ACOUSTIC MEASUREMENTS IN THE "TEATRO VERDI" IN SALERNO (ITALY)

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ABSTRACT

The Teatro Verdi is a historical theatre built in Southern Italy in the tradition of the Baroque-style. It was opened in 1872. Nowadays the Verdi serves various purposes like opera and drama performance. This paper reports a survey about its acoustics. Measurements were carried out a first time when the theatre was set for an opera performance and a second time when it was set for drama. Reported acoustic parameters for opera and drama are discussed in the light of these uses.

BRIEF HISTORICAL NOTES AND MAIN FEATURES

The Teatro Verdi is an important sample of historical theatre in Southern Italy. Its shape is rooted in the classical mould born in our Country since the start of the 17th century. Today it serves various purposes like opera performance, drama, popular music and conference. The Teatro Verdi was conceived by the Municipality of Salerno in 1843 as a substitute of the "Real Teatro di San Matteo" because Ferdinand the II of Bourbon had decided to return this building to its former religious use. Subsequent "*querelles*" about the design, the location of the building, the costs involved and other causes, delayed the construction of the new theatre which could be started only in 1864. Finally, the Teatro Municipale, which was renamed Teatro Verdi in 1901, was opened in 1872.
The plan of the auditorium was inspired by the horseshoe shape of the Teatro di San Carlo in Naples, save a longitudinal elongation that yielded a smoother curvature of the walls towards the proscenium arch (experts call it a racket shape). The Verdi displays 69 boxes arranged in four tiers. The boxes are built as two cascaded small rooms connected with a door-less opening. This solution had been adopted also in other theatres built in the 19th century. An upper gallery at the fifth level has the same partitioning columns of the corresponding boxes but no dividing walls are behind them. 220 well upholstered chairs are arrayed in the stalls and a variable number of chairs are located in the boxes and in the gallery, so that 670 seated people can be hosted in the theatre. The length along the central axis from the pit edge to the back wall is 14.7 m. The maximum width is 13.9 m. The area of the floor of the auditorium is about 372 m^2. The average height, from the wooden floor to the flat ceiling, which is embellished with a painted canvas representing the Apotheosis of Rossini, is about 14 m. The volume of the main

hall is about 2500 m^3. The orchestra pit is 12 m wide, 4.9 m long and 1.55 m deep with respect to the main-hall floor. A wooden balustrade .55 m high is mounted along the rim of the pit on the side of the audience. The walls and the floor of the pit are made of wood. The suspended floor of the stage is made of wood. It is 20 m wide and 21 m long. The volume of the stage-house is 5300 m^3 approximately.
This historical theatre has undergone few minor changes during its life. The last restoration was carried out after an earthquake, on November 23, 1980, that had produced little structural damage. Fig.1 shows a view of the auditorium toward the stage and a view from the stage.

(a) (b)

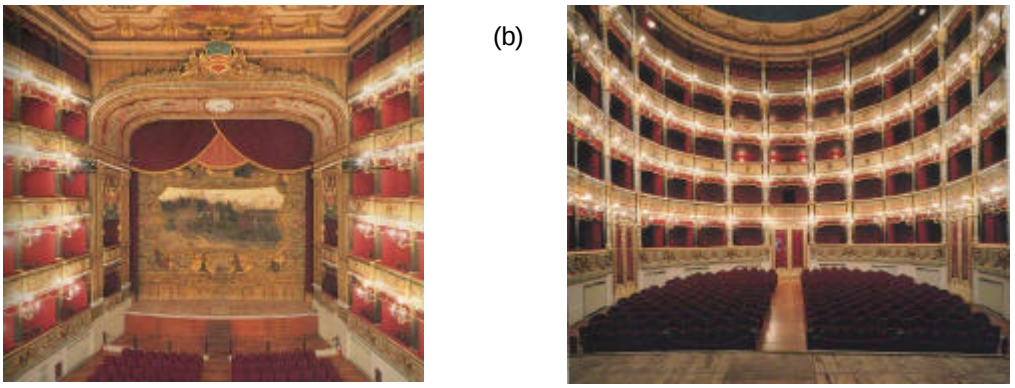


Fig.1- Views of the auditorium of the "Teatro Verdi". (a) toward the stage; (b) from the stage.

ACOUSTIC MEASUREMENTS – OPERA SETTING

Acoustic measurements were carried out in the unoccupied theatre on the occasion of the performance of La Boheme by G. Puccini. As shown in Fig.2 (a), the scenery in the stage-house was constituted of a large vertical canvas backed by a separated plastic curtain. This back-drop was located 12.6 m from the proscenium edge. Stairs at each side, a large overhung and a bed completed the scenery. Chairs, music stands and some large instruments were located in the open pit. The proscenium edge of the stage floor determined a 2.9 m long overhung over the pit floor. Two sets of impulse response were recorded by a MLSSA ^{TM} – based measurement system [1]. The dodecahedral sound-source was located a first time on the stage (height = 1.2 m), along the longitudinal axis 3.10 m from the proscenium edge. A second time the same sound source was located on the orchestra-pit floor at the same height along the longitudinal axis, 2.5 m from the pit wall nearest to the audience. Thirteen listener locations were considered. Eight receivers in the right half of the stalls and five receivers at the front of boxes at four levels of tiers. Fig.2 (b) reports the above-mentioned sound source and receiver locations in the plan of the "Teatro Verdi".

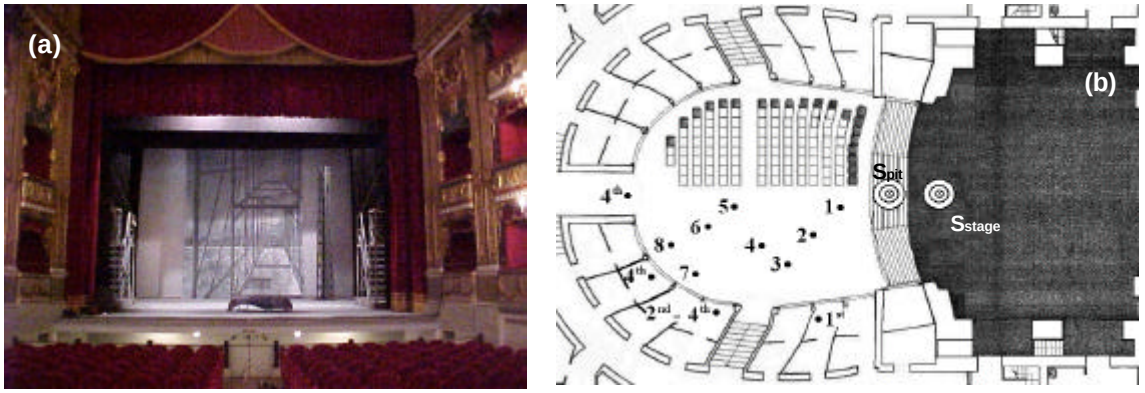


Fig.2 – (a) Stage fitting for La Boheme. (b) Locations of the sound source and receivers in the plan of the "Teatro Verdi".

Objective acoustic parameters, relevant for opera performance, were computed from each impulse response for the octave bands from 125 Hz to 4 kHz. RT, EDT, D_{50}, C_{80}, G and LF were considered. For each receiver location the early energy lateral fraction LF, averaged over the octave bands from 125 Hz to 1 kHz, was calculated by combining a pair of impulse responses recorded at two points at the distance of 6 cm. This allowed the simulation of the behaviour of a figure-of-eight microphone aiming a null-sensitivity direction toward the sound source.

Barron [2] stated in simple terms some subjective attributes for good listening in an opera house as follows. 1) The speech should be intelligible. 2) The orchestral sound should have a suitable clarity and convey an adequate sense of reverberance. 3) Both the voice of the singer on the stage and the sound of the orchestra in the pit should reach the listener with a sufficient loudness. 4) The balance between the singer's voice and the sound of the orchestra should be in favour of the singer adequately. 5) The sound envelopment may be of minor importance with respect to the requirements of loudness and balance. The Author described the aspects for orchestral music with the objective parameters reverberation time RT, early decay time EDT, clarity index C_{80}, sound strength G and early lateral fraction LF. These parameters were measured with a non-directional sound source in the pit. On the side of singer's voice Barron evaluated the objective clarity by measuring the early energy descriptor D_{50}. He used a sound source (on the stage) that simulated the directivity of the human voice roughly. The same sound source was used for the measurement of the sound strength G related to the loudness of the singer's voice. The balance at a listener location was described by the difference between the sound strength measured with the directional sound source on the stage and the sound strength measured with a non-directional sound source emitting the same sound power in the pit. The results reported herein are in terms of descriptors suggested by Barron, except the use of the dodecahedral sound source in every case. Fig. 3 reports the average values of the objective parameters for orchestral music measured with the sound source in the pit.

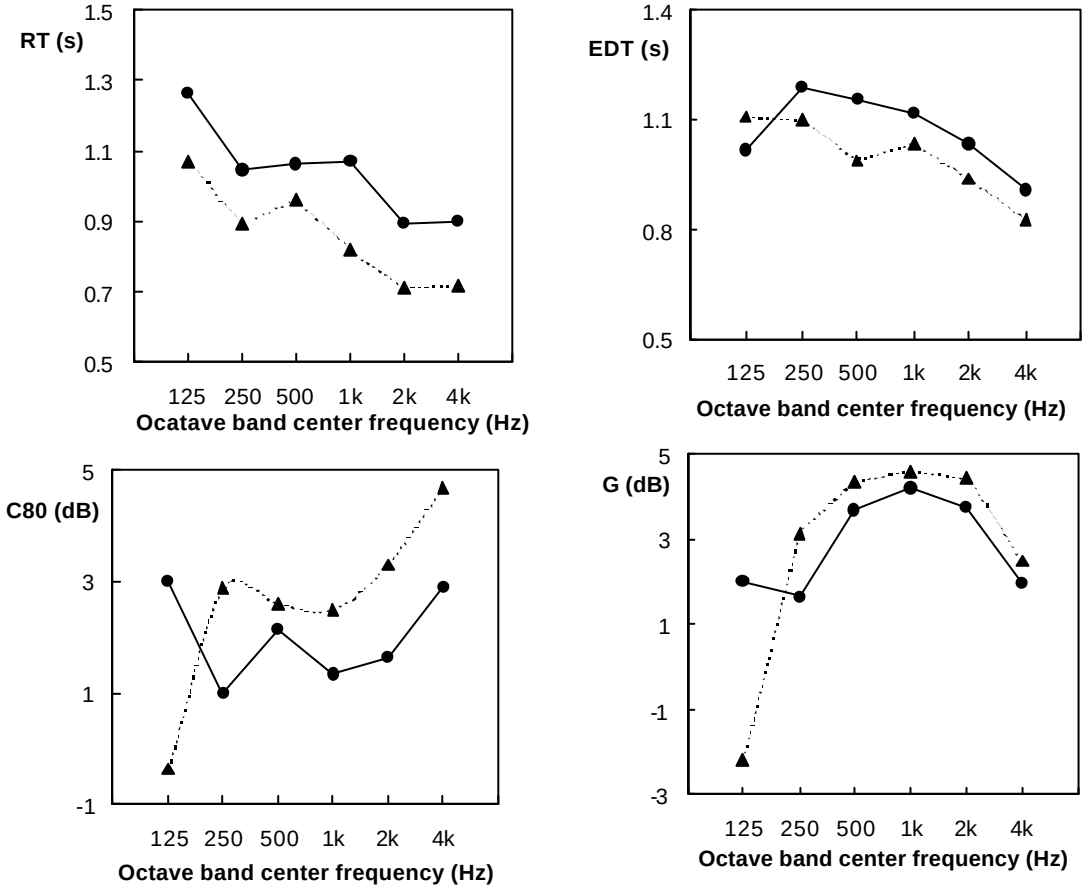


Fig.3 – Average values of RT, EDT, C_{80} and G in the "Teatro Verdi". Sound source in the pit. (□—□—□) stalls; (σ---σ---σ) boxes.

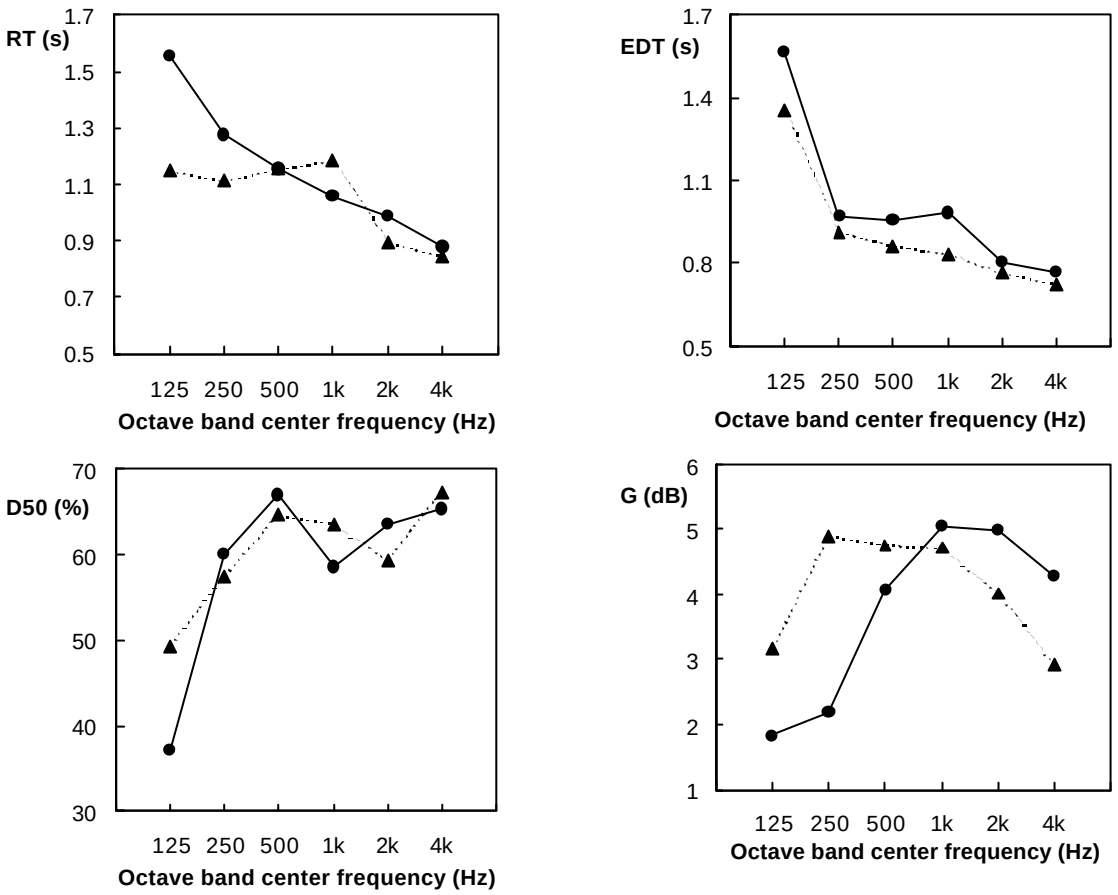


Fig. 4 – Average values of the objective parameters related to the voice of the singer in the "Teatro Verdi". Non-directional sound source on the stage. (□—□—□) stalls; (σ---σ---σ) boxes.

Table 1 reports the average, the minimum and maximum values of the early lateral fraction LF, measured with the sound source in the pit, and the corresponding for the total balance $\Delta G_{stage\text{-}pit}$. For the sake of brevity this parameter is calculated on the basis of the strength G averaged in the octave bands at 500, 1k, 2k and 4k Hz for the source radiating from the stage minus the same for the source radiating from the pit.

Table1- Early lateral fraction (source in the pit) and .5,1,2,4 kHz-averaged total balance.

	LF min	LF ave	LF max	$\Delta G_{stage\text{-}pit}$ min (dB)	$\Delta G_{stage\text{-}pit}$ ave (dB)	$\Delta G_{stage\text{-}pit}$ max (dB)
Stalls	0.02	0.40	0.54	-0.02	1.20	2.00
Boxes	0.22	0.35	0.48	-1.20	0.14	1.00

The "Teatro Verdi" can be considered as a medium-size opera house of the Italian style. Opera houses like La Scala in Milan and the San Carlo in Naples were huge with respect to many Italian theatres of the time. However they do not lack praise for their acoustics for opera still today. For incidence, the volume of their main-halls is about five times that of the Verdi. It is well known that opera was developed initially in theatres that were not that large. At Mozart times, clarity and intimacy were at their best in Baroque theatres of moderate size. A panoramic comparison of the objective parameters measured in the Verdi with those reported for its older and larger like, the San Carlo [3], shows that both are short of sense of reverberance, at least for orchestral music. The clarity of music is higher at the front of boxes with respect to the stalls in both cases. C_{80} appears higher for the smaller theatre on average. The clarity of voice, as described by D_{50}, is almost the same in the frequency range of interest for the human voice. As one could expect, the sound strength is higher in the similar-but -smaller theatre. As regards the aspect of spaciousness of music described by the early lateral fraction, one may suppose that an orchestra in the pit of the Verdi yields a sensation of apparent widening of the sound source

higher than that produced by the same orchestra in the pit of the Teatro di San Carlo. The conventional measure of the balance $\Delta G_{stage\text{-}pit}$ seems to be more in favour of the singer in the Verdi than in the San Carlo.

ACOUSTIC MEASUREMENTS – DRAMA SETTING

The use of the Verdi for drama performance is more frequent than its use for shows of different genre. A repeated informal inquire about the intelligibility of dialogue, carried out among both drama habitual goers and staff people, revealed that there were no evident complaints about this issue. Objective descriptors of the speech intelligibility require the consideration of aspects related to voice level, voice spectrum and directivity, background noise level and room response. There are objective descriptors that try to take into account all the above-mentioned factors [4] but no definitive agreement has been reached yet about which is the best. For example, Onaga et al. [5] criticize some drawbacks of the complicated Speech Transmission Index as a predictor of speech intelligibility. Therefore, only simple and classical parameters related to the room response which are relevant for speech intelligibility are reported herein.
A further set of measurements was carried out in the unoccupied theatre on the occasion of the performance of the farce “Le metamorfosi di un suonatore ambulante” by P. De Filippo. Fig.5 (a) shows the scenery in the stage-house. It was constituted of a painted-canvas back-drop that was visible through the large window of a furnished room. During these measurements the orchestra pit was closed with a plank floor completely. Two sets of impulse responses were recorded with the dodecahedral sound-source at two locations on the stage. The first location was along the longitudinal axis 3.90 m from the proscenium edge. The second one was 5.20 m from the proscenium edge shifted 1.50 m to the left. Fifteen listener locations were considered. Eight receivers in the right half of the stalls and seven receivers at the front of boxes and gallery. Fig. 5 (b) reports the above-mentioned sound source locations (not in scale) and the receiver locations in the plan of the “Teatro Verdi”.

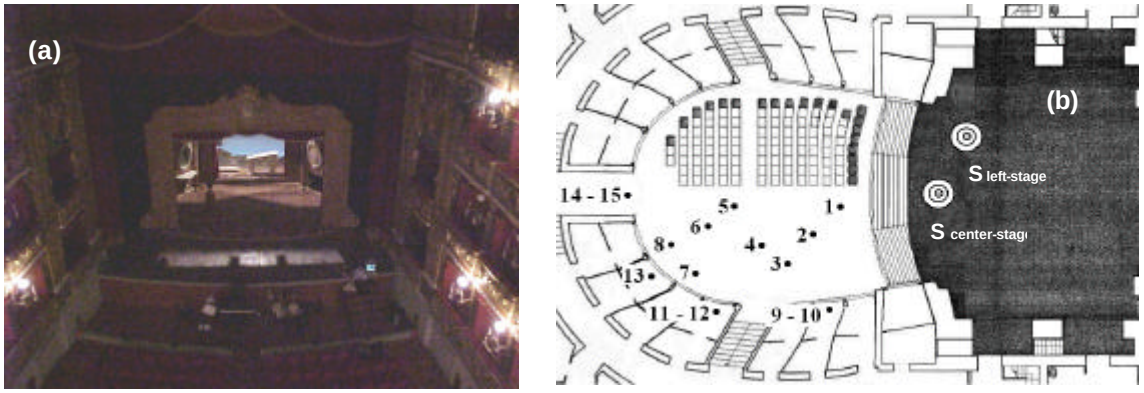
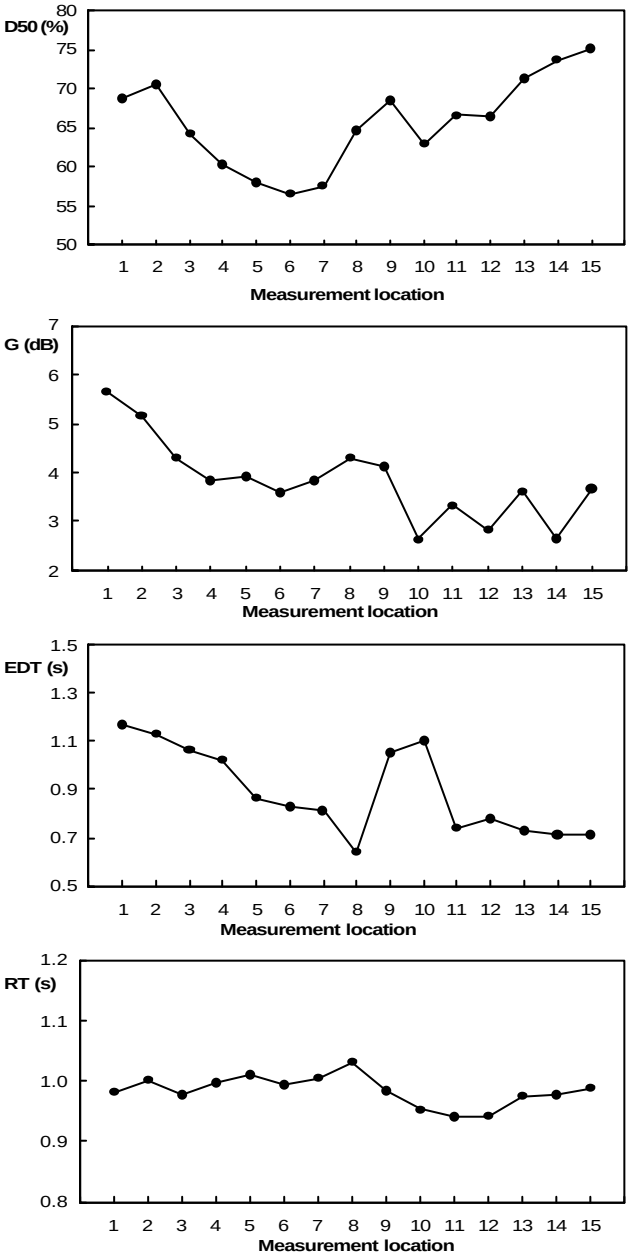


Fig.5 – (a) Stage fitting for drama. (b) Locations of the sound source and receivers in the plan of the “Teatro Verdi”.

When the background noise-level is low enough, e.g. 25 dBA or less, the major concern for speech intelligibility is how the room delivers strong and useful early sound to every listener without masking reverberation and disturbing echoes. Therefore, D_{50} , G, EDT and RT were computed from the thirty (2 sound source locations x 15 listener locations) available impulse responses. These acoustic parameters were averaged with respect to the octave bands with the central frequencies 500, 1k, 2k and 4k Hz. A further averaging was performed with respect to the location of the sound source on the stage. Fig. 6 reports these averaged parameters for each considered receiver location.
This data shows that the early energy ratio D_{50} varies between 55% and 75%. As expected for these theatres, listeners at front of the boxes and the gallery benefit of higher early useful sound. However, the criterion D_{50} > 50% is satisfied at every observed location. The minimum value of G is a little less than 3 dB far from the stage. This suggests that the voice of the speaker on the stage can be perceived louder than in free space at the distance of 10 m. The reverberation time in the range of frequencies which are important for speech intelligibility is adequate with respect to the criterion RT = 1s.



	Location	D (m)
1	Stalls	7.6
2	Stalls	9.4
3	Stalls	11.2
4	Stalls	12.5
5	Stalls	14.2
6	Stalls	15.8
7	Stalls	16.6
8	Stalls	18.2
9	Box First tier	11.5
10	Box Third tier	13
11	Box Second tier	17.7
12	Box Fourth tier	19.3
13	Box Second tier	20.3
14	Box Fourth tier	22.9
15	Upper gallery	24.0

Fig.6 – Frequency and source-location averaged D_{50} , G, EDT and RT for each receiver location reported in Fig. 5 (b). D is the receiver distance from the centre-stage sound source.

CONCLUSION

The findings of the objective survey in the "Teatro Verdi" confirm that these typical historical Italian theatres of medium-size, although on the dry side, display a balance of room-acoustic qualities which are suitable for multipurpose use.

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