THE ALBERTA JUBILEE HALLS REBORN WITH UP-TO-DATE ACOUSTICS

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1 INTRODUCTION

In August 2005 the nearly fifty years old Jubilee Halls in Calgary and Edmonton were reopened after a major renovation project. In 1955-57 the two almost identical halls were built in commemoration of the first fifty years of the province Alberta, Canada. Although the halls were built according to the best acoustical knowledge of that time, it had become clear that the halls suffered by several acoustical problems, and thus the government of Alberta wanted the halls to be brought up-to-date for the 100 years jubilee of the state. The Canadian architect Fred Valentine together with other North American consultants and the Danish acoustical company JORDAN AKUSTIK were chosen for the renovation project. In this remodelling project the ODEON room acoustic modelling program turned out to be a very efficient tool. The various proposals for changes in the auditorium were analysed and compared to each other and to the original conditions in grid calculations covering all seats in the auditorium. The final design was also presented at auralisation sessions. The paper presents the major steps in the design process, starting by the identification of the acoustical problems, and ending with the final results that have been achieved in the new halls.

2 IDENTIFICATION OF THE ACOUSTICAL PROBLEMS

Figure 1 – Photos from one of the halls (Calgary) February 2001, before the remodelling

The twin halls were officially dedicated in April 1957, and they were designed according to the best available knowledge on auditorium acoustics at that time. The group of acoustic consultants involved in the project included Dr. Vern O. Knudsen, Dr. Leo L. Beranek, Dr. Cyril M. Harris, Dr. T. D. Northwood, and Dr. Michael Rettinger. The acoustics of the halls was compared most favourably with two of the world's most famous concert halls at that time, the Royal Festival Hall in London and the Kleinhans Music Hall in Buffalo.

The auditorium design was a wide fan shape with two balconies and inwards tilted side walls as can be seen on the photos, Figure 1. The seating capacity was around 2800. The ceiling was designed to provide early reflections from geometrical analysis of the section, and thus the ceiling reflections were efficiently directed towards the audience area causing relatively dry acoustics. In fact later acoustic measurements have shown that the EDT was very short in the rear part of the auditorium, whereas quite long EDT values were measured in the front part. The averaged values of measured room acoustic parameters are shown in Table 1. Over time it became clear that the acoustics was not quite as satisfactory as originally thought.

The Jubilee Auditoria have operated as multipurpose halls from their initial commissioning, supporting opera, ballet, multicultural events, musicals, rock shows, graduations, and many other performance types. For the remodelling project the demanding performance requirements of opera and ballet were taken as a benchmark for achieving optimum natural acoustic conditions. Likewise, sound-reinforced performances such as Broadway productions, rock shows, and graduations were used as a benchmark for achieving a very dry hall, with a high amount of sound absorption. In order to satisfy this mandate for a flexible acoustic environment, a series of architectural modifications were proposed, see section 3. The design goal for the acoustic parameters in the opera configuration is shown in Table 1.

Acoustic parameter	Measured before remodelling	Design goal (Opera)	Measured after remodelling 2005
T_{30}	1,55 s	1,6 to 2,2 s	2,1 s
EDT	1,6 s	1,6 to 2,2 s	2,1 s
C_{80}	4,2 dB	-2 to +4 dB	0,1 dB
G	2,2 dB	+2 to +6 dB	3,8 dB
LF	0,14	≥ 0,20	0,31

Table 1 – Room acoustic parameters averaged over receiver positions and at mid frequencies (500 – 1000 Hz), empty halls, source on stage.

The identified acoustic problems include:

- Reverberation time, T_{30}, and EDT are rather short for non-amplified music
- Distribution of EDT is very uneven, high in the front and low in the rear, see fig. 4
- Clarity, C_{80}, is rather high for non-amplified music and very unevenly distributed, see fig. 5
- Strength, G, is rather low for non-amplified music
- LF is low in most of the auditorium and very low in the front where a black triangle is seen on the grid map, see fig. 6
- Echo problems could be observed at the stage and in the front of the auditorium

In addition to this the sight lines were not satisfactory, particularly not in the two balconies.

3 REMODELLING FOR IMPROVED ACOUSTICS

3.1 Architectural Changes to the Auditorium

In order to address the acoustic problems in the auditorium several architectural changes were suggested, among which the most important are:

- New stepped side terraces to create lateral reflections and at the same time improve the sightlines, see Fig. 2 and D in Fig. 3
- Additional volume above a transparent ceiling in the front part of the room to increase reverberation and reduce too strong early reflections to the rear of the hall, C in Fig. 3
- Sound diffusing structures on the side walls to improve reverberation and a more uniform sound distribution, A in Fig. 3
- Broader and stepped proscenium frame to improve the communication between pit and stage, H in Fig. 3

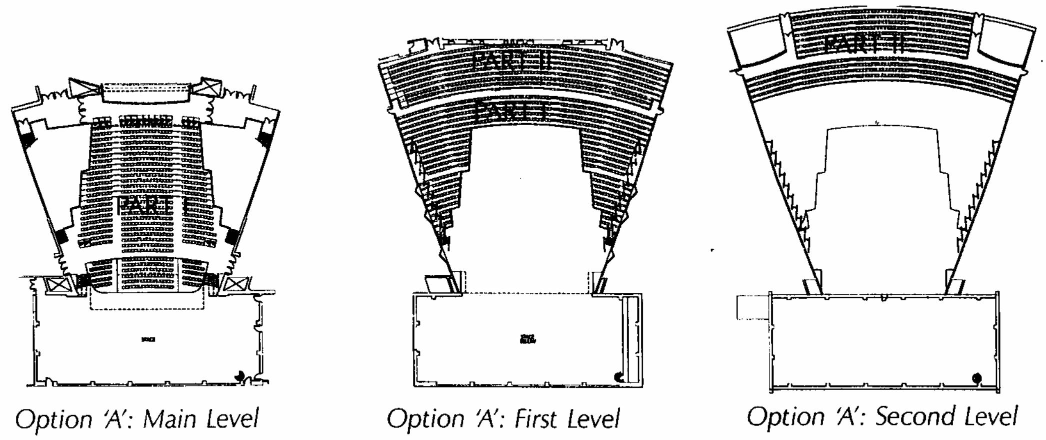


Figure 2 – Proposed changes, Plan, July 2001

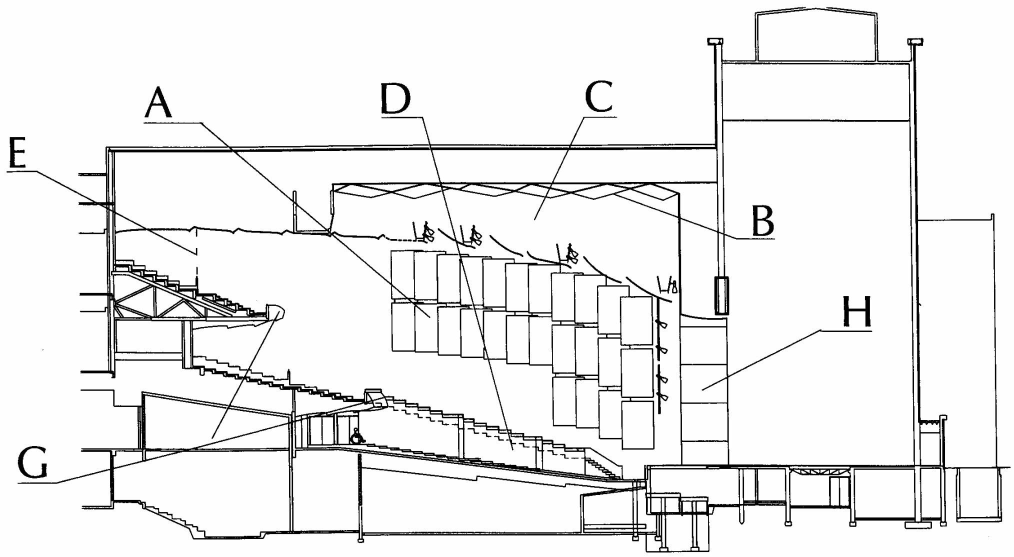


Figure 3 – Proposed changes, Section, July 2001. See the text for explanation.

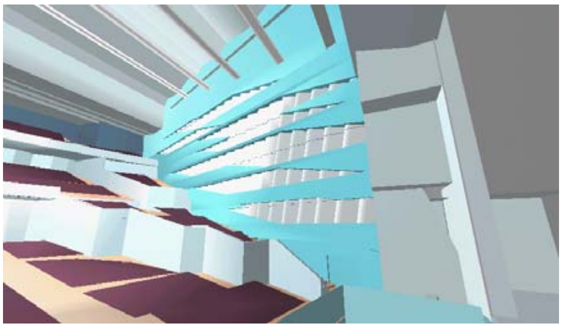
The side wall panelling also needed to be addressed, both for aesthetical and acoustical reasons. It was made from walnut and was considered an important part of the visual identity of the auditoriums. However, it was considered to contribute too much to the sound absorption at low frequencies. So, to create a warmer tone acoustically the original 1/8-inch panels were attached to eight inches of drywall and remounted. The flat brown colour of the panelling was stripped and refinished in a rich reddish-brown hue to emphasize the grain. For the final result see the photos in Figure 12.

3.2 Computer Modelling as a Design Tool

The ODEON room acoustic modelling software was used for the acoustic calculations during the whole project. First the original auditorium was modelled and with estimated absorption coefficients the results were compared to the measured results. With special emphasis on the reverberation time the absorption coefficients were slightly adjusted in order to obtain a close agreement between the measured and the simulated results.

Next step was to use the simulations, and particularly the grid responses for the various parameters to identify more precisely the acoustical problems. Some examples are shown in the left side of Figures 5 – 7. The uneven distribution of the EDT and LF is striking. These displays were found very useful in the process of discussing possible architectural changes.

During the period from February 2001 to September 2002 there was a lively exchange of design proposals from the architect and results from acoustic computer simulations. Particularly the treatment of the side walls with sound reflecting/diffusing structures led to many proposals which should be simulated and evaluated acoustically. In this process it was very important to have possibility to import the wall details in the DXF format into the ODEON program. In this way it was possible to report the acoustic evaluations very quickly after the electronic drawings were received. Examples from this process are seen in Figures 4 – 7.



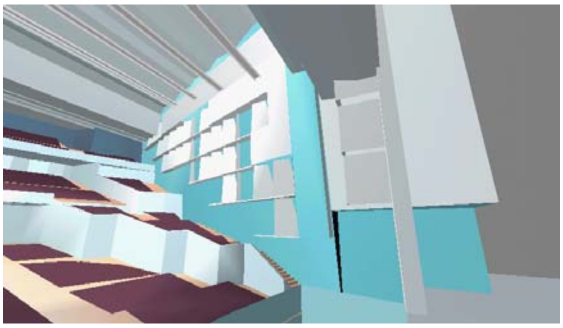


Figure 4 – Different wall configurations tested September 2002

In order to identify and solve the echo problems in the original auditoria a large number of point responses were calculated and analysed. One example is shown in Figure 8 with a source position at the centre cluster above the stage and the receiver at the front of the stage. The point response calculation in ODEON allowed a quick identification of the surfaces that created the unfavourable reflections. In the example in Figure 8 and 9 the echo is clearly seen in the calculated impulse response. But the echo problem could also be evaluated by listening to the impulse response or to a speech signal created with the auralisation technique.

Several times during the project the auralisation was used to present the acoustical importance of various suggested solutions to the members of the steering committee. This was found a very useful technique and a good background for discussion of the solutions between acousticians and non-acousticians.

In the final stage of the design project the adjustable acoustics was investigated. Calculations were made with additional sound absorption from banners located on the side walls, on the back walls on the second balcony and in the ceiling void above the acoustically transparent ceiling, see Figure 10.

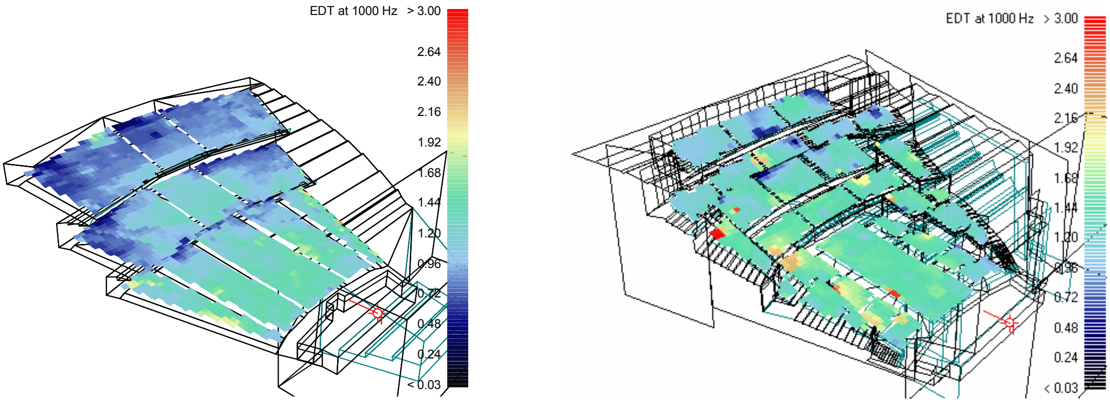


Figure 5 – Distribution of EDT at 1 kHz, left: Old hall, right: One of the tested proposals, September 2002

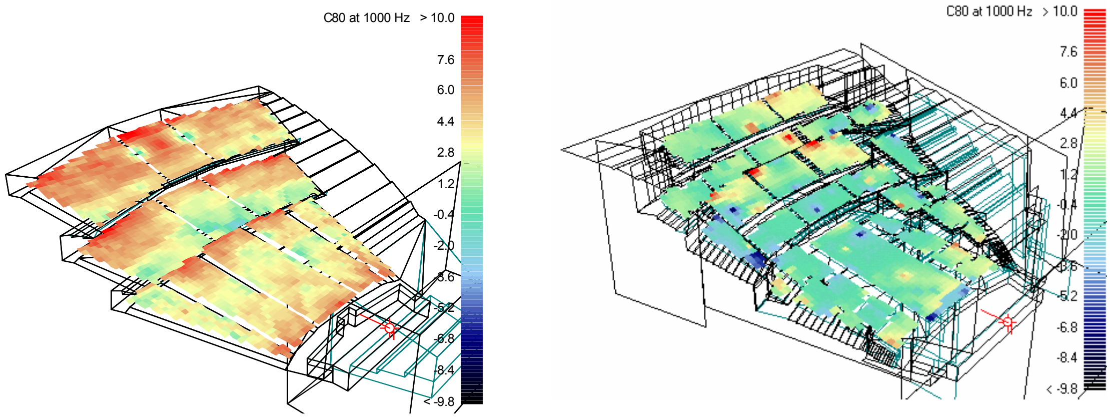


Figure 6 – Distribution of C_{80} at 1 kHz, left: Old hall, right: One of the tested proposals, September 2002

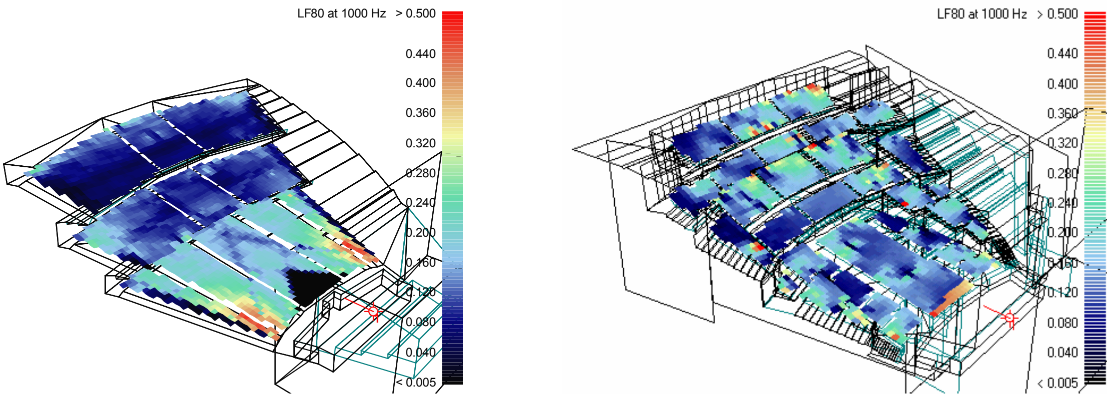


Figure 7 – Distribution of LF at 1 kHz, left: Old hall, right: One of the tested proposals, September 2002

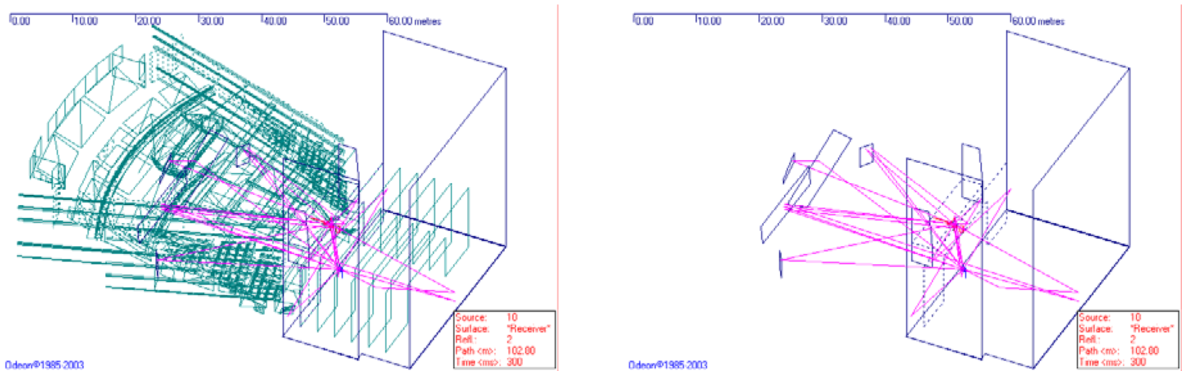


Figure 8 – 3D analysis of early reflections and possible echo problems from surfaces on the first balcony. Source is elevated 9,5 m above stage, receiver height 1,65 m. Right: Only reflecting surfaces are shown

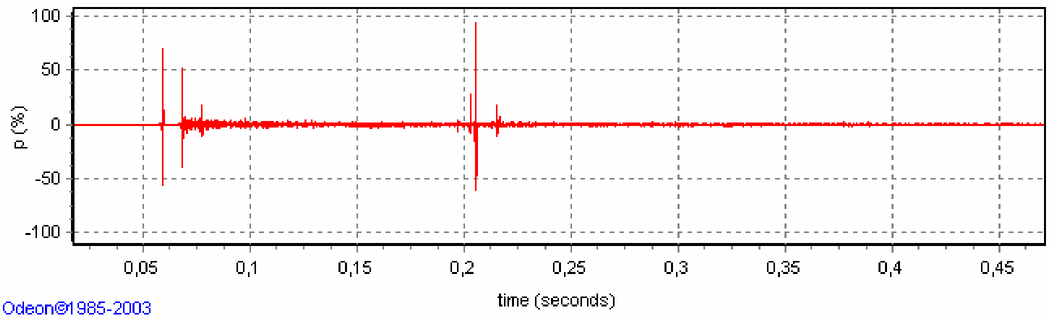


Figure 9 – Calculated impulse response in positions as in Figure 8. The echo is clearly seen.

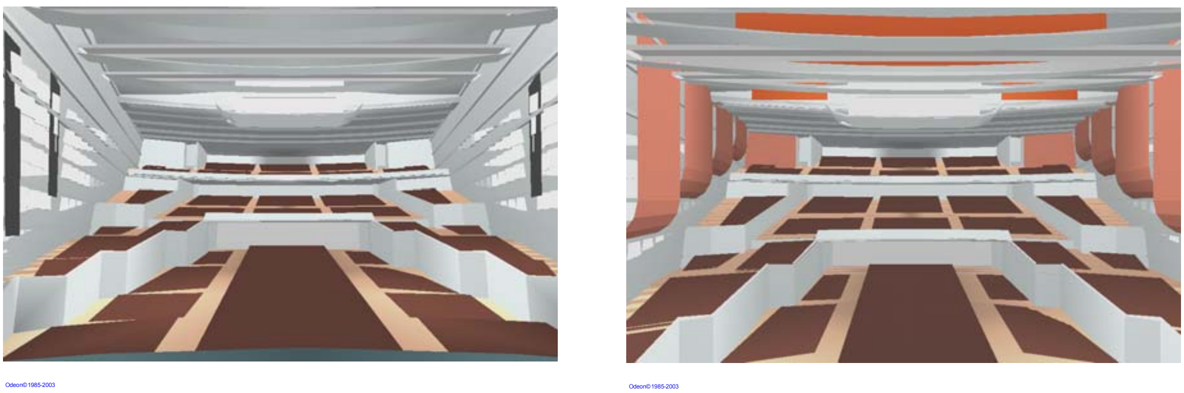


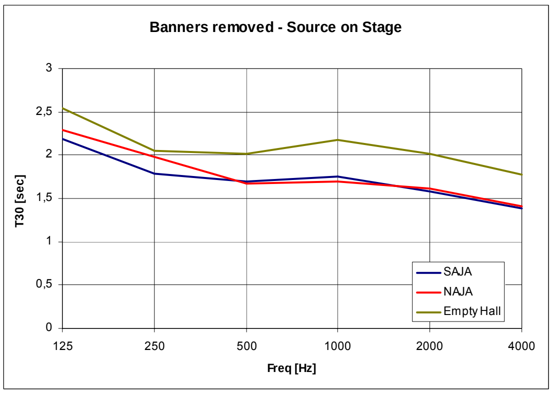
Figure 10 – Computer model of the final design, left: Opera configuration, right: Conference configuration with acoustic banners on walls and in the ceiling void.

4 FINAL RESULTS

4.1 Reverberation

Reverberation time T_{30} and EDT have increased substantially and are far more uniform throughout the audience area compared to the previous halls. Measured reverberation times are shown in Figure 11. SAJA is the Southern Alberta Jubilee Auditorium, Calgary, and NAJA is the Northern

Alberta Jubilee Auditorium, Edmonton. With audience and in the opera configuration the reverberation time is 1,7 s at mid frequencies increasing at low frequencies up to 2,2 s at 125 Hz. This is in perfect match with the design goal.



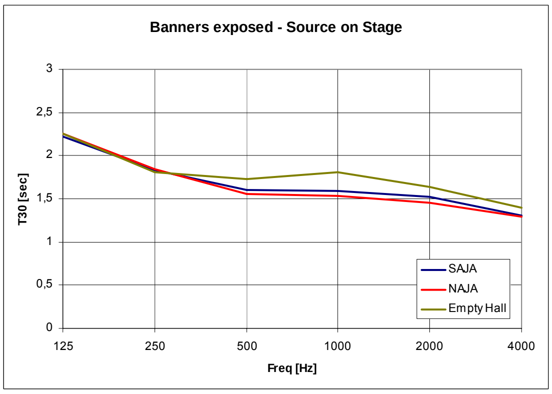


Figure 11 – Measured reverberation times with audience during the test concerts 16 and 18 August 2005. Left: Without acoustic banners, Right: With acoustic banners exposed.

Measurements were also made with the acoustic banners on the walls and in the ceiling void exposed. They do reduce the reverberation by a noticeable amount but not as much as expected. For speech and amplified music a shorter reverberation time is recommended. It is concluded that the banners in the ceiling void are not as efficient as expected, and additional changeable sound absorption should be introduced in the ceiling void.

Acoustic parameter	Empty, no banners	Empty, with banners	With audience, no banners	With audience, with banners
T_{30}	2,1 s	1,8 s	1,7 s	1,55 s
EDT	2,1 s	1,9 s	1,9 s	1,8 s
C_{80}	0,1 dB	1,5 dB	0,0 dB	0,2 dB
G	3,8 dB		2,0 dB	1,1 dB
LF	0,31			

Table 1 – Room acoustic parameters averaged over receiver positions and at mid frequencies (500 – 1000 Hz), source on stage. The results with audience are based on very few positions.

4.2 Clarity

Clarity C_{80} has been reduced as expected, since the reverberation has been increased. It is now much more uniform and has reached an appropriate level for opera, as expressed by the design goal.

4.3 Strength

The strength G has increased by 1,6 dB on average compared to the original halls, and this is considered a significant improvement. As expected the strength decreases with additional sound absorption from audience and the banners, but still comfortably within the range of the design goal.

4.4 Lateral sound

LF has increased substantially. The original halls had almost no lateral sound. The feeling of intimacy and envelopment is now clearly evident at most seats. The measurements indicate that the LF has generally increased on the main floor and is even greater than expected.

Figure 12 – Photos from the remodelled halls

5 CONCLUSION

The remodelling of the Northern and Southern Alberta Jubilee Auditoria was a top priority for the celebration of the 100th birthday of the province of Alberta, Canada in 2005. Both architecturally and acoustically the final project has been very well received and is evaluated as very successful. At the same time the project illustrate the huge development of room acoustic design principles and methods over the last fifty years. There is no doubt that the original auditoria were designed in accordance with the best available acoustical knowledge around 1955. Since then the room acoustic parameters in addition to the reverberation time have appeared together with a better understanding of the room acoustical aspects important for the subjective evaluation of acoustic quality in a hall. For instance the importance of lateral reflections was not known at that time.

The development of acoustical design tools is also amazing. In 1955 the use of scale models and development of the necessary measurement technique was not yet ready for a design purpose. So, the design of the Alberta Jubilee Auditoria was based on two-dimensional geometrical analysis of the longitudinal section of the auditorium, leading to a ceiling design with too much early sound reflected to the audience area.

In contrast the modern computer modelling technique offers a very efficient design tool. The coloured grid responses for various acoustical parameters offer a quick overview of how uniformly the sound is distributed to the audience and where the weak spots are located, if any. The tracing of early reflections in 3D allows quick and efficient analysis of possible echo problems. The possibility to listen to the sound by the auralisation technique is another new amazing tool, which is found very useful when comparing alternative proposals and presenting the suggested solutions to the steering committee.

6 ACKNOWLEDGEMENTS

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