ACOUSTIC RENOVATION OF TWO DANISH THEATRES

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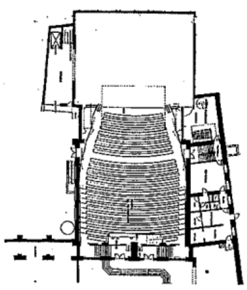
1 INTRODUCTION

Around New Year 2002, two theatres in Denmark re-opened after substantial renovations. The two theatres are the theatre in “The Works” in Randers and The "New Stage" of the Royal Theatre in Copenhagen. In certain ways, the objectives behind these two renovation projects were opposites. In Randers the needs were to increase the seating capacity, to improve the stage facilities and to give the room a different and more modern visual appearance, while in Copenhagen the agenda was to reduce the seating capacity but to maintain the architecture of this listed building. The wish to reduce the seating in The "New Stage" was partly motivated by a planned change in the use of the hall; but first of all it was a means to overcome old problems with lacking seating comfort, poor sight lines and bad acoustics in remote seats.

2 THE WORKS, RANDERS

2.1 THE RENOVATION PROGRAM



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“The Works” is a former electricity plant in the middle of Randers built between 1906 and 1924. Between 1987 and 1990 it was converted into a cultural complex including a 610 seat theatre, a 465 seat concert hall and a small cinema. The theatre has been used for drama, popular music concerts, meetings and sometimes opera. However, opera was difficult as not only the stage house, but also the orchestra pit was very small. With the fly tower and auditorium confined within the old - very nice looking - brick building, neither the stage facilities nor the seating capacity met the needs of the city. Consequently, it was decided to build a new, larger stage house behind the existing stage and enlarge the seating area by adding most of the former stage area to the auditorium as seen in Figure 1.

Hereby the auditorium became eight meters longer that before. The ambition was to be able to seat an audience of nearly 1000 - i.e. a 60 % increase - only through this extension in length of the auditorium and by a new balcony design.

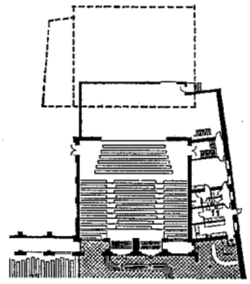

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Figure 1:Plan of the theatre “The Works” after (top) and before (bottom) the renovation with increased seating capacity and new stage house (also shown as dotted line in the bottom drawing).

With the stage front being moved, part of the old stage basement was included in a new 90 m^2 orchestra pit (60 % larger than the old one).

2.2 ACOUSTIC DESIGN

It should be mentioned right away, that (apart from some problems with background noise) the acoustic conditions in the old theatre were regarded satisfactory. However, with the program for the changes as listed above, the acoustician faced serious challenges regarding maintaining sufficient loudness and clarity particularly in the rear part of the auditorium. Consequently, the main tasks were associated with trying out different layouts of the balconies and different shapes of a new suspended ceiling and wall reflectors in order to distribute the early reflected sound as evenly as possible over the new extended audience area.

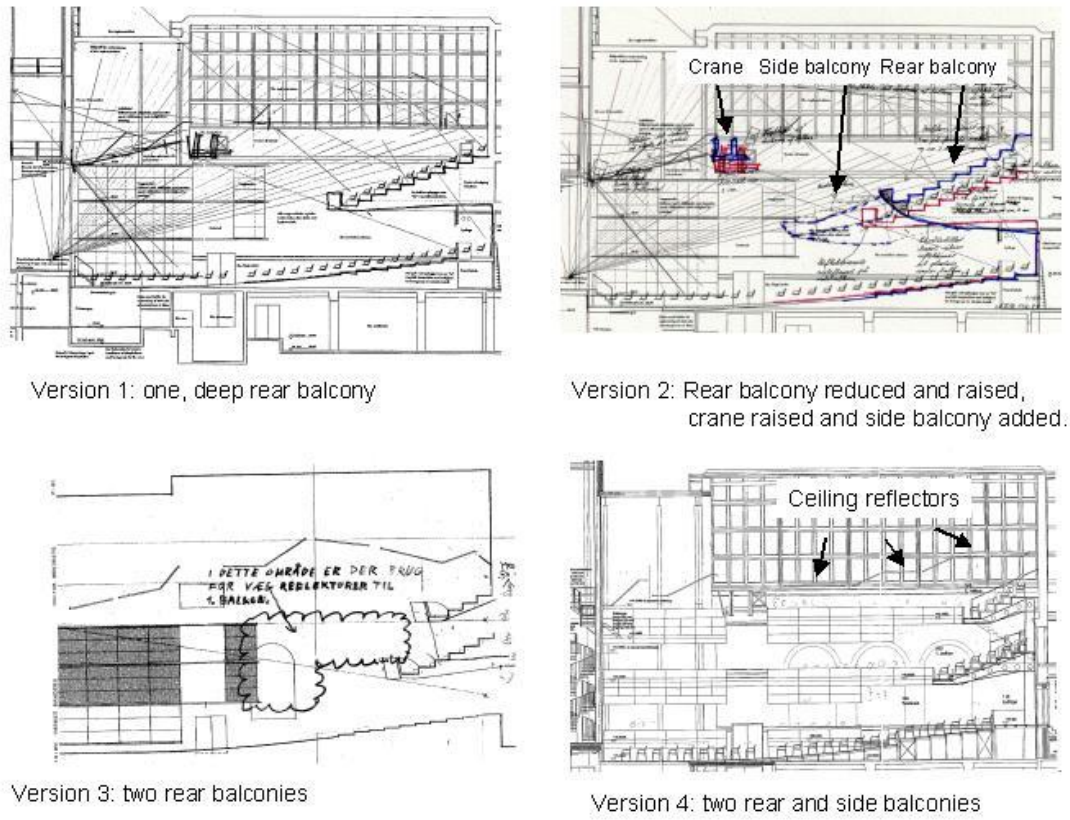


Fig. 2: Various stages in the design of the balconies. The final version is in the bottom-right corner.

The evolution of the balcony design as described in the following and illustrated in Figure 2 was experienced as a fine example of a creative ping pong between architect and acoustician. The original proposal by the architect (who was also the technical manager of the venue), was to introduce one, large balcony in front of the rear wall (top-left in Fig. 2). However obviously this left a substantial number of main floor seat rows below a much too deep balcony overhang. In order to reduce this overhang; we first suggested removing the first two rows from the balcony, raising it slightly in front and to add two small side balconies to accommodate the removed seats (Fig. 2, top-right). The height and shape of the side balconies should be chosen so that the fronts would help reflect sound to the seats under the rear balcony. However, instead the architect presented a new design with rear balconies in two levels (Fig. 2, bottom-left). In spite of the fact that the depths of the balconies were now much reduced, the acoustics in the overhung seats was still not satisfactory because the total free room height was quite limited. At this point the architect again adopted the idea of using side balconies, which now spanned all along the side walls from the rear balcony to the proscenium frame and in two levels (Fig. 2, bottom-right). Hereby the number of seat rows in the rear balconies was also substantially reduced. The side balcony fronts were now suggested as large, vertical reflecting surfaces, which helped transmit the sound from the stage to the rear parts of the auditorium. Along with the shaping of the balconies, also the design of the reflecting ceiling panels developed. The use of the ceiling area as an efficient sound reflector was however hampered by the wish to preserve a large traverse crane spanning between the side walls, which had remained as a symbol of the original use of the building. This crane obstructed free propagation of sound from the stage to a large portion of the ceiling area, which consequently could not be active in distributing sound to the audience. To reduce this problem, we suggested lifting the entire crane about one meter (see Fig. 2, top-right); but this was not accepted because the crane should also act as a light bridge (- an example of the usual fight between light and acoustics in theatre design). After this we only wished that the crane would fall down during the renovation work; but as usual, old constructions proved to be very solid.

2.3 ACOUSTIC RESULTS

The evaluation of the different versions of the design (nine all together !) was supported by computer modelling using the ODEON programme. The key parameters considered were RT, EDT (Early Decay Time), SPL (Strength) and STI (Speech Transmission Index). Besides, the model provided auralization, which proved to be an efficient tool in illustrating to the client and architect the acoustic impact of the possible choices.

In Figure 3 is shown the measured reverberation time of the auditorium before and after the renovation. The slightly lower values at middle and high frequencies after the renovation was intended in order to improve the conditions for speech and amplified music. At the middle and low frequencies, there is practically no difference due to the main wall and ceiling surfaces being unaltered. The slight reduction in reverberation time is mainly a result of the increase in number of seats being larger than the increase in volume, as no other sound absorbing elements were added. (Rather, some old sound absorbers were actually removed.) It is interesting to notice, that EDT (averaged over the range 250 – 2000 Hz octave bands) dropped with a larger amount that RT, (ΔEDT= -0.25 Sec versus ΔRT = -0.1 Sec.) indicating that we succeeded in improving the level of early reflection energy as well as reducing RT.

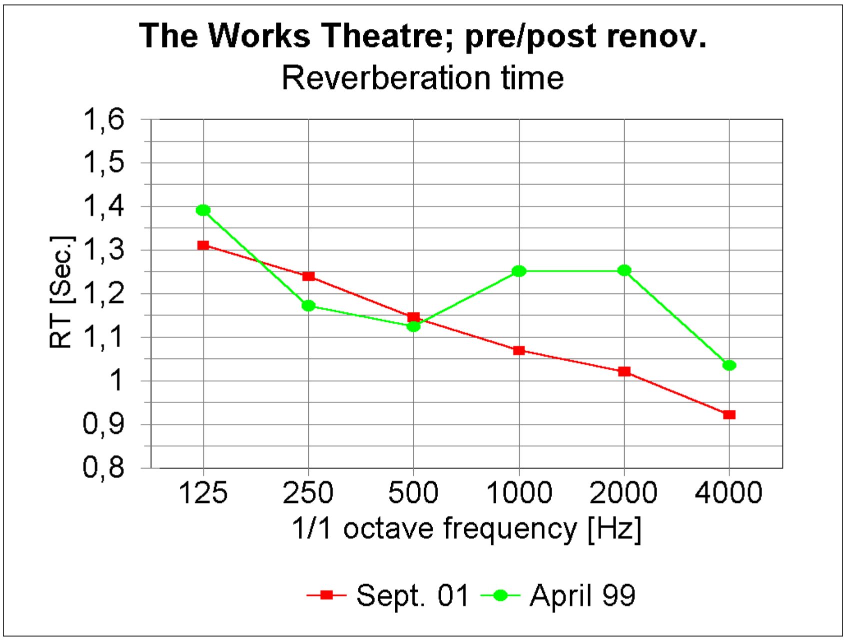


Fig. 3: Reverberation time in the "Works" theatre before (oval points) and after (rectangular points) the renovation

In Figure 4, measured results of the sound level (G) as a function of source receiver distance are shown both before and after the renovation. It is very satisfying to see, that with the exception of one single measurement position, we succeeded in maintaining relatively high levels also beyond 22 meters, which was the length of the old auditorium. Measured STI values were all very close to 0.6.

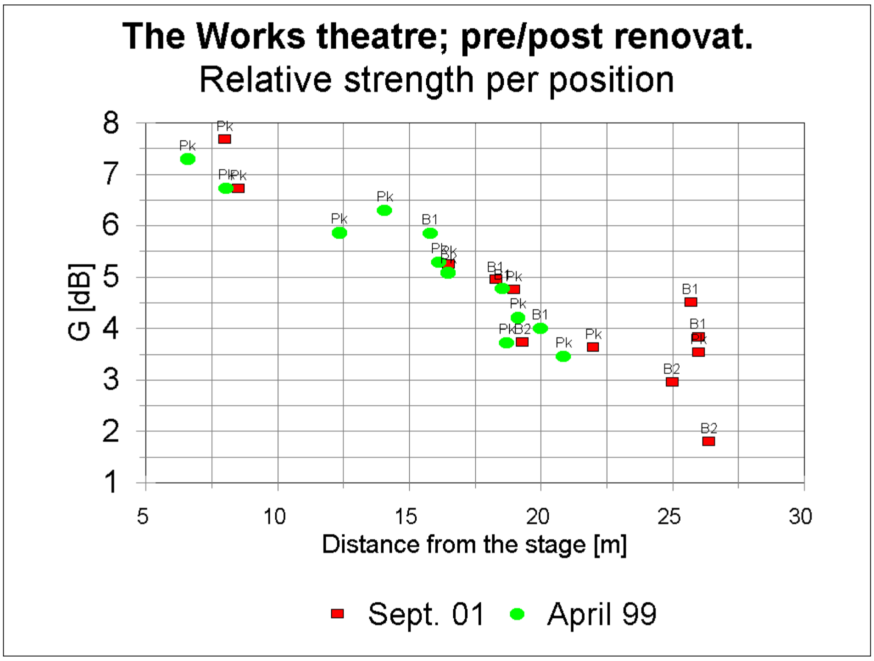


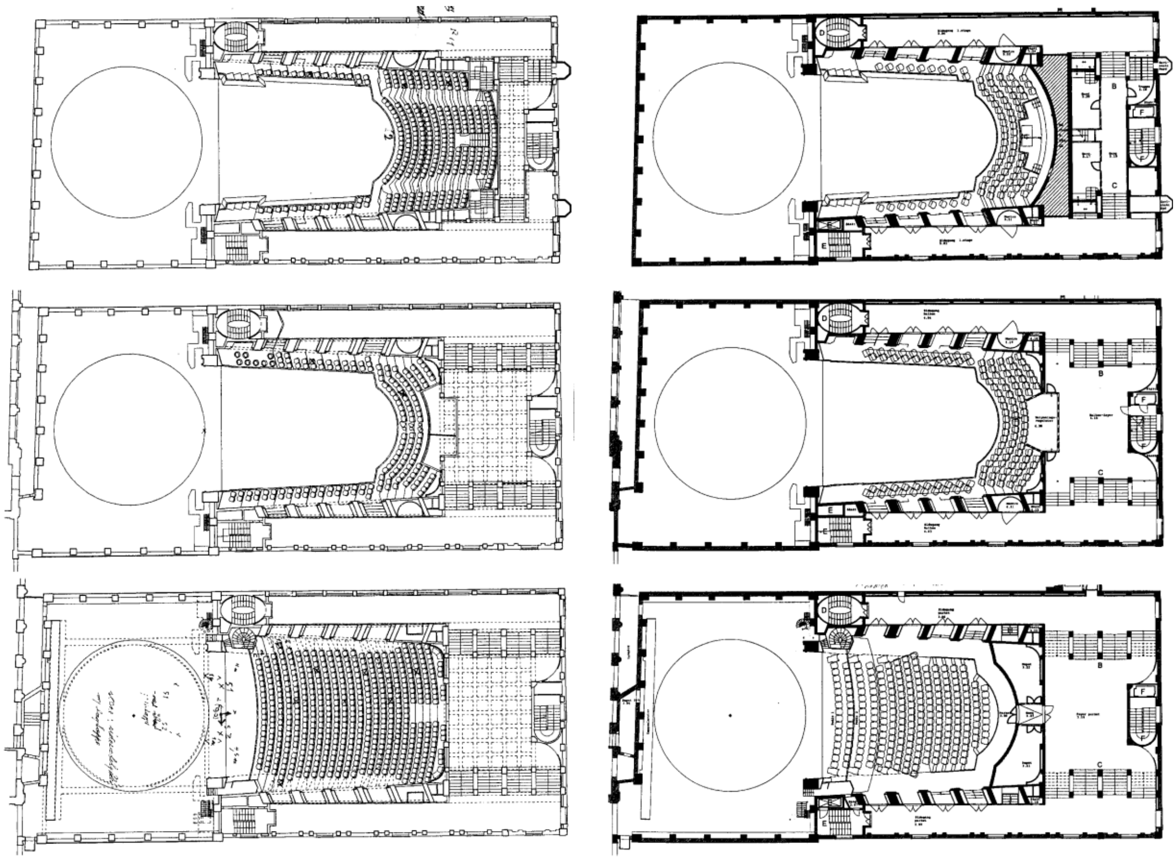
Fig. 4: Measured sound levels as a function of distance from an omni directional sound source in the "Works" theatre both before (oval points) and after (rectangular points) the renovation.

3 THE "NEW STAGE", THE ROYAL THEATRE, COPENHAGEN

The "New Stage" building is probably the most important example of Art Deco architecture in Denmark. It was Inaugurated in 1931 as a combination of a drama theatre extension for the Royal Theatre and home for the Danish Radio - with the theatre also functioning as the first concert hall for the Danish Radio Symphony Orchestra. The functional aspects of the building were heavily criticised from the very start. After only two years the combined use of the building stopped and the Danish Radio became the only inhabitant until this institution moved into new facilities in 1941. In 1945, The Royal Theatre reluctantly took over the building again and have used it primarily for drama ever since, although several attempts have been made to raise a new drama stage. In 1999, the government decided to renovate the now listed building but also realized, that it will never fulfil the functional demands of modern drama. Therefore, when a new Royal playhouse has been built (hopefully by 2007), the Royal Theatre will limit the use of the "New Stage" to workshops, meetings and educational purposes for new generations of actors, opera singers and dancers.

3.1 THE RENOVATION PROGRAMME

Apart from a general restoration of external and internal surfaces and improvement of the technical facilities on stage, the objectives were to improve the auditorium regarding seating comfort, sight lines ventilation and – if possible – improve the acoustic conditions for speech and theatrical music performances.



The measures towards better seating comfort and sight lines had three elements: 1) moving the rear wall in the stalls and on the second balcony closer to the stage, whereby the deep rear balcony overhangs were reduced, 2) increasing the slope of the main floor and 3) substituting the 950 bad, old seats with 450 new, more comfortable ones. These measures are illustrated in Figure 5 by floor and balcony plans from before and after the renovation.

Fig. 5: Floor and two balcony plans from the "New Stage" of the Royal Theatre, Copenhagen before (left) and after (right) the renovation.

3.2 ACOUSTIC PREDICTIONS

As no changes of the major surfaces were possible (apart from the introduction of the new rear walls), we used the ODEON program to predict the acoustic changes resulting from the three elements of modification listed above. The old hall suffered from very uneven sound distribution and very dry acoustics in general. Like in "The Works" project, we also in this case created a model of the existing hall and fitted the absorption values of the surface materials based on measured RT values before implementing and letting the model predict the future conditions.

The predictions indicated that RT could be increased by about 10 % to around 1.0 Sec. and that the level would increase by 2 – 3 dB in the remaining seats in the rear balconies and in the rear part of the stalls area, which was quite promising. The expected increase in RT and in level can be attributed to the seating area being reduced without reducing the “free” volume in the hall by a comparable amount. The volume of the auditorium excluding the stage house is now about 3,100 m^3 or about 7 m^3 per seat.

In order to avoid echoes or focussing from the new, concave rear wall elements, these were designed as perforated plate absorbers primarily absorbing in the middle and low frequency regions. In the second balcony, where the sound control would be situated right in front of the concave wall, additional diffusion in the form of variation in the perforation pattern was introduced.

One other important acoustic issue was the reverberation time in the stage house with its thick, concrete.walls. Measurements had indicated that with the stage moderately furnished and only few drapes stored in the fly tower, RT could easily become higher than two seconds at low frequencies. In particular, this could be critical for the functioning of the reverberation enhancement system described later. Consequently, we recommended low frequency absorption to be installed on available wall areas in the stage house; but unfortunately this has not been realized yet.

3.3 THE REVERBERATION ENHANCEMENT SYSTEM

As the expected moderate increase in RT would still leave the hall very dry for music, it was decided to include in the renovation installation of a reverberation enhancement system. A LARES system from Lexicon, USA was selected and the system was installed with about 70 self powered Genelec 1029 loudspeakers built into the walls and into the soffits of the door niches plus 6 sub woofers (Genelec 1092A) hidden in the ventilation plenum under the raised, new wooden floor. The locations selected for the 1029 loudspeakers are indicated in the section drawing in Figure 7.

The microphones for the system consists of two B&K cardioids suspended from the ceiling over the orchestra pit (which can be raised and covered with chairs when not in use) while two more are hidden behind the proscenium wall for proper pick up of sound from the stage. The two stage microphones are of an array type (Microtech KEM 970) providing a very even coverage of the stage combined with a very narrow vertical pick-up angle whereby the influence of noise and excessive reverberation from the stage house is reduced.

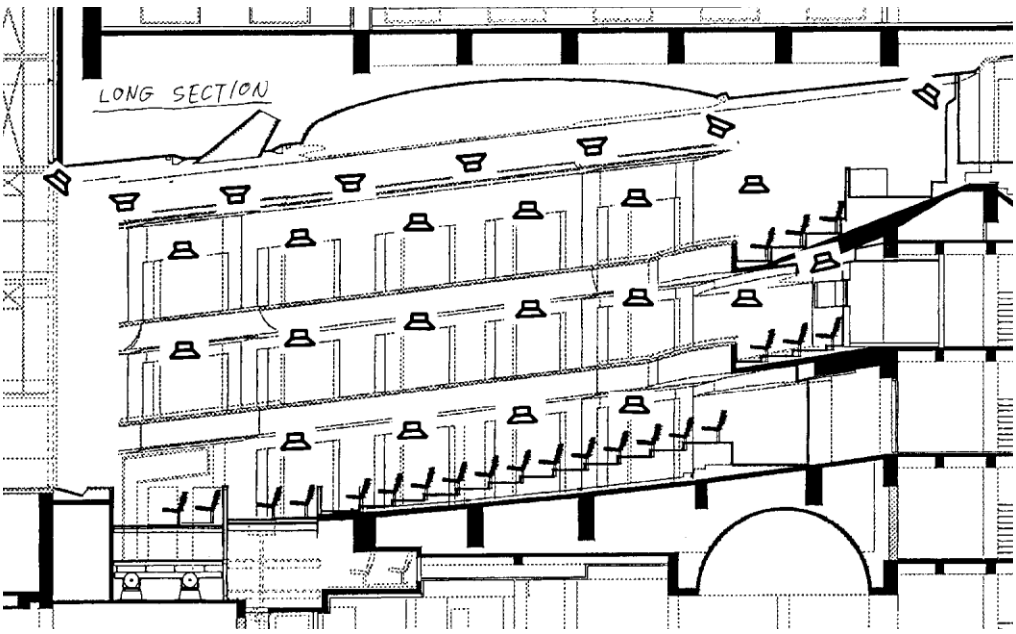


Fig. 6: Long section of the "New Stage" auditorium after renovation with placement of the loudspeakers for the enhancement system and the raised stalls floor indicated.

As one could fear that the formerly poor speech conditions might prevail (as no major changes in room geometry or surface properties were possible), the theatre management asked us to work on a special setting of the enhancement system for improvement of the intelligibility in possibly “weak” areas. As in principle the lay out of a loudspeaker system for improvement of speech intelligibility (few, centrally placed and highly directive loudspeakers) is very much different from that of a reverberation enhancement system (many, widely distributed loudspeakers with large coverage angle), we responded that only if the poor intelligibility was caused by lacking sound level rather than lack of clarity, it might be possible to obtain a slight improvement – and only in seating areas rather close to one or more of the loudspeakers in the system. In the “speech” setting, the system is programmed to deliver only a single or very few early reflections from all or a selected number of loudspeakers.

At present (June 2002) the final tuning of the system has not yet been completed, but a primary demand - both for music and speech enhancement – will be that the presence of electro acoustic means must not be noticed by the audience or performers as an artificial add-on to the acoustics of the hall. However, from the present experience both with this system and with another recent Lares installation in the “Old Stage” of the Royal Theatre, fulfilment of this demand still leaves room for worthwhile improvements of the acoustic conditions. Actually, the theatre has been satisfied with the effect delivered by both systems when the reverberation time has been increased by just 20 – 40 %, i.e. before the systems have reached any limits for naturally sounding enhancement and long before any feed back colouration can be detected.

3.4 SOME ACOUSTIC RESULTS

As all work and tuning of the hall and reverberation system have not been finalized by the time of writing, our present measurement data must be regarded as preliminary and not suitable for publication. However, the trends so far can be revealed.

In terms of level distribution, the conditions have improved as expected. Typical differences in levels between different seats are now about half of what they were before with the lowest levels still being found in the rear corners under and on the balconies. Regarding intelligibility of speech, the distribution of Rasti values is quite satisfactory with only a few dark spots in the middle of the stalls and on the side balconies remaining. However, the increase in RT to about 1.1 Sec. at mid frequencies has obviously reduced the average Rasti value (unoccupied) by almost 0,1 from the 0.65 before the renovation. Still, this is not experienced as a serious reduction as it is well compensated for by the general increase in sound level.

In January this year, a special test session was arranged for the drama department of the Royal Theatre to evaluate whether they would like to use the enhancement system during their regular rehearsals and performances. However, at that point the answer from the actors was no, as they felt that the sound lost its "focus" in the room, whereby they feared to loose their acoustic intimacy with the audience. It is interesting to notice that this is in obvious contrast to normal preferences with music performances, where a "broadening of the sound source" is a highly regarded property – and one of the clear effects of using electro acoustic enhancement as well. Another reason why the drama people disliked using the system was that the male voices in particular sounded booming at low frequencies. To the author this was a clear indication that the stage house needed the low frequency absorption mentioned earlier - in spite of the use of highly directive microphones. Consequently, it has been decided to implement the stage absorption in the near future.

The press has received the renovated "New Stage" very positively; while the actors have been less enthusiastic. However, besides possible objective reasons, their expressions may also be influenced by a political interest: they do not want the politicians to forget their need for the new, up to date drama theatre !

4 CONCLUSIONS

Above, two recent projects regarding renovation of theatres in Denmark have been presented. In both cases, the potential for the acoustician to improve - or even maintain - the acoustic quality in the process was limited by demands from other interests, from limited budgets and foremost from physical constraints of the existing buildings – as in many other renovation projects.

Still, both projects have been fruitful experiences – mainly because no one involved had unrealistic expectations regarding what the acoustic outcome would be. Of course, maintaining this link to reality is largely the responsibility of the acoustic consultant (and one of his/her most important virtues !); but the appearance of reliable prediction tools - like Odeon - with excellent means even for audible "illustration" of the results to the client - has made this part of our work much easier.

Consequently, it feels natural for the author to bring thanks - not only to the clients, the architects and others with which he has cooperated directly in these projects – but also to the staff members at DTU behind the development of the Odeon program.