation:* The excitation velocity is independent of the properties of the excited structure; an example of this is a light and flexible structure excited by a relatively massive source.

3.9 *Quasi-static response:* Response of the machine at frequencies below the lowest resonant frequency.

3.10 *Resonant response:* Response in a frequency range of distinct resonances.

3.11 *Multi-resonant response:* Response in a frequency range with many resonances.

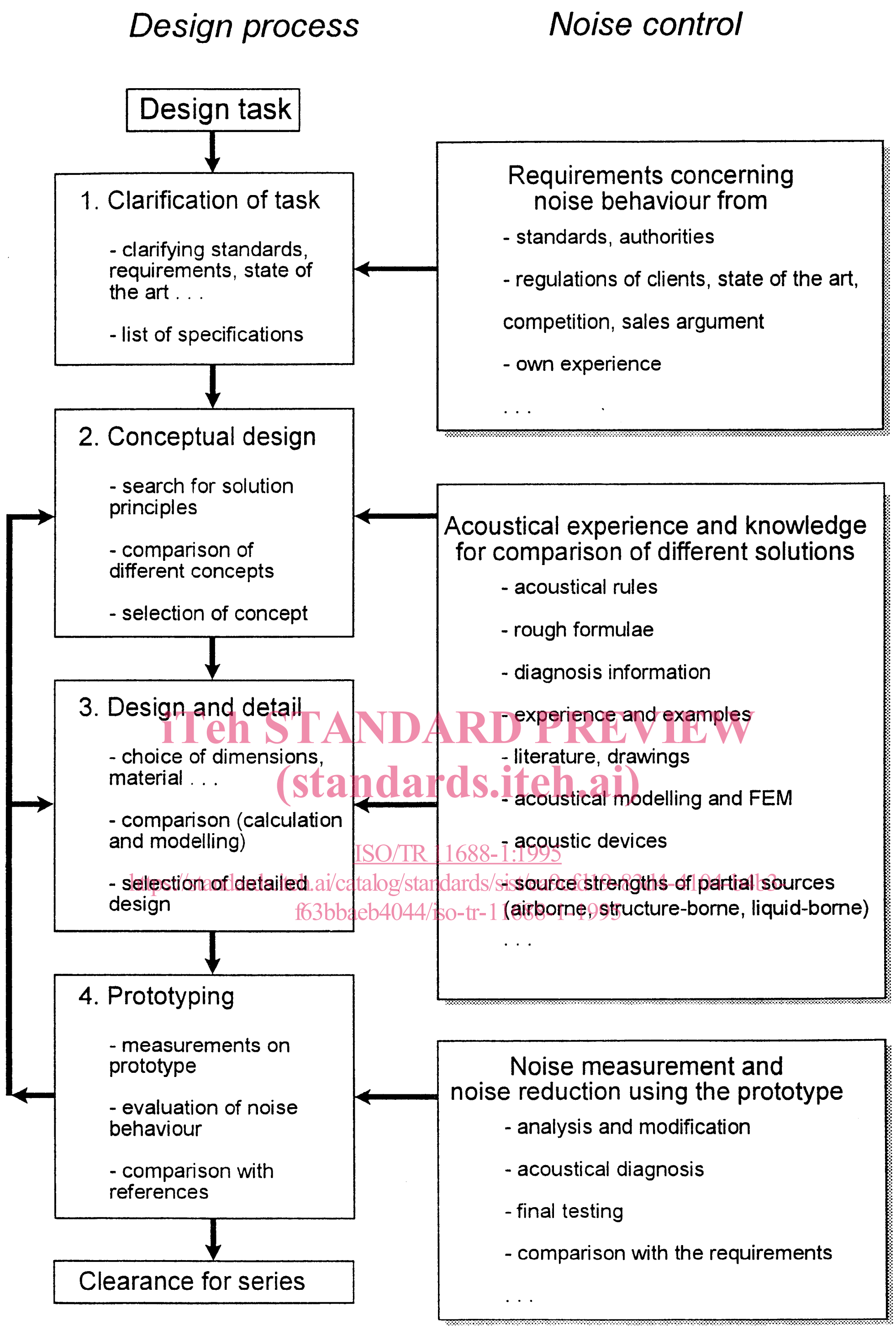


Fig. 1: Stages of the design procedure; support of design process by noise control methods

4 Methodical design and acoustic aspects

Methodical design is an operational approach which makes use of information from a variety of disciplines, for example machine acoustics. This way a basis is set for achieving targets and making decisions in design and development.

The design procedure can be divided into four phases (listed below) which are increasingly specific (see Fig. 1). Increase of information from phase to phase makes it possible to sort alternative solutions with respect to specific design criteria such as low noise level. The phases of systematic design are:

1. **Clarification of task:** Make a list of requirements which is the controlling document for the whole design task. Include noise specifications in this list with reference to legislation, the state of the art, competitors' products, client demand or the weighting of machine noise as a company sales argument. (See Annex B.)

2. **Conceptional design:** This phase of the design process concentrates mainly on achieving the desired objectives. Little information is available about the final product at this stage and the noise behaviour is often assessed by comparison to known designs.

3. **Design and detail:** As the design and choice of individual components progress, quantitative estimates of noise behaviour can be made through the selection of design options.

4. **Prototyping:** Measurements on the prototype allow quantification of major noise sources and sound paths. This may indicate specific measures leading to design changes. Compliance with the requirements can be confirmed by measurements.

The following procedure can be applied in each of the four phases described above. It is very important to follow the methodology of eliminating the most dominant noise problems in the earliest possible stage of design:

- The first step of the process is determining the major sources of noise in the machine and establishing a priority list or scheme (see 5.2).

- Once the major sources are recognised, a more detailed analysis of the noise mechanisms must be carried out (see 5.3).

- The next step is analysing and describing the direct radiation of noise from the sources to the receiving position(s), and the transmission through the structure to the radiating surfaces (see 5.4).

- The final step is to analyse the radiation from those surfaces and to determine the various contributions to the sound pressure level at the receiving position(s).

- Evaluate which combination of noise control measures is optimal.

In designing low-noise machinery one should try to identify the basic acoustic mechanisms involved by consideration of the causal chain (Fig. 2).

All design processes have a recursive element. So at every phase a decision has to be made as to whether the next phase can be entered or whether previous steps shall be repeated.

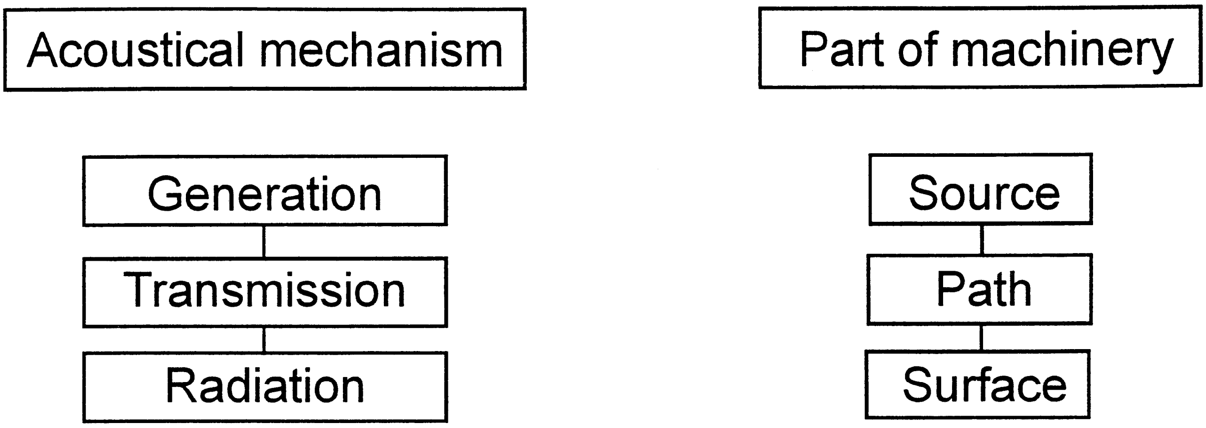


Fig. 2: Causal chain of noise generation

An illustration of how the different noise mechanisms are connected is shown in Fig. 3. The first priority in noise control is to identify the source. Different types of sources are shown in the first and second ring with key words corresponding to the headlines of the following clauses.

Once the source type is determined, transmission through the particular medium will take place as seen in the third ring. Finally the noise will radiate into free air or excite a structure. The figure can be used to show that every sound source has its own characteristics, its specific transmission path through the structure and excitation of the radiating surfaces. To control the noise from a machine with many different types of sources, it is necessary to analyse each noise source, transmission path and radiating surface on its own to be able to evaluate the relative importance. The next clause shows an example of such a machine.

5 Conceptual and detailed design

5.1 General

Since a design solution always comprises the choice of a physical operating principle and the choice of a functional system, it is possible to make the following general comments for the choice of design concepts.

- With a high degree of probability, the mode of operation with the lowest speed and acceleration will provide the best acoustic solution.

- For a given operational principle the noise from a machine can be reduced by altering the mass, stiffness and damping of the structure. Design parameters such as material, shape, position, number of elements, dimensions, structure and type of connections can have a large effect on the noise emission. If applied in the proper way such alterations may reduce the vibration and/or radiation of the machine.

- Steady flow of gases and liquids is quieter than unsteady flow.

Both in the conceptual phase and in the detailed design, the procedure described in Clause 4 and elaborated further in the following clauses can be used for diagnosis and noise control measures. In the conceptual phase only rough estimates, common design rules or a comparison with existing solutions is possible. In the detailed design phase the results of detailed calculations, modelling and survey experiments can be applied.

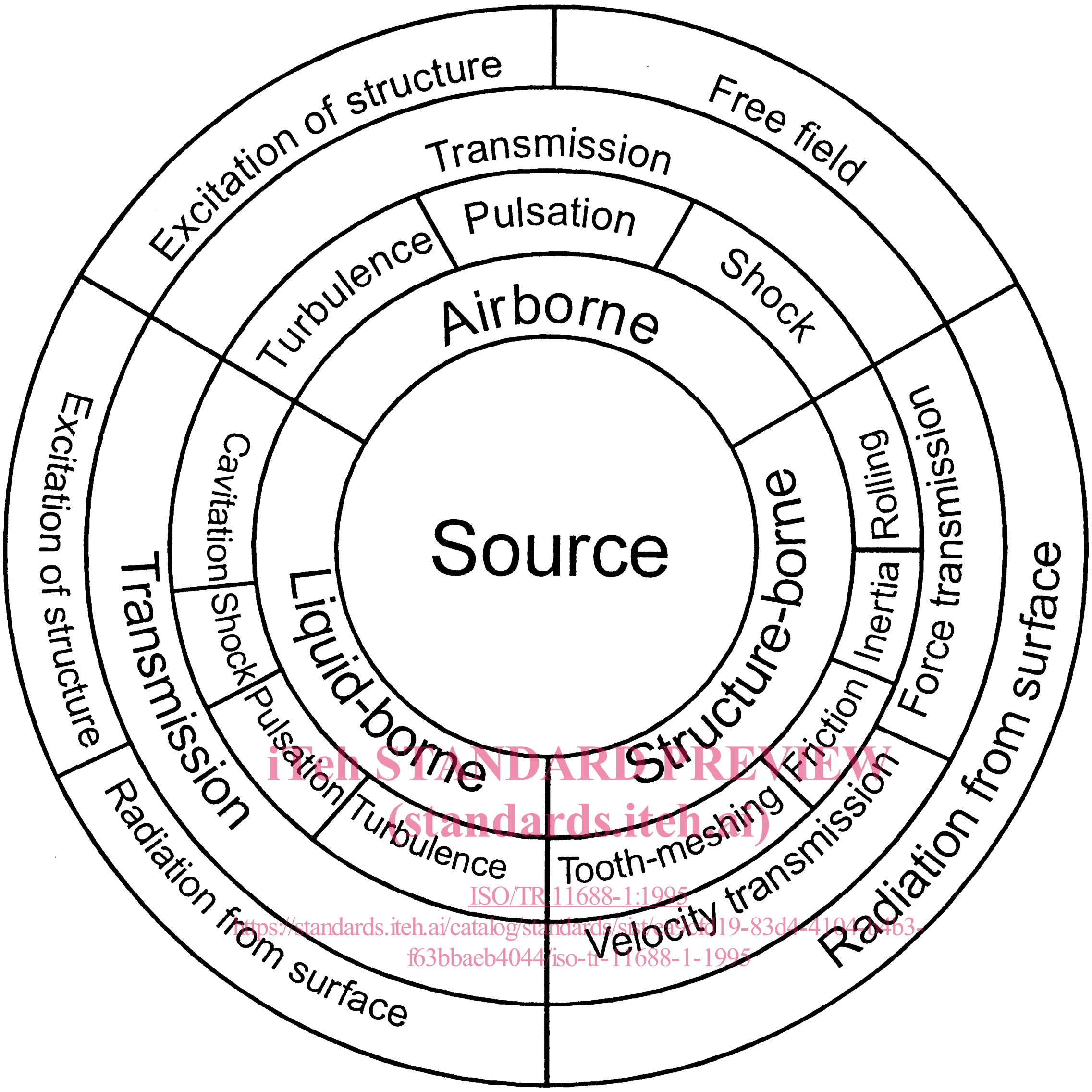


Fig 3: Basic model of noise generation in machines

5.2 *Basic steps*

5.2.1 Acoustical modelling and ranking

The noise behaviour in machinery with different noise sources can be visualised by an acoustic model of the machine (see Fig. 2). To elaborate this model, the designer must first divide the machine into active and passive noise components.

The active and passive noise components may have the capability of generating, transmitting and radiating airborne, liquid-borne and structure-borne noise. Therefore it is necessary to analyse the noise components for these three types of noise. The purpose of subdividing the noise components is the identification of the dominating noise sources, transmission paths and radiating surfaces.

Then the designer must analyse along which paths noise can be propagated. Structure-borne, liquid-borne and airborne sound paths shall be considered. Furthermore, possible direct radiation of airborne sound from the individual active components must be considered.

Finally the sound radiating surfaces of the machine must be identified.

When the most important noise sources with their transmission paths are identified, an analysis of the process parameters must be carried out. The dominant noise contributions have to be controlled first. It is recommended to control the sources first before dealing with transmission paths and the radiating surfaces.

Severe noise problems can be caused by the coincidence of driving frequencies and resonances in the active and passive components.

General design rules:

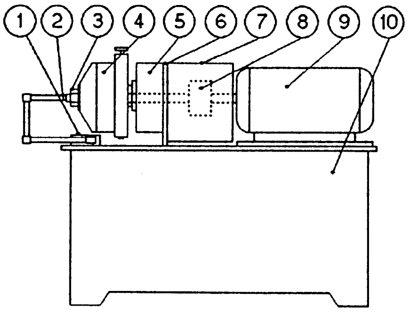
- Divide machine into active and passive noise components;
- Locate airborne, liquid-borne and structure-borne noise sources;
- Locate the airborne, liquid-borne and structure-borne sound paths;
- Locate the sound radiating surfaces;
- Identify the strongest contributions (sources, transmission paths, radiating surfaces).

5.2.2 Example

The purpose of this example is to demonstrate how acoustic modelling and noise source ranking can be carried out.

Fig. 4 shows a hydrostatic power pack having active noise components such as: electric motor, hydraulic pump and a valve.

They are all connected to the reservoir in a closed circuit.



1) Relief valve
2) Outlet tube (12 mm)
3) Reduction fitting (25 mm - 12 mm)
4) Pump
5) Vibration-isolated flange
6) Mounting flange
7) Cover
8) Vibration-isolated coupling
9) Electric motor
10) Reservoir

Fig. 4: Hydrostatic power pack

The power pack has active noise sources representing airborne, structure-borne and liquid-borne noise sources.

To visualise the transmission of noise from the different noise sources in the machine a block diagram, Fig. 5, is drawn which in graphical form illustrates the noise mechanisms of the power pack.

A list of the noise sources, paths and surfaces is shown in Tables 1 to 3.

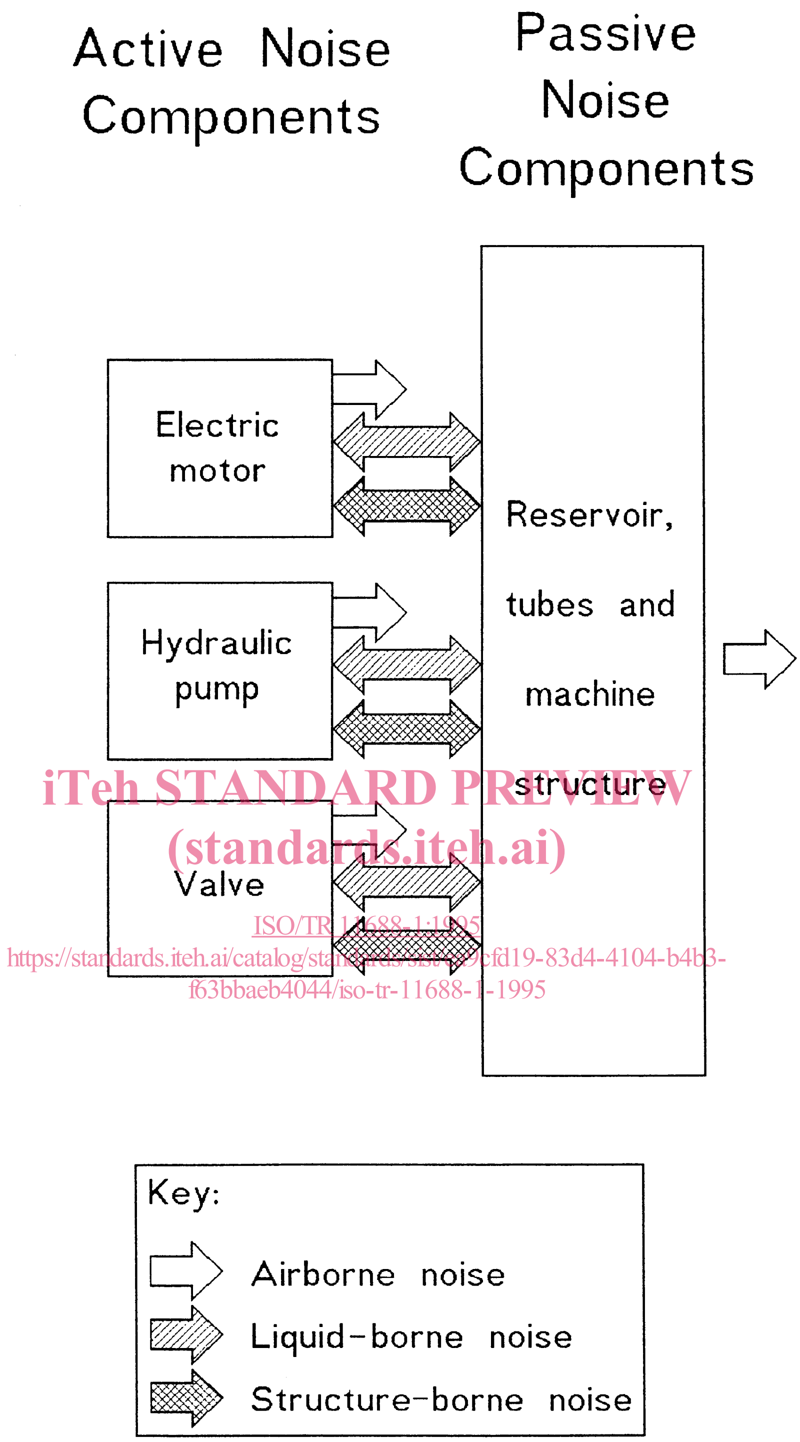


Fig. 5: Acoustical model of power pack