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Noise and Vibration Reduction in Compressors for Commercial Applications

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ABSTRACT

One of the main sources of noise in commercial refrigeration systems is the compressor, whether due to the level of noise directly radiated, or due to the interaction with the system. This interaction with the system also occurs as a result of gas pulsation and vibration levels that excite the components connecting the compressor to the system.
This work presents studies carried out on reciprocating commercial compressors in the attempt to identify, quantify and to determine the generating sources of the noise, the ways of transmission and the influence of the final irradiator in the total noise and the vibration of the compressor through sensibility analysis of the product and process. The results show how important it is for the design engineer to choose the right components when defining new components for the development of quieter products or to modify existing products for the purpose of making them quieter.

1. INTRODUCTION

The sound power level of a refrigeration system is basically formed by sound sources, energy propagation paths and irradiation of several parts and components, with these excitation, transmission, and radiation features playing an important role in refrigerator noise reduction.
The J compressor family is basically used in commercial application as cold store, air conditioning, refrigerating chamber, etc. As it is a very old design, this compressor presents a sound power and vibration level above the limits defined for the final customer. The need to reduce noise limits for this kind of application has become more and more urgent over recent years.
Considering the noise limits, it is possible to verify that the J compressor has high total noise and the predominance of noise peaks at low and high frequency which can be observed through subjective analysis.
The noise problem was supported based on the Six Sigma approach.
The job was divided into three steps to accurately characterize all noise problem solving phases:

- Identify predominant source through an analysis of main sources of compressor noise generation;
- Characterization of the main paths of vibratory energy transmission;
- Irradiation energy reduction through the redesign of the shell, this being the cause of irradiation.

The analyses were conducted considering the total noise and 1/3 octave band to enable sound quality improvements impact strongly on customer perception.
The main objective of this work was to reduce 5.0 dB the total noise level of J compressor on average. Reduction of vibration and noise levels in low frequency is also considered very important for improving the sound quality of the refrigeration system for the final customers.
In order to reach the noise reduction goal an analysis was conducted consisting primarily of an investigation into the main paths of vibratory energy flow in the compressor and the identification of the main points requiring modification.
A detailed study of the main points responsible for the noise enabled a guided approach, which only concentrated on modifications to the parts affecting the final result.
This approach starts with a road map defining each step in the noise analysis and the understanding of the sound power level in the system.

2. ROAD MAP

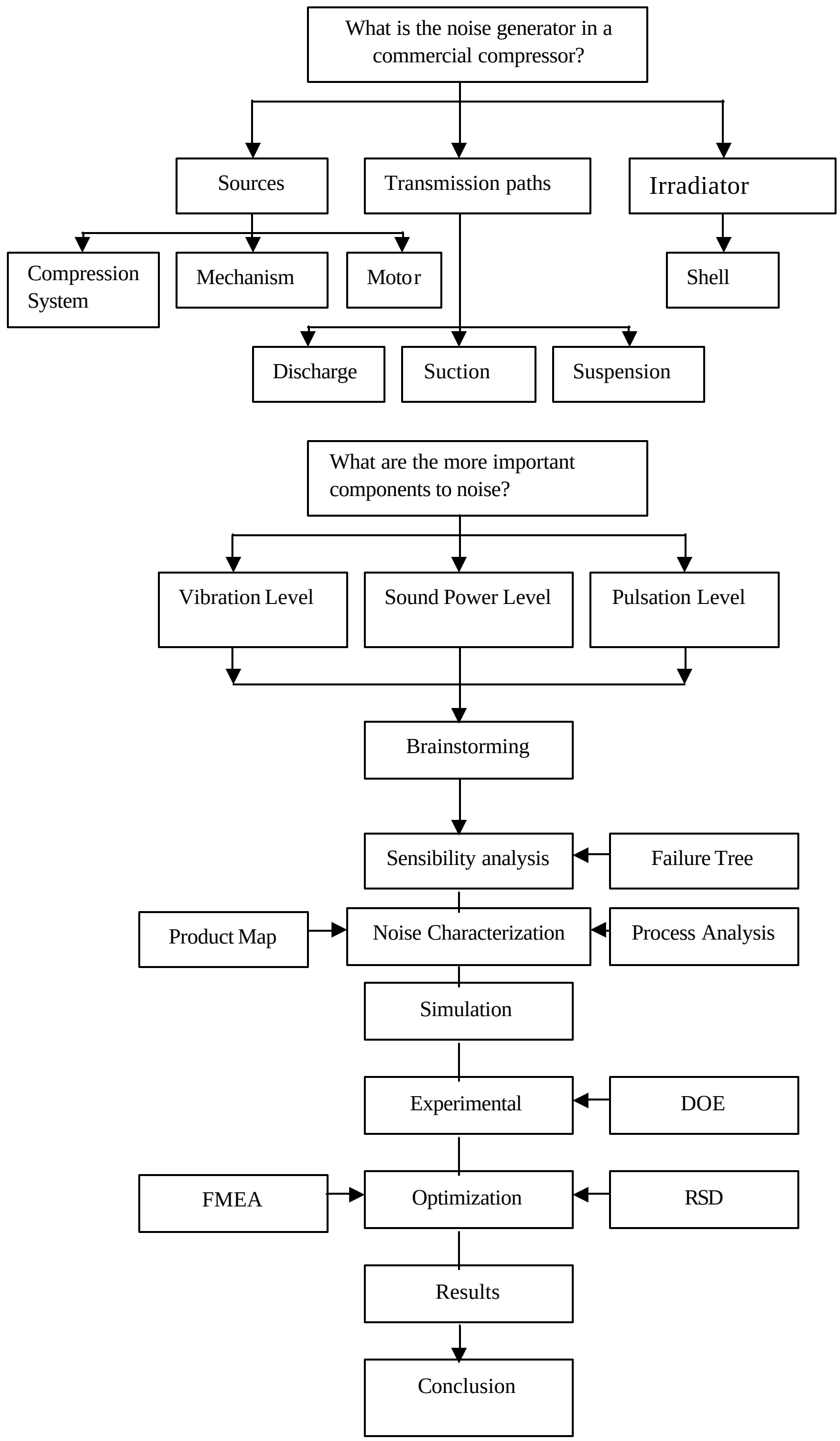


Figure 1: Road Map simplified

3. NOISE CHARACTERIZATION

The noise diagram in a commercial compressor can be divided as shown in figure 2 below. It is possible to observe that the vibratory energy transmission in the final process will be perceptible by the customer as high noise level.

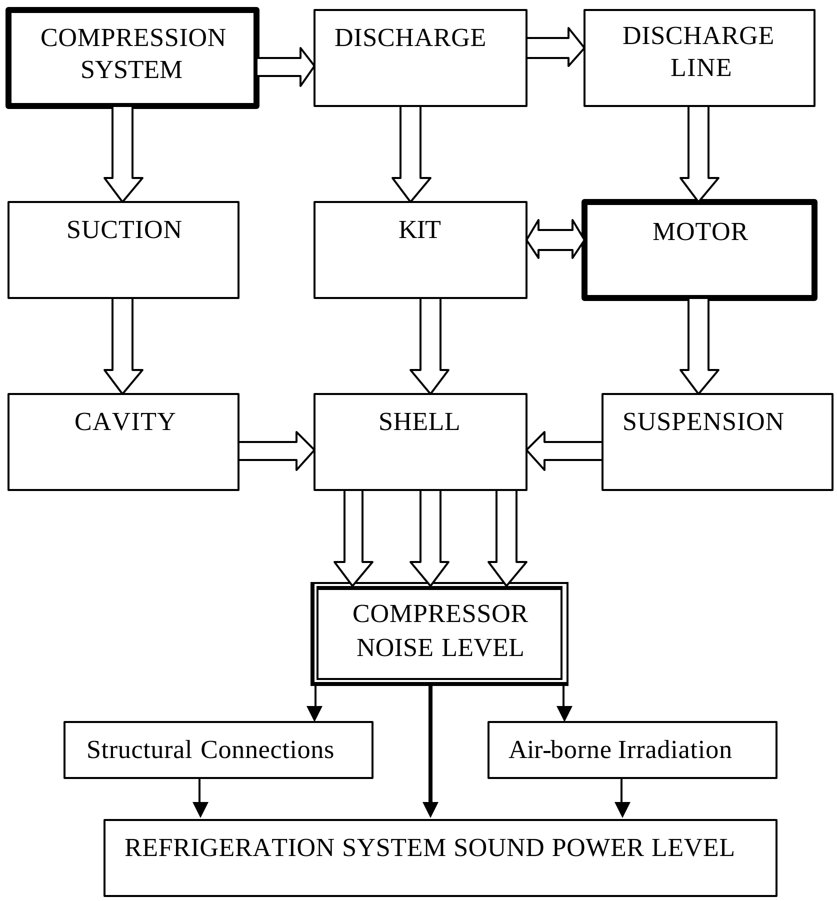
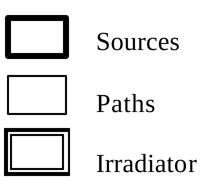


Figure 2: Energy vibratory flow of compressor



4. NOISE CONTRIBUTION

The sensibility analysis enables the contribution of each system to the frequency band to be identified and, consequently, the total noise of compressor. Figure 3 shows the contribution in the frequency spectrum of the 5 most important components in the compressor.

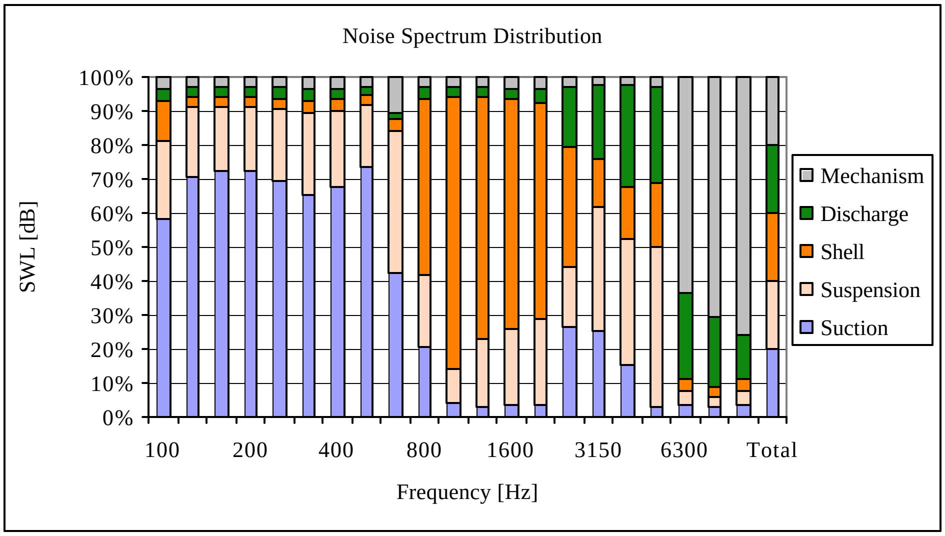


Figure 3: Noise contribution of the components in the compressor

5. DEVELOPMENT

With the contributions defined, the new J compressor project was defined with the follow options:

A - New Shell

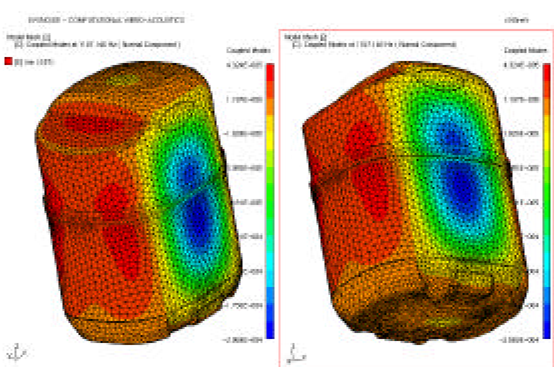


Figure 4: Shell Modal analysis Simulation

B - New Muffler

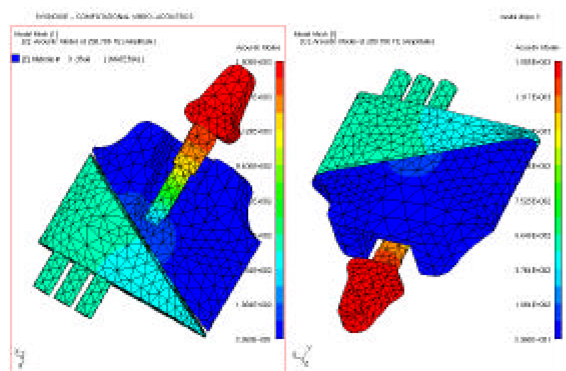


Figure 5: Muffler Modal analysis Simulation

C - New Suspension

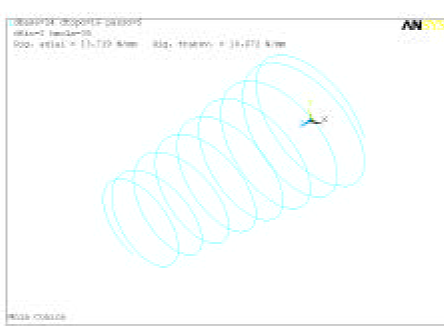


Figure 6: Spring Response Simulation

D- Discharge Modified

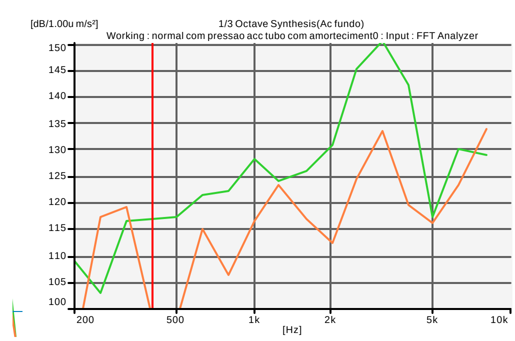


Figure 7: Discharge Damping

This proposed J compressor received a new name - NJ

In figures 8 and 9 it is possible observe all the proposed modifications and to comp are them with the old one.

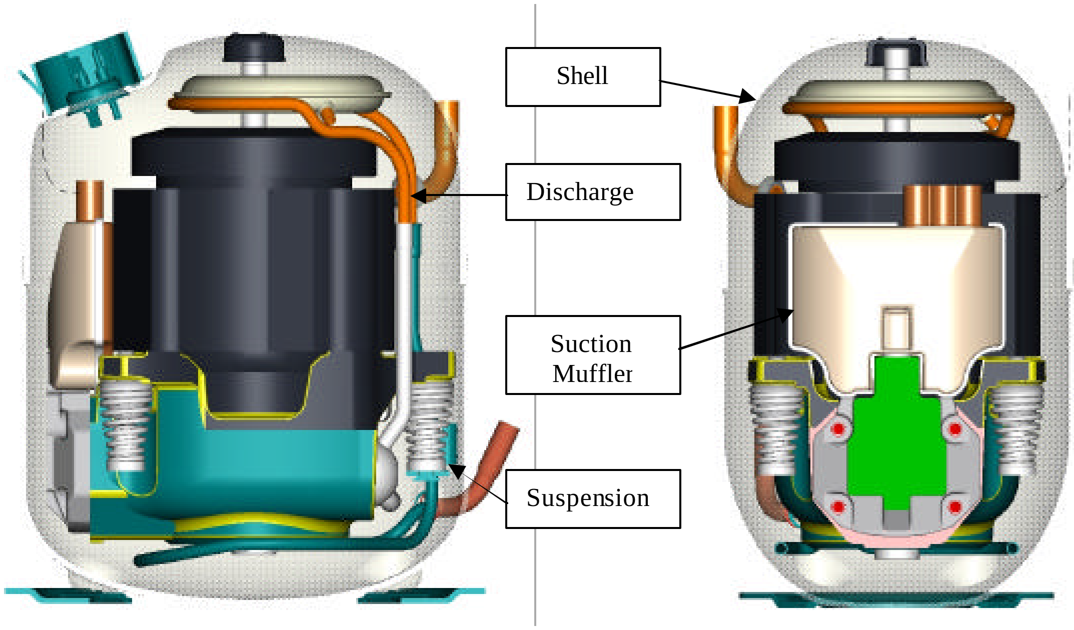


Figure 8: NJ compressor

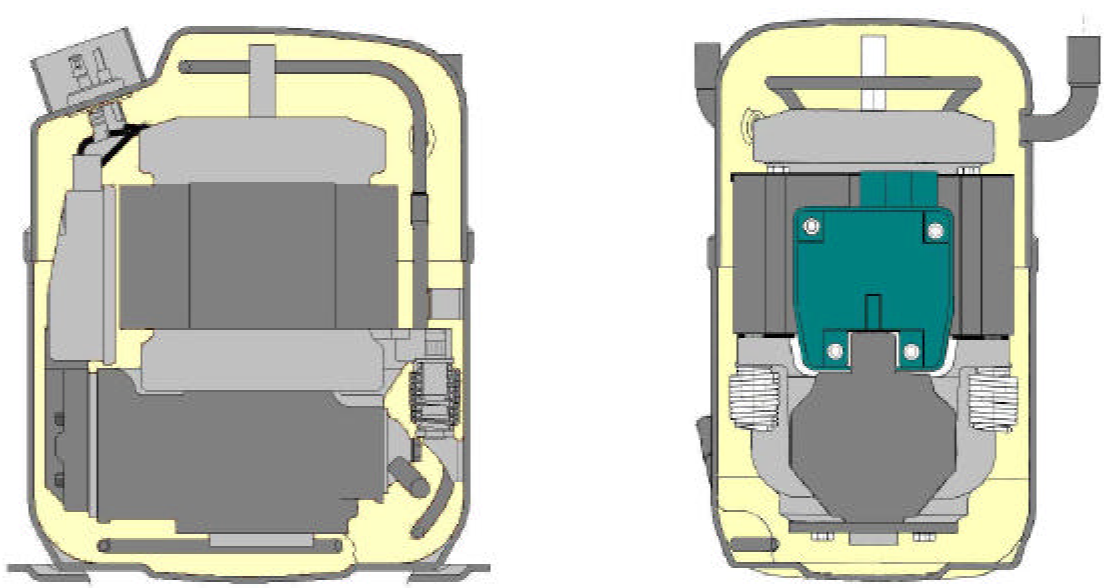


Figure 9: Current J compressor

6. RESULTS

6.1 Compressor Noise

The noise results of some models are shown in the table below. The frequency spectrum is shown in figure 10 for model NJ2192GK.

Table 1: NJ vs. J noise comparison

Refrigerant	**Sound Power Level [dBA]**		
	NJ	**Current J**	D **Reduction**
R404	65.0	71.0	6.0
R22	61.5	67.0	5.5
R134a	59.0	65.0	6.0

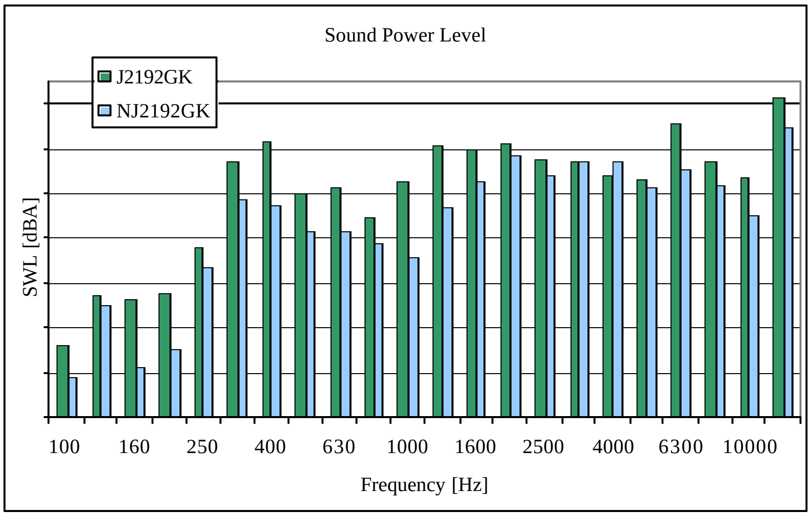


Figure 10: Noise Comparison NJ vs. Current J compressor

6.2 System Noise

Figure 11 presents the noise impact in a refrigeration system when the NJ compressor is applied in the refrigeration system.

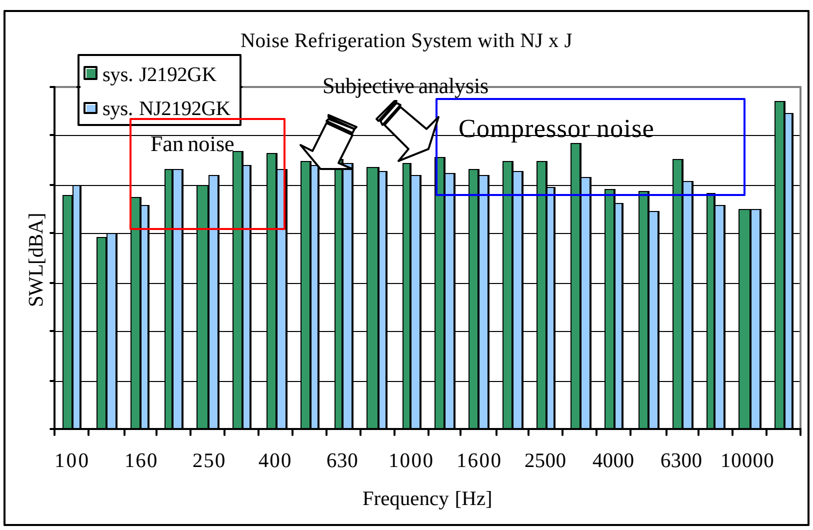


Figure 11: Noise Comparison in the Refrigeration System

6.3 Compressor Vibration

The vibration levels present a reduction of more than 30% as shown in the table below:

Table 2: NJ vs. J vibration comparison

Model	Vibration Level		
	NJ	**Current J**	**D Reduction**
R404	3.20	6.73	6.0
R22	3.40	5.45	5.5
R134a	3.90	6.00	6.0

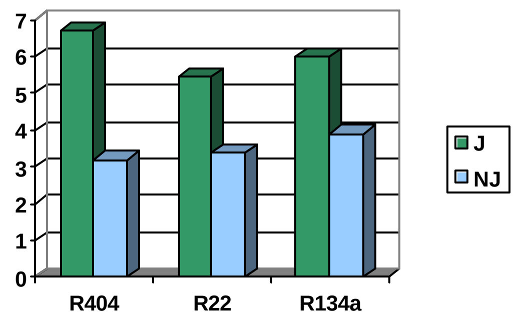


Figure 12: Vibration Comp arison NJ vs. Current J compressor

6.4 Jury Analysis

The jury analysis system comparing the same system with current J and NJ is shown in figure 13:

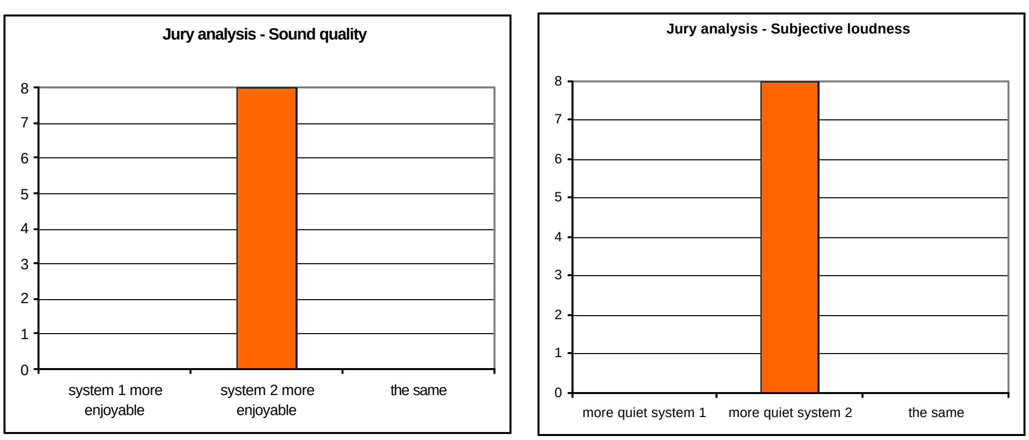


Figure 13: Jury Analysis Comparison NJ x Current J in a system

7. CONCLUSIONS

With the proposed modification a significant total noise reduction was gained in the NJ compressor as well as a reduction in the frequency bands, improving the sound quality, which could be perceived by the final customer. The vibration reduction was considerably higher than 30% helping reduce the sound impact in the refrigeration system. The main object was reached considering the total noise reduction in the compressor and the gain to the customer when using the compressor in the refrigeration system.

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