Acoustic Upgrades – Prototype Testing April and November 2016, April 2017

1. Introduction

As part of the design development phase for the Concert Hall upgrades, a series of full scale tests of the proposed stage risers, acoustic reflectors, and the acoustic absorption drapes were undertaken in 2016 and 2017.

The first prototyping exercise occurred from 4 - 16 April 2016 in which just the stage risers were used for a series of rehearsals and performances of the Sydney Symphony Orchestra.

The results of the April stage riser tests were extremely positive and provided the confidence to proceed to full scale tests of both stage risers and acoustic reflectors in November 2016.

The November tests included rehearsals and performances by the Sydney Symphony Orchestra, and rehearsal by the Sydney Philharmonia Choirs and Australian Chamber Orchestra.

Following this week of testing, a test of the absorption characteristics of the proposed banners to be used for amplified mode in the Concert Hall was carried out. A further prototype test of the absorption banners was conducted in April 2017.

2. Stage Riser Trials – April 2016

The Sydney Opera House had previously undertaken a trial of “arena style” stage risers in 2006. The April 2016 tests were set up to improve on this earlier trial and to provide input to the design process for the proposed acoustic upgrades to the Concert Hall.

A full-scale prototype of the stage risers was built offsite and installed on the Concert Hall stage on 3 April 2016. The risers remained mostly in situ for two weeks until 16 April. They were disassembled, removed and reinstalled three times during testing to allow other productions to take place .

Risers were set at 20cm, 40cm, 60cm and 80cm with depths of 125cm/150cm. Around 70 sections locked together, providing a strong, stable, platform where musicians and crews could work with no increased risk of tripping or falling.

The SSO rehearsed and performed on the risers so they could test the geometry of the new stage and make sure the design and shape was optimised.

Figure 1 shows the riser prototypes being installed on the Concert Hall stage. Figure 2 shows the SSO rehearsing on the prototype risers.

Figure 1: Prototype Stage Risers Being Installed, April 2016

Figure 2: Sydney Symphony Orchestra Rehearsal with Stage Risers, April 2016

The benefits of the stage risers were expected to include:

- Musicians would get improved sightlines of each other and the conductor, and an improved ability to hear each other play;
- Faster stage set-up and clearing, and quick conversions for different types of performances – while the mock-up for the testing period was static, in the final design the new stage risers will be automated;
- Greater flexibility for performances – in the final design the risers will be able to be set at whatever heights are required;
- More acoustic-reflective areas within the orchestra set-up.
- Greater visibility of the orchestra for the audience.

The stage riser trial was generally considered to be a success. A number of meetings were held with the SSO management and musicians during the trial period to gain feedback on the impact of the stage riser layout. The eminent German conductor, Christoph von Dohnányi, who conducted the SSO in rehearsal and performance during the riser trial, was also interviewed. The maestro was complimentary about the Concert Hall and based on his experience compared to what he had been told to expect, he thought the riser trial a success.

3. Acoustic Reflector and Stage Riser Trials – November 2016

During these tests, full size prototypes of the choir, over stage, and front reflectors, and mock-ups of the cannon port reflectors, were flown above the stage. A full size mock-up of the stage risers was also used by the orchestra.

The proposed reflectors are shown in an architectural render in Figure 3.

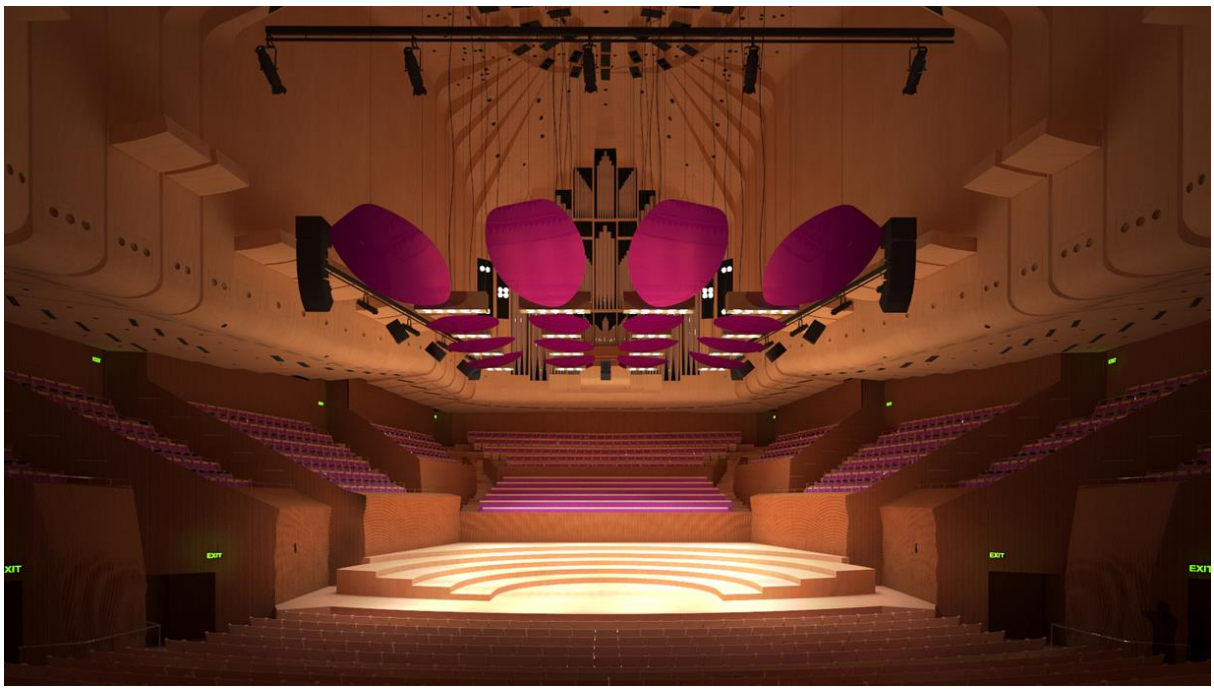

Figure 3: Architectural render showing proposed overstage reflectors and cannon port reflectors

The configuration of the reflectors and the stage risers for these trials is shown in Figure 4 and Figure 5.

As can be seen in Figure 4, the mock-ups of the cannon port reflectors were only flown above the stage and choir.

Figure 4: Reflectors and Stage Risers during SSO Performance

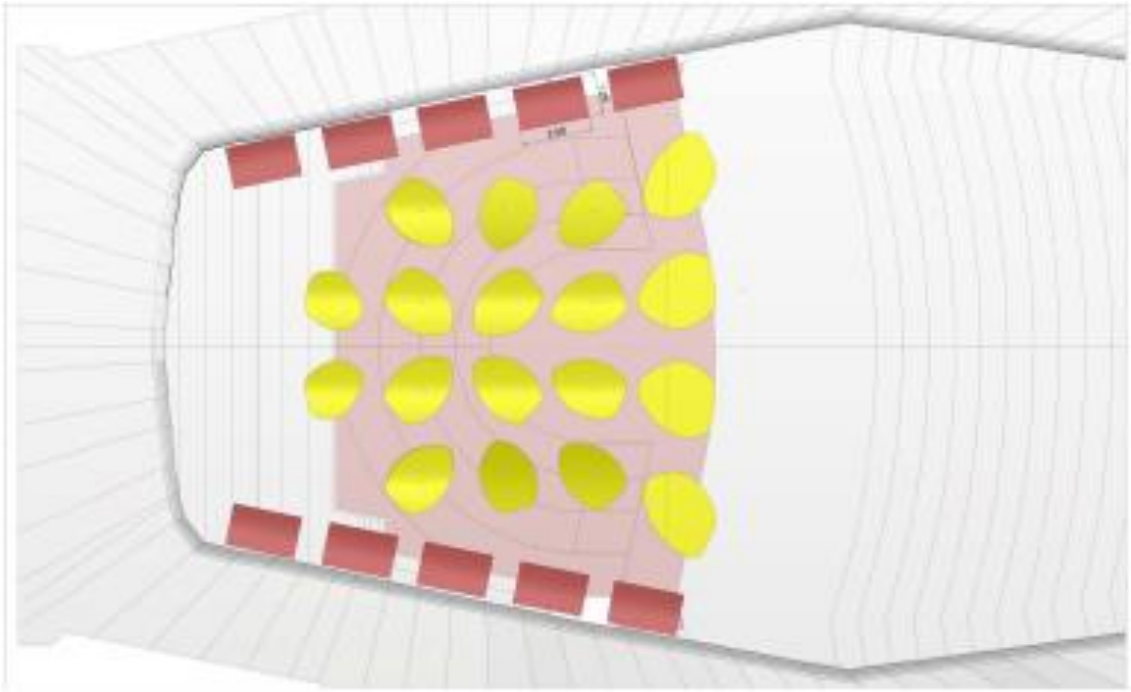

Figure 5: Plan of Reflectors Layout for Trials

The Sydney Symphony Orchestra (SSO) conducted five rehearsals, and performed two programs across four performances under the baton of Maestro Pinchas Zukerman. In addition to the SSO rehearsing and performing with the stage risers and reflector prototypes, the Australian Chamber Orchestra rehearsed, and the Sydney Philharmonia Choir conducted a rehearsal under the direction of Brett Weymark.

3.1. Acoustic Testing & Measurements

During the reflector prototype testing, acoustic engineers (Müller-BBM) performed a number of acoustical measurements to quantify the impact of these reflector prototypes and stage risers. In addition to these tests, acoustical measurements were performed to assess the impact of the proposed absorption drapes. A report by Müller-BBM, *Sydney Opera House Concert Hall, Reflector Testing – Measurement Results, Report No. M122899/33*, is attached.

For the testing of the reflectors and stage risers, Müller-BBM used sound sources at eight locations on the podium, and one located in the choir stalls. Using acoustical measurement dummies at 16 locations around the seating areas, and at 12 locations on the podium, measurements of sound pressure were taken for each of the sound source locations with different reflector configurations, including a set of measurements without the prototype reflectors and with the existing "donut" reflectors in their normal position. The acoustical measurement dummy is shown in Figure 6.

The measurements taken by Müller-BBM showed on average a significant increase in early sound energy for the audience areas in the stalls and the circle. A comparison between the situation with the new reflector layout and the existing donuts is shown in a number of diagrams in the Müller-BBM report. The diagrams show the difference in sound energy, arriving at the receiver locations in the time window of 5 milliseconds to 50 milliseconds, between the situation with the prototype reflectors and the situation with the donuts. An example of the comparison diagram is shown in Figure 7. Green to red colours at the receiver locations express positive values with more energy with the new reflectors, and green to blue colours show negative values with more energy with the existing donuts.

Figure 6: Acoustical Measurement Dummy in Concert Hall Seats

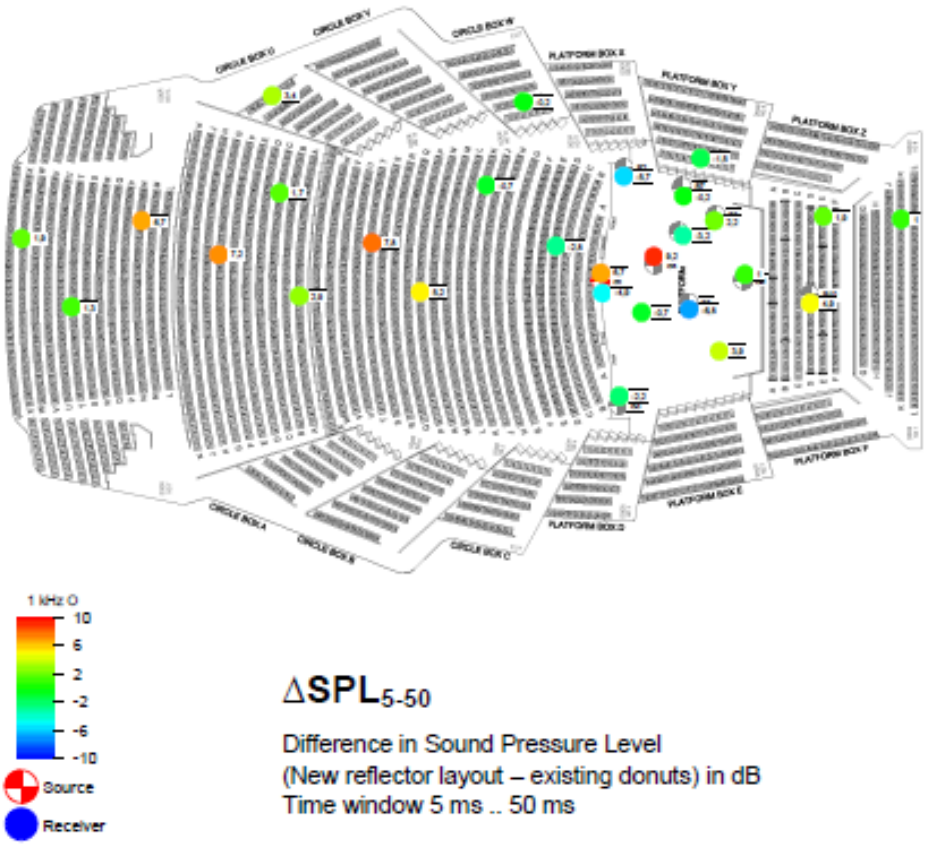

Figure 7: Difference in Sound Pressure Level (Sound source at centre rear stage)

Reflections arriving during the 5 ms to 50 ms time window and coming from above are expected to be helpful for a better clarity and the feeling of a connection to the stage (Müller -BBM). The figures in the report show the difference in sound energy level in the octave band centred around 1 kHz to concentrate on a very important frequency band. The figures in the report show positive values at most positions. This means that the prototype reflector layout is creating more early energy than the existing donuts supporting the perceived connection to stage.

3.2. Listening Impressions

During the program of reflector trials, subjective feedback was obtained from a panel of expert listeners, and from many patrons at the various performances. Along with this feedback, the acousticians from Müller-BBM also reported their subjective listening impressions.

3.2.1. Müller-BBM

“The sound of the orchestra at listener positions on stage with the new reflector layout and the arena risers feels much more compact and stronger than with the donuts … the new reflector layout is already creating a good standard regarding the contact in between the musicians on stage which will be even more improved by the intended changes of the box fronts surrounding the stage.”

“In the stalls and circle a quite dramatic change of the acoustic characteristics of the hall could be perceived. Instead of the strong reverberation cloud coming from the front and above, a clear and transparent sound was perceivable. The feeling of being acoustically disconnected from the stage when sitting in the upper circle has disappeared. With the donuts the reflections created by the horizontal ceiling above the upper part of the upper circle can be perceived very well when moving between covered and uncovered zones (about row S/T marks the border line). With the tested reflector layout, the transition between the open and the covered seating area was nearly not noticeable anymore. This means that the whole area is heavily improved by the additional reflections coming from stage.”

“In general many of the worst seats were improved most. This means that the huge difference in acoustical quality between different seating areas in the hall was narrowed down considerably.”

3.2.2. Expert Listeners

To ensure a broad range of opinions were sought, the Opera House identified a group of ‘expert listeners’ to participate in the trial process. These individuals were invited to attend both rehearsals and performances and to provide feedback during the trials. The group was drawn from a range of backgrounds including education, orchestral management, radio production and acoustics. This group provided constructive feedback which was overwhelmingly positive. The following quotes from this listening group have been extracted.

“I joined the orchestra in 1988 and there have been many experiments with the acoustics, but this is the best I have ever heard the orchestra sound.”

Goetz Richter, Professor of Violin – Sydney Conservatorium of Music, former Assistant Concertmaster SSO

“The difference is very marked. From my seat in Row S of the stalls I could hear clearly every note of this concert featuring the welcome return of Canadian-based Israeli violinist Pinchas Zukerman, even down to concertmaster Andrew Haveron’s discreet tuning of a new E string after one snapped just before the start of the famous (and challenging) piccato scherzo in Tchaikovsky’s Symphony No.4.

“ The acoustics and the orchestra both passed with flying colours and the audience’s reaction for both was enthusiastic, so much that Zukerman was called on to give an encore, which he did leading some community singing of Brahm’s Lullaby on a borrowed violin.”

Steve Moffat, review of the Friday night concert, Sydney Daily Telegraph

“It was a privilege and a pleasure!

“I can only say that the long wait for correcting some of the acoustical challenges the choir has always faced may be close to being solved.

“The feedback from the singers was extraordinary at the end as we had quite a few choristers who have been singing with the choir over many years and they said that for the first time in the choir stalls they could hear another part other than their own”.

Brett Weymark, Music Director, Sydney Philharmonia Choir

“Brass did not have the strident sound which is typical in this hall (especially the trombones); generally well balanced within the full orchestral picture. Well defined timpani sound. Violin sound stays in the air longer, instead of dying away so quickly.”

Luke Shaw, Australian Chamber Orchestra

“The low frequency response has improved dramatically and the overall sound has also improved.

“... I sat through the rehearsal on Wednesday afternoon. The performance was of an essential a (sic) small orchestra therefore a significant conclusion cannot be made. Nevertheless there is good news and some not so good news. First the good news, the stage tiering has been successful, The sound of the double basses is exceptional. We have gone from the original setup where the double basses were inaudible (they may as well stayed at home) to a wonderful warm sound.

“The overall sound in Box B (a reasonable size orchestra playing)was good with good connectivity to the performers together with a nice warmth.

“However it was not as good at D13 and D33 of the Circle, there was the beginning of harmonic distortion, the lead violin did not sing. However the warmth of sound was very good.

“In area around L23 of the Circle the richness of the sound was missing and the sound was slightly muddy however the warmth of sound prevailed.

“After the afternoon break the performance was only a string quintet, well this revealed a lot. In all previous areas the sound was exceptional, it was an amazing sound for such a small group. There was good connectivity between you and the performers. In some ways this is better than Angel Place on the main floor.

“… Keep up the good work, you are off to a good start. I don’t think you have to improve the double basses anymore now that you have the tiered stage.

Peter Knowland, Acoustician

“This afternoon I heard the SSO and Zukerman playing in the Concert Hall, with the reflectors.

“It was as if a door had suddenly been opened between the orchestra and the audience. I am blown away by how magnificent it sounds …”.

“It is incredible. Well done”!

Louise Herron, Chief Executive Officer, Sydney Opera House

The following observations were noted in an evaluation session at the end of the testing period:

Ben Schwartz (Director of Artistic Planning, Sydney Symphony Orchestra) reported an overall positive experience from the testing, and observed:

- The string sound was rich and full, improving on the advances noted during the stage riser tests
- The brass sound didn't stick out like it used to.
- Disagreed with observations of harshness in the brass sound. The sound was full and big, but not direct or harsh. The Principal trumpet part was being doubled.
- The musicians observed that they could hear themselves better.

Aernout Kerbert (Director of Orchestral Management, Sydney Symphony Orchestra) endorsed Ben Schwartz's comments, and added:

- Noticing the most dramatic change in the circle, upper circle and boxes
- The least improved seats were the stalls
- Some of the harshness reported was likely caused by the musicians playing too loud
- After the final renovation and fine tuning, the orchestra will learn to approach the music and the way they play their instruments in a different way. This can only happen once the final solution is in place.

Jack Woods (Head of Production, Sydney Symphony Orchestra) observed that:

- It looks great, it sounds great. It's a thousand times better. Just make it happen.
- The reflectors look graceful and fit perfectly into the room.
- The improved conditions will make the Production team's role of servicing the orchestra easier.

Tim Calnin (Director, Performing Arts, Sydney Opera House) observed that:

- The benefits observed during the stage riser trial were intensified.
- There was a greater body of string tone, greater section sound from the violins, and increased presence of the cellos. The cellos for the first time really came into balance with the rest of the string sound.
- There was a greater bass sound. TC found the greatest resonance of the bass sound from the front to the rear of the circle; heard the bass sound coming through the floor for the first time.
- There was a wonderful quality to the timpani.
- There was quite a big difference from the stalls as compared to further back in the hall.
- The rear of the upper circle was certainly distant, but it didn't have the veil in front of it normally present.
- The woodwind had clarity pretty much everywhere in the hall, particularly the oboes and bassoons.
- The violins were quite harsh at times, probably caused the players having spent their working lives in the Concert Hall. The players will learn to trust the hall and play less aggressively.
- The results of the trial with Sydney Philharmonia were incredible. The choir trialled a number of positions both on the stage and in the choir stalls. The most impressive part was when the singers were positioned compact in the middle of the choir stalls.

Jeremy Christian (Head of Sound & AV, Sydney Opera House) observed that:

- Both the stage risers trial and this latest trial have built confidence that the project is heading in the right direction.

- The team should rule out the use of an electro-acoustic enhancement which was suggested in the peer review. It is great that the results of the trial suggest that a purely non-amplified solution can be pursued.

3.2.3. Audience Feedback

During the public performances by the SSO, audience feedback forms were distributed and audience members were asked to help evaluate the reflectors by describing any differences from previous performances that they had heard in the Concert Hall. A selection of their comments follows:

“Best ever! Crystal clear. Incredible range! (Circle F15)

“Wonderfully warm and much richer. The pizzicato ostinato was ‘visual’; all individual segments were so clear it felt as if you could follow each one through all dynamic levels. Only slight query is if flutes and piccolo were just a bit too bright as a result? Overall fabulous.” (Box Y20)

“The orchestra has come alive. Don’t remove the reflectors” (Box X13/14, Full member of Australian Acoustical Society since 1967)

“Good. Sounded much sharper, clearer. Maybe louder.” (Box Y9)

“Much better than usual.” (Stalls F10)

“General consensus is that the sound is better – clearer and fuller. It kept the man next to me awake – a rarity!” (Stalls S34)\

“The violins always predominate when sitting in Box X. With these reflectors, all the other instruments seem much more distinct, and overall the sound has much less echoing.” (Box X21/22)

“Excellent acoustics. Every instrument distinct. Brass maybe a bit strident.” (Circle X2)

“A richer and warmer sound. Improved strength. More engaging.” (Circle A40)

“Much better than normal. Seemed clearer and louder than previously. Nice sound, even the pizzicato bits were excellent. Very positive change.” (Circle A33)

“Generally the sound is better – one can distinguish the different instruments and voices more clearly. The basses especially, sound louder and clearer.” (Circle Y25)

“The sound was brilliant. Each instrument clean and clear.” (Box W12)

“Late arriving reflected sound seems to have diminished making the sound of the small (Mozart) orchestra clear, instruments distinct. Larger orchestra playing Tchaikovsky symphony – sounded ‘briliant’ – good high frequencies come through. An excellent improvement.” (Stalls X35)

“The scaffolding, and ‘boogie boards’ are most distracting and why is the orchestra on tiered podiums? Generally acoustics in the circle are quite acceptable; this is why we choose these subscription seats. However, the orchestra sounds clearer; sharper and the tones

more distinct. The solo violin, however, sounded rather 'tinny' in the bass notes. Hopefully the final reflectors will not be so obvious and more discreet. The symphony was altogether much clearer and distinct!" (Circle L26)

"Seems to be better; more intimate, warmer, clearer." (Stalls W11)

"We usually sit in Box W, and we sat at the back of Box U (Friday night). The sound of the whole orchestra in full flight was very rich, resonant and vibrant. Though we were further away from the stage than usual, the sound was not diminished in any way. (It always sounds good to us.) The sound seemed to be resonating well in the space – both in the adagios and the louder sections – very rich!! (Box U44/45)

"Much much improved sound. Risers make huge difference. French horns a bit lost." (Box U)

'It sounded as though the orchestra was metres closer. I liked the stepped arrangement of the musicians and the lighting. I felt each section of the orchestra was much clearer. Bring it on." (Stalls S22)

"They looked unattractive BUT the sound from the orchestra was spectacular. I could pick out the sounds of each group so distinctly and the rearrangement of the orchestra also was much better, hearing the violas away from the violins." (Box V25)

"Much improved sound overall. The most obvious improvement is greater sharpness/clarity." (Box V15)

"Clearer and easier to hear individual performances. Especially easy to hear brass and percussion." (Circle D28)

"The clarity of the instruments is a delight – thoroughly agree with the experiment." (Circle F32/33)

"The sound was so much better than previously. The orchestra sounded much bigger and louder, more immediate and surrounded me, making the performance so much more engaging. The balance seemed good. The reflectors made the SSO sound like the Berlin Phil did in the Opera House Concert Hall (without the reflectors!)." (Stalls K33)

"I attended the Saturday night performance and found the acoustics very much superior to previously and look forward of hearing more of the same. My seat is number 31 in Box D. This is my regular subscription location so the difference I noticed was not due to change in seating position. My neighbours made similar observations." (Box D31)

"I thought the sound was better, the high end was not as sharp and the midrange was smoother. Overall I thought the sound was more "cohesive" ..... it was a good concert and the orchestra sounded fantastic " (Circle L14)

"We agreed that the temporary acoustic reflectors provided outstanding sound, both in the solo violin Mozart and the orchestral Tchaikovsky." (Circle C14/15)

"What an improvement in the sound on Thursday night with the temporary acoustic reflectors we could hear every note so clear and wonderful.

“Note sure what else I can tell you other than it was fantastic compared to the past a shame they cannot be left in place for us all to enjoy until the upgrade mid 2019.
“I would be interested to know if the tiered stage configuration was part of the acoustics test however I hope this will be a feature of the upgrade it was great to be able to see each member of the Orchestra rather than them hidden from sight in a sea of heads.” (Circle D16/17)

“I never realised how bad the acoustics in the concert hall with the old doughnuts was until I heard Zuckeman (sic) this Friday. Fantastic, each instrument has a voice, the overall sound is great to the extent that the musicians could actually tum the volume down by a few notches. Hope you keep the deflectors (sic) on until 2019.” (Box D7)

“We attended the Thursday night Zukerman concert, sitting in the Stalls E 32 and 33. This is closer than we've sat before and we wondered whether the sound would be odd or skewed but it was excellent! The sound was clear and each instrument was distinct. Even the Tchaikovsky symphony was well balanced and dynamic. Wonderful! Please keep these new reflectors in place into the future and forever.” (Stalls E32/33)

“The acoustic in both the Boccherini Quintet and Mendelssohn Octet was excellent. It was possible to identify the individual voices of the players in both works, although the blended sound of the ensemble was beautiful. From my standpoint, the new acoustic reflectors were a complete success, Congratulations on tackling the chronic problem of the acoustics in the Concert Hall so successfully.” (Circle U41)

3.3. Images of Reflector Testing

Figure 8: View from stalls of set up of reflectors and stage risers

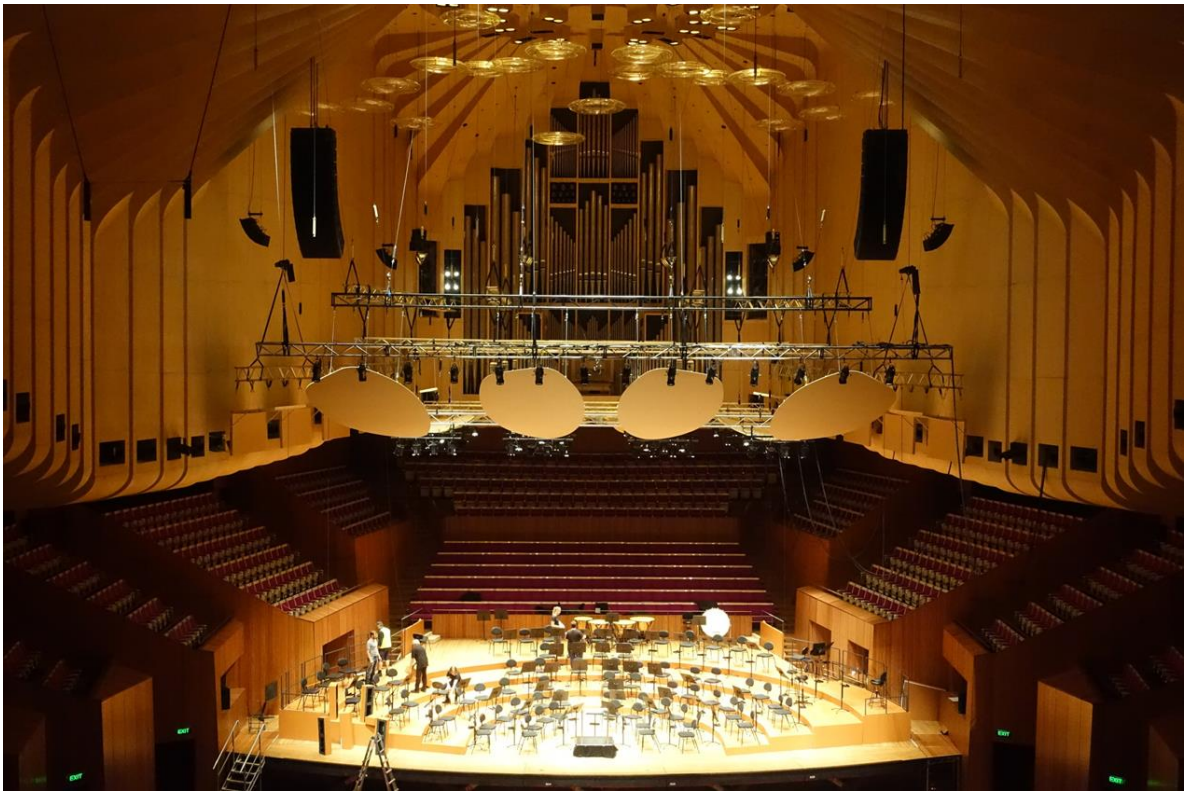

Figure 9: View from circle of reflectors and stage risers

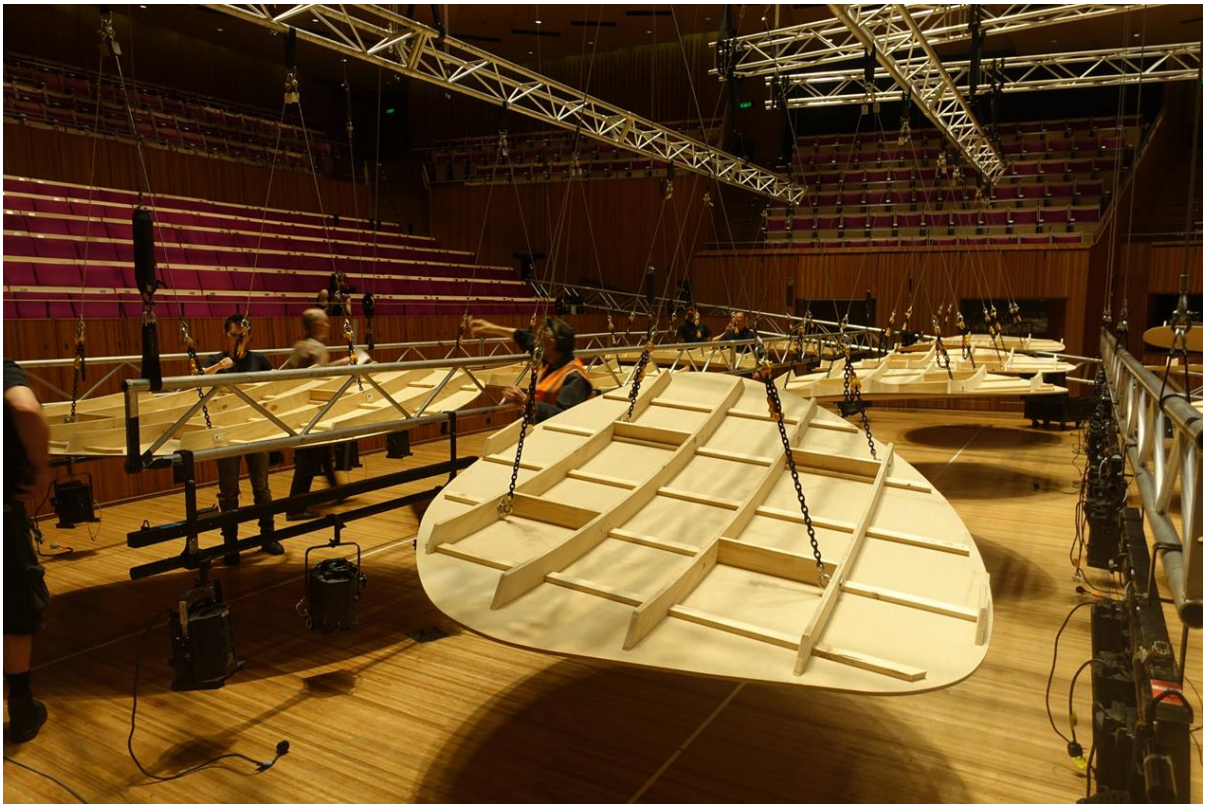

Figure 10: Reflectors about to be flown over stage

Figure 11: Stage set up for acoustic measurements (sound source towards the left hand side, covers over music stands to simulate 'absorption' effect of orchestra)

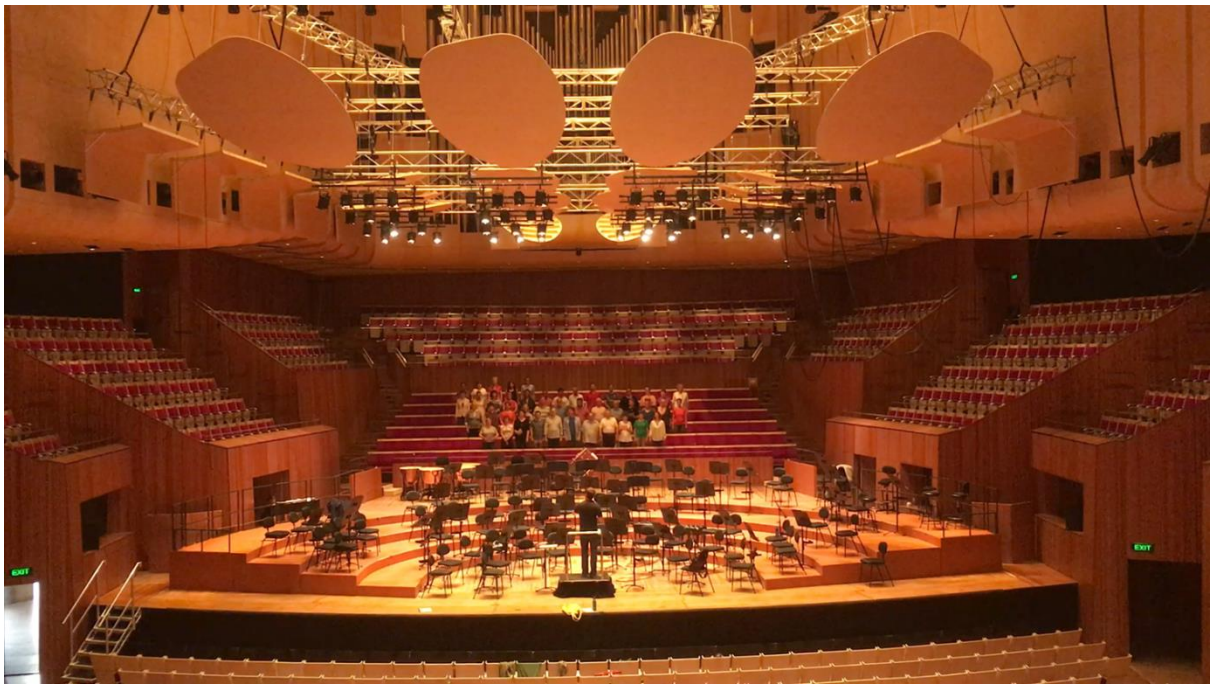

Figure 12: Sydney Philharmonia Choir rehearsal

Figure 13: Sydney Symphony Orchestra rehearsal

Figure 14: Australian Chamber Orchestra small ensemble rehearsal

4. Absorption Tests

The planning for the amplified mode of the Concert Hall aims to achieve a reduction in reverberation time equivalent to or better than the currently used canopy solution, combined with a more simple method of change-over from concert mode. A possible solution could be to use rings of long vertical banners above the stage instead of the horizontal canopy.

4.1. November 2016 Absorption Test

After completion of the reflector test in November 2016 an additional test with a simplified setup of this alternative absorption arrangement around the stage was performed. This test was intended to indicate whether the usage of long absorbent banners above the stage instead of the current fabric canopy method could produce acceptable results for the amplified mode of the hall. (Müller-BBM)

Due to the limited preparation time available a reduced and simplified version of the planned setup was used for the test. In the original planning two rings with a diameter of 5.5 m and 11.0 m are provided.

In this test a ring with a diameter of 8.0 m was rigged above the stage. Eight absorbent banners with a length of about 9.0 m were attached to this ring supplemented by two banners of the same size in the middle of the ring. In front of the side walls above the stage large fabric curtains were installed (also with a reduced size compared to the planned solution) and all temporary curtains in front of the boxes were used. The stage floor was covered by an absorbent carpet. Views of this set up are shown in Figure 15, Figure 16 and Figure 17.

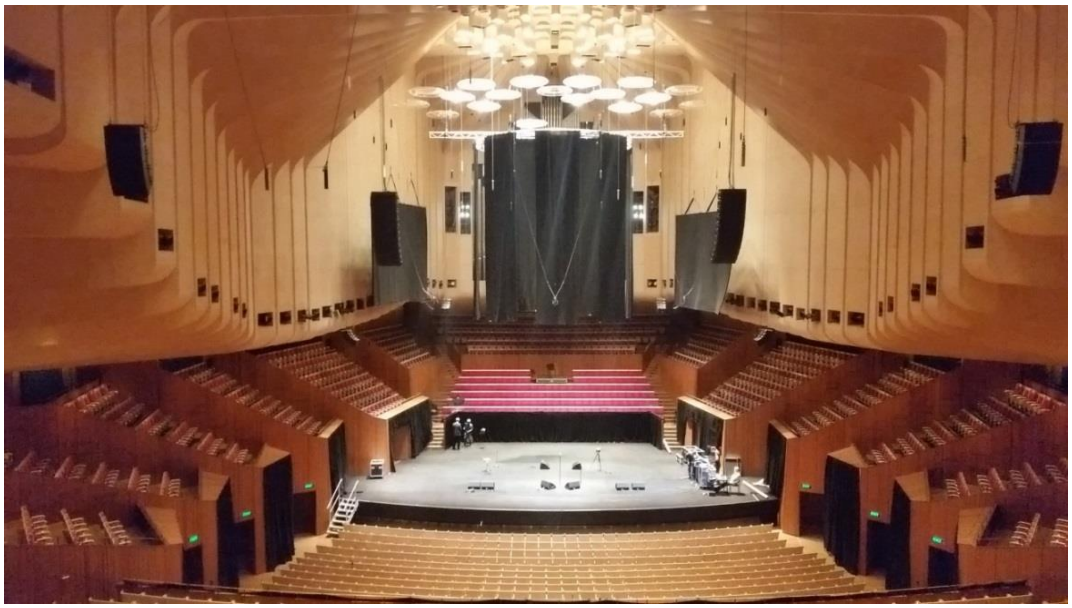

Figure 15: Absorption drapes test, view from upper circle

The measurements taken during these tests show that the achieved total absorption with this setup is surprisingly similar to the currently used standard setup with the canopy which had been measured in 2015. The measured reverberation time is shown below in Figure 18.

These measurement results show that the aimed reduced reverberation time in the amplified mode compared to the current amplified solution can be achieved with the planned additional absorption.

Figure 16: Absorbing curtains around the stage, absorbent carpet on stage (setup not finished)

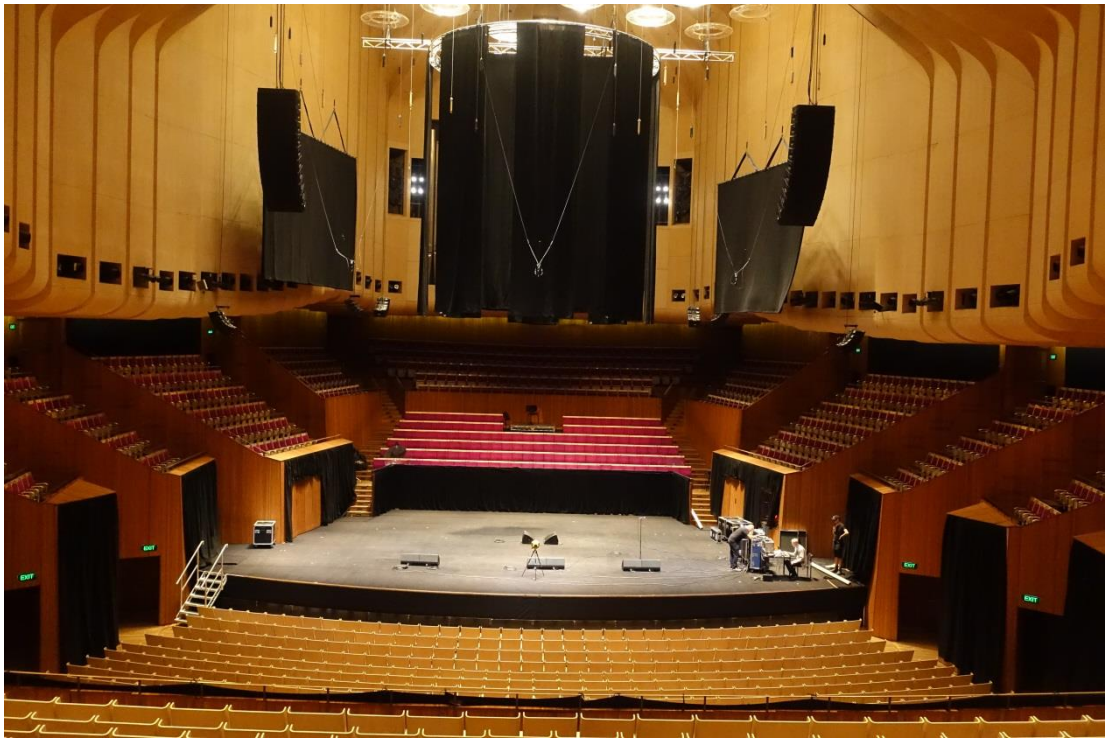

Figure 17: Concert Hall set up for acoustic testing of absorption drapes, Müller-BBM acousticians and test equipment on stage

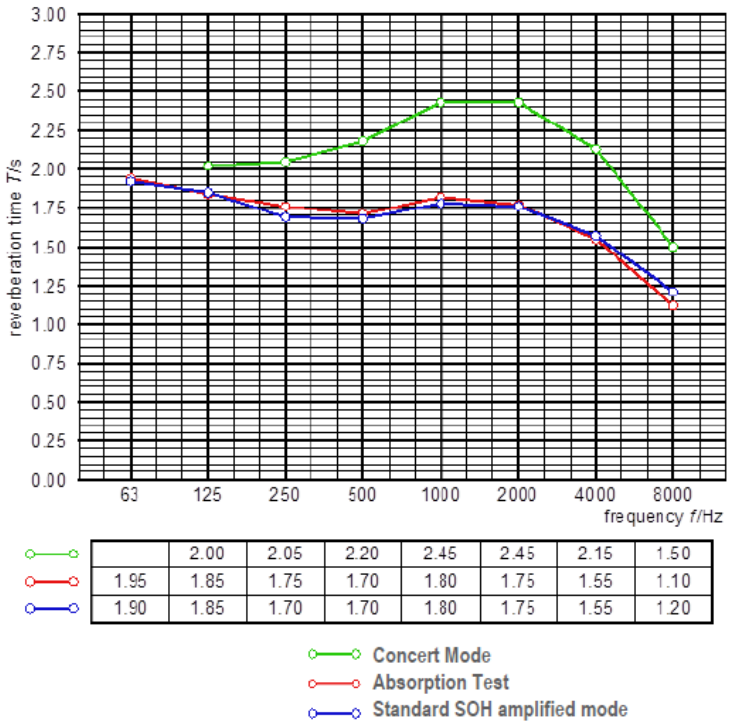

Figure 18: Measured reverberation time during concert mode, during the absorption test and with the actually used standard SOH amplified mode

4.2. April 2017 Absorption Test

A further test of the proposed absorption drapes was undertaken in April 2017. The prototype reflectors were also flown in combination with the drapes to simulate the final configuration.

During the second absorption test, the planned positions of the draw banners and the Crown banners were reconstructed as realistically as possible. In addition, the banner lengths were as they are intended to be used in the final design, and the style of fabric appropriate to be used in associated with the speciliast theatre machinery which would support it.

A shortcoming of the previous test was the areas between the crown drapes which had no absorptive coverage. The acoustic solution for preventing sound from propagating to the Concert Hall ceiling are the over stage reflectors which are installed at their usual position between the Crown banners and then tilted by approx. 40°, to reflect sound energy into the fabric.

During the second absorption test 12 over stage reflectors were used (these being the reflectors used during the November 2016 prototype testing). The choir stalls reflectors as well as the four down stage reflectors were not used.

Photographs of the drapes configuration are shown in Figure 19 and Figure 20.

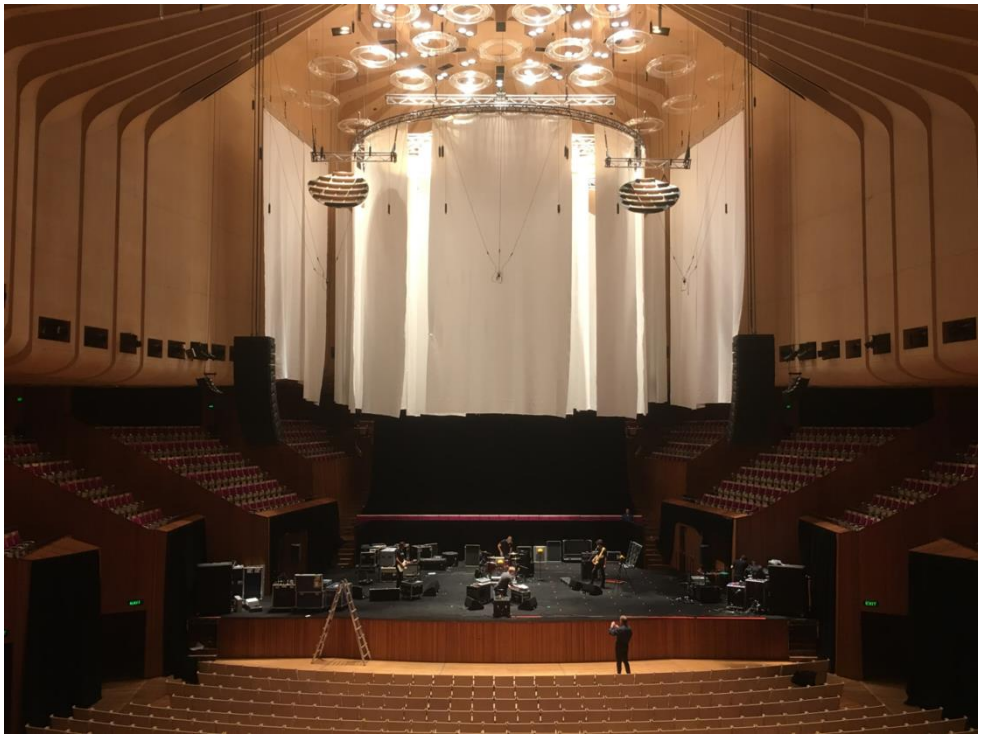

Figure 19: Absorption Drapes Test, April 2017, as viewed from Circle

Figure 20: Absorption Drapes Test, April 2017, as viewed from Stage

From an acoustical point of view, particularly for the Crown banners a realistic banner fabric should be used for achieving precise results for the test setup, even with a touching sound incidence. Therefore, the Sydney Opera House ordered the fabric Absorber CS 450 from

Gerriets in Umkirch, Germany; a manufacturer of stage equipment which also specialises in acoustic banners.

This fabric is rollable and can be used up to a length of 15 m at the Crown banners.

Along the lateral walls – the future side wall banners – the fabric was installed with its original width of 4.50m (refer to the pictures). Since the Crown banners have to be smaller, the fabric was cut in half for a width of 2.25m. In total, 750 square metres, corresponding approximately to the planned Crown banners were suspended from two rings (diameters approx. 5 m and 11 m).

Reverberation time measurements

For the reverberation time measurements during the second absorption test, the Crown banners and drawer banners as well as the over stage reflectors were installed as described above. Furthermore, the following absorption measures were activated as are typical in the Concert Hall:

- All banners in front of the box fronts.
- Thick carpet on the entire stage area.
- Banner in front of the podium rear wall.
- Banner in front of the auditorium rear wall under the organ.
- Banner at the stalls rear wall in the transition area to the 1st circle.

During the measurements, a dodecahedron loudspeaker served as a sound source at more than five positions on stage; it emitted a so-called sinus sweep covering the entire relevant frequency range which was then recorded by seven measurement microphones located throughout the auditorium and on stage.

We averaged the individual measurements and then calculated the following reverberation times.

Figure 21shows the measurement for the second absorption test as compared to the results for the amplified mode, i.e. the current situation during amplified events in the Concert Hall (canopy).

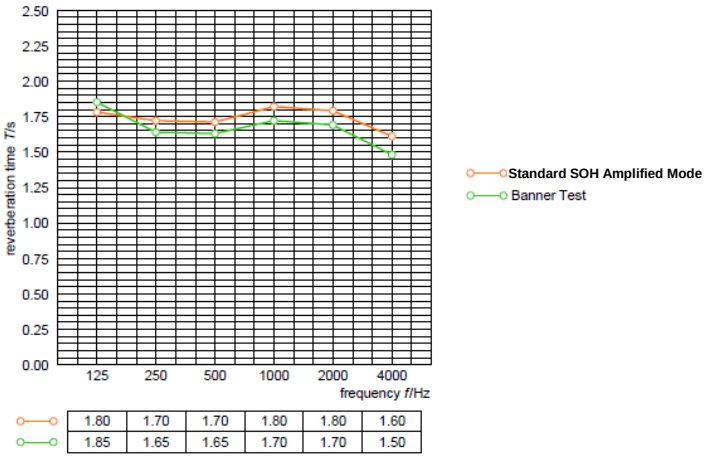

Figure 21: Reverberation times measured during the amplified mode (i.e. current conditions

Thus, the planned measures which were installed during the second absorption test lead to considerably shorter reverberation times.

As compared to the current amplified mode conditions, this represents a slight improvement, i.e. somewhat shorter reverberation times.

The fact that even more banners are planned on the lateral walls and rear walls will lead to a further reduction in reverberation times.

For a realistic, subjective acoustic experience, the "SOH Band" performed loud and medium rock music passages on the Concert Hall stage. Both during this very realistic amplified usage as well as during further subjective listening tests with loudspeakers, no disturbing reflections from the Crown area were perceived.

Consequently, the planned measures will create very favourable acoustic conditions for amplified concerts. Both the measurements and the subjective impressions gained on stage confirmed the effectiveness of the banners and the additionally installed reflectors, i.e. the measures taken prevent any disturbing late reflections.

5. Summary

In general the performed tests show that the chosen reflector layout gives the right direction and basis to achieve the intended huge acoustical improvement and to transform the acoustical conditions in the Concert Hall into the intended high quality for the musicians on stage as well as for the audience. (Müller-BBM)

As discussed above, the acoustic measurements taken during the reflector trials demonstrated that the proposed overstage and cannon port reflectors provide increased sound energy to most audience positions, as compared to the standard set up of the concert hall for non-amplified music.

The objective evidence of the acoustic measurements has been supplemented by the subjective listening impressions of the acoustic consultants, a panel of “expert listeners” and the impressions of the members of the public who attended performances during the reflector trial period.

The overwhelming response of the “experts” is that the reflectors and stage risers are a major improvement for the orchestra.

Whilst some members of the public were critical of the reflector trial, from both an acoustic and visual impact perspective, much of the feedback was extremely positive.

The absorption tests provided objective evidence to support the design of the absorption drapes for the amplified mode.

Attachments: Müller-BBM Report No. M122899/33
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