THE ACOUSTICS OF THE AMSTERDAM OPERA HOUSE "HET MUZIEKTHEATER"

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Introduction

The first opera house ever to be built in the Netherlands opened its doors on 26 September 1986. Erected in the heart of old Amsterdam, the building houses the Dutch Opera Company, the National Ballet and the Ballet Orchestra.

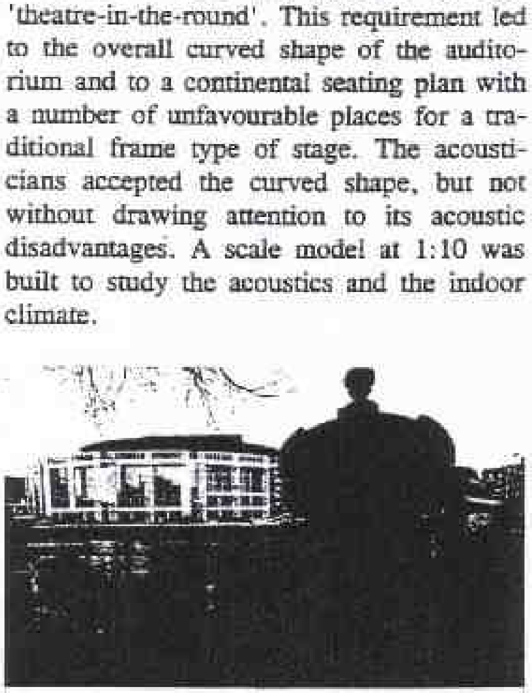
The design and planning of the building has an interesting history. The original architect, Mr. B. Bijvoet, drew up his first plan in 1958. The final design was completed in 1963, but the decision to start construction was not made. Bijvoet died, aged 91, in 1979 without knowing whether his building would ever be built.

The Opera house is constructed essentially from Bijvoets original plan. However, it was strongly modified because, for political and financial reasons, a much criticized link had to be made with W. Holzbauers plan for the new City Hall (the result of an international contest, 1967). So a combined City Hall - Opera building was created at the cost of approximately Dfl. 300 million.

Professor De Lange, the main acoustical consultant for the project, has been involved with it since 1960. He worked for the first three years together with the late professor C.W. Kosten. The following article discusses the acoustical issues involved with the project.

Shape and size

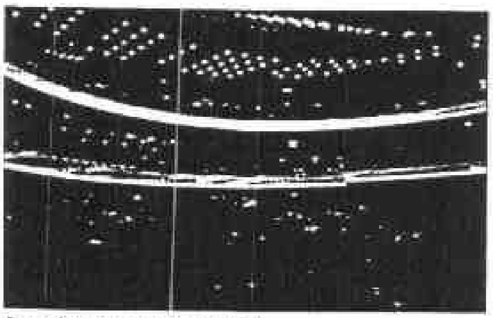
At the time of the design the future users of the opera insisted on a lay-out which would allow for a then very popular concept, 'theatre-in-the-round'. This requirement led to the overall curved shape of the auditorium and to a continental seating plan with a number of unfavourable places for a traditional frame type of stage. The acousticians accepted the curved shape, but not without drawing attention to its acoustic disadvantages. A scale model at 1:10 was built to study the acoustics and the indoor climate.



The Amsterdam Opera House.

The hall has a raked floor, and two semicircular balconies both of which have seats with good sightlines. The hall is relatively small. It has 1689 seats. As a result linear dimensions are limited, providing an unmistakable acoustical advantage: strong direct sound. From the centre point of the stage the radius of the hall on the first floor is approximately 25 m. The maximum distance to the stage is less than 30 m. The acoustic risk of the semi circular shape - the focussing of the sound energy - has been neutralised with articulation of the walls. This was checked in the scale model.

The ceiling height was fixed between 15 and 17 m to get a volume of approximately 10,000 m^3 for the original design's 1500 seats in order to obtain a reverberation time (RT) of 1.4 to 1.6 s at mid-frequencies, this was a commonly accepted value for opera at the time of design. Materials have been chosen such that the reverberation time at the lower and the higher frequencies does not differ much from 1.5 s (no thin wood, no extra porous materials). However, the number of seats has been increased subsequent to the original design to 1689, as a result, the volume per seat was reduced from 6.7 m^3 to 5.9 m^3.



Interior view of the hall.

In concert-hall acoustics the great importance of lateral reflections is well-known. Opera-halls apparently do not require them. In the first author's experience with the Circustheater in The Hague, (see "Halls for music performance" 1962-1982, A.S.A. 1982) the surroundings of the orchestra were found to be comparably important in respect to acoustic success. V.L. Jordan draws attention to the acoustic importance of the 'proscenium arch', which in traditional opera-houses, forms the transition between the stage-house and the auditorium. This area has a width of some 4-6 m, a horizontal ceiling (that also extends above the pit), and vertical diffusing walls. The role this zone played in the transmission of sound both to the audience and to the orchestra, in balancing the singer on the stage and the orchestra in the pit, and in feeding back sound to stage and pit, is worth considering. In the new Opera house design the functions of the proscenium arch have been 'translated' into the surroundings of the orchestra pit. The walls next to the orchestra-pit provide the audience with the important lateral reflections necessary for the music envelopment. Moreover, they give reflections to and from the musicians in the orchestra-pit and the singers on the stage.

The overall curved shape of the hall in plan necessitated the introduction of highly diffusing surfaces all around; these are clearly visible in figure 2. The ceiling consists of bands, curved in plan and corresponding to the rows in the audience. For equal distribution of the sound these bands have different slopes. At a later stage diffusing elements, made of 0,8" and 1,2" thick reflective material (chipboard) were added.

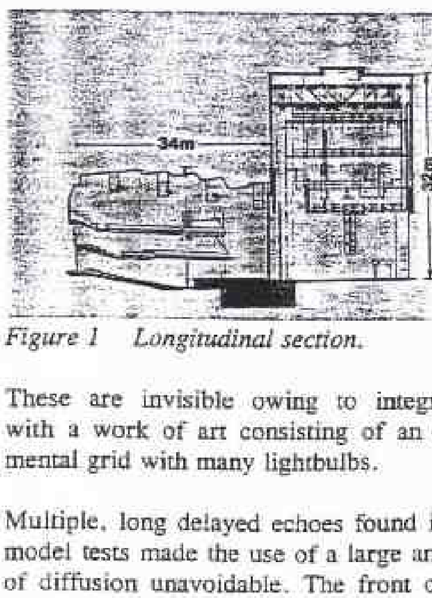


Figure 1 Longitudinal section.

These are invisible owing to integration with a work of art consisting of an ornamental grid with many lightbulbs.

Multiple, long delayed echoes found in the model tests made the use of a large amount of diffusion unavoidable. The front of the mezzanine, though shaped in such a way that echoes to the stage are prevented, sent concentrated sound upwards which in turn was reflected by the (at that time) flat ceiling: this resulted in a marked echo to the seats in the stalls.

There are four light-bridges hanging under the ceiling. The acousticians tried to make them as transparent as possible. However they regret placing one in the position directly above the pit as it resulted in altering the reflection pattern of sound from the pit.

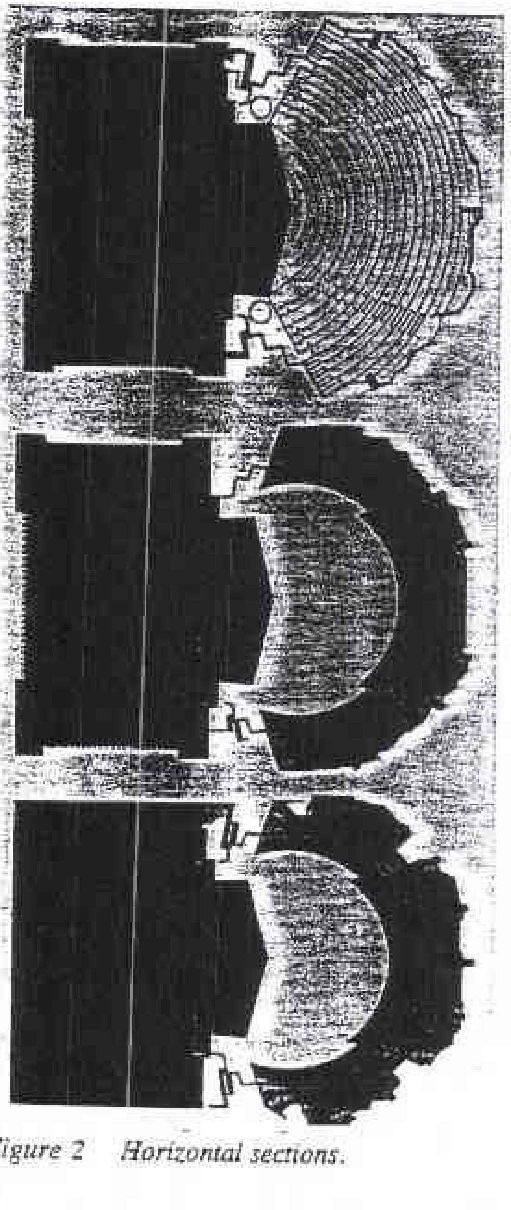


Figure 2   Horizontal sections.

The orchestra pit

Playing in a pit is generally disliked by musicians, mainly because of the high sound levels, but also for psychological reasons. There seems to be only one remedy: make the orchestra pit more roomy. In this case the pit is both deep and very large in area (180 m^2), but it can be adjusted to the size and musical needs of the orchestra. The floor can be elevated in 3 parts. The side-walls and backwall are movable in order to decrease and increase the area as required.

Measures have been taken to reduce low frequency sound by absorption (plywood linings) and high frequency sound (locally) by curtains (similar to what was done in pit of Sydney Opera).
The resident orchestra tested the pit on two seperate occasions in a full size mock up to check on seating and sightline conditions.

The position of the pit relative to the stage was established based on a rule of thumb: 1/3 of the pit covered, 2/3 open to the hall. At full capacity however only an area of 75 m^2 of the floor area of 180 m^2 will be open, resulting in a ratio of open to closed of 3:4. Acoustically this seems less attractive. However this ratio will only occur when the full 180 m^2 are used, i.e. for very large orchestras. When the orchestra is smaller, as usually the case, 'empty' spots will be in the covered part of the pit. When the hall is used for playing "in the round" a semi-circular 'moat' surrounds the stage.
The acoustical importance of the stage surroundings was discussed earlier in this paper.

Stage house

The stage house is immense in size. The fly-tower is 37m wide by 20m deep and 32 m high with a side- and backstage of 1100 m^2.

Acoustically, measures have been taken to control reverberation in the stage house. Approximately 50% of the wall area is moderately absorptive. Side stages and backstages are reasonably well-isolated from the main stage.

Noise control for the hovercraft operated stage wagons proved to be difficult.

The maximum stage opening is 21 x 10 m^2. This very large width (design requirement) causes acoustic problems. Reflecting surfaces are far away.

Materials in the auditorium

The floor of the auditorium is of concrete with carpeting in the aisles. The walls consist of plastered brickwork with a thin plastic 'wallpaper'. The ceiling consists of bands, curved in plan to correspond to the rows in the audience. The bands have different slopes with diffusing elements made of 0,8" and 1,2" thick chipboard. Underneath the ceiling is an ornamental grid with many lightbulbs. The balconies are made of concrete. The upholstered chairs provide the main contribution to the total absorption in the auditorium.

Acoustic measurements

After the inauguration several measurements have been carried out by TNO and other acoustic experts including TAK Associated Architects (Tokyo, Japan) and Akustikon AB (Göteborg, Sweden). Also, a panel of trained listeners was asked to judge the hall.

The sound level and dynamic range, especially of the orchestra, were said to be too low and the reverberation time is, despite the measured reverberation time, experienced to be too small. A number of performers reported a weak acoustic response from the hall. Singing, intelligibility and definition of the instruments are judged to be good.

The subjective response of the panel is in accordance with the results of the measurements.

The reverberation time measured in the occupied hall (60%, decor opera Fidelio) was:

Frequency [Hz]	RT_{60} [s]
125	1.9
250	1.7
500	1.5
1000	1.4
2000	1.2
4000	1.0

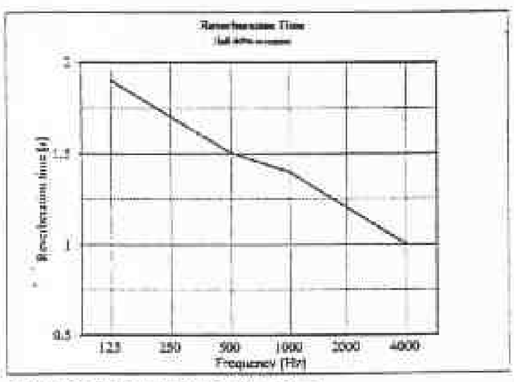


Figure 3 Reverberation time

The values for the high frequencies (2000-4000 Hz) are a bit smaller than what was designed for. This may be caused by the increased number of seats and the coupling of the hall with the acoustically treated stage house.

The sound levels were also measured for two indentical sound sources: one in the orchestra pit and one on the stage. In figure 4 the sound pressure levels in dB(A) are given.

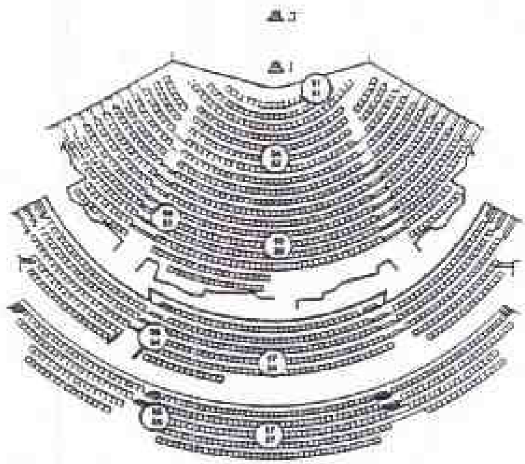


Figure 4
Sound pressure levels measured in occupied hall (60%, decor opera Fidelio) in dB(A) with sound source in the pit (I) and on the stage (II).
Values above: source II
Values below: source I

The results indicate that the sound coming from the pit was not as strong as the sound from the stage. For seats in the centre of the stalls a difference of 12 dB(A) was found and of 7 dB(A) for seats in the sides. The differences are negligible in the balconies. It was found that the influence of the audience on the sound level is of no importance.

The values for the clarity as measured in octave bands varied from -6 to +6 dB. The overall mean value for the hall is -1,2 dB.

The measured values for the 'Deutlichkeit' (D50) are good when the source is set above the stage floor. The averaged values are 27% at 250 Hz and 31% at 500 Hz.

The measured 'Schwerpunktzeit' varies from 98 ms to 127 ms, so it stays within the published limits.

The overall mean value of the measured rapid speech intelligibility is 0,57 without amplification and 0,62 with amplification (see figure 5).

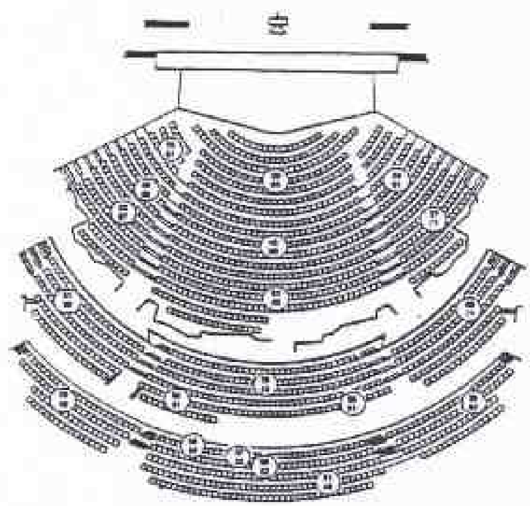


Figure 5
Results of the Speech Transmission Measurements. Sound source on stage.
Values above: STI in % no sound-amplification.
Values below: STI in % with sound-amplification.

The lateral energy fraction measured varies between 0,06 and 0,2.

The overall sound level due to technical installations is NR 27. This rather high sound level is consistent with the panels findings that the orchestral sound is weak.

A conductor's opinion

A leading Dutch newspaper published an article by its chief music critic in February 1996 based on an interview of the Opera's main conductor, Hartmut Haenchen. We quote from his published opinion in this article entitled: "Haenchen improves opera-acoustics". "He (Haenchen) now knows how to handle the sometimes difficult acoustics of the Amsterdam Muziektheater. He even succeeded in a performance giving the impression that the acoustics are quite good." The ideal, Haenchen is quoted as saying, would of course be a truly classic hall. And in his empty office he points to a photograph of the Dresden Semper Opera. "That hall is fantastic, an opera should sound as this one. In the Amsterdam hall the orchestra sounds as a radio playing at too low a level." All the same Haenchen also states that since the opening in 1986 a lot has been done to improve the acoustics. "There is a ceiling above the orchestra, the side walls of the proscenium have been altered in order to direct the sound of the orchestra into the hall. The pit has been changed, some musicians are sitting a bit higher. The wood has been taken out, the bare concrete reflects now as much as possible. By placing a microphone near the woodwind and a loudspeaker near the brass the playing together within the orchestra has been very much improved. Now at least the musicians can hear each other." "We still have plans for further improvements", Haenchen says, without telling which plans. He states that the absence of the "first reflection" is the main shortcoming.

The comment of the authors on these statements is that:

a.) during construction a fourth light bridge was added ,above the pit, against the will of the acoustic consultants. To accommodate the bridge the ceiling had to be shifted in height. The ceiling of the hall had been designed and tested in the scale model with a horizontal part in the same place;

b.) the side walls of the proscenium were designed to do just what Haenchen wants;

c.) the side walls of the hall, although well-diffusing, probably fail to create enough strong and early lateral reflections, indispensable for the well-liked acoustics of a concert hall and notably for the listener to feel enveloped by the sound. The shape of the front of the balconies is such that they do not provide any strong lateral reflection; and

d.) although the changes to the hall's interior are minor, the conductor and the critic who wrote the article state that since the 1986 the acoustics have improved considerably. This is almost certainly caused by the process of getting used to or adjusted to the hall's acoustic character. The floor of the pit is movable in parts; obviously the conductor used this opportunity. An adjustable frame for the stage is suggested and seems to be a good idea but was suggested earlier. Finally it should be noted that Haenchen's comparison to Semper opera is unfair.

Regardless good design orchestras performing in a pit cannot achieve the same sound quality as orchestras on the platform of a good concert hall.

Conclusions

After the opening of Amsterdam's new Opera House public and critics reacted mainly positively.

Although the Amsterdam Opera House is sold out constantly there are still some complaints about the acoustics, that mainly come from performers and composers.

The sound level and dynamic range of the orchestra are said to be too low. This is mainly caused by the lack of strong reflections from the proscenium arch and side walls of the stage. Also the side walls of the hall, although well-diffusing, probably fail to create enough strong and early lateral reflections.

The sound level in the hall caused by the HVAC- installation is too high.

The reverberation time is critical in the frequency range of 2000 to 4000 Hz. This corresponds to the experience of some performers who report a weak acoustic response of the hall.

It is well known and generally accepted that an Opera House is not judged only on its acoustics. There is a strong link between performance, composition, interpretation and experimentation of the opera that is performed and the hall. It is important that the hall has its own characteristics and intimacy. The challenge in improving the acoustics of the hall is to balance acoustic measures with other technical provisions.