On the Room Acoustics for Theater, Rehearsals and Concerts -The new Festival Hall in Landau, Germany

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ABSTRACT

The acoustics of concert halls is still a secret. High expectations exist both for a new building and a remodeling from the first day on The hall has to fulfill many desires and somehow contrary requirements related to the different uses as a multipurpose hall, suitable for concerts and rehearsals with and without audience, for TV and radio broadcasting, for shows and theater with or without electro-acoustical amplification. Usually chairs can be removed to turn the hall into a dance floor or a sport arena. The Festhalle in Landau had to reach all this goals and has fulfilled the expectations. But what is the history behind it? Was it only a simple remodeling? In 1952 with an audience of 2000, Wilhelm Furtwängler conducted the Berliner Philharmoniker and was impressed by the excellent acoustics of the old hall. 6 years later a total change from the former Jugendstil into a modern stil “of the 50’s” was carried out. Why? The reason was another acoustical feeling, a new movement towards more knowledge about acoustics including direct sound separated from the first and later reflections, e.g. more or less Deutlichkeit. Today, a reconsciousness takes place. No wonder that the original building of 1908 with its beautiful Jugenstil-Architecture had to be rediscovered. During the almost 100 year history, many different influences have changed the building. It was used for military purposes, as a ware house, hospital and for horse stables, for political demonstrations and for big concerts.

The knowledge of acoustics has grown tremendously over the past decades. For instance, the “Precise structure of sound” or the “Distance of privacy” require consequences in acoustical design for both musicians on the stage or in the pit and for the listener in the audience.

The remodeling of the Festhalle started in 1997 and was finished with the opening ceremony on January 12, 2002 with an audience of 1100. The paper summarizes decisions, steps of work and results. Some comparisons with other halls will be made.

1 Introduction

From the beginning on in 1908, the Festival Hall of Landau was used for many different purposes. It was not only a theater or a concert hall. Fairs, meetings and political demonstrations took place. The hall became hospital and warehouse. In October 1952 Wilhelm Furtwängler conducted the Berlin Philharmonic Orchestra in the old hall with 2000 listeners in the audience. He praised the good acoustics of the hall. Jugendstil as Art Nouveau was originally a great movement from 1900 on. It was the pep and verve of the youth to follow their feelings and intentions freely, as e.g. indicated in many ornamentations in architecture. The strong and straight lines of the 50’s /1/ did no longer match the Jugenstil. A new age had begun leaving back many old traditions. Scientific work started at universities and in companies. Schools were founded, such as by Prof. Dr. Hermann Scher-chen in Gravisano 1950 /2/3/. Direct sound, sound reflections and reverberation were studied /4/. The “Feinstruktur des Schalles ” (Precise structure of sound) became well known. Weisse constructed sound fields with direct and reflected sounds arriving at different times and locations /5/. Echoes and their effects on speech intelligibility were investigated by Haas in 1951. He defined the Haas Effect /6/ which became important for room-acoustical design. Thiele described concert halls and radio studios and found his famous “Igels” (hedgehogs) indicating the arriving sound reflections /7/. In 1956 Kuhl proposed acoustical measures for studios to improve sound recordings and listening conditions in 1959 /8/. At this time in 1957, Dr. Weisse became acoustical consultant for the Festhalle in Landau. He changed the hall from Jugendstil to a smaller theater and concert hall. The Newspaper Rheinpfalz wrote on February 24, 1958 with reference to the old hall: "The acoustics of the old Jugenstil hall was bad". This is at first surprising because 6 years earlier Furtwängler was enthusiastic about the acoustics of the old Jugendstil hall with 2000 listeners in the audience. However, both statements are understandable and based on the same facts. The Jugendstil hall was much bigger with a longer reverberation time and was more appropriate for a large orchestra. The remoduling in 1957 however was more directed towards speech intelligibility without a sound reinforcement system. Weisse knew that a reduction of reverberation time was inevitable. He predicted a reverberation time of 1,45 s /9/ while the public and the press were still in favor of the great orchestral sound of Furtwängler.

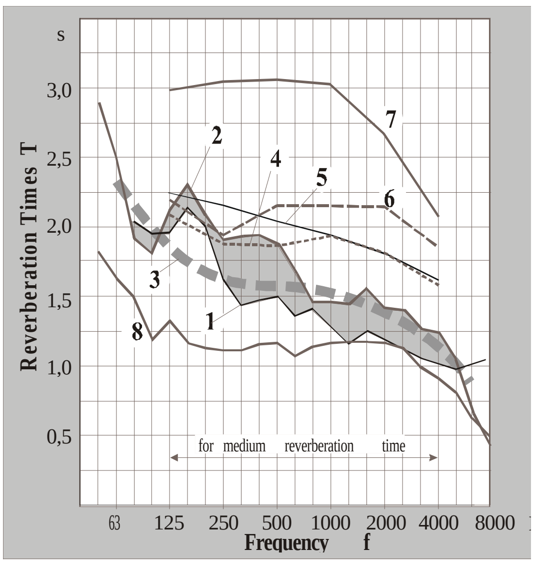


Fig. 1 Reverberation times of Landau Festival Hall

1	Opening concert on 2002-01-12, 1041 seats, 60 musicians pit covered for additional seats, V=6900m³	Tm=1,44s
2	as 1, Hall unoccupied	Tm=1,66s
3	Proposed in March 2000	Tm=1,51s
4	Berlin Philharmonic Hall /10/ occupied 2325 seats	Tm=1,80s
5	Vienna Vereinsmusiksaal /10/ occupied 1680 seats, V=15000m³	Tm=1,98s
6	as 4, unoccupied	Tm=2,08s
7	as 5, unoccupied	Tm=2,81s
8	Landau after remodeling in 1958 measured 1997	Tm=1,21s

Unfortunately the hall had only around 1,2s. For many years the hall suffered under these acoustical conditions. The intention was to reach the Großer Musikvereinssaal of Vienna (Vienna Concert Hall) with a reverberation time of 2,0 s /10/ 11/ or of the Berlin Philharmonic Hall with 1,86s as shown in Figure 1.

2 Reverberation Times RT

Wilhelm Furtwängler had praised the hall in 1952 for its good acoustics when it was still the old Jugendstil hall since 1908. Some years later, the acoustical conditions became insufficient. Changes were required. But why? Firstly, the empty hall was very rich in reverberation, comparable with curve 7 in Figure 1. The RTs were longer due to the wooden chairs without sound absorption Secondly, with an audience of 2000, the remaining reverberation times were however ideal like curves 5 or 4. But how was the absorption of the huge mortar areas on walls and ceiling? Thirdly, the hall had a long reverberation time for other purposes, such as theater or musicals (Operetten) with a smaler audience of only 500. Fourthly, 40 m distance to the backwall was too far away from the stage for speech.

Dr. Weisse predicted only 1,45 s. for the change in 1958. The measurement in 1998 carried out in this hall led to only 1,16s instead. This RT is too short and even shorter with audience. What a difference between curves 8 und 5 from 1,2 to 2,0s. Figure 2 gives an answer. The requirements for speech and music are really very different. The best solution would have been to build different halls for each purpose, like a speech theater, a concert hall or a rehearsal room for a symphony orchestra, like for instance the building for the Pfälzische Philharmonie in Ludwigshafen, Germany /12/. For Landau a reverberation curve from 1958 does not exist. Figure 2 shows a survey on common reverberation times indicating the big differences between speech and music.

What could be a compromise? The concert halls 10 and 11 are far beyond standard. They even do not match the recommendations of Kuhl for classical and contemporary music 2. The RT is too long, the volume too big. With 1680 and 2325 seats the human voice can not reach the listeners properly. Lothar Cremer spoke freely with a loud voice when he explained the acoustics of the new Philharmonic Hall in Berlin. That was on April 9, 1964.

But, in a larger distance the intelligibility was poor. In his publication he proposed a little "Make up" with an electro acoustical amplification for voices in addition to his "Weinbergterrassen" which are typical for the Berlin Hall /16/. Theaters only have to have a short RT according to Jonson curve 8 in Figure 2 /15/. Weisse had reached 1,16s and was near the area for speech and theater. But, with RT 1,16s he was too far away from desired values for musical events. No. 9 in Figure 2 is the Landau Festival Hall located in the middle of many other halls. Surprisingly large is the RT for the rehearsal room 12 which was required /12/.

Leif Segerstam, former Chief-Conductor of the Rheinland Pfalz Philharmonic Orchester, said in 1987 : "The new Philharmony in Ludwigshafen is important for my work. I find that the acoustics are definitely good and comparable to the acoustics of the Alte Oper in Frankfurt or the Liederhalle in Stuttgart" /17/. Segerstam felt the necessity to rehearse in real acoustical conditions of a concert hall like the Alte Oper Frankfurt when the brass players were doubled. He wanted the big sound, above all from the brass players. His orchestra had to fill huge halls with the appropriate sound of high musical quality.

3 Sound pressure levels

The orchestra should produce a sound level at the listening positions similar to that in the Vienna Musikvereinssaal of 90 dB as proposed by Meyer /11/. Using 90 dB as a reference, which applies for a normal sized orchestra Landau is louder with 92,2 dB in Figure 3. With 16000 m³ Volume and 2,0s reverberation time for Vienna 90 dB(A) follows. Calculations for other halls can easily be obtained as shown in Fig. 1:

$$Lp_{Diff} = L_W + 10\lg\left(\frac{4T}{0{,}16V}\right) = 90\mathrm{dB(A)} \qquad 1$$

T is the reverberation time in s, V the volume in m3. Both are known for the Vienna Musikvereinssaal. LpDiff is the diffuse sound field level in the hall. Lw indicates the total sound power level which is irradiated from the orchestra. Lp follows as Lw=115 dB for Vienna.

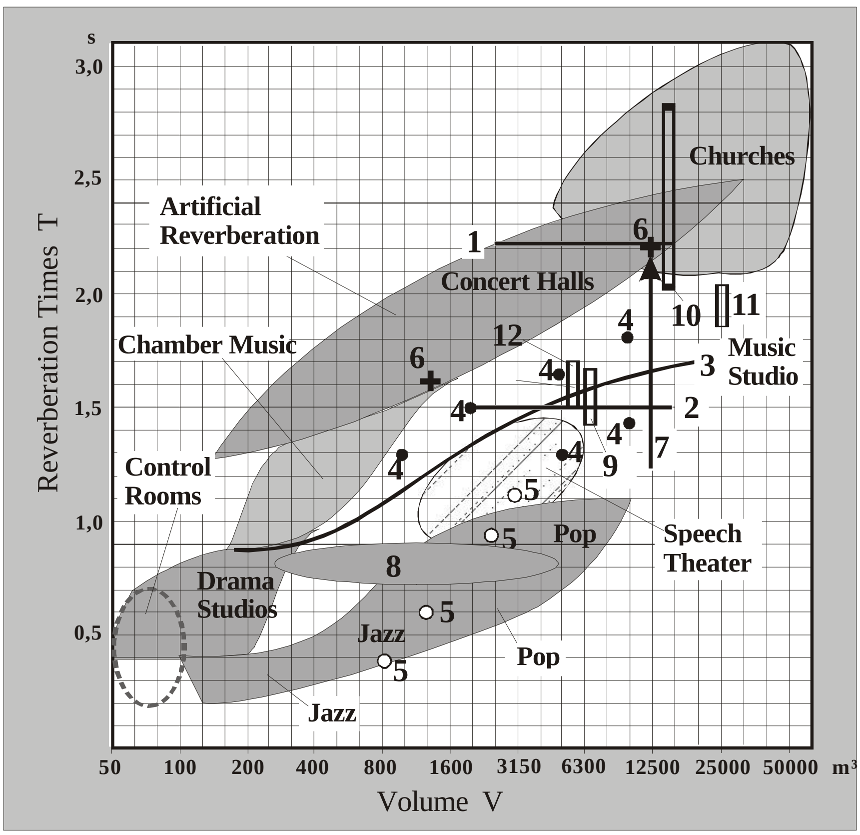


Fig. 2
Survey of reverberation times RT for different rooms and purposes

1 Optimal for romantic music in accordance with Kuhl /13/
2 as 1, but for classical and contemporary music
3 Multipurpose halls as average from 4
4 Well known halls
5 Radio studios for pop and big bands in accordance with Voelker
6 Artificial reverberation of a recording in accordance with Voelker /14/
7 as 6, from approx. 1,2 to 2,3s
8 Cinemas, conference rooms, theaters according to Johnson /15/
9 Festival Hall Landau 2002
10 Vienna Musikvereinssaal in accordance with Beranek /10/
11 Berlin Philharmonic Hall in accordance with Cremer /16/
12 Pfälzische Philharmonie Ludwigshafen /12/

With the sound power level of this orchestra of 85 musicians the Landau Festival Hall follows
equation 2:

$$L_{p\,Diff} = L_W + 10\lg\frac{2T}{0{,}16V} = 115 + (-22{,}8) = 92{,}2\ \text{dB} \qquad 2$$

The sound pressure level near the orchestra can be calculated using the reference level of Lp1m with equation 3:

$$\begin{aligned} L_{p1m} &= L_W + 10\lg\left(\frac{1}{r^2} + \frac{16\pi}{QA}\right) \qquad 3 \\ &= 115 + 10\lg\left(\frac{1}{15^2} + \frac{16\cdot\pi\cdot 1{,}44}{2\cdot 0{,}16\cdot 6900}\right) \\ &= 115 - (-14{,}3) = 129{,}3\ \text{dB} \end{aligned}$$

or for 1 musician as an average with equation 4:

$$\begin{aligned} L_{p1m1Mus} &= L_{p85Mus} - 10\lg 85 \qquad 4 \\ &= 129{,}3 - 10\lg 85 = 110\ \text{dB} \end{aligned}$$

Q is the directivity factor of hemisphere sound irradiation from both the musical instrument and the player, Q=2.
These SPLs are measured at microphone positions during recordings and rehearsals /18/. The sound level of music played with fff is therefore very different. Vienna has 90 dB, Landau Festival Hall however has 92 dB which is much louder. The Alte Oper in Frankfurt shows the opposite, only 88 dB. The Royal Albert Hall is poor with 81 dB. As a consequence the usage of electro-acoustical amplification becomes necessary. This was confirmed during a recent visit of the opera Carmen in the Royal Albert Hall. The sound was totally reproduced by loudspeakers. Whereas the Pfälzische Philharmony in Ludwigshafen is loud /12/. The orchestra produced a level of 94-96 dB at the end of Wagner’s Meistersänger measured in front of the orchestra, up to 110 in the middle of the orchestra. Other authors found the same with 117 according to Meyer (1984), 108 by Buhlert (1974), 96-105 by Kuhl (1956), 95-108 dB by Karlson (1983).

4 Room impression for concerts and theater

The overwhelming impression of a concert hall is related to the high sound level. This is why Segerstam wanted this impression. The Pfälzische Philharmonie Ludwigshafen has been built for this reason, s. No. 5 in Fig.3 and the reverberation time in Fig. 2, Number 12. Landau follows similarly with a quite long RT in a room with only 6900 m³ volume

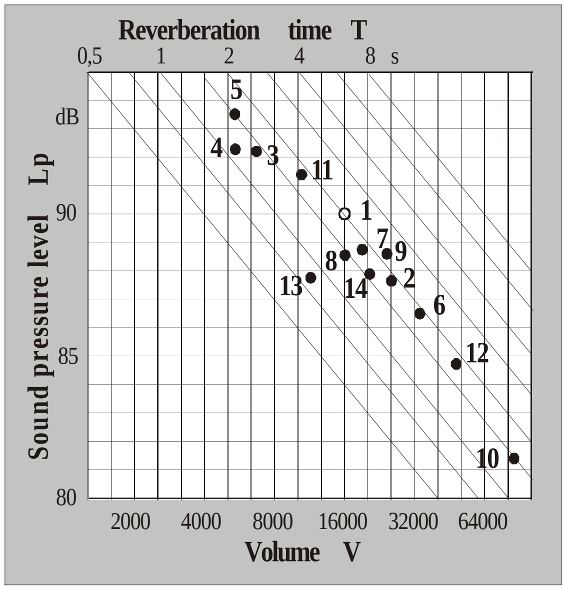


Fig. 3 Sound Level of a 85 musician orchestra in different halls, calculated in accordance with Meyer /11/

1	Musikvereinssaal Vienna	16000 m³	2,00 s	occupied
2	Phiharmonic Hall Berlin	25500 m³	1,86 s	occupied
3	Festival Hall Landau	6900 m³	1,44 s	occupied
4	Stadthalle Oberursel	5500 m³	1,17 s	unoccupied
5	Pfälzische Philharmonie Ludwigshafen	5500 m³	1,50 s	occupied
6	Stadthalle Hannover	32000 m³	1,90 s	occupied
7	Boston Symphony Hall	18750 m³	1,80 s	occupied
8	Cleveland Severence Hall	15690 m³	1,48 s	occupied
	Liederhalle Stuttgart	16000 m³	1,50 s	unoccupied
9	New York Carnegie Hall unoccupied	24270 m³	1,82 s	occupied
10	Royal Albert Hall	86660 m³	1,39 s	occupied
11	Basel, Stadtcasino	10500 m³	1,81 s	occupied
12	Storthalle Oberwerth 5500 Sitze	48000 m³	2,00 s	occupied
13	TV studio of Hessian Broadcasting company (A2274)	11600 m³	0,85 s	unoccopied
14	Alte Oper Frankfurt	22200 m³	1,78 s	unoccupied

to produce a high sound level. The loudness is related in a large part to the early strong direct and lateral reflection within 0 to 80 ms /28/. The greater part of the decay or even the full RT is heard.

An omni-directional microphone receives at the listeners place both the direct sound and the later arriving reflections. The measurement technique is based on TEF technology measuring in the Time, Energy, and Frequency domain / 19/20/. The result is an energy time curve as a room response or impulse response when an omni-directional loudspeaker on the stage irradiates sound into the hall, see Fig. 4.

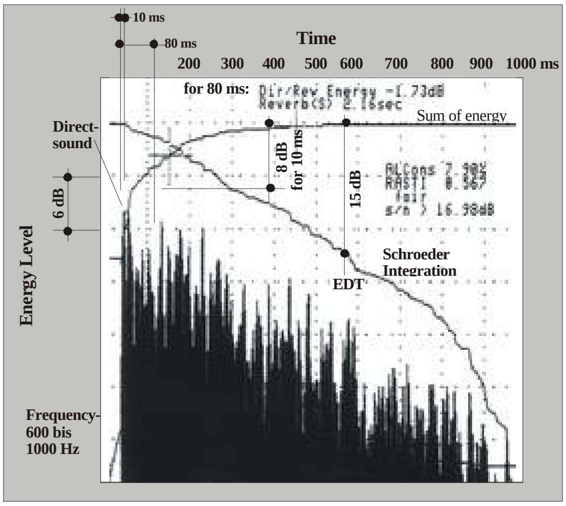


Fig . 4 Impulse diagram of Landau Festival Hall with energy ratios and indexes, reverberation times and decay curve

Energy ratio of direct sound und reflec-tions dependnig on times :
* 10 ms for lateral index according to Kuhl (1978)
* 50 ms for D as Deutlichkeit according to Thiele (1953)
* 80 ms for C as Clarity according to Reichardt (1975)

Strength factor G as ratio between 80ms (0-80 ms) part und direct sound D
Calculation of the decay curve from invers integration according to Schroe-der, here 2,16 s
Early decay time EDT for -10 or -15 dB decay.
Loudspeaker omni directional : On the stage middle, 2m apart of the pit
Mikrophone: omny-directional, in the middle of the hall
Measurements on 2002-12-23, Job Nr. 32
Measurements with the Techron TEF Analyser of Company Crouwn, USA

The different energy ratios can be measured regarding the following equation
equation 5 in acc. with Kuhl 1978 /21/
equation 6 in acc. with Reichardt 1978 /29/
equation 7 in acc. with Lehmann

$$K_l\,room = 10\lg \frac{\int_{10ms}^{80ms} p^2(dt)}{\int_{0}^{10ms} p^2(dt)} \quad dB \qquad 5$$

$$C = 10\lg \frac{\int_{0}^{80ms} p^2(dt)}{\int_{80}^{\infty} p^2(dt)} \quad dB \qquad 6$$

$$G = 10\lg \frac{\int_{0}^{\infty} p^2(dt)}{\int_{0}^{5ms} p^2_{Direct}(dt)} \quad dB \qquad 7$$

From zero to 80 ms, direct sound and first reflections have arrived. Kuhl defined the late reflections as coming from the stage and the side walls within the time range of 10 to 80ms. He wanted the direct sound to be excluded according to equation 5 and Fig. 4. Measurements in the Landau hall led to the following late energy indexes.

* 6th row on balcony, middle 9,5 dB
  Clarity C = 13,5 dB
  Strength G = 7,5 dB
  Values indicate: Strong direct sound, designed for speech theater, high loudness
* 1st row on balcony, middle 7,3 dB
  Clarity C = 1,8 dB
  Strength G = 7,8 dB
  Values indicate: Strong direct sound, designed for speech theater and music, high loudness, more room impression
* Parquet below the leading edge of the balcony 11,7 dB
  Clarity C = 1,8 dB
  Strength G = 7,1 dB
  Values indicate: Strong direct sound, designed for speech theater and music, high loudness, more room impression
* Parquet, middle of the hall 6,7 dB

Clarity C = - 1,7 dB
Strength G = 7,8 dB
Values indicate: Less direct sound, more diffuse sound, designed for speech theater and music, high loudness, more room impression

Vienna Musikvereinssaal:	C=-3,5 dB
	G= 7,0 dB
Stuttgart Liederhalle:	C=-0,2 dB
München Gasteig:	C=-0,7 dB
	G= 2,5
Cleveland Severance Hall:	C= 0,4 dB
Berlin Philharmonic Hall:	C=-0,5 dB
	G= 4,5 dB

* Parquet, middle, 3 m in front of the stage 2,6 dB
Clarity C = - 0,6 dB
Strength G = 9,0 dB
Values indicate: Less first reflections, more diffuse sound, good for music, high loudness, designed for speech theater and music

High values indicate that an increased number of early reflections arrive compared with a smaller influence of the direct sound. In the back of the parquet, near the balcony, early sound predominates. Smaller value of clarity means: More late reflections, more room impression.

Beranek describes the Strength Factor G which follows the equation 7 /10/ p 574. When taking the direct sound from Fig. 4, as a direct sound measurement of TDS the comparison with the energy from 0 to 80 ms is possible. The calculation for a seat 8m in front of the pit leads to G=8 dB for 500-1000Hz. As expected the results are similar to those of Kuhl. For Vienna G=7 dB which means the first row balcony or the parquet of Landau have almost the same values.

Clarity is easy to judge. The audience prefers usually being bathed in sound with more late reverberant reflections equivalent to C-values of -1 to -4. For theater however a bigger C is nescessary rating from 1 to 4. Regarding the C values above, the hall has reached the estimated figures. The back part of the balcony had to get more direct sound and comparably only small lateral energy. This is good for speech. The balcony and the back part of the parquet have a good clarity. It is well known that the first rows in a concert hall have less early sound energy, except direct sound, but relatively more late sound energy from 80ms to infinity. This is on the other hand of advantage for the conductor and the musicians to receive a room response or a feedback from the hall.

Orchestra rehearsals do not need a large C. Instead, room impression is desired. This is equal to late arriving reflections if possible later than 80 ms. For two years the Symphony Orchestra of the Frankfurt Radio Station has chosen the Multi-purpose Hall of Oberursel as a rehearsal room. The orchestra performed in the middle of the hall with fairly large distances to the walls. The ceiling reflected sound into the hall. Walls were partly sound absorbing. With the RT of 1,4 s and the late arrivals the hall was ideal for rehearsals /22/. The intimacy or acoustical privacy remained which applies for both the musicians and the orchestra including the conductor. They listened to each other and recognized first impulse sounds of their and other neighboring instruments as part of the “Direct Sound Package DSP”/23/ up to approx. 10 to 15 ms. Side walls or the orchestra shell on the stage are therefore dangerous. First strong sound reflections must be directed towards the audience, but not back to the nearby musicians /21/.

The orchestra probably plays best in its own concert or rehearsal hall where the musicians feel comfortable and find their optimal musical conditions.

5 Speech intelligibility

The concert is only one use of the Landau Festival Hall. Speech theater is equally important for the success of the hall. The compromise to be found has many faces:

* Reverberation times RT should be optimal for all purposes equal to approx. 1,4 s
* The music sound level is expected high to get big room impressions
* Clarity high with >1, approx. 1,8 dB for theater, not as for Vienna with C = -3,7
* Many reflections early and late to mask the echos from the back wall in 33m distance

This seems to be against the acoustics of a concert hall, but necessary to make speech theater possible. Additional measures can be taken e.g. using huge curtains in front of windows and walls to reduce reverberation, noise and disturbing reflections.

Fig. 5 shows values of speech intelligibility measured in several halls for comparison reasons. The intelligibility of speech is good on the balcony as suspected and in the first rows. The parquet is rated fair.

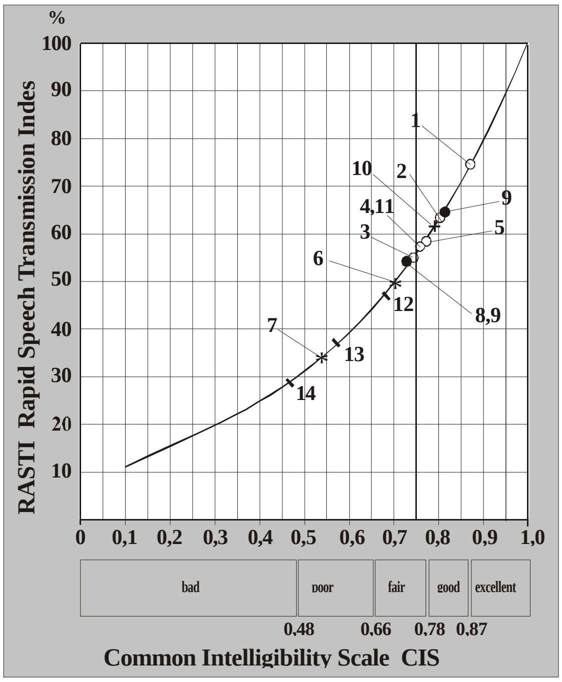


Fig. 5 Speech intelligibility for Landau Festival Hall
and comparisons with halls and theaters

1	Festival Hall Landau 6th row at balcony, middle RASTI/STI	74 %
2	1st row at balcony, middle,	63 %
3	below 2 in the parquett	55 %
4	middle of paquett, 8 m in front of the pit	57 %
5	3m in front of the pit	58 %
6	St. Michaelis church in Ham- burg with sound system	50 %
7	as 6, without sound system	34 %
8	Multi-purpose Hall Kronberg without sound system	54 %
9	Multi-purpose Hall Forum Leverkusen 20th row, middle, without sound system	53 %
10	Multi-purpose Hall Hattersheim without sound system 18th row, middle	62 %
11	Multi-purpose Hall, Sporthalle Koblenz, with sound system, middle of the hall	57 %
12	Cathedral of Mainz with sound system near the speakers, 4 m	47 %
13	as 12, 8m	38 %
14	as 12, without sound system	29 %

Fig. 6 Opening ceremony on 2002-01-12
Festival Hall Landau after 5 years of remodeling
Reconstruction of the old Jugendstil of 1900

Speech theaters as Forum Leverkusen or some smaller multi-purpose halls are better. Other large rooms as churches need a sound system although the Hamburg St.Michaelis (Michel) is quite good even without loudspeakers /24/.The reason is the open room with rising seats comparable with the Royal Albert Hall. Landau has made it possible both for concerts and theater. The newspaper Rheinpfalz wrote on 2002-05-27, five months after the opening: "With the acoustic-sails a great sound is reached. Musicians are enthusiastic about the good acoustics. Theater artists are content with the intelligibility of speech." Good acoustics was the goal. It seamed this has been reached.

6 Acoustical measures

Many questions came up when the reconstruction was decided for in 1997. The opening in 2002 was the happy end after a long rocky road with far-reaching decisions and consequences. 1,5s reverberation time, a good to fair speech intelligibility, a sufficient room impression, a good understanding among musicians on the stage and some other delicate wishes did accompany the crew of experts during these years. The opening concert

Fig. 7 Total remoduling for new orchstra pit, balcony and ceiling in the Jugenstil (Art Nouveau 1900)

Fig. 8 Landau Festival Hall during reconstruction Ceiling of the old Jugendstil building from 1908 which was left in this condition until the change in 1958.

The opening concert on 2002-01-12 fulfilled the expectations totally. Looking back to the first measures many constructions and parts of the building had to be changed .The acoustical situations and consequences were not known at all. How to make a acoustical measurement of the "Old hall" like in Figure 7, 8 or 9 ?
The results were very uncertain. Therefore the hall had to be simulated in the computer. Over 600 different areas were found with more than 45 different sound absorbing properties, all calculated for frequencies from 50 to 5000 Hz. The architect wanted stone walls with fine mortar and for the ceiling and arches even structured in comb form as to be seen in Fig. 9.

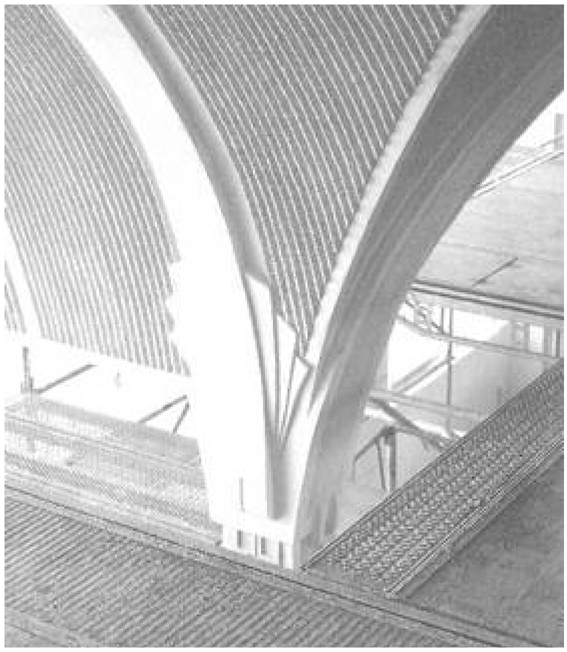


Fig. 9 Arches and ceilings with a mortar cover in comb form with dangerous sound absorption for high frequencies

The question was: How to avoid too much absorption at high frequency? Which kind of paint should be used?. Then the decision was made to measure the construction in a test chamber /25/ including and with the right painting. Later, nobody wanted to guarantee that the first ceiling renovated really has in situ these absorption properties. A measurement during completion was done and disappointing. An additional layer of color paint was required by the acoustician.

Fortunately the PC calculations indicated more and more precise results. The many chairs, 604 for the parquet as stack chairs, 357 fixed ones for the balcony had to be regarded. Chairs play an important role for the hall, either being occupied or not or for the difference between concert and rehearsal or for speech with audience or when some places are unoccupied. Therefore the specification was strict. But later the supplier could not guarantee the requirements and specifications. Consequence: Measuring the chairs in a test laboratory /25/. Result: At low frequencies the sound absorption was just good, but on the lower limit. Instead, the absorption of high frequencies was too big. As sometimes unavoidable the measurements took place too late. A change of the chairs was no longer possible. Everybody in the planning team knew this. The question was: How will the hall react acoustically. Will the reverberation time be too small at high frequencies? Last minute changes loose their sense when they introduce additional absorption. Originally they were required for avoiding echoes, e.g. from the back wall in 33m distance. These echoes can be overcome since early arriving reflection should help to mask them. Therefore every little mirror reflection was important such as on the

Fig. 10

Ceiling of the Landau Hall shortly bevor completion with structural and filigree ele- ments

They serve as mirror reflectors with many short reflections into the hall and back to the stage to mask out echos. Perforations of the ceiling were later closed from above to lower high frequency absorption

balcony balustrade, below the balcony or with the structural elements underneath the ceiling for which a maximal height as big as possible was required. Even small reflectors were sufficient according to Cremer /26/. So far, it was an important moment, when - after removing the scaffolding and closing the back wall of the balcony - the echo was or was not audible when listening on the stage or in the first rows of the parquet. Fortunately, the echos were masked.

In a very early planning stage, the worry came up that the old ceiling above the pit may not be good enough to provide all areas with sufficient first reflections. But, how to decide when the scaffolding fill the hall entirely? Nobody could really see how the hall would look like, e.g. with the new columns, the shape of the ceiling or the new form of the balcony. An architectural model in the scale of 1:15 should help /27/. The acousticians looked back to some experiences with similar models. First investigations in the Landau model made it clear. There was a huge problem. Sound reflection did not reach the balconies on both sides sufficiently. Fig. 11 shows the work within the model. Consequences were: Introduction of sound reflectors above the pit. Additionally they can provide the parquet and other parts of the hall with useful reflections when sound leaves the pit or the stage. Measurements used the laser pointer with which the arriving reflection was visible e.g. in the parquet. The model was built very detailed to see clearly the sound rays and reflections.

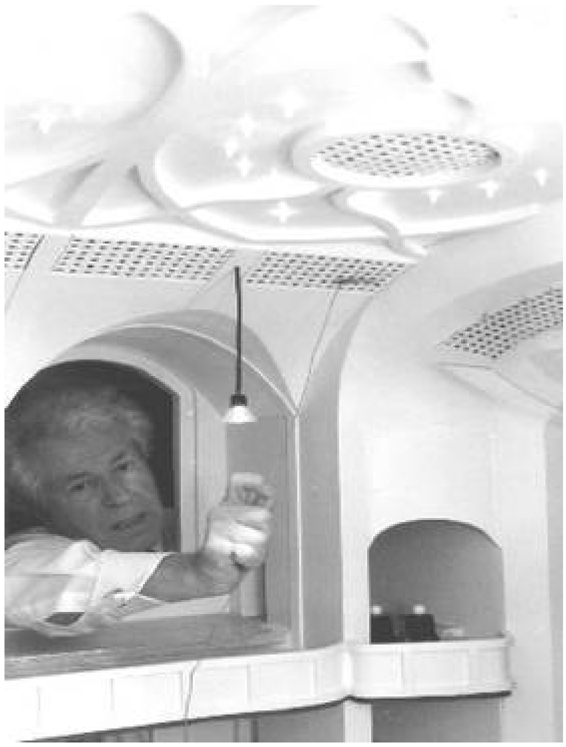


Fig. 11: Measurements in the model of Landau Hall
here with a little mirror reflector using
laser as a point source

Fig. 12 Festival Hall of Landau, opening on 2002-01-12 with a concert of the Pfalz Philharmonic Orchestra
Volume 6900 m³, 1100 seats, length 35m from middle of the stage, RT = 1,44/1,66s, remoduling of the Jugendstil (Art Nouveau) of 1900

Fig. 13 View from the stage to the ceiling
with reflectors as acoustical seals

5 reflectors were mounted above the orchestra pit to direct sound to the balcony in the back where seats go up into the appendix, Figure 12 with reflectors in Figure 13. With the reflectors both the balconies left and right and the seats on the balcony were reached. With the help of laser ray the coverage was easely to be seen and controlled. The same applied for the way vice versa. The reflectors lead the sound back to the stage what is desired as a feedback from the hall.

7 Noise levels of the air ventilation system

Good acoustics means **-** both for concerts and speech theater **-** silence. The noise reduces the intelligibility of speech and affects the room impression. Long RT decays are masked. Therefore strong limits were required with maximal 23dB(A) with a tolerance of maximal 2 dB(A) that is to say permitted 25 dB(A) in the lowest adjusting of the ventilation system. Fig. 14 shows the permitted and achieved values in one third octave bands. The disturbing noise level is still too high. Reductions are still in preparation. They are necessary to allow the hall to sound better. Appendix A shows ground plan and a cross-section with the main foyer and the first floor with the hall. Volume 6900 m³ and 604 seats in the parquet and 357 as fixed chairs on the balcony. Reflectors in 8m height and the distance to the back wall with 33 m is indicated.

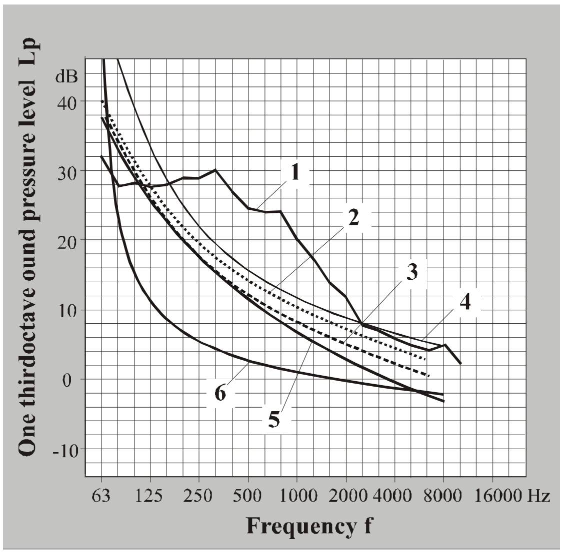


Fig. 15 Air conditioning noise levels

1	Festival hall Landau V=6900m³, Tm=1,5s, unoccupied	Lp=33,0 dB(A)
2	NR 15 Noise Rating Curve 15	Lp=25,0 dB(A)
3	NR 13 Noise Rating Curve 13	Lp=23,0 dB(A)
4	Permitted levels for TV studios ARD recommendation	Lp=29,0 dB(A)
5	NCB 10 according to Beranek für Radio- and recording studios, distance microphone recording	Lp=18,0 dB(A)
6	Permitted noise levels for drama studios, close pick up recordings IRT Recommendation	Lp=13,0 dB(A)

8 Warmth and Brilliance

Looking at the reverberation times of the hall, ratios can be defined between different parts of the frequency response curve of the reverberation time /10/. Warmth is the ratio of the reverberation times at low frequencies (average of the RT´s at 125 and 250 Hz) to the reverberation times at mid-frequencies (average of the RT's at 500 and 1000 Hz). For Landau with the RT's of Fig. 1 and for other halls the following ratios may be found with audience:

*	Landau	1,21
*	Berlin Schauspielhaus Concert Hall	1,23
*	Vienna Vereinsmusiksaal	1,10
*	Liederhalle Stuttgart	1,00
*	Berlin Philharmonic Hall	1,03
*	Multi-purpose Hall Oberursel	1.13
*	Pfälzische Philharmony	
	Ludwigshafen /12/	1.00
	unoccupied, without 280 chairs	0,83
*	Salzburg Festspielhaus	1,23
*	München Concert Hall Am Gasteig	1,00
Average		1.08

The longer the reverberation times are at low frequencies the warmer the hall sounds within the ratio and best values of 1,10 und 1,25 according to Beranek /10, page 513). Reverberation times should therefore be long enough at low frequencies to reach this sound in the hall.

Brilliance is the opposite. A room sounds brilliant when the reverberation times are longer at high frequencies. Brilliance is the ratio between the reverberation times at high frequencies (average of the RT´s at 2000 and 4000 Hz) and the reverberation times at mid-frequencies (average of the RT´s at 500 and 1000 Hz).

For some halls with audience the following ratios can be calculated:

*	Landau	0,85
*	Berlin Schauspielhaus Concert Hall	0,71
*	Vienna Vereinsmusiksaal	0,80
	unoccupied	0,77
*	Berlin Philharmonic Hall	0,86
*	Multi-purpose Hall Oberursel	0,88
*	Pfälzische Philharmony	
	Ludwigshafen /12/	0,94
*	München Concert Hall Am Gasteig	0,77
Average		0.82

Shorter reverberation times at high frequencies are usually due to many sound absorbing areas, curtains and boxes. Many sound reflections and therefore a longer RT at high frequencies of 2000 to 4000 Hz means the hall sounds bright and brilliant. Instead, the Vienna Vereinsmusiksaal has unoccupied only

0.77 /10/. In Landau it was attempted to avoid a strong roll-off at high frequencies. The ratio of 0.85 indicates the hall is near the avarage. The sound is brilliant. 0.94 for Ludwigshafen seems too high when additionally considering the high sound level of the orchestra as in Fig. 3. In Ludwigshafen curtains are adjustable to change the acoustics.

The Landau Festival Hall shoes the rise of the reverberation times at low frequencies to achieve warmth and a sufficiently long reverberation time at high frequencies for Brilliance.

9 Summery and outlook

The Landau Festival Hall has become again the old Jugendstil Hall, for which the people of Landau have been waiting for many decades. The former hall of 1908 had some acoustical problems, which were first solved with the remodeling in 1958. The stil of the 50's with its strongly directed sound was no longer a replacement for the great acoustics which were expected for the Jugenstil Hall. However everybody knew a compromise had to be found between concert and theater, between the great sound in a reverberant hall and the speech intelligibility. With the opening concert on 2002-01-12, it became clear this compromise was found. With a reverberation time of 1.44 s all acoustical parameters are positive. The hall has the Warmth and the Brilliance of sound. The hall sounds loud which increases the room impression. There is a great sound too for smaller orchestras. Diffuse sound fills the hall and covers the unavoidable echoes originating from back walls in 33-35 m distance. The acoustical reflectors are directing the sound towards the audience.

Computer work and the help of a 1:15 model in addition to measurements on absorbing products had to be carried out. Discussions followed and decisions had to be made. The Festival Hall of Landau has shown that a consequent planning with a team of experts can lead to a good result. The responsibility of everybody engaged is of importance and should be appreciated largely.

Acknowledgements:

The authors have to express their thanks to the colleagues of the Landau planning team, first the representative of the city, Mr. Pohlmann, then Mr. Leimbrock as the project manager. The contact to the architects of company Dissing and Weitling has been excellent, to Mr. Peters and Mr. Degele, thank you. Mr. Kern was the architect in situ to watch and control everything. We are grateful for the cooperative work. The same applies for Mr. Schlatter as housekeeper and man for everything representing the builder and user. The preservation of historic buildings was an important part of the total reconstruction. Many questions were discussed with Mr. Mienhardt and Mrs. Reitmeier, e.g. about the urfaces of walls and the ceiling.

The authors thank the colleagues in the IAB-Institute for Acoustics and Building Physics in Oberursel and Zweihausen. Mrs. Fischer was engaged in water protection and the heat insulation calculation certificate. Mr. Langlotz and Mr. Fischer have built he model in scale 1:15 for presentation in Landau. The authors congratulate the City of Landau and the Holding Company which handles all activities. Mr Jacobi was permanently present to enforce the work and the decisions. We wish the Landau Festival Hall a great success and an always happy audience.

Literature

/1/ Unbekannter Spender finanziert den ganzen Bau, Die Rheinpfalz Nr. 10 from 2002-01-12 (2002)

/2/ Scerri, A.: Centre sperimentale elektroacoustico Dr. Hermann Scherchen Gravesano, Gravesaner Blätter 1 (1955)

/3/ Voelker, E.J.: Akustische Behaglichkeit am Büroarbeitsplatz durch schalltechnische Simulierung Lärmbekämpfung 34 (1987

/4/ Cremer, L.: Die wissenschaftlichen Grundlagen der Raumakustik, S. Hirzel Verlag, Stuttgart (1950)

/5/ Weisse, K.: Raumakustik für Architekten, Verlag des Druckhauses Tempelhof, Berlin (1949)

/6/ Haas, H.: Über den Einfluß eines Einfachechos auf die Hörsamkeit von Sprache, Acoustica 1 (1951)

/7/ Thiele, R.: Raumakustische Untersuchungen in zahlreichen Konzertsälen und Rundfunkstudios unter Anwendung neuerer Meßmethoden, Acoustica Heft 2 (1956)

/8/ Kuhl, W.: Obtimale akustische Gestaltung von Räumen für Aufführenden, Zuhörer und Schallaufnahmen, Die Schalltechnik Nr. 20 (1959)

/9/ Die Festhalle im Wandel der Jahre, Die Rheinpfalz Nr. 187 (1992)

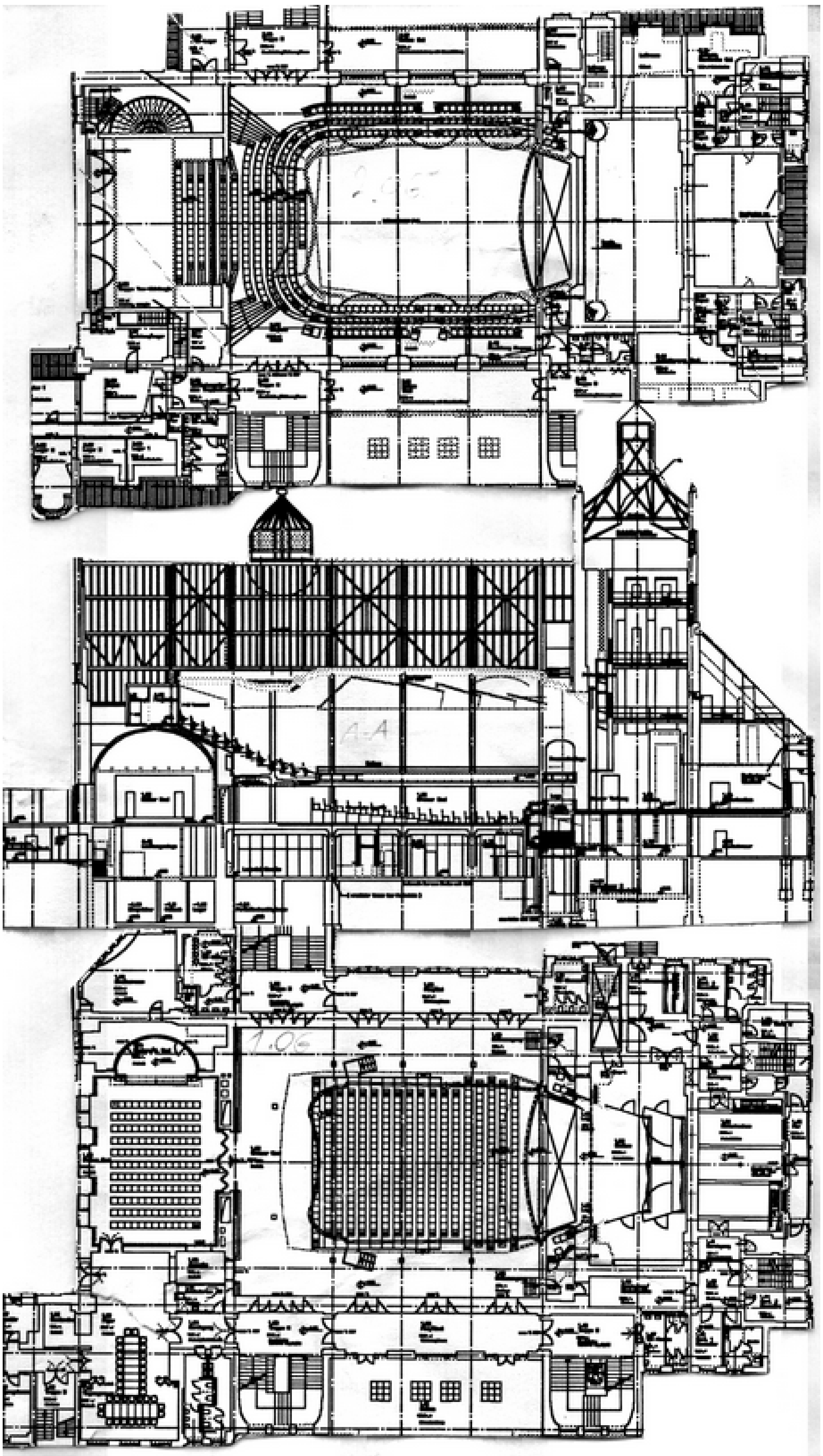
/10/ Beranek, L.: Concert and opera halls - How they sound, Acoustical Society of America (1996)

/11/ Meyer, J.: Raumakustik und Orchesterklang in den Konzertsälen Joseph Heydns, Acustica Nr. 3 (1978) S. 145-162

/12/ Voelker, E.J.: Zur Akustik der Phälzischen Philharmonie für Proben, Konzerte, Tonaufnahmen für Hörfunk und Fernsehen, DAGA in Bad Honef (1986)

/13/ Kuhl, W.: Über Versuche zur Ermittlung der günstigsten Nachhallzeiten großer Musikstudios, Beiheft 2 zur Acustica Heft 4 (1954)
/14/ Voelker, E.J.: The alteration of the reverberation times in a small theater and a concert hall using loudspeaker equipment, AES Convention in Los Angeles (1971) preprint 785
/15/ Johnson, R.: Acoustics for music performance, Musical America (1960)
/16/ Cremer, L.: Die raum- und bauakustischen Maßnahmen beim Wiederaufbau der Berliner Philharmonie, Die Schalltechnik Nr. 57 (1964)
/17/ Leif Segerstam, interview on March 7, 1987, Die Rheinpfalz (1987) (A13248)
/18/ Voelker, E.J. and Teuber, W.: Zu Schallpegeln am Kopf - Grenzwerte für qualitatives Abhören, DAGA in Bochum, Fortschritte der Akustik (2002)
/19/ Heyser, D.: Acoustical measurements by Time Delay Spectrometry, JAES 15 (1967), p. 370-382
/20/ Voelker, E.J., Teuber, W.: Anwendung der Time Delay Spectrometry bei bauakustischen Messungen, DAGA, Fortschritte der Akustik (1991)
/21/ Kuhl, W.: Räumlichkeit als Komponente des Raumeindrucks, Acustica 40 (1978)
/22/ Voelker, E.J.: Zur Akustik von Orchester-Probenräumen, DAGA in Bad Honnef, Fortschritte der Akustik (1988)
/23/ Völker, E.J.: Zur Bedeutung der ersten 15ms bei der Beurteilung von Schallaufnahmen im Regieraum, Dissertation an der Technischen Universität Berlin, Nr. D8 (1996)
/24/ Völker,E.J.,Teuber,W.: Some acoustical aspects for sound system design in churches, 96th AES ConventionAmsterdam (1994) preprint
/25/ Institut für Akustik und Bauphysik, Oberursel und Zweihausen, Prüfzeugnisse über Messungen an Putzflächen und Stühlen (2000)
/26/ Cremer, L.: Early lateral reflections in some modern concert halls, JASA 85 (1989)
/27/ Voelker, E.J., Langlotz, T.: Über Modelle als Entscheidungshilfe für raumakustische Maßnahmen, DAGA 2001 in Hamburg, Fortschritte der Akustik (2001)
/28/ Beranek, L: Subjective Rank-Orderings and Acoustical Measurements for Fifty-Eight Concert Halls, Acta Acoustica Vol 89 (2003) 494-508
/29/ Reichardt, W., Lehmann, U.: Raumeindruck als Oberbegriff von Räumlichkeit und Halligkeit, Ertläuterungen des Raumeindrucksmaßes R, Acustica, Vol 40 (1978) Nr. m5

Attachment:
Ground plan and cross-section of Festhalle Landau



Attachment A

Ground plans and cross-section of the Landau Festival Hall

Opening 2002-01-12
1041 seats
6900m³ Volume
Medium Reverberation time 144s occupied with 60 musicians on the stage

Built: 1908
First reconstruction 1958
Last reconstruction: 1997-2002

Heat Insulation Certificate of 1995 standard
Sound isolation from neighbourhood