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Acoustic characteristics of concert hall Zaryadye in Moscow

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ABSTRACT

In the autumn of 2019, a new concert hall Zaryadye for 1578 seats was opened in Moscow; it was designed and built in less than four years. The peculiarity of the architectural solution of the hall is its location in the underground space of an artificial hill in Zaryadye Park in the Centre of Moscow. The hall is used for concerts in the mode of natural acoustics and for concerts with using PA system. It also has the ability to transform the floor level of the stalls.

Keywords: concert hall, architectural acoustics, acoustical parameters, reverberation time, bass ratio

1. INTRODUCTION

Zaryadye concert hall with a capacity of 1,578 spectators was opened in Moscow on September 2018. The hall was built in 30 months; it is situated in the city center, on the site of the demolished hotel "Rossiya", on the embankment of the Moscow River, half a kilometer from the Kremlin and Red Square. Initially, the hall was planned to be used only for the performance of symphonic music, and the highest demands on its acoustic characteristics were placed. But, considering the favorable location of the hall and the high requirements of society for musical art, the management of the project decided to use it as a multifunctional hall for concerts of both classical music performed by the orchestra and popular music using sound amplification system.

Concert Hall Zaryadye became the fourth hall in Moscow, where concerts of the highest level are held. In addition to Zaryadye, there is the Great Hall of the Moscow Conservatory (capacity 1,737 seats), the Great Hall of Moscow Philharmonic named after P. Tchaikovsky (capacity 1505 seats) and the Svetlanov Hall of the Moscow International House of Music (capacity 1699 seats).

2. Architectural solution of the hall

2.1 Space-planning solution of the hall

At the initial stage, the architects of the hall have adopted as the prototype the visual image of the new Philharmonie de Paris: the first Zaryadye hall plan was a shape close to an oval. The tiers of balconies and lodges in the form of terraces/vineyards were envisioned, the balcony fencing resembled fluttering ribbons. After the first correction of the form by acoustic consultants of the “Acoustic Group” company, the hall was narrowed and stretched as much as it was possible, without reducing the capacity of the hall and observing the requirements for the area and width of the stage, taking into account the limitations of the building spot. The hall in the plan began to represent a compromise between the oval and the rectangle. The height of the hall was also raised to the possible maximum. The height of the hall was limited by the height of the artificial hill of Zaryadye Park, in which the volume of the hall was placed. The height of the hill, in turn, is limited by the height of the towers of the Moscow Kremlin. At the same time, the number of spectator seats behind the stage was reduced to 5 rows, the shape of the ceiling was optimized to reflect the maximum part of sound energy by the ceiling area towards the seats.

During the construction process, “NAGATA ACOUSTICS” was involved as an acoustic consultant, which made additional adjustments to the planning solution and proposed finishing materials. After changes, the total length of the hall was 52.3 m, the length to the proscenium was 31.2 m, the average width was 31.5 m, and the average height was 15.2 m.

Fig. 1 shows photographs of the finished hall: view from the front and rear walls. Fig. 2 shows plans (1^{st}, 2^{nd}, 3^{d} levels) and the longitudinal section of the hall.

Figure 1 – Views of the hall

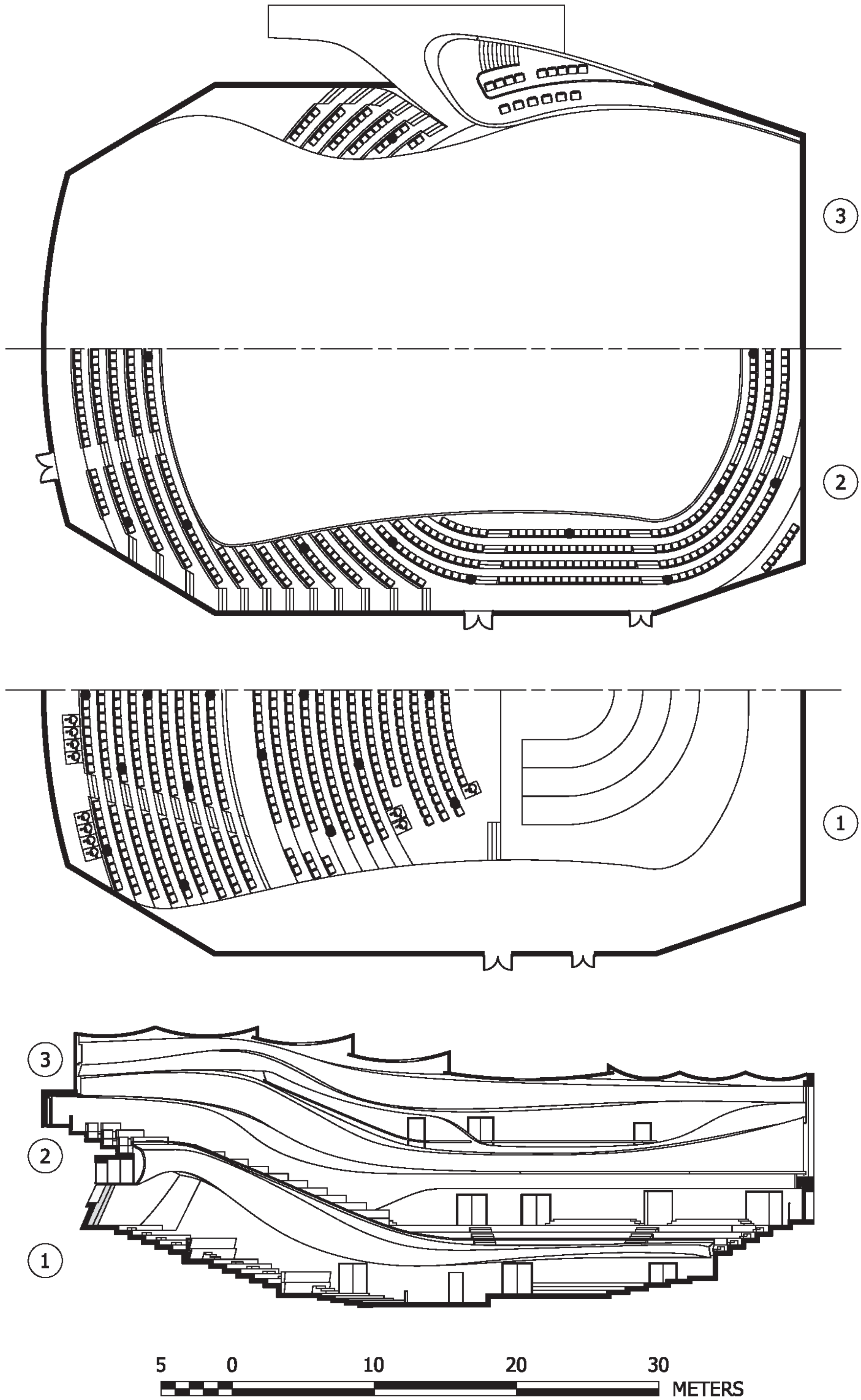

Figure 2 – Plans and the section of the hall. The receiver positions during acoustic measurements are depicted by black dots.

2.2 Interior finish

The walls of the hall were decorated with 3D panels from solid oak and mahogany, massive gypsum panels, panels from MDF boars and CBPB. The surface density of wall finishing materials is 30 - 120 kg/m^2. Massive gypsum panels with a surface density of 120 kg/m^2 were used in the decoration of the ceiling. Fig. 3 schematically shows the types of wall and ceiling decoration materials.

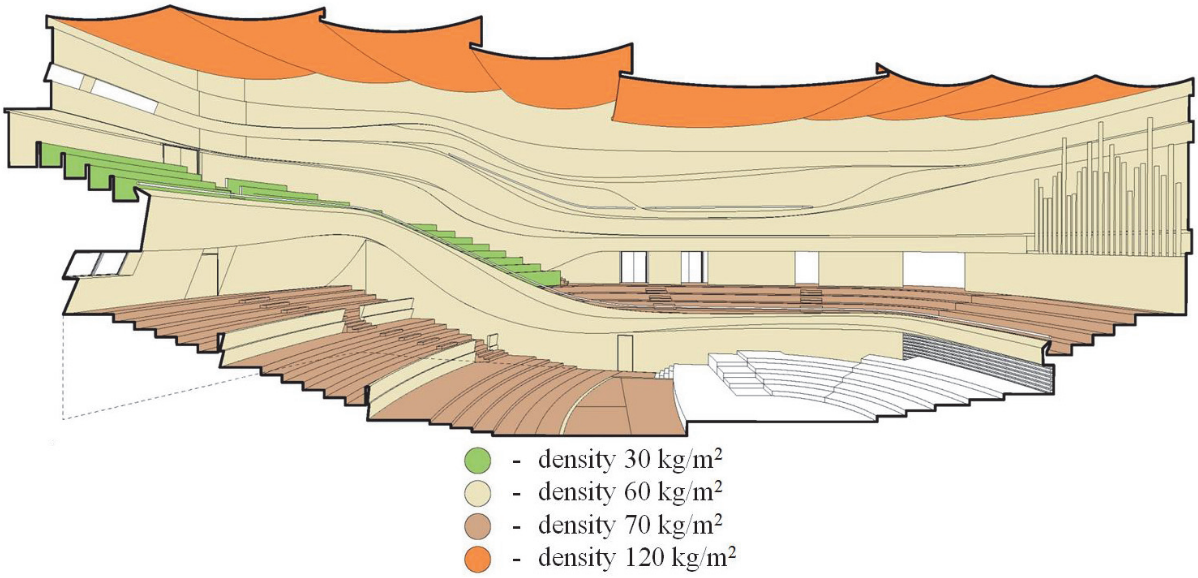

Figure 3 – The surface density of the finishing materials used in the interior of the hall

In the decoration of the floor of the stage and the orchestra pit, a massive board of softwood on the wooden joists was used. Parquet was used in the decoration of the floor of the hall.

Proposals of the acoustic consultants for the use of a mechanical variable acoustic interior finishing system to make changeable acoustics of the hall were not implemented.

3. Results of measurements of the acoustic characteristics of the hall

On February 18, 2019, “Acoustic Group” engineers performed acoustic measurements in the finished hall Zaryadye. The measurements were carried out in unoccupied hall according to the standardized procedure regulated by the ISO 3382 [1]. An omnidirectional sound source (dodecahedron) was located on the stage, 25 spectral points were chosen on the spectator seats, evenly distributed over the ground and balconies, in which impulse responses were measured. Figures 2 and 4 shows the receiver positions and process of acoustic examination of the hall.

Figure 4 – Acoustic examination of the hall

To evaluate the acoustic properties of the hall, the following acoustic parameters were selected and measured:

1. Reverberation time RT, s – It is the time that passes after an acoustic source in a room has been turned off until the mean steady-state sound-energy density decreased by 60 dB.

2. Early Decay Time EDT, s – It is the time that passes after an acoustic source in a room has been turned off until the mean steady-state sound-energy density decreased by 10 dB.

3. Clarity of music C_{80}, dB – it is the ratio of the energy in the first 80 ms of an impulse sound arriving at the listener’s position divided by the energy in the sound after 80 ms.

4. STI speech transmission index – a parameter characterizing speech intelligibility, ranging from 0 to 1.

The STI speech intelligibility index and uneven distribution of the sound field energy were also measured using a PA system in the hall. In this case, the test signal was applied to the PA system.

The results of measuring the acoustic parameters RT, EDT, and C_{80} averaged over different zones and averaged in the hall are presented in Fig. 5 and in Table 1.

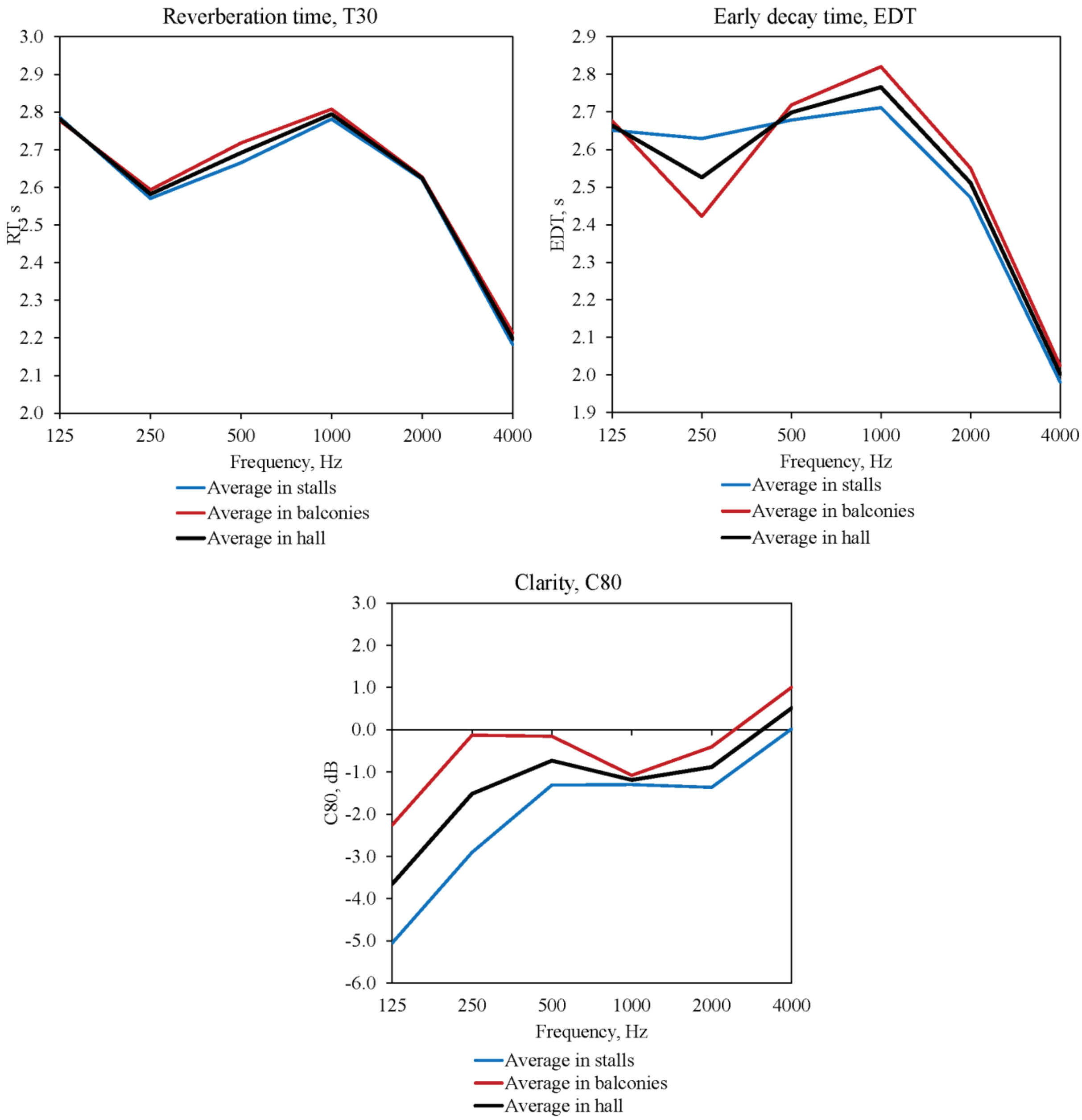

Figure 5 – Acoustic measurement results in the unoccupied hall

Table 1 – Results of the acoustic measurements in an unoccupied hall

Parameter	Acoustic parameters in octave frequency bands, Hz					
	125	250	500	1000	2000	4000
RT, s	2.78	2.58	2.69	2.79	2.62	2.20
EDT, s	2.66	2.53	2.70	2.77	2.51	2.00
C_{80}, dB	–3.7	–1.5	–0.7	–1.2	–0.9	0.5

In accordance with the measurement results, the RT reverberation time at medium frequencies was 2.69 – 2.79 s. The parameter BR (Bass Ratio) was 0.98 in the unoccupied hall. The decay time of early reflections at medium frequencies was 2.70 – 2.77 s, the musical clarity index C_{80} at medium frequencies was about –1 dB.

The STI speech intelligibility index, measured using an omnidirectional sound source on stage, averaged over the audience, was 0.44, which corresponds to satisfactory speech intelligibility. The STI speech intelligibility index, measured using a PA system, averaged over spectator seats, was 0.48, which also corresponds to satisfactory speech intelligibility. The values of the uneven distribution of the sound field energy, when using a PA system are presented in Table 2. As a reference value, the impulse response measured in the stall along the central axis of the hall is selected. In accordance with the measurement results, the unevenness of the sound pressure level from the operation of the PA system does not exceed 6 dB, which is a good indicator.

Table 2 – Sound field unevenness measurement results

Deviation	Sound field unevenness, dB, in octave frequency bands, Hz					
	125	250	500	1000	2000	4000
Maximum deviation	1.3	1.1	1.4	2.5	3.1	3.8
Minimum deviation	–3.7	–3.7	–2.8	–0.9	–1.7	–1.7
Unevenness	5.0	4.8	4.2	3.4	4.8	5.5

4. Comparative analysis of measurement results

Table 3 shows the comparative characteristics of Zaryadye Hall and other well-known halls of similar functional purpose, volume and capacity. There are several halls of a shoebox shape among them - the Great Hall of the Moscow Conservatory (Moscow, Russia), Musikvereinsaal (Vienna, Austria) and Concertgebouw, (Amsterdam, Netherlands), as well as vineyard forms - Berlin Philharmonie (Berlin, Germany), Elbphilharmony (Hamburg, Germany) and Philharmonie de Paris (Paris, France).

Table 3 – Geometric parameters of the halls

Hall	V, m^3	V per pers., m^3	N	L, m	W, m	H, m	L/W/H
Zaryadye hall	25900	16.4	1578	31.2	31.5	15.8	2/2/1
Great Hall of the Moscow State Conservatory [2]	15700	9.0	1737	42.7	21.5	17.8	2.5/1.3/1
Musikvereinsaal [3]	15000	8.9	1680	35.7	19.8	17.4	2/1.1/1
Concertgebouw [3]	18780	9.2	2037	26.2	27.7	17.1	1.5/1.6/1
Berlin Philharmonie [3]	21000	9.5	2218	29.0	42.7	12.8	2.2/3.3/1
Elbphilharmonie [4]	24000	11.4	2100	30.0	40.0	20.0	1.5/2/1
Philharmonie de Paris [5, 6]	36000	15.0	2400	32.0	40.0	22.0	1.5/1.8/1

Table 3 uses the following terminology: V – air volume of the hall, V per pers. – air volume per person, N – number of seats, L – average room length (measured from the stage front to the back wall), W – average width of the hall, H – average height of the hall. As can be seen from table 1, the air volume of the Zaryadye hall (both full and per person) is between the halls of Elbphilharmony and Philharmonie de Paris, at the same time, the length / width / height ratio of the hall (L/W/H) is closer to the parameters of the classical Concertgebouw Hall.

Table 4 shows the RT (Reverberation time, s) and Bass Ratio (BR) for the selected halls. The RT and BR values are given for occupied halls. For Zaryadye hall, a recount of RT for filling by the audience was completed according to the method [7].

Table 4 – Acoustic parameters of the occupied halls – RT (in octave frequency bands) and BR

Hall	125	250	500	1000	2000	4000	BR
Zaryadye hall	2.28	2.12	2.02	1.95	1.82	1.57	1.11
Great Hall of the Moscow State Conservatory [2]	2.40	2.30	2.20	2.00	1.90	1.80	1.12
Musikvereinsaal [3]	2.25	2.18	2.04	1.96	1.80	1.62	1.11
Concertgebouw [3]	2.20	2.15	2.05	1.95	1.80	1.55	1.09
Berlin Philharmonie [3]	2.10	1.85	1.85	1.95	1.80	1.60	1.04
Elbphilharmonie [4]	2.30	2.30	2.30	2.20	2.10	1.80	1.02
Philharmonie de Paris [5]	2.70	2.65	2.50	2.45	2.30	2.00	1.08

Figure 6 shows the values of the reverberation time at medium frequencies (500 Hz and 1000 Hz) for the halls selected for comparison, depending on their air volume. A direct line is also shown in Fig. 5 is the recommended values for symphonic music halls from the Russian standard [8]. It follows from the graph that the reverberation time in the Zaryadye concert hall with the public complies with the recommendations [8], and it is also close in its values to the reverberation time in the concert halls Concertgebouw, Berlin Philharmonie and Musikvreinsaal [3].

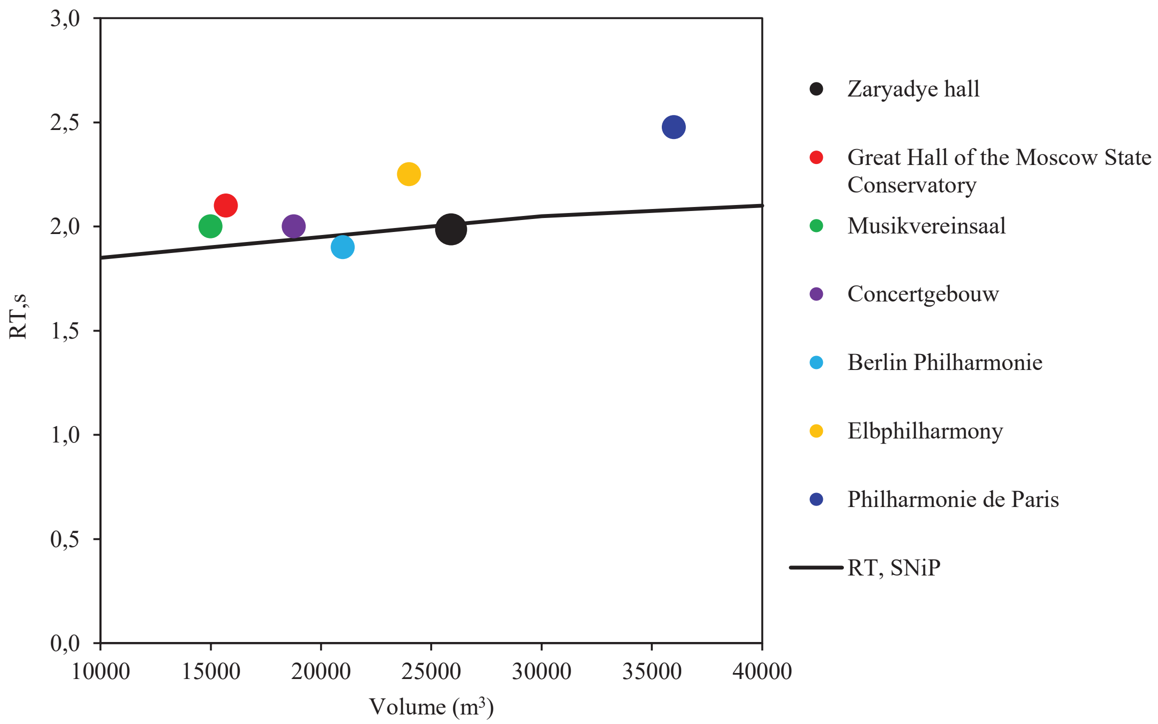

Figure 6 – Comparison of RT in different halls

Thus, thanks to a good space-planning solution and selection of finishing materials, the acoustics of Zaryadye Hall occupies a rightful place among the world-wide recognized concert halls.

During the year of operation, dozens of concerts of classical music without sound amplification and variety music with the use of a sound reinforcement system took place in the hall. In general, the hall received a good acoustic rating. Especially flattering reviews received concerts with a large composition of the orchestra. The acoustic quality of concerts with sound reinforcement depends, among other things, on the tuning of sound reinforcing equipment.

5. CONCLUSIONS

The article presents the results of measurements of the acoustic parameters of the new Zaryadye hall, opened in 2018 in the center of Moscow. The hall received a high acoustic rating, both in terms of objective acoustic parameters and subjectively according to the results of surveys of listeners and artists. Comparison of the acoustic parameters of the Zaryadye Hall with the acoustic parameters of other well-known concert halls with recognized acoustics shows that the acoustics of the Zaryadye Hall occupies a rightful place among the world concert halls.

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