# Investigation on aerodynamic noise evaluation and attenuation in a globe valve using CFD analysis

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**ABSTRACT**

Noise pollution will soon become the third greatest menace to the human environment after air and water pollution. Since noise is a by-product of energy conversion, there will be increasing noise as the demand for energy for transportation, power, food, and chemicals increases. In the field of control equipment, noise produced by valves has become a focal point of attention .In this paper aerodynamic noise evaluation of a globe valve was carried out using a three dimensional Computational Fluid Dynamic technique(CFD). The results obtained from numerical analysis are compared with the experimental measurements and are found to be in good agreement. Reduction in sound pressure level was achieved by doubling the number of flow passages in the cage at full open condition and at the same operating conditions. Hence sound attenuation is established by changing the cage configuration with no change in total area of flow passage in the cage.

## 1. INTRODUCTION

Aerodynamic noise is a direct result of the conversion of the mechanical energy of the flow into acoustic energy as the fluid passes through the valve restriction. The proportionality of conversion is called acoustical efficiency and is related to valve pressure ratio and design. Aerodynamic noise generation is a natural consequence of any gaseous flow through a control valve. Though this noise can be small and of little or no consequence for some valves, it is often high enough in globe valves to damage hearing or even high enough to mechanically damage downstream piping and, less often, the valve itself. Limits of the maximum sound pressure level allowed in a working environment have often been set by regulatory bodies in an effort to prevent hearing damage. Control valve noise predictions and control is necessary to comply with regulatory norms and standards. Noise from a control valve surfaces from numerous sources but predominantly generated by the valve trim and at the exit of the valve exit. An important step in noise attenuation of a system lies in clear identification of noise source and quantification.

Du Xi [1] analysed flow through a valve in steam turbine system by applying different turbulence model and comparison of results. This paper gave an insight into the capability of CFD tool in predicting flow parameters and its effect on performance characteristics.

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Ryo Morita, et.al. [3] investigated the detailed flow characteristics around the valve in a semi- opening condition and the unsteady flow phenomenon associated with the valve flow. Noise simulation studies of the caged type Globe valves are not reported and hence it was taken up for study.

## 2. NUMERICAL SIMULATION

Numerical simulation of 2" Globe valve was carried out using FLUENT, a finite volume based CFD code, for evaluation of sound pressure level in valves with multiple cage configurations. Aerodynamic noise simulation studies are carried out on a 2" control valve assembly as indicated in Figure 1. Details of the multi aperture cage flow domain of a globe valve are indicated as Figure 2.

Two cases were analysed. Figure 3 indicates a portion of the computational domain for 100 percent opening of the valve with 8 nos. of circular flow passages (case no.1). Computational domain of the valve is extended up to 10D (D is diameter of the pipe) upstream and 15D downstream of the valve to get fully developed flow at both ends. Three dimensional unsteady compressible flow solver of FLUENT was used for simulation. Pressure inlet and pressure outlet boundary conditions are used at the inlet and outlet. Flow medium is air. No slip boundary conditions are applied at the walls.

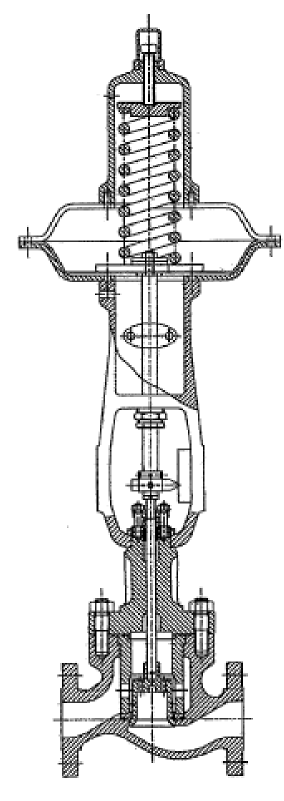

Figure 1: Globe Valve assembly

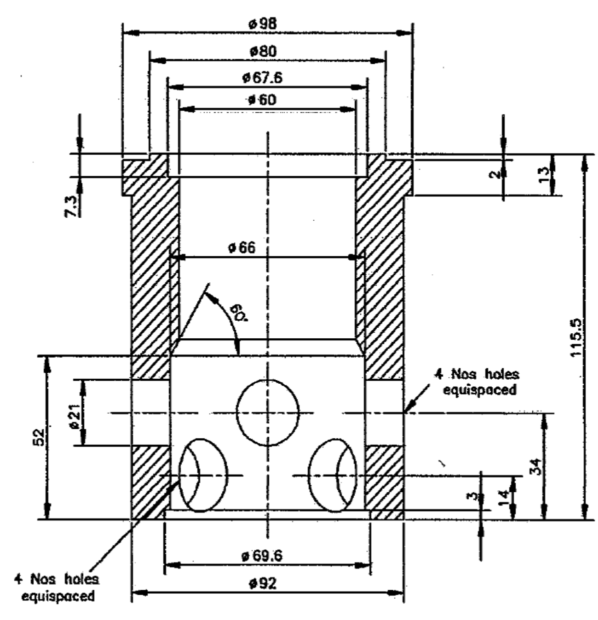


Figure 2: Cage with circular shaped flow passage

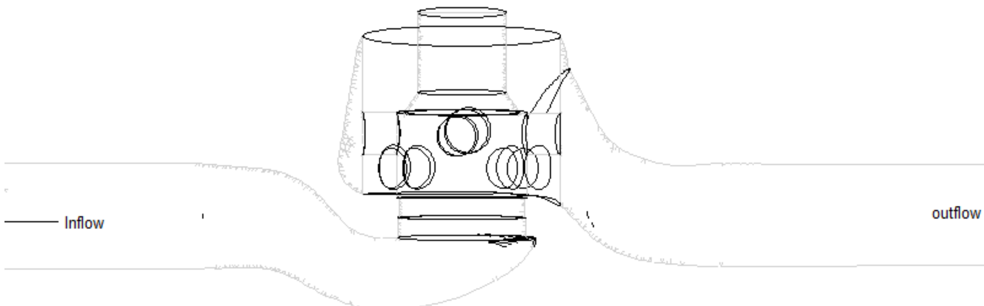


Figure 3: Valve Flow Domain

RNG k-ε turbulence model is used for turbulence modeling. RNG Model follows the two equation model and is derived from the fundamental governing equations for fluid flows using Renormalization Group (RNG) theory. As compared to standard k- ε model an additional term is added to the ε equation as formulated by Yakhot ,et al.[4]. This term changes dynamically with the rate of strain of turbulence, providing more accurate predictions for flows with rapid distortion and anisotropic large-scale eddies. Applications of the RNG k- ε model to a number of complex flows such a separated flows have also yielded excellent results in cases where standard k- ε model predictions have been unsatisfactory. Hence RNG k- ε turbulence model was considered for the present analysis.

Figure 4 shows the mesh structure of the valve having cage with 8 circular apertures. Grid independent study was carried out with mesh size varying from 15 lakhs, 25 lakhs, 29 lakhs and 32 lakhs. For the mesh size of 29 lakhs ,flow parameters are not found to be varied with 32 lakhs and hence mesh size of 29 lakhs was considered for study.

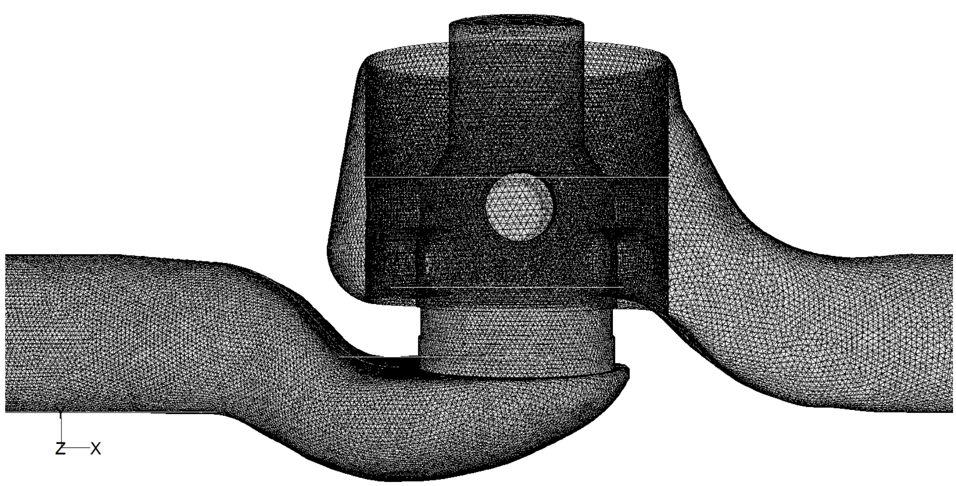


Figure 4: Mesh Structure

The cage configurations were simulated at various differential pressures. At each pressure ratio, pressures and flow rates were noted at the upstream and downstream of the valve. Unsteady flow analysis was carried out in order to obtain the pressure time variations at the downstream of the valve. FFT analysis was carried out using the pressure - time data obtained from CFD analysis and overall sound pressure level was found out. The CFD results thus obtained are as indicated in Figure 5 for case no.1. As the differential pressure, Dp is increased sound pressure level also increased.

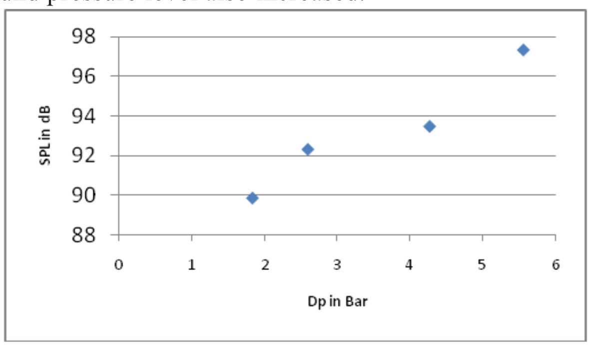


Figure 5: Dp Vs SPL

In Figure 5, Dp is p1-p2, where p1 and p2 are pressures at 2D (D is pipe diameter) upstream and 6D downstream of the valve respectively. Noise attenuation studies were carried out using CFD for valve having cages with 8 & 16 nos. of apertures (cases 1&2) arranged in two rows in zigzag manner. Sound pressure level (SPL) for valves with 8 nos. of apertures and 16 nos. of apertures are compared under the same operating and flow conditions. Figure 6 and Figure 7 show the variation of Mach number (Ma) at the exit of the valve for the two cases. From the figures, it is clear that mach number at the exit of the valve is reduced by 30 percent as the number of apertures doubled. Hence, noise level was reduced.

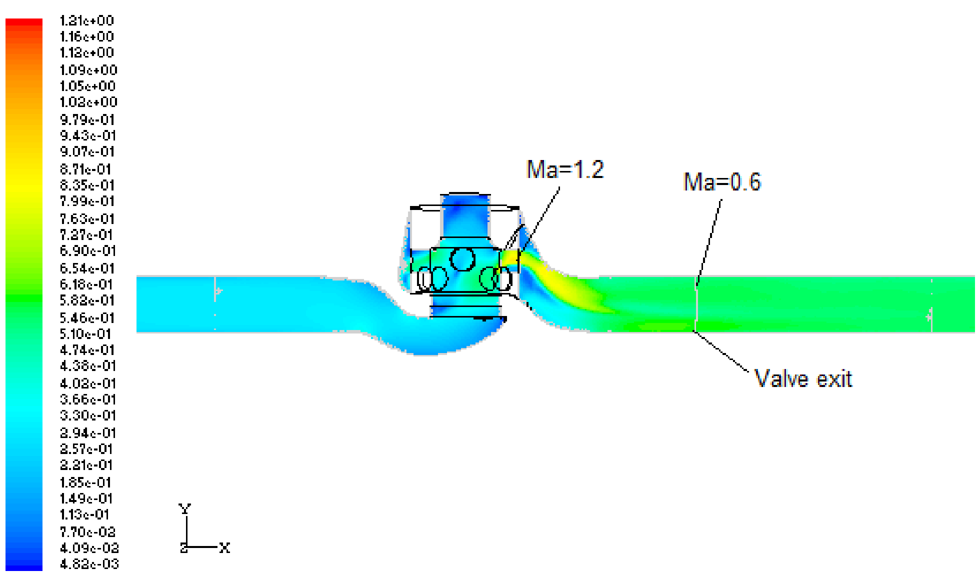


Figure 6: Contours of Mach number for case1

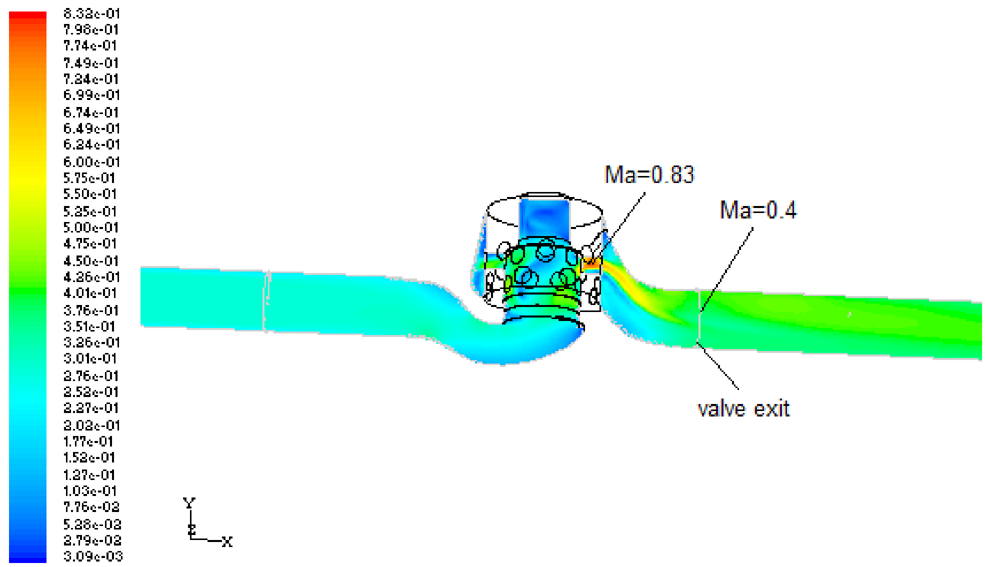


Figure 7: Contours of Mach number for case2

Results are indicated in Table1. The total area of the flow passage is fixed in all cases. Overall sound pressure levels were evaluated at full open condition to study the noise reduction effect.

As the number of apertures are doubled, reduction in noise is attained. As the number of apertures increases conversion rate of mechanical energy to acoustical energy is reduced. Table 1 shows the effect of multi-holed trim in noise reduction. As the hydraulic radius decreased, Mach number at the valve exit was decreased and hence sound pressure level was reduced. From Table 1 it is clear that when orientation and number of flow passages inside the cage were changed, the sound pressure level was reduced by 10 dB.

Table 1: Sound Pressure Level Variation

| Case no. | Nos. of apertures | Upstream pressure | Area(A) mm2 | Perimeter (P) mm | Hydraulic radius R=A/P | Mach no.at the valve exit |
|---|---|---|---|---|---|---|
| 1 | 8 | 4 bar | 346.36 | 65.97 | 5.25 | 0.6 |
| 2 | 16 | 4bar | 173.18 | 46.65 | 3.71 | 0.4 |

## 3. EXPERIMENTAL AERO DYNAMIC NOISE TESTING

### 3.1. Experimental set up and procedure

The noise measurements were carried out for Case no.1 in accordance with IEC 60534-8:2005 [2]. The overall noise level of the valve for the tested condition was found out experimentally. The noise measurement was done at the valve opening of 20 to 100% in step of 20 %. The schematic of the test setup is as indicated in Figure 8 and the assembled valve in the test loop is as in Figure 9. The upstream pressure and flow through the valve assembly was controlled by using pressure vessel and ball valve as indicated in Figure 8.

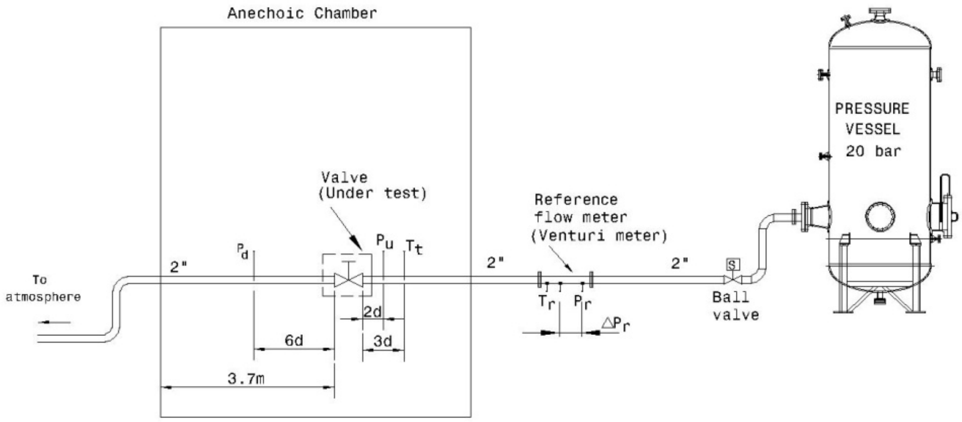


Figure 8: Schematic of Test set up

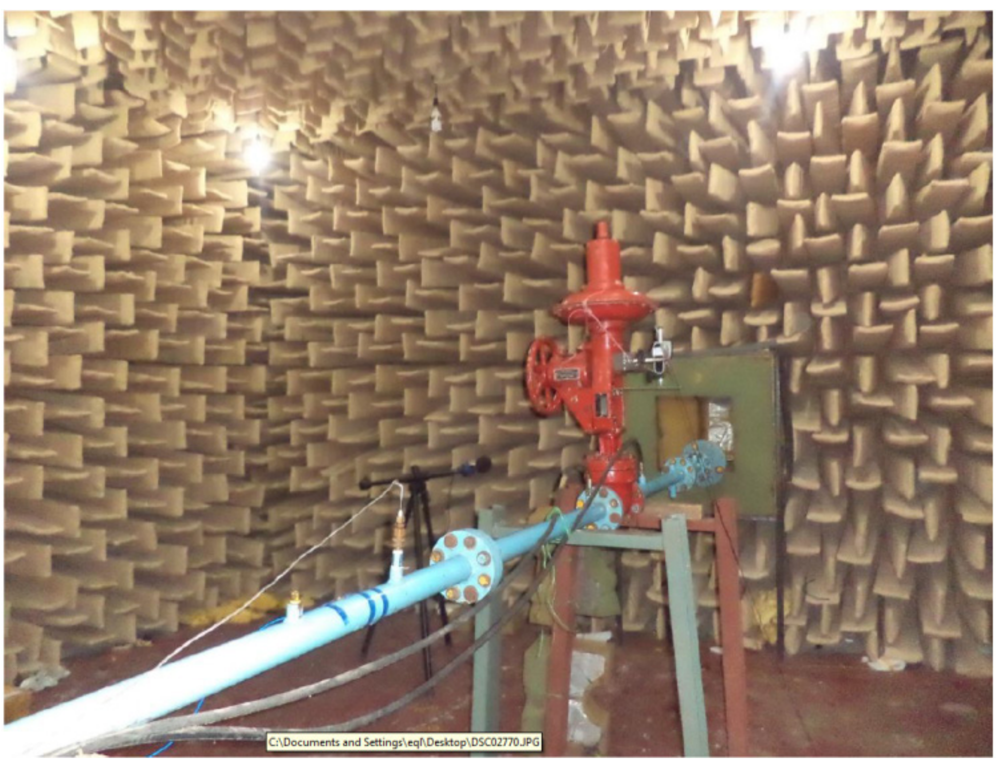


Figure 9: Valve assembly in Test line

Downstream was vented freely to atmosphere, outside of the hemi anechoic chamber. Flow through the valve assembly was measured using a venturimeter. The valve pressure was measured at 2D (D is pipe diameter) upstream and temperature was measured at upstream of the valve. Schedule 40 CS pipes were used in the test loop. The microphone was positioned at a distance of 1m downstream of the valve and 1m away from the mid plane of the downstream pipe for measurement of aerodynamic noise generated during the test condition. Measurement was done for a period of 2 to 5 minutes and it was averaged & updated once in 182 milliseconds as per IEC Standard [2].

## 3.2 Experimental Results

Valve upstream pressure and the overall sound pressure level for various valve openings are detailed in Table 2. There are several important reasons to limit the noise levels emitted by valves and piping. From Table 2, it is clear that the noise level in the globe valve is within the maximum limit of 100dB.

Table 2: Noise level in dB

| **Valve upstream pressure in bar** | **100%** | **80%** | **60%** | **40%** | **20%** |
|---|---|---|---|---|---|
| | **Overall sound pressure level in dB** | | | | |
| 15 | 98.71 | 98.67 | 98.54 | 100.03 | 100.04 |
| 14 | 98.59 | 98.33 | 98.08 | 99.82 | 99.47 |
| 13 | 98.27 | 97.79 | 97.99 | 98.72 | 99.24 |
| 12 | 98.04 | 97.36 | 98.15 | 98.68 | 98.55 |
| 11 | 97.12 | 97.04 | 97.92 | 98.39 | 98.24 |
| 10 | 96.89 | 96.49 | 97.29 | 97.5 | 97.5 |
| 9 | 95.91 | 95.88 | 96.91 | 97.38 | 96.5 |
| 8 | 95.07 | 95.45 | 96.19 | 97.38 | 95.25 |
| 7 | 94.47 | 94.65 | 95.25 | 96.23 | 94.75 |
| 6 | 93.73 | 93.21 | 94.44 | 95.57 | 93.52 |
| 5 | 92.18 | 92.09 | 93.08 | 93.25 | 90.79 |
| 4 | 91.72 | 86.92 | 91.56 | 45.71 | 30.81 |
| 3 | 91.26 | 54.9 | 90.98 | 45.64 | 30.78 |

Experimental results were compared with computational results for the valve at full opening condition for case 1. Figure 10 shows the comparison of experimental and computational sound pressure levels. In Figure 10, Dp is p1-p2, where p1 and p2 are pressures at 2D (D is pipe diameter) upstream and 6D downstream of the valve respectively.

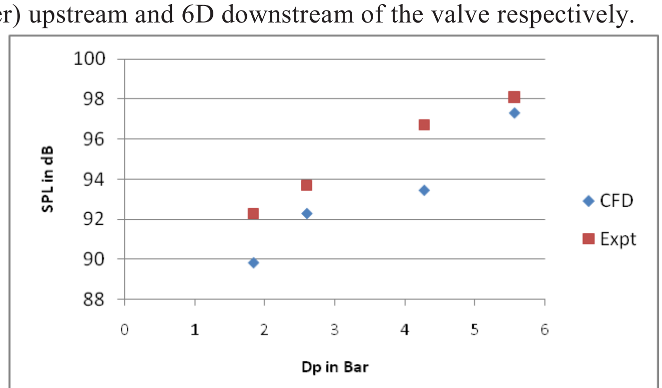


Figure 10: Validation of Results

## 4. DISCUSSION OF RESULTS

CFD simulation was carried out for the valve having cage with 8 nos. of apertures for full opening at different pressure ratios and validated with the experimental results as shown in Figure 10. Simulation was also carried out for valve with cage having 16 nos. of apertures at full opening condition to compare the sound pressure levels outside the valve. Figure 6 and 7 clearly show the reduction in Mach numbers with change in cage configuration and which indicates the noise level reduction and hence noise attenuation. From Table 1 ,it is clear that with the same valve flow area, as the number of apertures increased noise levels decreased and which shows the effect of multi holed trim aiding in attenuation of noise level of valves. Also as the hydraulic radius was reduced, noise levels were also reduced.

Experimental aerodynamic testing was carried out for valve having cage with 8 nos. of apertures at five openings and are indicated in Table 2. From this Table 2, it is clear that all sound pressure levels are found to be within the limit as per the IEC standards [2].

## 5. CONCLUSION

Both computational and experimental aerodynamic noise evaluation in globe valves were carried out and validated. CFD results are found to be in good agreement with experimental results. Unsteady compressible flow simulations are carried out using FLUENT for sound pressure level evaluation. Percentage error between computational and experimental results are found to be less than 10%. From the results it is clear that noise levels are within the IEC standard limits in general. 10% noise attenuation can be achieved by doubling the number of flow apertures in the cage. Here as the number of apertures in the cage were doubled, sound pressure level reduced from 91dB to 81dB at the same operating conditions. Hence, about 10dB reduction in noise was achieved and Mach number at the valve exit was reduced from 0.6 to 0.4. Also maximum Mach number inside the valve was reduced from 1.2 to 0.83. Attenuation of noise levels in the valve is established by changing the cage hole configuration. More studies are being carried out with different cage designs for SPL comparison.

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