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3aAAb7. Acoustic evolution of the Moscow Conservatory Great Hall after renovation in 2011

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The Great Hall of the Moscow P.I. Tchaikovsky Conservatory is one of the best concert halls in Russia. Its acoustics is appreciated very much by both musicians and audience. In 2011 the Great Hall was renovated, after renovation its acoustic conditions remained at very high level that was confirmed by means of objective impulse response measurements and subjective estimations. In order to control how acoustic conditions are changing with time the observation of main acoustic parameters is carrying out with half year gaps. In this work we present the results of four measurements fulfilled in June 2011 (just after the renovation), December 2011, June 2012 and December 2012. The reverberation time decreases at low frequencies, whereas it is stable at middle frequencies. Periodic variations of the reverberation time take place at high frequencies. These variations are probably connected with seasonal changes of temperature and humidity conditions in the hall. Changes of other acoustic parameters correlate to the reverberation time.

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INTRODUCTION

The acoustics evolution of concert halls seems to be an actual problem of modern architectural acoustics, although there are few publications on this subject. Usually changes in hall acoustics are documented after renovation or tuning actions in operating halls. But the long-term behavior of acoustics is not investigated systematically. It is possible to compare results of acoustic measurements of any hall carried out at different times, some data for such analysis can be found, for example, in [1]. However we cannot be fully confident that these measurements were fulfilled under the same condition and by means of the same procedure.

Acoustic evolution in the initial stage of hall exploiting is of particular interest. In new or renovated halls finishing material can change their properties due to natural aging. For example, the plaster can emit excess moisture, the wooden elements of constructions have to adapt themselves to new conditions. It may result in changes of the absorbing properties of some surfaces. But the value of these changes and their characteristic times are not known.

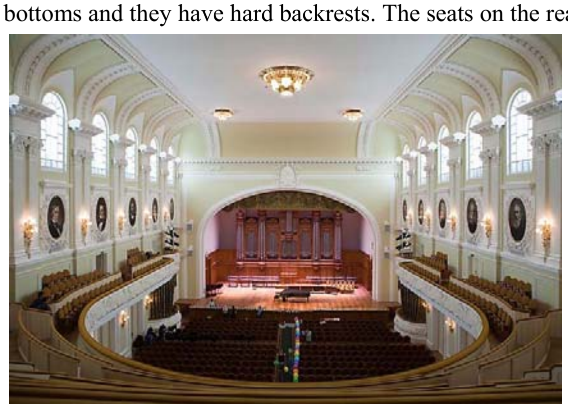
The Great Hall of Moscow Conservatory was renovated in 2010-2011. It gave an opportunity to control its acoustic changes during the first years after the renovation. It was decided to measure acoustic parameters of the Great Hall with half a year intervals. Today we have results of four measurements, which are presented in this paper. Here we report only about evolution of the acoustic parameters, but we do not investigate its nature. In addition acoustic changes due to the renovation are described and the reverberation time values measured in 1989 and 2009 are compared.

DESCRIPTION OF THE GREAT HALL

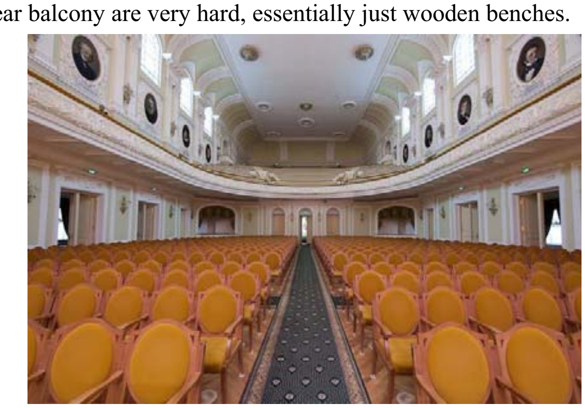
The Great Hall of Moscow Conservatory is one of the famous concert venues in Russia. Its wonderful decoration and acoustics are the qualities that characterize its uniqueness. The Hall was opened on the 7 April. 1901. The building and the Hall were designed by architect V. Zagorsky. The organ Cavaille-Coll installed in the Hall was regarded as one of the best in the world during the Paris exhibition of 1900. The organ is successfully used until now. International festivals and competitions take place in the Great Hall, and among them is the famous Tchaikovsky competition. Best soloists, orchestras and ensembles perform here.

The Great Hall is basically a shoe-box form, with one, very deep rear balcony and side balconies extending to about 3 m from the stage front. The overall length of the Hall (from the organ to the back wall) is 56 m, from the edge of the stage to the back wall is 45 m. The overall width of the Hall is 21.8m and its width between the side balconies is 17 m. The height of the auditorium itself is 17.7 m. The height of the stage is 1.2 m. The depth of the stage is 10.7 m, it was measured from the edge of the stage to the front of the organ. The width of the stage-house is 17.4 m and the height of the stage house is 11 m. As for the seat number, there are 1737 seats in the Great Hall.

The interior of the Hall is made of materials which were traditional for the beginning of 20th century. Pinewood boards nailed to wooden beams form a flat ceiling. The boards are glued over with cotton canvas which is covered with several layers of oil-bound paint. The brick walls are plastered up with a complex mortar. There is a lot of plaster decor on the walls. The seats in the parterre and on the side balconies have a very light upholstering on the bottoms and they have hard backrests. The seats on the rear balcony are very hard, essentially just wooden benches.



(a)



(b)

FIGURE 1. View from the balcony towards the stage (a) and from the beginning of the parterre towards the balcony (b).

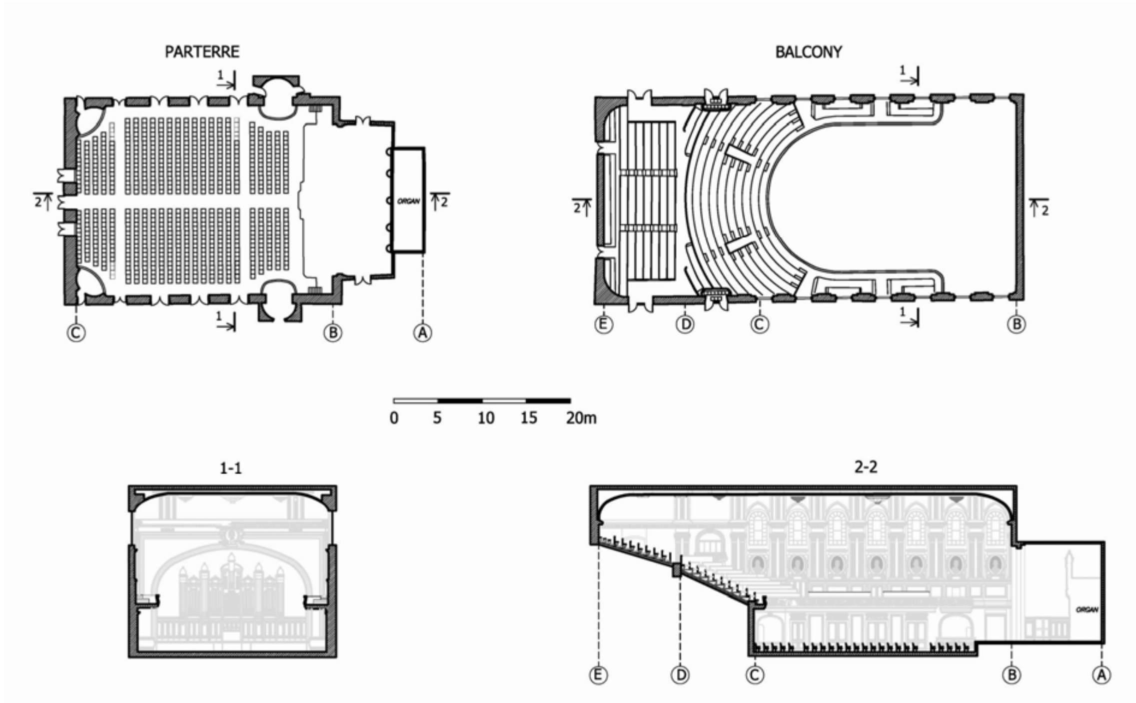


FIGURE 2. Plans and sections of the Great Hall.

The subjective acoustic quality of the Great Hall was investigated in 2009 by questionnaires to both audience listening panel and to members of orchestra during one concert and one rehearsal [2]. The results quite clearly showed that the acoustic conditions in the Hall are evaluated as good, both from the audience and from the musicians' point of view.

Acoustics parameters of the Great Hall were measured in 1989 [3], 2009 [2] and 2011 [4].

ACOUSTICS EVOLUTION

We have an opportunity to observe some acoustics changes of the Great Hall. First of them is connected with long-term behavior of acoustics. Due to the measurements carried out with twenty year interval [2,3] acoustics parameters changes can be found. Second change of acoustics took place after global renovation in 2011 [4]. The main goal of this work is an investigation of acoustics evolution after renovation of the Great Hall.

Changes from 1989 to 2009

Results of acoustic measurements in the Great Hall were published only in two papers. First measurement was carried out by Research Institute of Building Physics (Russia) in 1989 [3]. Then in 2009 Akukon Oy Consulting Engineers (Finland) explored the Great hall before renovation [2]. On the basis of their results we can compare the reverberation time RT. As far as we know there were some minor repairs of the Great Hall during this period. These repairs included painting the ceiling and the walls, replacement of upholstering on the seats, restoration of ornaments. It seems the repairs did not result in significant changes of the Hall's acoustics.

In Fig. 3 the reverberation time in the unoccupied hall is shown. We can see that the difference of the reverberation time at frequency range 250-1000 Hz is within 5%. This variation is not significant; furthermore it can be connected with different measurement techniques. At low and high frequencies one can find essential distinctions. The reverberation time at 125 Hz was reduced by 19%. According to [2] it is possible that the acoustic properties of the parterre floor were changed over 20 years. At 2000 and 4000 Hz the reverberation time was reduced by 15 and 37% respectively which seemed to be connected with changes of the ceiling and walls properties.

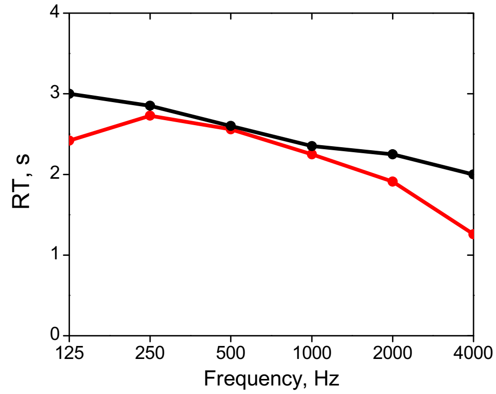


FIGURE 2. Comparison of the reverberation time measured in the Great Hall in 1989 (black line) and 2009 (red line).

Acoustics after Renovation in 2011

By the beginning of 21st century the Great Hall demanded a global renovation and reconstruction. The bearing structures of the balcony were close to damage, the parquet floor needed to be renewed, the interior details had to be restored. The renovation started on May, 2010 and finished on June, 2011. Detailed description of the renovation one can find in [4].

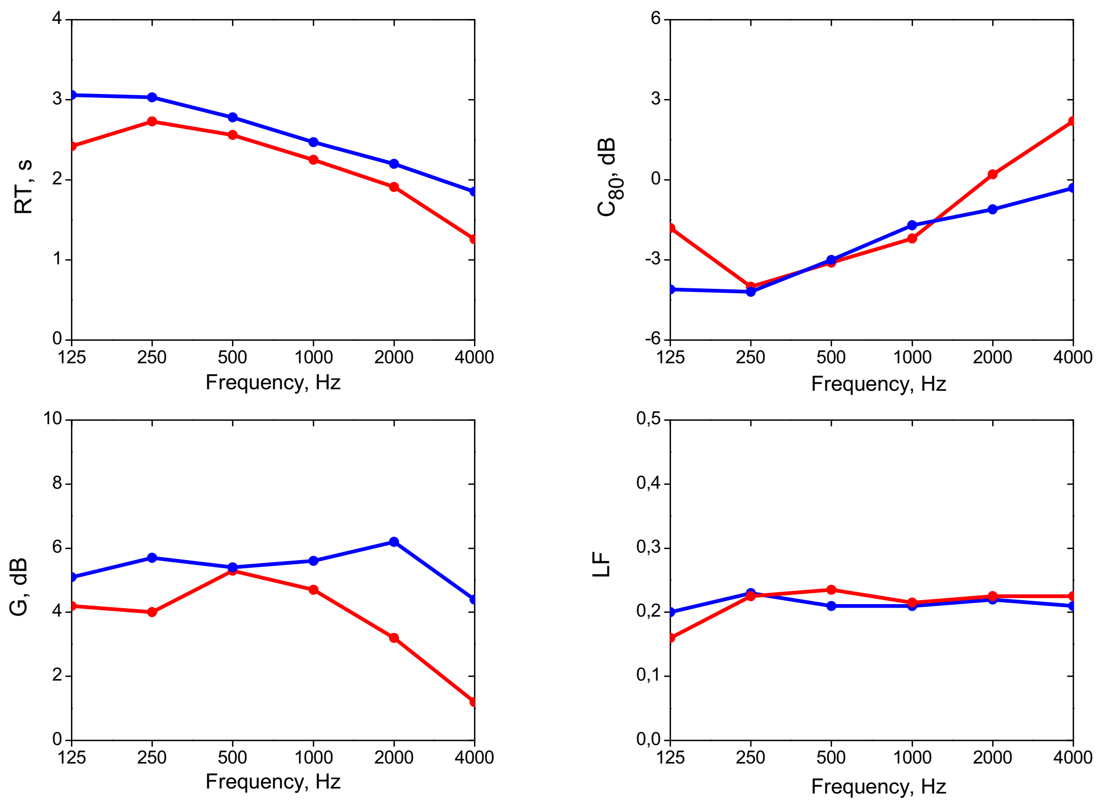


FIGURE 4. Acoustic characteristics of the Great Hall before (red lines) and after (blue lines) renovation.

Before the renovation the Great Hall had a fine acoustic reputation. Therefore the main goal of the renovation from the acoustic standpoint was to save the acoustic properties of the Hall. Overall this purpose was fulfilled. Fig. 4 shows comparison of four acoustic parameters measured in the unoccupied hall before and after renovation. The deviations of these parameters are not quite substantial. The reverberation time has increased around 10% at 250-2000 Hz. But its growth at 125 Hz has been 27%, at 4000 Hz – 47%. We can note that the reverberation curve has become straighter. Changes of C80 and G are similar, the main deviations are observed at low and high frequencies. Parameter LF has not changed significantly at all frequencies. Subjective estimations confirm the Great Hall has saved very good acoustics.

Change over a Year and a Half after Renovation

In order to control acoustic changes of the Great Hall in the initial stage of exploiting we decided to carry out acoustic measurements in the unoccupied hall at intervals of half a year. First measurement was executed on the 6 June, 2011 just after the end of the renovation and before the official opening. Next measurements were carried out in December 2011, June 2012 and December 2012. It is important to note that all measurements were fulfilled with the same equipment and by the same personnel. So by now we have results of four measurements, which are presented in Tables 1-3. Together with absolute values of RT, EDT, C80 their deviations relative to initial state in June 2011 are given.

First of all let us consider the behavior of the reverberation time. In Fig. 5 the deviations of the reverberation time at main frequencies are shown. The curves at 125-1000 Hz (Fig. 5a) are similar, but the deviations decrease with increasing frequency. The main changes at 125-500 Hz took place during the first half a year after opening, and then the reverberation time varied within 2 %. Maximal deviation was observed at 125 Hz and was about 6%. Note that the bass ration BR was reduced from 1.16 in June 2011 to 1.13 in December 2012. The reverberation time at 1000 Hz is very stable, overall deviation is less than 2%. The different behavior revealed at high frequencies (Fig. 5b). As it is easy to see the curves seem to be oscillating. Indeed the reverberation time measured in summer was longer, whereas winter reverberation time was shorter particularly at 4000 Hz. Obviously it can be connected with seasonal variation of temperature and humidity conditions in the Hall. At the same time one can note that the reverberation time tends to decrease at 4000 Hz and the decreasing rate is significant. So we can propose that the reverberation time has stabilized after the first half a year at low and medium frequencies, but at high frequencies it will be evolving during the first years after the end of the renovation.

TABLE 1. Reverberation time in the Great Hall in the period from June 2011 to December 2012

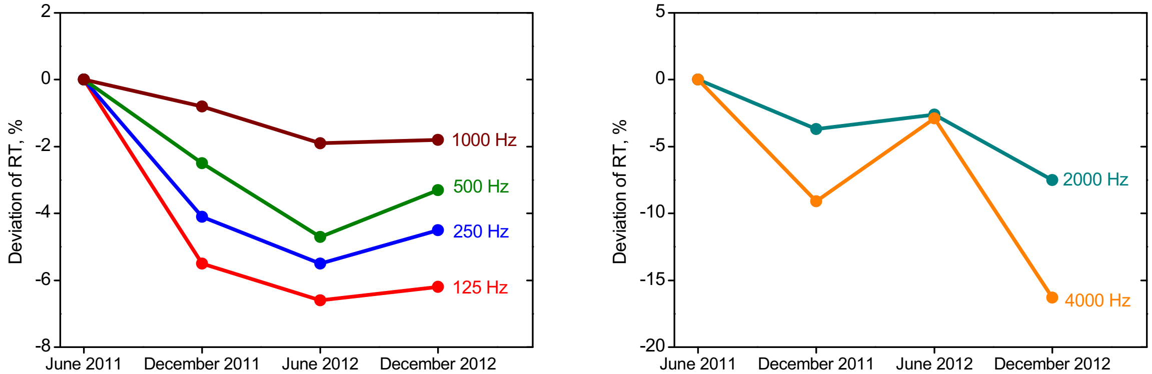
Time of measurement	RT, s						Deviation relative to June 2011, %					
	125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
June 2011	3.06	3.03	2.78	2.47	2.15	1.85	0.0	0.0	0.0	0.0	0.0	0.0
December 2011	2.89	2.91	2.71	2.45	2.07	1.68	-5.5	-4.1	-2.5	-0.8	-3.7	-9.1
June 2012	2.86	2.86	2.65	2.42	2.10	1.80	-6.6	-5.5	-4.7	-1.9	-2.6	-2.9
December 2012	2.87	2.89	2.68	2.43	1.99	1.55	-6.2	-4.5	-3.3	-1.8	-7.5	-16.3

TABLE 2. Early decay time in the Great Hall in the period from June 2011 to December 2012

Time of measurement	EDT, s						Deviation relative to June 2011, %					
	125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
June 2011	2.77	2.88	2.74	2.44	2.12	1.76	0.0	0.0	0.0	0.0	0.0	0.0
December 2011	2.71	2.86	2.69	2.45	2.05	1.58	-2.1	-0.6	-1.8	0.5	-3.2	-10.5
June 2012	2.59	2.81	2.70	2.41	2.06	1.71	-6.5	-2.3	-1.7	-1.3	-3.0	-2.7
December 2012	2.67	2.80	2.70	2.38	1.96	1.44	-3.8	-2.9	-1.5	-2.4	-7.4	-18.5

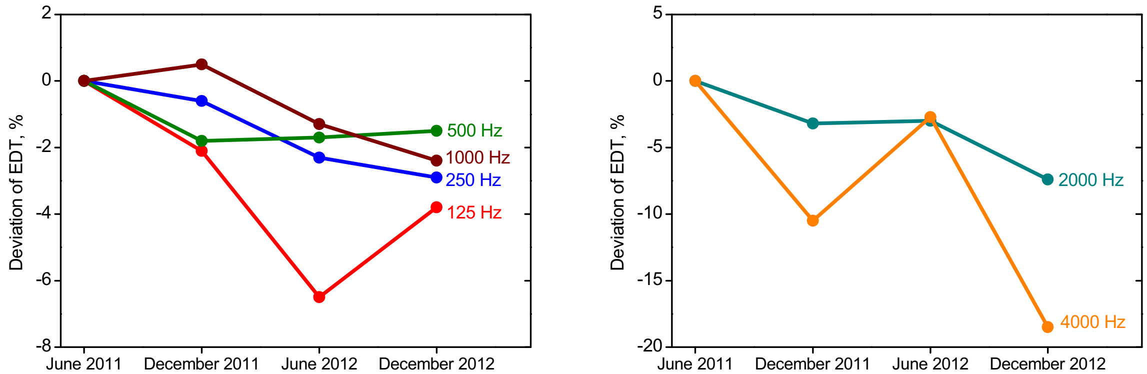
TABLE 3. Clarity C80 in the Great Hall in the period from June 2011 to December 2012

Time of measurement	C80, dB						Deviation relative to June 2011, dB					
	125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
June 2011	-4.1	-4.2	-3.0	-1.7	-1.1	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
December 2011	-4.3	-4.6	-3.1	-1.7	-1.0	0.1	-0.3	-0.4	-0.1	0.0	0.1	0.4
June 2012	-3.6	-3.8	-3.0	-1.9	-0.7	0.3	0.4	0.5	0.0	-0.2	0.4	0.6
December 2012	-3.6	-4.5	-3.3	-2.2	-0.9	1.0	0.5	-0.3	-0.3	-0.5	0.2	1.3



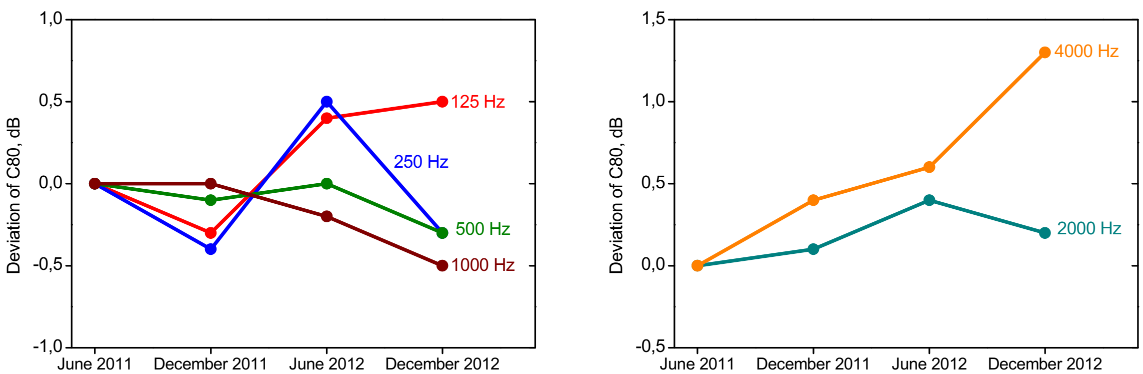
(a) (b)

FIGURE 5. Deviations of the reverberation time at different frequencies.



(a) (b)

FIGURE 6. Deviations of the early decay time at different frequencies.



(a) (b)

FIGURE 7. Deviations of the clarity at different frequencies.

In Fig. 6 deviations of the early decay time at different frequencies are shown. The curves at high frequencies (Fig. 6b) are similar to the reverberation time curves. The deviations at 250-1000 Hz are less that the reverberation time deviations. They do not exceed 3% over a year and a half. Maximal deviation at 125 Hz is about 6 %, but last measurement showed the growth of the early decay time.

Fig. 7 shows the deviations of the clarity index C80. As in previous plots the curves separated into low and medium (Fig. 7a) and high (Fig. 7b) frequencies. The deviations at frequencies 125-2000 are within ±0.5 dB. The most stable curve is at 500 Hz, maximal deviation is merely -0.3 dB. Only at 4000 Hz the clarity C80 exhibited evident changes. Over the first year and a half it was growing with an average rate of 0.85 dB per year.

It is interesting to evaluate the significance of detected variations. For rough estimation it is possible to compare the variations with just noticeable difference (JND) characterizing the sensitivity of listeners to small changes in sound fields of auditoria. Currently we have very limited information on JNDs of room acoustic parameters. Following [5] we assume the JND for the reverberation time and early decay time is equal to 5 % and the JND for the clarity C80 is equal to 1 dB. The deviations of the reverberation time and early decay time do not exceed the JND at 250-1000 Hz. At 125 and 2000 Hz the deviations are greater than the JND by 1-2 %. Taking into account that these deviations occur during relatively long time (about half a year), listeners and musicians are unlikely able to notice them. While the deviations at 4000 Hz are much greater than the JND. The deviations of C80 are also close to the JND and cannot be noticed.

CONCLUSION

Acoustics evolution of a new-open hall over the first year and a half is presented in this paper by the example of the Great Hall of Moscow Conservatory opened after the global renovation. Due to acoustic measurement it has been found that the deviations of acoustic parameters are small at low and medium frequencies. These changes took place over the first half a year after opening of the Hall. Significant reduction of the reverberation time and early decay time has been fixed at high frequencies and these parameters are still changing. We will continue to control acoustics of the Great Hall in future.

Obtained results proved that the long-term acoustic changes of halls can be considerable. The investigation of this problem seems to be relevant for modern architectural acoustics. It requires observation for different type of halls consisting in values of acoustic parameters changes and their characteristic times. Particular problem is to determine the reasons of observed changes and predict the acoustic behavior of new halls.

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