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DIRECTIVE 2000/14/EC – NOISE LIMITED FOR OUTDOOR EQUIPMENT

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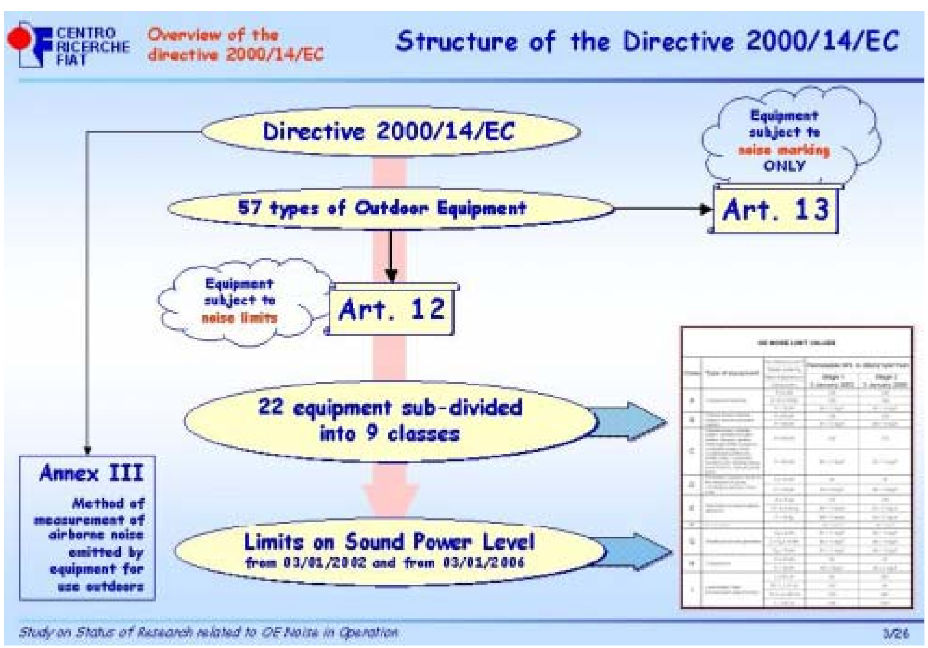
Extended Abstract: Outdoor equipment (OE) covers a wide range of very different mechanical devices. A survey on these types of equipment can be found in the EC directive 2000/14/EC [1]. Although the variation of OE is very wide, the predominant noise sources are similar in many cases due to the fact that most of these devices are operated by internal combustion engines. This means that there are two major noise sources on most of these devices – "engine" and "cooling system (fan)".

Outdoor equipment (OE) covers a wide range of very different mechanical devices. A survey on these types of equipment can be found in the EC directive 2000/14/EC [1]. Although the variation of OE is very wide, the predominant noise sources are similar in many cases due to the fact that most of these devices are operated by internal combustion engines. This means that there are two major noise sources on most of these devices – "engine" and "cooling system (fan)".



Concerning the engine noise, the research activities and also the noise control technologies are mostly the same as for automotive engines (Section 2.2.). Also the cooling technologies are similar in the case of water-cooled systems.

However, very often air-cooling systems are in use for practical reasons. This implies special care for low fan noise.

Basic design guides for low noise axial fans are given in [2], examples for the practical application of a low noise cooling fan and system is described in [3], [4], [5]. Another study on acoustic emission of OE has been published in [6].

The use of lawnmowers often leads to high noise pollution of the adjacent environment because of its high and specific noise emission (engine, rotor blades). The fact that the lawnmowers are mainly used in residential areas results in serious annoyance of neighbours. Due to this special noise situation of lawnmowers, a study on "possibilities and limits of noise reduction on lawnmowers" was carried out by CETIM as described in [7]. The study shows that the main noise generators are the engine (combustion engine, electric drives) and the aerodynamics of the cutting device. More research work can be found in [8], [9], [10]. Concerning noise radiation, the deck of the lawnmower can give significant contributions besides the airborne noise contributions directly radiated from the engine and cutter blades. The noise reduction technologies for lawnmowers refer to quieter combustion engines (quieter combustion) including more efficient cooling fans and better exhaust silencers. Some manufacturers use elastic mounting of the engine, but with only slight acoustic benefit, since the mounting elements must not be too soft for safety reasons. Also the deck structure has been developed towards lower vibration and noise radiation by optimised deck profiles or use of sandwich materials.

An important topic of OE is the correlation (or divergence) between its legislative testing (defined by the Directive 2000/14/EC [1]) and typical noise-relevant modes of real-life operation of OE [11]. Although the Directive provides a classification of the machines according to their type, no specifications are made regarding different operating conditions. Yet in practise, they substantially affect the noise level of running OE. For each machine, the Directive includes a particular section relating to:

- Basic standard on acoustic emission
- Operating conditions during the test

While the first point in each case refers to the EN ISO 3744:1995 standard [12] unifying procedures for signal acquisition and elaboration with only relatively marginal differences, the second point presents significant differences between machines due to the diversity of the operating conditions in practice.

The description of the operating conditions for each machine includes:

- The configuration of the machine;
- The description of the test ;
- The observation time interval;

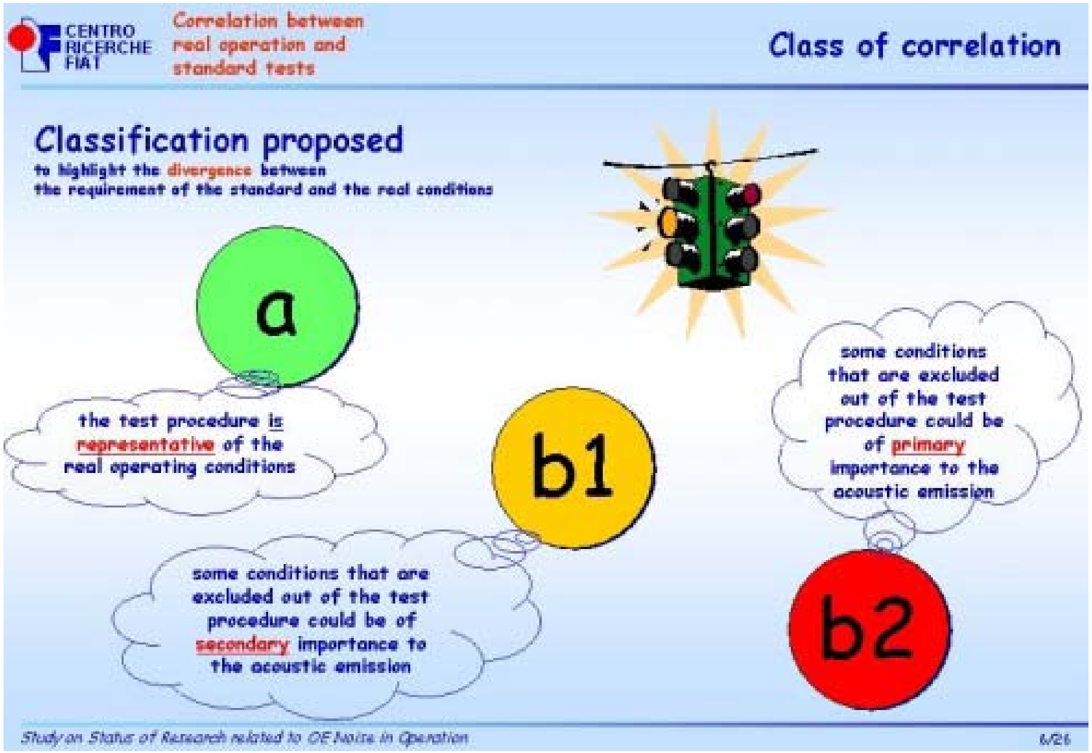
In order to highlight the differences between the procedures for the experimental characterisation of OE as prescribed by the standard and the real operating conditions, a separate classification can be made of the machines (covered in Art. 12 of the Directive) with the following distinction:

a: Representative of the real operating conditions;

b1: Potentially incomplete, because certain significant operating conditions are excluded but which, on subsequent verification, are found to represent an issue of **secondary** importance in terms of acoustic emission;

b2: Potentially incomplete, because certain significant operating conditions are excluded which could, on subsequent verification, be found to be of **primary** importance with regard to acoustic emission.

The summary of this evaluation regarding divergence between the requirements of the standard and the real operating conditions is pursuant to [11].



Especially for construction machinery the test standards or testing procedure might differ considerably from real operating conditions. In many cases this is related to the lack of interaction with the ground, which may often correspond to the prevalent source of noise in practice. Thus, the significance of the test standard with respect to the real operating condition represents an essential aspect to guarantee the effectiveness of the legislative requirements through the progressive reduction of acoustic emission limits in order to decrease the noise pollution of that specific machine. In fact, if the test conditions for the machine are not completely representative of the effective mode of operation, it is possible that a reduction in the maximum level allowed does not correspond to a real benefit in terms of an acoustic emission reduction during the equipment's life.

A further important topic is related to the feasibility of an acoustic quality index to quantify and classify the annoyance caused by the noise of OE.

Specific features ("quality") of the noise emitted and the way in which these are perceived by observers ("listeners") are also of great concern, e.g. [13]. In terms of perception, it is known that the level of emitted sound power is generally one of the most important aspects, though not the only.

For instance, the noise produced by a mosquito is around 30 dBA but is generally agreed to be highly annoying, whereas orchestra music can reach levels of 90 dBA without representing a disturbance for those attending the concert.

Evidently, the relation between the sound emitted and the perception of pleasantness depends on the diverse nature of the sources and the general incompatibility of the contexts. The project SVEN started to study the sound quality of the exterior noise.

The effect of the combination of OE noise sources on the perception is of particular interest and high importance. It considers the issue of noise being caused from a number of machines operating close to each other at the same time in order to evaluate and address the potential combination effect of several sources emitting noise simultaneously.

The EC directive does not suggest any general testing procedure. The only relevant standard ISO 8297/94 [14] specifies an engineering method to determine the sound power emitted from industrial equipment based on the post-processing of microphone measurements taken around the equipment itself. A relatively common procedure is the superposition of continuous noise sources (that are assumed to be uncorrelated), yielding the energetic sum as result.

Such an approach can provide a qualitative first approximation, though it is certainly not exhaustive, particularly when coherent sources of noise may need to be taken into account. (For example, an approximate approach may prove sufficient to predict the noise emitted from a site in the far field, whereas in the vicinity of the site the noise perceived strongly depends on various factors including the position of the equipment with respect to the reference listening location.)

Considering more specifically the real equipment and not ideal continuous acoustic sources, another complication arises due to the variations in time depending on the type of operation being performed.

A more sophisticated approach to obtain the equivalent sound pressure level Leq on a working site is described in [15]. The algorithm is based on neural networks taking into account the type of equipment in operation and the type of operation being performed.

An initial attempt at defining a prediction methodology to evaluate the effect of combing the noise emitted from several machines has been proposed by C.P.T., a local authority located in Turin, Italy, [16]. Specifically a database of measurements from approximately 360 machines has been created, including the sound power (overall and in third-octave band) measured in real operational conditions. Furthermore, approximately 125 standard modes of operation have been catalogued, indicating the activities performed in a specific phase of the on-site work progress together with the type machine that is deployed.

Correspondingly, in order to determine a quantitative measure of significance, a relative proportion has been assigned to the machines, the operations performed and the duration of the activities. Based on the data available, a method has been proposed for determining the average sound power emitted from the site. By taking into account the proportion of time that machine is used to perform a specific operation, a weighted sum has been proposed with regard to the effective contribution of generated noise to the sound power level for each single machine.

In this context, the subsequent EU research projects are of particular importance:

• Modelling sound generation and propagation in fluid machinery systems (FLODAC)-Project led by KTH Stockholm, Sweden.
• Sound Quality of Exterior Vehicle Noise (SVEN)-(Goal: Investigation of acoustical emission of vehicles causing significant annoyance.)-Project from 2000 to 2003 led by Head Acoustics, Germany.
• Sound Quality of Exterior Vehicle Noise (EMISSIO)-(Goal: Measurement and simulation of vehicles and machinery regarding noise emission.)-Project from 1999 to 2002 led by VTT, Finland.
• Vibration and noise control of transport equipment and mobile work machines(Liikku VÄRE)-Project since 1999 led by VTT, Finland.
• Vibration control of rotating machinery (Pyöri VÄRE)-Project since 1999 led by VTT, Finland.

Exemplary list of technology and research centres for OE noise:

- ABB Ventilation Products, Vaexjoe, Sweden;
- AV Technology Ltd., Cheshire, UK;
- Centro Ricerche Fiat (CRF), Italy;
- CETIM, Senlis, France;
- IMAMOTER Institute (National research Council of Italy), Ferrara, Italy;
- TORO Company, Bloomington, MN, USA;
- UNACOMA, Bologna, Italy;
- VTT Industrial Systems, Tampere, Finland;
- Engine manufacturers (like Hatz, Lombardini, Briggs&Stratton, ...)

Organizations :

❖ Members of Euromot (European Association of Internal Combustion Engine Manufacturers, Frankfurt, Germany, www.euromot.org);

❖ Members of Cema (Japan Construction Equipment Manufacturers Association, Tokyo,Japan, www.cema.or.jp);

Limits of acustic power level in conformity of Art. 12 by Directive 2000/14/EC

Type of equipment	Net installed power P (in kW) Electric power Pel (1) in kW Mass of appliance *m* in kg Cutting width L in cm	Possible sound power level in dB/ 1p W	
		Stage I as from 3 January 2002	Stage II as from 3 January 2006
Compaction machines (vibrating rollers, vibratory plates, vibratory rammers)	$P \le 8$	108	105
	$8 < P \le 70$	109	106
	$P > 70$	$89 + 11 \lg P$	$86 + 11 \lg P$
Tracked dozers, tracked loaders, tracked excavator - loaders	$P \le 55$	106	103
	$P > 55$	$87 + 11 \lg P$	$84 + 11 \lg P$
Wheeled dozers, wheeled loaders, wheeled excavator - loaders, dumperes, graders. Loader - type landfill compactors, combustion engine driven counterbalanced lift trucks, mobile cranes, compaction machines (non-vibrating rollers), paver - finishers, hydraulic power packs	$P \le 55$	104	101
	$P > 55$	$85+ 11 \lg P$	$82 + 11 \lg P$
Excavators, builders' hoists for transport of goods, construction winches, motor hoes	$P \le 15$	96	93
	$P > 15$	$83 + 11 \lg P$	$80 + 11 \lg P$
Hand - held concrete - breackers and picks	$m \le 15$	107	105
	$15 < m < 30$	$94 + 11 \lg m$	$92 + 11 \lg m$
	$m \ge 30$	$96 + 11 \lg m$	$94 + 11 \lg m$
Tower cranes		$98 + \lg P$	$96 + \lg P$
Welding and power generators	$P_{el} \le 2$	$97 + \lg P_{el}$	$95 + \lg P_{el}$
	$2 < P_{el} \le 10$	$98 + \lg P_{el}$	$96 + P_{el}$
	$P_{el} \ge 10$	$97 + \lg P_{el}$	$95 + \lg P_{el}$
Compressors	$P \le 15$	99	97
	$P > 15$	$97 + 2 \lg P$	$95 + 2 \lg P$
Lawnmowers, lawn trimmers/lawn edge trimmers	$L \le 50$	96	94 (2)
	$50 < L \le 70$	100	98
	$70 < L \le 120$	100	98 (2)
	$L > 120$	105	103 (2)

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