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NOISE FROM BUILDING SERVICES: COMPARISON OF TECHNICAL REQUIREMENTS IN SIXTEEN COUNTRIES

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ABSTRACT

Building services comprise many systems such as HVAC equipment, ductwork, drainage, lifts, energy supply systems, water supply systems, etc. which are potential noise sources affecting other parts of the building. For that reason, several countries have requirements on sound pressure levels from building services and/or sound insulation requirements between plant rooms and other sensitive spaces such as bedrooms and living rooms.

This paper shows a comparison of the acoustic requirements on service and equipment noise in multifamily housing of 16 countries. It also analyses how regulations deal with different types of noise produced by building services, such as intermittent noise or low frequency noise. It provides updated information on key aspects related to the fulfilment of requirements, such as descriptors, verification procedures and the existence of guidelines for practitioners.

The information provided is based on the responses to a questionnaire developed by the Department of Building Quality of the Eduardo Torroja Institute for Construction Sciences-CSIC, which was sent to the IRCC (Inter-jurisdictional Regulatory Collaboration Committee) and several other European countries.

1. INTRODUCTION

The impact of noise produced by building services on occupants depends on the characteristics of each building system, the type of noise emitted, the way it is implanted in the building and their control and operating conditions.

For that reason, regulations usually set maximum sound pressure levels inside buildings. In addition, other countries have requirements for sound insulation between mechanical rooms and dwellings or other noise sensitive rooms.

This paper shows a comparison of the acoustic requirements on service and equipment noise in multifamily housing of 16 countries. It also analyses how regulations deal with different types of noise produced by building services, such as intermittent noise or low frequency noise. It provides updated information on key aspects related to the fulfilment of requirements, such as descriptors, verification procedures and the existence of guidelines for practitioners.

The information provided is based on the responses to a questionnaire developed by the Department of Building Quality of the Eduardo Torroja Institute for Construction Sciences, IETcc - CSIC, which was sent to the IRCC (Inter-jurisdictional Regulatory Collaboration Committee)

and several other European countries: Denmark, Poland and France.

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2. QUESTIONNAIRE AND RESPONSES RECEIVED

The questionnaire aimed at compiling the state of the art of regulations on noise from building services and included many aspects, such as descriptors, evaluation procedures, requirements, guidelines and pre-completion measurements, which are being subject of study currently in Spanish regulations.

The questionnaire was divided into six parts: Scope, requirements for sound pressure levels due to building services, sound insulation requirements of mechanical rooms, acoustic classification, assistance to designers and precompletion tests.

It contained questions on descriptors, frequency ranges, time intervals, corrections, standards and measurement procedures.

Twelve IRCC countries sent back the completed questionnaire on July 12th, 2019. In addition, the questionnaire was also sent to other non IRCC countries: Denmark, France and Poland, which also sent their responses back. This paper is based on the replies of the questionnaires completed. It summarizes the main conclusions derived from the comparison of the responses.

Table 1 contains the list of countries which responded to the questionnaire and the indication of the type of requirements they have regarding building services: maximum sound pressure levels due to building services and sound insulation requirements between habitable rooms and plant rooms.

Some countries do not have regulations concerning service equipment noise, but they have guidelines or recommendations, which support best practices to minimize noise from building services.

All regulations apply to new-build constructions, but some countries apply them also to existing housing. That is the case of France, Germany, The Netherlands, Norway and Sweden. Most of them apply requirements for service equipment noise to extensions and conversions.

3. REQUIREMENTS FOR SOUND PRESSURE LEVELS

Table 2 contains the sound pressure limit values due to service equipment noise in dwellings for the 16 countries which completed the questionnaire or provided

information. The reference of the regulations and the different documents of each country are included in brackets.

| Country | Requirements on service equipment noise | Sound insulation requirements ¹ |
|------------------------------------|---|--|
| Austria (AT) [1] | YES | YES |
| Australia (AU) [2] | --- | YES |
| Germany (DE) [3] | YES | YES |
| Denmark (DK) [4] | YES | YES |
| England and Wales (EN) [5 - 6] | --- ² | --- |
| Spain (ES) [7 - 8] | YES | YES |
| France (FR) [9] | YES | YES |
| Japan (JP) [10 - 11] | --- | --- |
| The Netherlands (NE) [12] | YES | YES |
| Norway (NO) [13] | YES | --- |
| New Zealand (NZ) [14] | --- | --- |
| Scotland (SCO) [15 - 16] | --- ³ | --- ³ |
| Sweden (SE) [17] | YES | YES |
| Singapore (SG) [18] | YES ⁴ | YES ⁴ |
| United States of America (US) [19] | --- | YES |
| Poland (PL) [20] | YES | YES |

¹ Sound insulation between mechanical rooms and habitable rooms
² Requirements apply only for schools, referred in AD2003 to Building Bulletin 93
³ No regulations, but guidance is given.
⁴ Regulations refer only to boundary noise limits for air conditioning and mechanical ventilation systems in non-industrial buildings.

Table 1. List of countries that completed the questionnaire and existence of regulations regarding service equipment noise.

Table 2 indicates type of noise source, receiver room, descriptors, frequency range and limit values. Dashes in

boxes mean that no information has been provided or that there are not regulations.

Main descriptors are A-weighted equivalent continuous sound pressure level, $L_{A,eq}$, and maximum time-weighted and frequency-weighted sound pressure level, $L_{A,max}$. In Spain, $L_{K,eq,T}$ is the sum of the $L_{A,eq,T}$ and the corrections depending on components (tonal, low frequency and impulsive) and Sweden uses the descriptor $L_{pC,eq}$, C-weighted equivalent sound pressure level, to limit low frequency noise. Sweden and Poland use more than one descriptor for a certain noise source.

In Germany, Spain and Norway, requirements only apply to living rooms and bedrooms, whereas in Austria, Sweden, Denmark and France, there are also requirements for other spaces such as kitchens or bathrooms. Noise limits in these rooms are 5 dB higher than in bedrooms and living rooms.

In addition, some countries have different requirements for different types of equipment depending on the operation of the services (continuous or not), type of noise (broadband or impulses and tones) or the type of service (individual or communal). For example, requirements in Sweden and Austria are stricter for noises with clearly audible variations such as intermittent noises. In France, there are different limit values for individual heating, cooling and ventilation systems and other communal shared equipment. Scotland only applies requirements to continuously running extraction fans.

In summary, limit values for equivalent sound pressure levels, $L_{A,eq}$, range from 25 to 30 dB in bedrooms and living rooms in dwellings. Limit values for $L_{A,max}$ vary from 30 to 35. These values are in line with the WHO Guidelines [21].

| Country | Type of noise | Receiver room | Descriptor | Freq range (Hz) | Limit value |
|---------|---|---|-----------------|-----------------|---|
| AT | External to the dwelling service equipment noise sources | Bedrooms, living rooms, kitchen | $L_{AF,max,nT}$ | --- | 25 dBA (intermittent noise) 25 dBA (short-term noises) |
| | | Ancillary rooms (bathrooms, WC, utility rooms, store room, etc.) | $L_{AF,max,nT}$ | --- | 30 dBA intermittent noise 35dBA short-term noises |
| | Noise coming from mechanical ventilation systems from the same utilisation unit. | Habitable rooms with protection object "Sleep" | $L_{Aeq,nT}$ | --- | 25 dBA |
| | | Habitable rooms with protection object "Concentration" e.g. Classroom | $L_{Aeq,nT}$ | --- | 30 dBA |
| AU | --- | --- | --- | --- | --- |
| DE | Noise from sanitary equipment / water installations and other internal sources of building equipment, garages | Living rooms and bedrooms | $L_{AF,max,n}$ | --- | 30 |
| DK | Any noise coming from services | Rooms in dwellings including kitchens | L_{Aeq} | 125-2.000 | 30 |
| EN | --- | --- | --- | --- | --- |

| Country | Type of noise | Receiver room | Descriptor | Freq range (Hz) | Limit value |
|---|--|---|------------------|-----------------|--|
| ES | Any | Living rooms in dwellings or in public residential buildings. | $L_{K,d}$ | 16 – 12.500 | 40 |
| | | | $L_{K,e}$ | | 40 |
| | | | $L_{K,n}$ | | 30 |
| | | Bedrooms in dwellings or in public residential buildings. | $L_{K,d}$ | 16 – 12.500 | 35 |
| | | | $L_{K,e}$ | | 35 |
| | | | $L_{K,n}$ | | 25 |
| FR | Individual heating or cooling systems | Bedroom or living room in the same dwelling | $L_{As,max,nT}$ | 50 – 10.000 | 35 |
| | | Open kitchen in the same dwelling | | | 40 |
| | | Separate kitchen in the same dwelling | | | 50 |
| | Individual ventilation | Bedroom or living room in the same or another dwelling | $L_{As,max,nT}$ | 50 – 10.000 | 30 |
| | | Kitchen in the same or another dwelling | | | 35 |
| | Other individual equipment | Bedroom or living room in another dwelling | $L_{As,max,nT}$ | 50 – 10.000 | 30 |
| Kitchen in another dwelling | | 35 | | | |
| Other shared equipment | Bedroom or living room in any dwelling | $L_{As,max,nT}$ | 50 – 10.000 | 30 | |
| | Kitchen in any dwelling | | | 35 | |
| JP | --- | --- | --- | --- | --- |
| NE | Toilet, water tap, mechanical devices for ventilation, hot water units, pumps, elevators | Dwellings | $L_{I, Ak}$ | --- | 30 |
| NO | Noise from technical installations in the same building or in another building, garages | Living rooms, bedrooms | $L_{p,AF,max}$ | --- | 32 |
| NZ | --- | --- | --- | --- | --- |
| PL | Any | Rooms | $L_{A,eq,T}$ | 125-2.000 | 25 |
| | | Kitchens | $L_{AF,max,nT}$ | | 30 |
| SCO | Domestic buildings, continuously running extraction fans | Adjacent bedrooms | $L_{A,eq,T}$ | --- | 30 |
| | | | | | |
| SE | Broad band installations noise. e.g. from extract air devices and radiators | Bedrooms | $L_{pAeq,nT}$ | 31,5-8.000 | 30 |
| | | | L_{pCeq} | | 50 |
| | | | $L_{pAF,max,nT}$ | | 35 |
| | | In space for everyday social contact | $L_{pAeq,nT}$ | | 30 |
| | | | $L_{pAF,max,nT}$ | | 35 |
| | | | $L_{pAeq,nT}$ | | 35 |
| | Kitchens | $L_{pAeq,nT}$ | 31,5-8.000 | 35 | |
| | | $L_{pAF,max,nT}$ | | 40 | |
| | | $L_{pAeq,nT}$ | | 35 | |
| | Sound containing clearly audible variations, impulses or tones, e.g. from lift, toilet and washing machine | Room for personal hygiene | $L_{pAeq,nT}$ | 31,5-8.000 | 35 |
| | | | $L_{pAF,max,nT}$ | | 40 |
| | | | $L_{pAeq,nT}$ | | 25 |
| Bedrooms and spaces for everyday social contact | | $L_{pAeq,nT}$ | 25 | | |
| | | $L_{pAF,max,nT}$ | 35 | | |
| | | $L_{pAeq,nT}$ | 30 | | |
| Kitchens | $L_{pAeq,nT}$ | 31,5-8.000 | 30 | | |
| | $L_{pAF,max,nT}$ | | 40 | | |
| | $L_{pAeq,nT}$ | | 30 | | |
| Room for personal hygiene | $L_{pAeq,nT}$ | 31,5-8.000 | 30 | | |
| | $L_{pAF,max,nT}$ | | 40 | | |
| | $L_{pAeq,nT}$ | | 40 | | |
| SG | HVAC noise | Outside the building. In the site boundary | $L_{p,A}$ | - | 65/60/55 (day - 7-19/ evening 19 - 23/ night 23- 7) |
| US | --- | --- | --- | --- | --- |

Table 2. Limit values due to service equipment noise in dwellings in 16 countries

4. SOUND INSULATION REQUIREMENTS FROM PLANT ROOMS

Table 3 contains sound insulation requirements between dwellings and plant rooms, which are rooms for shared equipment, such as boilers, pumps, chillers, etc. Dashes in boxes mean that no information has been provided or that there are not regulations. This table indicates receiver rooms, descriptors, frequency range and airborne and impact sound insulation requirements.

Seven out of the sixteen countries have sound insulation requirements between dwellings and plant rooms. Spain, Germany, Sweden, Denmark and Poland have also

requirements for sound pressure levels produced by services, while Australia and the USA, have only sound insulation requirements.

Austria, Norway, The Netherlands and France have only requirements for sound pressure levels produced by services, but no sound insulation requirements from plant rooms.

Most of the descriptors of sound insulation refer to field sound insulation of the rooms for both cases: airborne and impact, except in Australia, where requirements refer to the sound insulation of walls and floors based on laboratory measurements. The USA allows two types of descriptors of sound insulation: field and laboratory.

| Country | Receiver room | Descriptor | Frequency range (Hz) | Limit value |
|-------------------|--|--|----------------------|-------------|
| AT ⁽¹⁾ | --- | --- | --- | --- |
| AU | Any habitable room within a residence (other than a residence in an aged care building) | R_w (walls) | 100-3.150 | ≥ 50 |
| | | $R_w + C_{tr}$ (floors) | | ≥ 50 |
| | | $L_{n,w}$ (floors) | | ≤ 62 |
| DE | Protected rooms (living rooms, bedrooms, classrooms, offices and the like) from machinery rooms in case of $L_{AF,max} = 75 - 80$ dB | R'_w (walls and floors) | 100-3.150 | ≥ 57 |
| | | $L'_{n,w}$ (floors) | 100-3.150 | ≤ 43 |
| | Protected rooms (living rooms, bedrooms, classrooms, offices and the like) from machinery rooms machinery rooms in case of $L_{AF,max} = 81 - 85$ dB | R'_w (walls and floors) | 100-3.150 | ≥ 62 |
| | | $L'_{n,w}$ (floors) | 100-3.150 | ≤ 43 |
| EN | --- | --- | --- | --- |
| ES | Protected rooms (living rooms, bedrooms, classrooms, bedrooms in hotels and hospitals, offices and the like) | $D_{nT,A} \approx D_{nT,w} + C_{100-5000}$ | 100-5.000 | ≥ 55 |
| | | $L'_{nT,w}$ | 100-3.150 | ≤ 60 |
| | Habitable rooms (kitchens, bathrooms, halls, corridors.) | $D_{nT,A} \approx D_{nT,w} + C_{100-5000}$ | 100-5.000 | ≥ 45 |
| JP | --- | --- | --- | --- |
| NE ^(a) | --- | --- | --- | --- |
| NO ^(a) | --- | --- | --- | --- |
| NZ | --- | --- | --- | --- |
| SCO | --- | --- | --- | --- |
| SE | Dwellings | $D_{nT,w,50}$ | 50-3.150 | ≥ 56 |
| | | $L_{nT,w,50}$ | 50-3.150 | ≤ 52 |
| SG | --- | --- | --- | --- |
| | | STC | 125-4.000 | ≥ 50 |
| | | $ASTC$ | 125-4.000 | ≥ 45 |
| | | IIC | 100-3.150 | ≥ 50 |
| | | $AIIC$ | 100-3.150 | ≥ 45 |
| DK | Dwellings | R'_w | 100-3.150 | ≥ 60 |
| FR ^(a) | --- | --- | --- | --- |
| PL | Dwellings | $R'_{A,l}$ | 100-3.150 | ≥ 58 |

^(a) Countries which only have requirements for sound pressure levels. See table 2

Table 3. Sound insulation requirements between dwellings and plant rooms

The field sound insulation descriptors used are R'_w , apparent sound reduction index, and $D_{nT,w,50}$ weighted standardized field level difference. Sweden is the only country whose descriptors include the low frequency range from 50 Hz to 100 Hz.

Five countries have also impact sound insulation requirements between plant rooms and dwellings. The main descriptor used is the weighted standardized impact sound pressure level, $L'_{nT,w}$ (100-3150), and again Sweden

is the only country that includes the low frequency range from 50 to 100 Hz.

Although translations between descriptors are not straightforward, it can be said that airborne sound insulation from plant rooms range from 62 to 55 dB, and impact sound insulation range from 43 to 60 dB.

In addition to requirements, Australia, Germany, Scotland, England and Wales and Spain have specifications for pipe casings and elevator shafts when adjoining rooms.

5. GUIDANCE TO DESIGNERS AND BUILDING CONTROL

Countries were asked whether they provided guidance to practitioners and designers concerning service equipment noise. This guidance comprises guidelines or standards.

Most countries have guidelines, catalogues or provide documents that explain acoustic concepts, regulatory terms, details and even, case studies to assist designers to comply with requirements. See references [1], [16] [22 - 31].

In most cases, building control depends on local administrations and pre-completion tests on sound pressure levels from building services are not compulsory.

Only the following countries specify that sound pressure level tests were required by building authorities:

- In Germany, tests are only compulsory in certain cases.
- In Spain, only some regional and local administrations require sound pressure level tests prior the first occupancy licence.
- In Sweden, sound requirements can be verified with a combination of calculations and site controls or measurements in the finished building. In addition, there has been a close cooperation between the Swedish Institute for Standards and the National Board, resulting in an Acoustic Classification Scheme connected to the Building Regulations based on SS 25267 [32] for dwellings and SS 25268 [33] for work premises.
- In Singapore, outdoor noise limits at the site boundaries must be measured.
- In France, multifamily residential buildings must be tested if they have more than 10 dwellings units. France also specifies the number of measurements which must be performed for each building service.
- In Scotland and England and Wales, sound insulation tests are mandatory for new-build and conversions, but it does not apply to service equipment noise. An alternative to testing is the Robust Details Scheme [34].

6. CONCLUSIONS

Building services comply any mechanical or electrical system that serves a building such as air conditioning, cooling, heating, power supply, ventilation, plumbing, etc. and any other equipment. These systems usually have the potential to generate high noise levels and the acoustic impact of them in the building depends on the characteristics of each building system, the type of noise emitted, the way it is implanted in the building and their control and operating. Some equipment operates long periods and produces a continuous noise, but other types of equipment such as lifts or plumbing systems, produce short-term noises which are non-steady [35].

In addition, low frequency noise is common of certain equipment such as air conditioning. Tonal components are

also common, especially if there are problems due to incorrect installation of equipment or deficient maintenance.

This paper compares the approaches of sixteen countries towards regulating noise from building systems. The information provided is based on the replies of a questionnaire sent to the sixteen countries listed in table 1.

Nine out of the sixteen countries, which sent the completed questionnaire, have indoor sound pressure level requirements. In addition, seven countries have also sound insulation requirements between dwellings and plant rooms or any room which allocates service equipment.

The Building Codes of all the countries analysed in this paper apply to new builds, and in some cases, they apply to conversions, extensions and retrofittings. However, it is common to update, change or introduce new building services when renovating existing housing, and requirements for sound pressure levels should apply, as occupants need the same protection against noise from building services as in new build.

Regarding indoor sound pressure levels, there are different descriptors used, but they are based either on the A-weighted equivalent continuous sound pressure level, $L_{A,eq}$, or the maximum time-weighted and frequency-weighted sound pressure level, $L_{A,max}$. Limit values for equivalent sound pressure levels, $L_{A,eq}$, range from 25 to 30 dB in bedrooms and living rooms in dwellings. Limit values for $L_{A,max}$ vary from 30 to 35 dB.

$L_{A,eq}$ assesses correctly continuous noise, whereas $L_{A,max}$ is better to assess the noise of distinct events and it is a better indicator of the disturbance to sleep and other activities.

Three countries, Austria, Sweden and Poland have requirements for both; $L_{A,eq}$ and $L_{A,max}$, but the rest of the countries rely on one descriptor, either $L_{A,max}$ or $L_{A,eq}$. Having only $L_{A,eq}$ requirements has the problem that the sound generated by single events or cycles produced by intermittent systems is not evaluated correctly.

Low frequency is addressed in Swedish regulations that require a certain limit value of L_{pCeq} in bedrooms. In Spain, corrections for tonal, low frequency and impulsive corrections must be added to the sound pressure level tested. In Spain, requirements for service equipment noise derived from an environmental noise law [7] and building services in Spain are assessed like any other environmental noise sources.

In this paper, sound insulation requirements between plant rooms and dwellings are also analysed. It may be easier for a designer to comply with a sound insulation value than to comply with a limit value of sound pressure level, but a low requirement of sound insulation may lead to situations where it may not guarantee comfort in sleeping units adjacent to plant rooms. E.g. if the equipment located in the plant room is very noisy.

Concerning sound insulation requirements between plant rooms and dwellings, main descriptors for field airborne sound insulation are R'_w , apparent sound reduction index, and $D_{nT,w}$, weighted standardized field level difference, from 100 to 3150.

Several countries also require a minimum impact sound insulation between dwellings and plant rooms. The main descriptor used is the weighted standardized impact sound

pressure level, $L'_{nT,w}$, from 100 to 3150. Sweden is the only country which extends the frequency range down to 50 Hz, for both: airborne and impact sound insulation.

There is not a typical value for sound insulation from plant rooms. Airborne sound insulation requirements range from 50 to 62 dB, and the limit for impact sound pressure levels vary from 62 to 43 dB.

Most countries have guidelines or provide assistance to designers to comply with requirements, although some of these guidelines only focuses on sound insulation and not in sound pressure levels generated by building services. See references [1], [16] [22 - 31].

Post-completion tests on sound pressure levels from building services are not compulsory in the sixteen countries. Local administrations decide the procedures for building control.

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