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ACOUSTIC DESIGN OF THE OVAL HALLS

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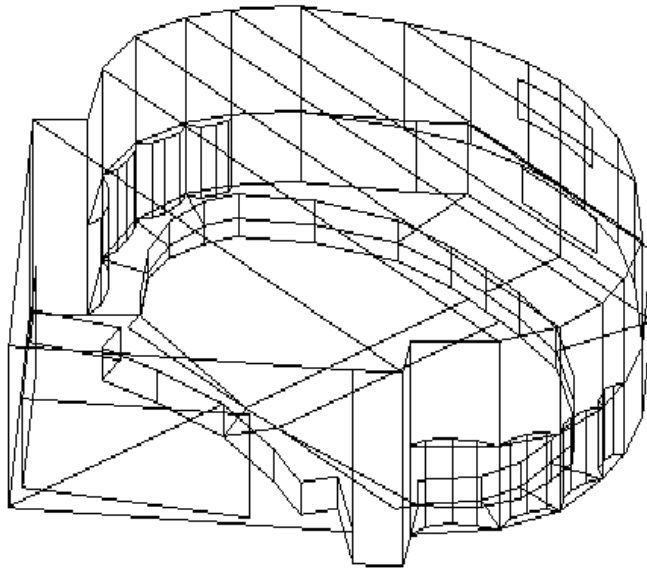
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It is well known that the concave form of the hall's plan is unsuccessful from the acoustic point of view. Such forms usually lead to a lot of difficulties during the acoustic design. There are presented the results of the design of two small halls. Both halls had an ellipse – like plan that could not be changed due to architectural demands. The results of the acoustic design are given. They include solutions on the extraction of the sound reflections from the concave walls that may cause the concentration of sound. In the first hall they were based on the usage of both the sound scattering constructions and the sound absorbing materials. It was not possible to use the sound scattering constructions in the second hall due to architectural demands. So only sound absorbing materials were selected and placed on the walls in an optimal way. Acoustic measurements (RT60, C80, RASTI, impulse response, ETC) were done in the first hall when it was ready. The results of these measurements lead to the conclusion that the acoustic design of the hall was done properly. The concentration of sound and echo are not perceptible.

Many halls have not proper forms for good acoustics that is estimated by the architect at the primary stage of their design. Such situation is rather common in the practice of the acoustic design. The most typical case is the large concave surfaces that are necessary to the architect for the embodiment of his creative work. It is necessary in such cases to find the optimal compromise solution that fulfill both architectural and acoustic requirements. Usually it deals with the preservation of common form of the concave surfaces and the usage of special measures to obtain the good sound quality. Such measures are well known. In most cases they deal with the placement of the sound scattering constructions or the sound absorbing materials on the concave surface which may cause concentration or echo. The exact solution depends on the architectural requirements to the hall's interior and many other facts. Two examples of the acoustic design of small halls with ellipse – like plan will be presented in this work. They deal with the usage of both the sound scattering constructions and the absorbing materials.

First hall is in the new building of the cultural center that belongs to the department of the diplomatic service (DDS) in Moscow. This hall has a plan in form of an ellipse with a stage in form of a triangle. There are 250 seats in the central part of the hall. The hard chairs may be removed, and the central [part with a parquet floor can be used for dancing. The narrow “gallery” runs along the walls of the hall. It is divided from the seat area by a barrier. The room should be used as a multipurpose hall for musical concerts, conferences, dancing, etc. The maximal width of the hall is equal to 18.5 m; the length from the edge of the stage to the back wall is equal to 12 m; the maximal height from the floor in the seat area to the flat ceiling – 6.6 m. The volume of the hall that includes the volume of the stage is 1534 m³. The view of the hall is given in Fig. 1. It is printed from the acoustic computer model that was used for the design of the room. One version of the sound scattering constructions on the walls is shown in this figure as well.

The main purpose of the hall was to provide concerts of the chamber music (without sound reinforcement). This item was estimated at the beginning of the design by the customer. So it was decided

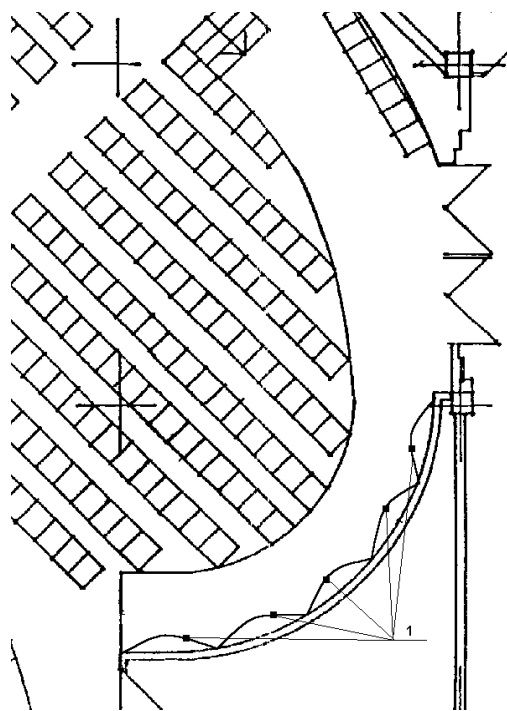


The view of the hall DDS.

to obtain in the occupied hall the values of reverberation time at the middle frequencies $RT_{60} \sim 1.1$. The calculated values of RT_{60} are given in row 1 of table 1. The main problem of the acoustic design was to minimize the concentration of sound caused by the concave walls. Many versions were analyzed. The customer refused for financial and architectural reasons to use the "digital" Schroeder sound scattering constructions that are manufactured by several companies (RPG, USA for example). It was decided at last to place at the low parts of walls the sound scattering constructions in form of polycylinder. **Fig. 1.**

Table 1. The values of RT_{60} , s.

	Frequencies of the octave bands	125	250	500	1000	2000	4000
1	Calculated for the concert version (occupied hall DDS)	1.29	1.26	1.08	1.06	1.04	1.00
2	Calculated for the speech version (occupied hall DDS)	0.76	0.66	0.64	0.65	0.63	0.61
3	Measured in the empty hall DDS	0.82	0.75	0.75	0.73	0.73	0.72
4	Calculated for the occupied cinema hall	0.63	0.53	0.44	0.42	0.40	0.40



The position of these constructions is shown in Fig. 2. They were made of the curved gypsum board and mounted on the special frame. The maximal projection of these polycylinders upon the surface of the walls was equal to 400 mm. The sound absorbing materials were placed on some other parts of the concave walls. They were covered by acoustic transparent grating. The suspended ceiling of the room was made of the gypsum board. The sound absorbing panels were placed on 40 m² of the ceiling's area.

Fig. 2. Hall DDS. Fragment of the plane. 1 – sound scattering constructions on the walls.

was found necessary to enlarge greatly the area of the sound absorbing panels on the ceiling on the hall in order to satisfy the mentioned demands of the customer. It was also proposed to use heavy up-

holstered chairs instead of the hard ones. The walls were left without any changes. The estimated values of RT60 according to this new version are shown in row 2 of table 1.

Acoustic measurements were done in the hall after it had been ready. They were done with the help of MLSSA system manufactured by DRA, USA. The measurement were made without the sound reinforcement when the sound source was placed on the stage, and with sound reinforcement system being switched on. In the last case MLS signal was send to the line input of the system and may be connected to any loudspeaker. All measurements were done in an empty hall. The measured values of RT60 (see row 3 in table 1) after correction on the presence of audience are found close to the calculated values. The measured values of C80 were from +1 dB to +7 dB at the middle frequencies. Such results are quite typical for a relatively small hall with low values of RT60. Some examples of the measured impulse responses are shown in Fig. 3. It was estimated from the measured ETC that there is no high level sound reflections that can form the concentration of sound. The irregularity of the sound field in various octave bands is not more than 5-6 dB when the sound reinforcement system is switched on. The sound quality in the hall was found to be good. Echo from the concave walls is not perceived.

Table 2. RASTI values in hall DDS.

Position of the Microphone in the seat's area	Sound reinforcement is switched on	
	The central acoustical system above the stage is switched on	The central acoustical system and the systems on the sides of the stage are switched on
1	0.78	0.76
2	0.81	0.78
3	0.76	0.76
4	0.73	0.73
5	0.71	0.73

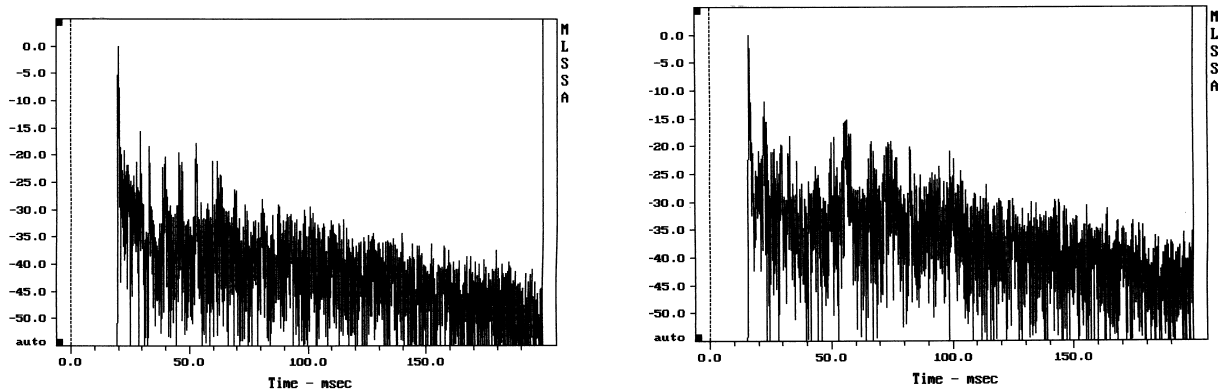


Fig. 3. ETC measured in 2 points of the seat's area in hall DDS. The sound source is on the stage.

The second room is a small cinema hall in the building N 38 at the territory of All-Russia Exhibition Center in Moscow. This hall had to be renovated for the new sound system in DOLBY surround format. The view of the hall is shown in Fig. 4 that is also printed from the acoustic computer model. There are 150 seats in the hall. The plan of the hall has a form of an exact ellipse. The large axis of ellipse (hall's width) is equal to 17 m, and the small axis (hall's length) is equal to 13.3 m. The ceiling is flat and is located 5.5 m above the central part of the seat's area. All the surfaces of the walls are covered with stone (travertine). The customer and the architect noted that: (1) the quantity of the seats should not be lower than 150; (2) it is not possible to remove the stone from the walls and the width of any construction above it should not be more 50-70 mm; (3) the walls and the ceiling of the hall after it's renovation must look like smooth surfaces. It was not possible to use sound scattering constructions at the walls due to such demands. As a result of the acoustic design the following solution was estimated. The frame was mounted on all the surfaces of the walls and the ceiling. Mats of rockwool were placed inside the frame. Some areas of these mats were covered by a thin 4 mm plate. It was done to obtain the required value of sound absorption at low frequencies. Such panels were placed at

the surfaces that not cause the concentration of sound at the seat's area. Their exact placement was estimated by the calculations on the acoustic computer model.

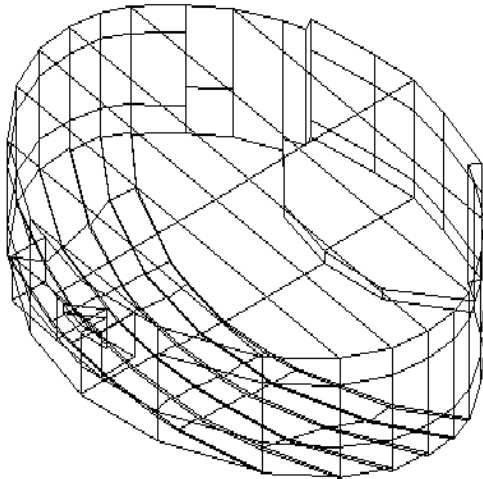


Fig. 4. View of the cinema hall.

The stretched ceiling was proposed for mounting under the frame with mats on the ceiling. For this ceiling acoustic transparent perforated synthetic membrane was chosen. All the walls were covered by color acoustic transparent curtain. It was mounted above the frame with mats on the walls. It was not possible of course to exclude at all the concentration of sound due to such solution. But the levels of sound reflections that cause the concentration from the walls were

decreased. One example is given in Fig. 5. The structures of sound reflections were calculated by imaginary source method for the 3-th order. The sound source was the central screen loudspeaker system, and the receiver was placed in the side part of the seat's area. The response on the left corresponds to the existing stone wall, and the response on the right to the proposed acoustic solution. The groups of sound reflections that course the concentration of sound (see digits 1,2) are highly decreased in the last case, and echo is not expected to be heard. The calculated values of RT60 are shown in row 4 of table 1. They correspond to THX requirements.

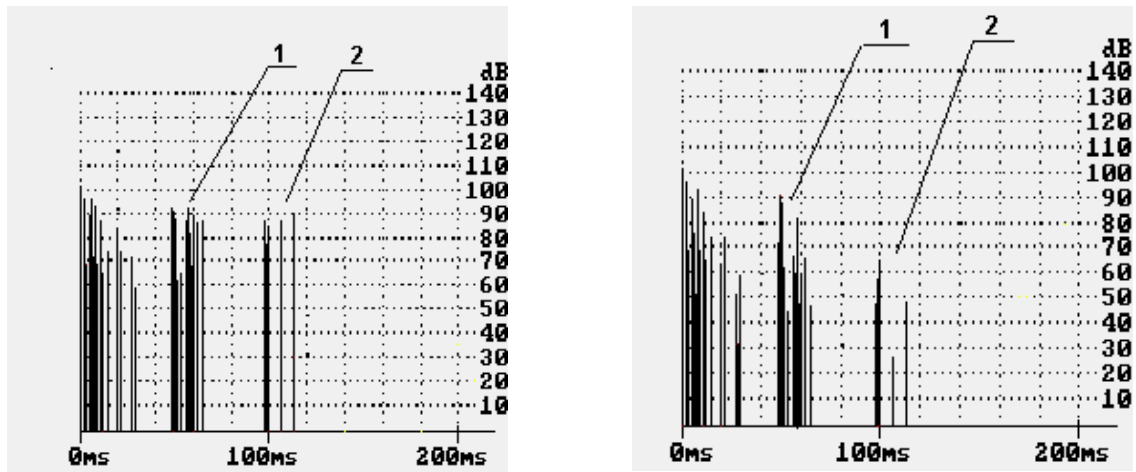


Fig. 5. Calculated structures of sound reflections (3-th order). Groups of sound concentration are marked by digits 1, 2. Left – stone wall; right – sound absorbing materials due to proposed acoustic solution. Octave band 1000 Hz.