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On a new, on/off broadband absorber system for music schools and other multipurpose facilities

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Previous studies have shown that what distinguishes the best from the less well liked halls for pop and rock music is a short reverberation time in the 63, 125 and 250 Hz octave bands. Since a quite long reverberation time in these bands is needed in order to obtain warmth and enough strength at classical music concerts, variable acoustics must address these frequencies in order to obtain desirable acoustics in multipurpose halls. Based on the results of a previous study of Danish rock venues as well as three newly built halls, acceptable tolerances of T30 were investigated. A new, variable broadband absorption product is presented. Absorption coefficients measured in situ are approx. 0.5-0.6 in the 125, 250, 500 Hz bands while decreasing at higher frequencies and in the 63 Hz band when in the ON position. In the OFF position the product attains absorption values between 0.0 and 0.2. Since the product is placed in the entire ceiling area the T30 of a hall can be lowered by almost 50% in the important octave bands.

1 Introduction

Today's musical geniuses are equally likely to be performing within the pop, rock, or jazz music genres as they are to be performing classical music. From the point of view of the musicians, live concerts are becoming increasingly important because of declining sales of recorded music. Both for the sake of musicians as well as to serve the vast masses of audiences attending their concerts, more focus on creating suitable acoustics for pop & rock music appears relevant. First section of this paper will look into what deviations from recommended T_{30} for pop and rock music can be tolerated and used advantageously.

Many classical as well as pop & rock concerts and rehearsals are held in the same halls in performing arts centres, recital halls, etc. In order to try to adapt the acoustics of these halls to the different needs of these different genres, variable acoustic systems – passive as well as active – are often employed. An unwanted flaw of the passive systems has been that they did not work at lower frequencies. The electronic systems have not always been well liked by classical musicians because of the fact that their acoustic music is not left acoustic but is added an artificial, electronic element. A new solution to this challenge, an acoustic passive, broadband absorber that can be switched on or off as needed and that is installed in the ceiling area, is presented in this paper. A low cost has been a focus point in the development of the system. This allows it to be implemented into almost any multi-musical venue such as music schools, high schools etc. This is the first system ever to cut the reverberation time also in the so important 125 and 250 and even 63 Hz octave bands considerably.

Of course, for most room-acoustic matters, many parameters other than simply T_{30} are of interest. For instance the level at any given position of the reverberant sound compared to the level of direct sound is often decisive for subjective impressions of the acoustics of a room. Since this ratio is correlated with T_{30}, and T_{30} is the primary criterion used in selecting materials in an acoustic design for a given hall volume, recommendable T_{30} as a function of hall volume for pop and rock music is discussed in this paper. The direct-to-reverberant energy ratio decreases with distance from the sound source, which is why the shape of a room is of course also critical in early phases of the design process. In [1] it was found that sound engineers preferred a very short T_{30}, but musicians preferred a slightly longer reverberation time. The reason for this is probably that the musicians prefer a sensation of envelopment and "togetherness" with each other and the audience. It is believed, but not proven, that the audience also has this desire. This also implies that people are not attending live concerts to experience a high fidelity sound quality adventure, but rather a good sounding social experience. To achieve this, a certain level of reverberant sound at live pop and rock concerts is required, so a design goal for a hall could be to create lateral reflections permitting a sensation of envelopment also at higher frequencies.

2 Proposed reverberation times for pop and rock music

The maybe most important finding in [1] was a proof that what distinguishes the best from the mediocre halls for pop and rock music is a significantly shorter reverberation time in the 63, 125 and 250 Hz bands (fig. 1). This is not surprising since amplified music is very powerful and syncopated at lower frequencies and since the audience does not absorb low frequencies to nearly the extent than higher frequencies they do provide the solution. Furthermore since the bass frequencies emerge the subwoofers almost omni directionally the critical distance becomes very short at low frequencies.

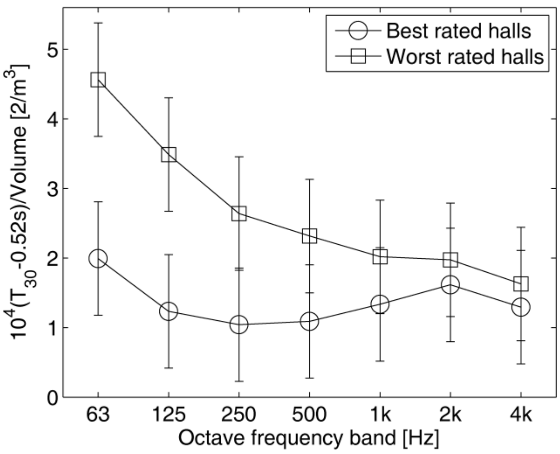

Fig.1: Average T30 divided with hall volume of ten best versus ten mediocre halls for amplified music

According to fig. 1 even good halls can have a somewhat longer T_{30} at 63 Hz than at 125 Hz. This has been confirmed by interpreting results from 3 newly built rock venues [4]. This acoustic gain seems alright also when consulting the data of Equal Loudness Contours. Even at higher sound levels the hearing rolls off below some 100-200 Hz. Especially when thinking in terms of reverberation time and thereby sound decay: as the sound decays, a 50 Hz tone is perceived increasingly softer by the human ear as for instance a 125 Hz tone. This is the reason for leaving out the 63 Hz band in the average of T_{30} in a new recommendation for T_{30} as a function of hall volume (fig. 2). It is a fact that the 125 Hz octave band is very powerful and boomy. On the contrary higher frequency reverberation especially above some 1-2 kHz can be helpful to create a sense of spaciousness and envelopment. Further, as mentioned, a packed audience has an absorption coefficient, actually of at least 1, at frequencies above 1 kHz.

At amplified music concerts in especially dead rooms, the sound engineer adds artificial reverb on higher pitched instruments or on the higher frequencies of instruments that have a broad range. He or she would never add reverberation to bass or bass drum other than for a special effect. As mentioned, reverberation at low frequencies, regardless of whether it comes from the hall itself or is added artificially, adversely affects pop and rock concerts. Also from this perspective, it seems plausible that as long the hall is dry at low frequencies it can be more live at higher frequencies.

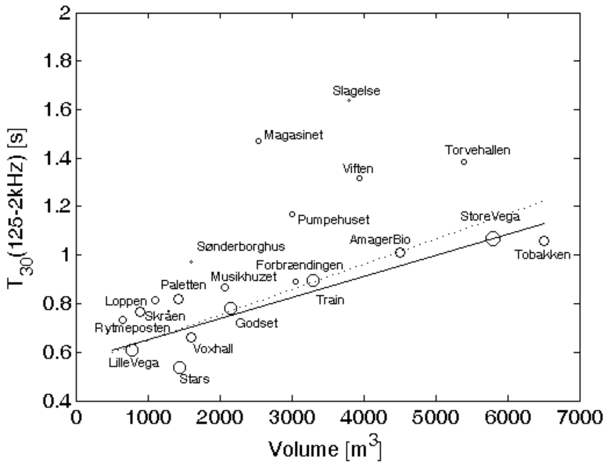

Fig.2: Recommended T30 as a function of hall volume in halls for pop and rock music. The previous recommendation (dotted line; from [1]) included the 63 Hz band whereas the current recommendation, solid line, does not.

After our previous study [1] was published, some sound engineers have reported that they like the hall to add reverberation at higher frequencies since the combination of artificial and real reverberation sounds more natural than artificial reverberation alone, and also because they want themselves and the audience to feel enveloped in sound. It seems that musicians and a group of sound engineers and probably also the audience prefer some reverberation at higher frequencies. Hence the values in Fig. 3 have been proposed [4]. Usually envelopment is related to lateral reflections, which suggests that sound absorbers should be placed in the ceiling. Another group of sound engineers likes, as previously mentioned, the halls to be as dead as possible at all frequencies.

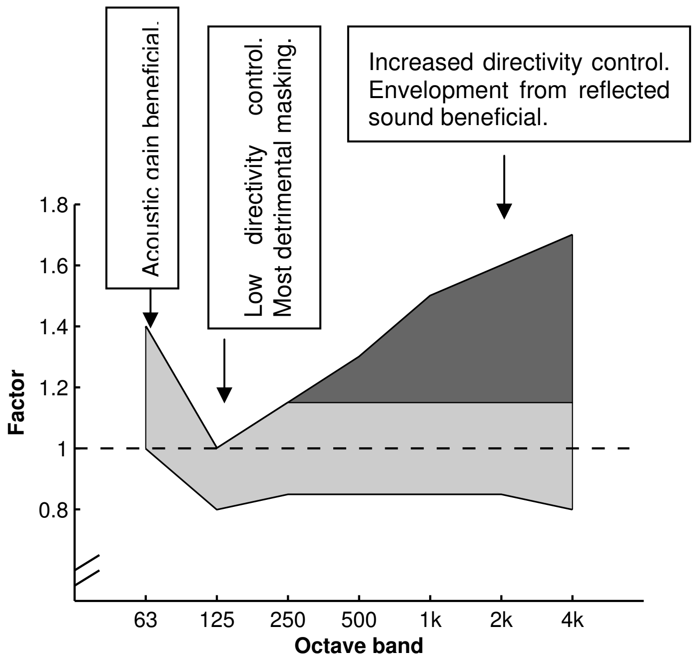

Fig.3: Approximate factors of T_{30} in the octave bands 63 Hz to 4 kHz relative to average value of T_{30} within 125 to 2000 Hz as proposed in fig.2. Light grey area: tolerances as proposed [4]. Dark grey area: possible tolerances [4].

If relatively live acoustics are designed at higher frequencies, care must be taken in the design of the shape of the venue to obtain diffusivity, but just as well so that the stage matches the liveliness of the hall so that the musicians receive enough early support compared to late [3]. Special caution must also be shown on the design and installation of the PA speaker system in such a room. If the back wall is not absorbent, and, with some speakers in the array pointing toward the rear wall an unwanted for extra reverberation and maybe even echoes will be created.

3 New, ON/OFF broadband absorber system

From our knowledge that a low T_{30} at low frequencies is required for amplified music while warmth and enough strength demands a higher value of T_{30} at classical music concerts, attaining a high absorption coefficient over a broad spectrum at lower frequencies has been one aim in the development of this new variable absorber. The basic technology of soft inflatable membranes as means for variability of reverberation time in multipurpose venues was presented in [2]. A new product, the AqTube™ absorber developed according to that principal in 2011, enables an inexpensive way to achieve enough absorption variability when installed in the ceiling to make it possible, for example, to present both symphonic music and rock concerts in the same venue with favourable acoustics. The product can be installed permanently for ON/OFF use (figure 7), or, since it is extremely thin and light, it could be installed temporarily in any hall.

The absorption coefficients were measured in the reverberation chamber at the Technical University of Denmark (fig. 6). Four absorbers each with a length of 3.30 m were placed side by side as baffles at a distance of 1 m. Hence the alpha values obtained correspond with the projected surface area and thereby a ceiling area. The arrangement that was measured for this purpose needs a cavity above e.g. a false, acoustically transparent ceiling of 125 cm.

A proof-of-concept installation has been implemented in a Danish music school. The room is a quite typical recital hall of a music school, a former gym, with dimensions app. 19x9x5.5 m. Figure 5 shows the measured T_{30} in the on and off positions respectively. Table 1 shows the calculated absorption coefficients, α, in the on- and off-positions based on the T_{30} measurements in the room. In this installation one baffle-line per 1.4 meters was installed. Usually there should be one line per 1.0 meter yielding a somewhat higher absorption coefficient that is estimated in the second row of table 1. Evidently in some ceilings there will be ventilation ducts etc. that will be determining where the tubes can be placed or vice versa. The T_{30} values obtained are believed to be close to optimum values for choir respectively pop/rock for this size venue. Further, T_{30} values in between the two extremes can easily be achieved by activating any number of tubes. Since there is usually no audience in the school porous curtains have furthermore been mounted on tracks on all side walls to be drawn manually. This of course most of all to bring down the sound level at higher frequencies. There exist no measurements of the room with curtains drawn. The teachers and leaders of the school as well as the pupils are very pleased indeed with the new acoustical possibilities that support their music to a level only seen in a handful of halls worldwide.

The reason why the product absorbs more in the 500 Hz band than for instance in the 250 Hz band is a combination of fire regulations and physics. The roll-off of alpha in the 63 Hz band and above 1 kHz was a part of the design strategy. Should these frequencies be incorporated the cavity of the absorber would have to be larger. There does not seem to be a need neither for higher values of α at these frequencies nor is a larger cavity practical. Moreover, the high frequencies are diffused by the convex shape of the activated product.

If the PA system is designed correctly, avoiding loudspeakers aimed directly against the back wall, suitable conditions for pop and rock concerts and rehearsals are obtained. Variable porous absorbers can be employed on the rear wall leaving the lower frequencies to be absorbed by the AqTubes. A false acoustically transparent ceiling can be mounted underneath the absorbers for aesthetic and utility purposes. This may include attachment of lighting, ventilation, fire sprinklers etc. The system is activated at the push of a button and is fully functioning in app. 10 min. The air pressure of the system is constantly surveyed to ensure maximum absorption at all times. The material is flame retardant to the European B,s1,d0 and US NFPA 701 and ASTM E 84 standards. It is the hope that the product will be used to benefit amplified as well as acoustic music in a variety of applications from music schools and recital halls, to arts performance centres and multi-purpose halls etc. The technology is patented [5].

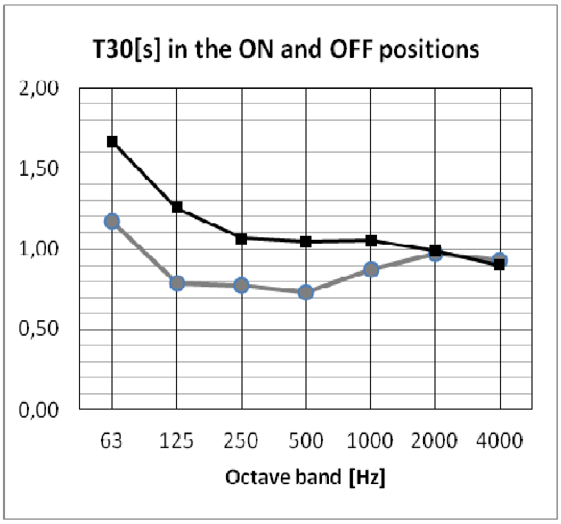

Figure 5: Measured T30 in the on resp. off position in the music school. There is only one tube per 1.4 m. There should normally be on per 1.0 m.

Table 1: In situ measured absorption coefficients for AqTube™ in the "ON" and "OFF" positions respectively (row one)

f [Hz]	63	125	250	500	1k	2k	4k		f [Hz]	63	125	250	500	1k	2k	4k
α ON[1]	0.23	0.43	0.32	0.37	0.18	0.02	0.00		α OFF	0.00	0.00	0.11	0.02	0.03	0.11	0.09
α ON[2]	0.29	0.55	0.41	0.49	0.23	0.02	0.00		α OFF	0.00	0.00	0.12	0.02	0.03	0.12	0.10

1) Row one: one baffle line per 1,4 m measured in music school 2) Row 2: estimated α with one baffle line per 1,0 m

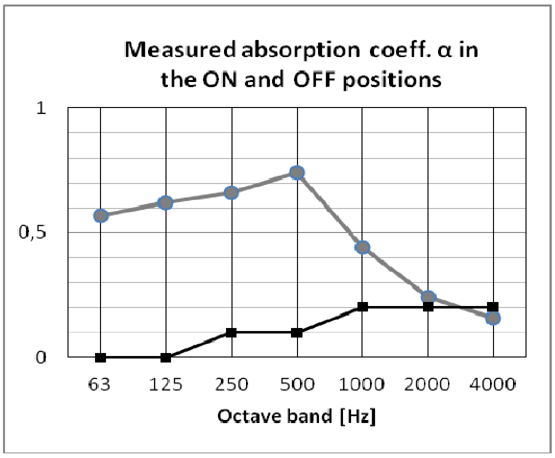

Fig. 6: Measurements from reverberation chamber at the Technical University of Denmark. Measurement of one baffle-line per 1.0 meter.

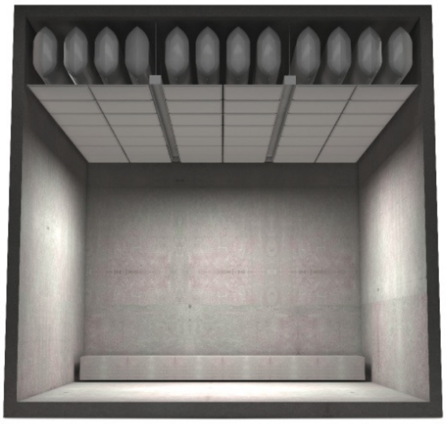

Figure 7: A false sound transparent ceiling is mounted beneath the AqTubes^{TM}.

References

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[2] N. W. Adelman-Larsen, E. R. Thompson, A. C. Gade: Variable Low-Frequency Absorber for Multi-Purpose Concert Halls. *Acoustical Society of America, Vancouver* (2005).

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