ASPECTS CONCERNING DIFFERENCES BETWEEN REQUIREMENTS IN A- AND C-WEIGHTED SOUND PRESSURE LEWEL CAUSED BY TECHNICAL INSTALLATIONS.

Eva Sjödahl
Ingemansson Technology AB
Hans Michelssensgatan 1B
211 20 Malmö
Sweden
Tel: +46 40 710 35
Fax: + 46 40 12 82 10
E-mail: eva.sjodahl@ingemansson.se

ABSTRACT
In the Swedish building regulations, requirements concerning technical installations (for example fans) are stated in both A-weighted and C-weighted sound pressure levels. In the Swedish sound classification standard (SS 02 52 67) for residential buildings the difference between A- and C-weighted levels is 20 dB. However, in the new standard, SS 02 52 68, which classify other buildings than residential buildings, for example schools, offices etc), the difference between the two levels varies between 10-20 dB. In schools it vary between 10 - 20 dB. Measurements in many rooms in schools show that the C-weighted level often is too high, even if the A-weighted level is correct. This paper will show the differences between requirements, results from measurements and a discussion about a realistic difference between the A- and C-weighted sound pressure level.

INTRODUCTION
Noise disturbance is a subjective reaction, especially for low sound levels. Many people are sensitive for noise with low frequencies and the sensitivity seams to increase the longer the exposition last. Low frequency noise is normally more difficult to accept and localize then noise which includes high frequencies. Many typical installations in buildings (fans and ventilation systems, elevators, heatingpumps and distant-heating system) produce low frequency noise. The low frequency noise causes certain types of effects compared to high frequency noise, for example fatigue and and difficulties to concentrate.

A typical low frequency feature in buildings is that the sound is not noticed until it stops. For example, a ventilation system during operation is not noticed during operation but when it stops there is normally a great feeling of relief. Sound slightly above the normal hearing threshold level is normally enough to detect symtom of tiredness, concentration problems, headache, a feeling of pressure over the ear-drums and in some cases dizziness and sickness.

There are reasons to suppose that the low frequency noise is disturbing at lower dBA-levels than other noise. When the low frequency noise is noticed as disturbing the habituation seems to be non-existing. Noises with tones seems to be even more disturbing than noises without tones.

In order to minimize the low frequency disturbance in buildings Sweden introduced a "difference-limit" between the A-weighted and the C- weighted levels in 1994. Furthermore, two new Swedish standards (SS 02 52 67 and SS 02 52 68) also use this approach to prescribe "low frequency limits". In this paper some practical considerations are shown and analysed.

DIFFERENCE BETWEEN dBA- AND dBC-LEVEL

For a noise large differences might be noticed between the dBA- and dBC-level particulary if the noise dominated by low frequencies. In these cases the dBA-weighted level tends to underestimate the degree of experienced disturbance. With low frequency noise you normally mean noise between 20-200 Hz.

To consider low frequency noise, especially at low sound levels, the authority have decided to complement the traditional requirement in dBA with an additional requirement in dBC.

DIFFERENT REQUIREMENTS FOR RESIDENTIAL BUILDINGS– SS 02 52 67 AND SOSFS 1996:7

The Swedish standard SS 02 52 67 state sound requirements in both A- and C-weighted sound pressure levels caused by technical installations. The requirements is valid for sleeping rooms and living rooms and vary depending on "sound class". The standard includes four classes A – D where class A corresponds to very quite conditions (best class) and class D corresponds to acceptable conditions in certain rebuilding projects. Class C corresponds to the minimun requirements in the Swedish building regulations. However, it is common to use class B in many new buildings.

In the table below the four classes and their prescribed sound pressure levels are written.

Sound class	Sound level, Leq, dBA	Sound level, Leq, dBC	Other requirements
Class A	22	42	No tones
Class B	26	46	No tones
Class C	30	50	No tones
Class D	30	-	-

The Swedish Social authority has issued some advisory notes in SOSFS 1996 :7 – it's a guideline which might be used to decide whether noise is classified as "sanitary inconvenience" or not. The advise says that:

- The A-weighted sound level should not exceed 30 dBA
- For music noise and noise with audible tones, 25 dBA might disturbe
- If the the dBA-level is higher than approximately 30 dBA and the difference between dBC and dBA is more then 15 – 20 dB the noise might be classified as low frequency noise.
- If the dBA-level is less than 30 dBA it is not possible to declare the noise as low frequency noise even if the difference between dBC and dBA-level is more than 15 – 20 dB (to be compared with the dBC levels in the building regulations)
- Instead of using dBC, it's better to measure the levels in third octave band and compare to the recommended values in the third octave bands 31.5 – 200 Hz, given in SOSFS 1996 :7

In the advisory notes, no values are given for the third octave frequencies 20 and 25 Hz, where also audible sound can be found.

Experiences have shown that the interval between the hearing-threshold level and the level where disturbance can be noticed is much less for low frequency noise than for noise including higher frequencies.

In the table below the highest recommended levels between 31.5 – 200 Hz are shown. Also the hearing-threshold levels are given.

Hz	20	25	31.5	40	50	63	80	100	125	160	200
Rec.	-	-	56	49	43	41.5	40	38	36	34	32
Hearing -limit	74	65	56	49	43	35	30	25	21	17	14

Rec. = highest levels, recommended in SOSFS 1996:7

At the frequencies 31.5 – 50 Hz the highest recommended level equals the hearing threshold level. An effect that shows that it's better to look at the recommended values at the third octav band is that you can mesure a noise level which is below the hearing treshold level and get a C-weighted level that is too high if you compare to the building regulation. If the noise that decide the dBC-level is below the hearing treshold level, then you can't hear it and then it can't disturbe you.

DIFFERENT SOUND REQUIREMENT IN OTHER BUILDINGS

In the Swedish standard SS 02 52 68 there are requirements for other buildings than housing buildings. However, in this paper only rooms for educational premises are considered. This standard also includes different sound standard classes. However in this case the number of classes is restricted to three.

In the table below a sample of requirements in different kinds of rooms is shown.

Kind of room	Class A Leq dBA / Leq dBC	Class B-C Leq dBA / Leq dBC	Class D Leq dBA / Leq dBC
Education, class-room	26 / 45	30 / 45	30 / 50
Group room	35 / 50	35 / 55	35 / 55
Diningroom	40 / 55	40 / 60	45 / 60
Kitchen	45 / 60	50 / 60	55 / -

There is not a consequent line concerning differences in levels between the various classes. Sometimes the difference between dBA and dBC is 10 dB, sometimes 15 dB and sometimes even 20 dB. It depends on type of room etc.

SOME TYPICAL EXAMPLES

Dwellings – sound from a fan at the roof

In a bedroom, experienced as very quiet, the sound level was measured, both dBA- and dBC-levels but also in third octave bands. The results are shown in the table below

	25	31.5	40	50	63	80	100	125	160	200	dBA	dBC
Measured	60	38	30	34	23	22	26	21	20	20	21	56
Rec	-	56	49	43	41.5	40	38	36	34	32	30	50

The dBC-level is higher than the prescribed maximum level 50 dBC. However the measured values between 31.5 and 200 Hz are all far below the recommended. The C-weighted value is determined by the level at 25 Hz. The hearing threshold at 25 Hz is 65 dB and the measured value was 60 dB i.e. the 25 Hz-noise is not audible.

The room is experienced as very quiet, all recommended values are far below the required apart from the dBC-level, which is caused by by the level at 25 Hz. Hence, the dBC-level is not always "perfect" to describe the sound quality in the room.

Dwelling – sound from a circulation pump

In a bedroom a lady complains about noise disturbances. Measurements were made after all accepted methods, to compare with the building regulation, the Swedish standard SS 02 52 67 and the recommended values in the third octave frequencies from SOSFS 1996 :7

The measured values in dBA, dBC and third octave bands are given in the table below.

	25	31.5	40	50	63	80	100	125	160	200	dBA	DBC
Meas 1	38	34	31	45	29	34	31	39	26	17	26	47
Meas 2	38	34	28	42	27	34	32	42	25	15	28	47
Meas 3	38	34	31	35	30	34	33	29	20	16	23	46
Rec	-	56	49	43	41.5	40	38	36	34	32	30	50

Measurement 1 = levels in the room with the pump operating
Measurement 2 = levels in the "most disturbing" position with the pump operating
Measurement 3 = levels in the room when the pump did not operate

In the house there were many fans and pumps. During the measurements the different installations were stopped and started one after another. When the pump that circulate the water to the radiator started, the typical noise was heard. It might perhaps be described as a tone. In the advisory notes from the Social authority it's written that it is the person who carries out the measurements that primarily shall decide, by listening, if the sound include a tone. In this special case the measurements were made by three persons (one after another) and it was actually no agreement at all between the different judgements.

Therefore, my opinion is that if there is a tone it must be possible to notice this in the measured values even if you haven't made a narrow band analyse. When deciding if there is a tone measurements have to be done at the position where the disturbance is most annoying. Here it was above the bed, the corner position.

In the freqency band 125 Hz the level was much higher than the levels at the adjoining two frequencies. The values were higher than the recommended values. When the pump was cut off the level at 125 Hz was at least 10 dB lower. We have found the source. It should be mentioned that without the corner position the level at 125 Hz would have been 35 dB and, hence, below the recommended value.

To define a tone correctly it is necessary to carry out a narrow band analyse, with certain instruments. However, measurements in third octaves are normally enough to decide if there exist a tone or not. The experience says that if the level in one third octave band is at least 10 dB higher than the levels in the two adjoining third octave bands it can be classified as a tone. This fact is fulfiled in this case since the level at 125 Hz is 10 dB higher than the level at 100 Hz, and 17 dB higher than the level at 160 Hz.

Both the dBA- and dBC-levels were very low. However, the measured level at 125 Hz is exceeds the recommended level. Noise with tones is more disturbing than noises without tones. In this case it seems reasonable to say that the noise should not exceed 25 dBA. Hence, The dBC-level was not a good measure to describe the annoyance in this case.

Dwellings – fan at a wooden floor structure

A person living just below an attic with a fan room is disturbed by low frequency noise The fan is standing on a wooden floor structure above the bedroom. The table below shows the measured values.

	25	31.5	40	50	63	80	100	125	160	200	dBA	dBC
Meas.	45	40	37	41	39	28	28	26	23	20	23	55
Rec	-	56	49	43	41.5	40	38	36	34	32	30	50

The sound was disturbing even if all the measured values in dBA and the third octave levels were below the recommended. However, the difference between dBA- and dBC-level was 33 dB.

When the difference between dBC- and dBA is high, much higher than the 10 – 20 dB than in the regulations, the low frequency noise is very obvious and can be classified as very disturbing.

School – measurements at a repaired school

A lot of measurements were made in a school. In the table below the difference beteen dBC- and dBA-level is shown in all 84 rooms.

Difference in dBC – dBA-level	Number of rooms
0-5	1
6-10	3
11-15	15
16-20	45
21-25	15
26-30	15
Total number of rooms	84

Measurements were made in both classrooms, grouprooms and rooms intended for the teachers. The maximum permitted differences between dBC- and dBA-level are 15 – 20 dB.

A difference below 15 dB were only measured in 19 of the 84 rooms. In 45 of the 84 rooms the differences were between 16 – 20 dB. In 20 rooms the differences were more than 20 dB. The sound /noise were not noticed as disturbing low frequency noise in any room.

Even if the difference between dBC- and dBA-level is more than 20 dB it's not obvious that the sound is experienced as disturbing low frequency noise.

CONCLUSION

Some final remarks:

- If the difference between the dBC- and dBA-level is equal to or even slightly more than 20 dB, this does not necessarily indicate that the actual sound is a disturbing low frequency noise.
- If the noise includes tone components there is an increased risk to be disturbed
- In cases where complaints exist and the noise does not has a tone, there is normally a very large difference between the dBC- and dBA-level, often more than 30 dB.
- Requirements given as a difference between dBA and dBC-levels is a very rough measure and must be used carefully, only to indicate low frequency noise.
- A third octave bands analyse in the low frequency range 20 – 200 Hz, using the recommended levels in SOSFS 1996 :7 (completed with values in the third octaves 20 and 25 Hz) seems to be an acceptable way to discribe annoyance
- It is normally not necessary to carry out narrow band analysis to detect a tone component.
- If the sound level at a third octave band is more than 10 dB higher than the levels in the adjoining third octave bands, it indicates a tone component. In those cases a 5 dB lower dBA – value, compared with an "equal noise" without tones, might be preferred.

REFERENCES

SS 02 52 67 (2nd edition), "Acoustics – Sound classification of spaces in buildings – dwellings"
SS 02 52 68, "Acoustics – Sound classification of buildings – Institutional premises, rooms for education, day centers and after school centers, room for office work and hotels
SOSFS 1996:7 General advices, Indoor sounds and high sound levels
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