COMPARATIVE STUDY ON THE QUALITY OF UPHOLSTERY WOVEN FABRICS II: ABRASIVE RESISTANCE AND FLAMMABILITY

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REZUMAT. Stofele de mobila reprezintă o categorie a textilelor de interior importanta in asigurarea confortului si durabilităţii amenajărilor spaţiilor rezidenţiale sau nerezidenţiale. Alături de proprietăţile estetice, stofele de mobilă trebuie sa prezinte o serie de proprietăţi funcţionale, cu utilitate atât în procesul de confecţionare a tapiteriei cât şi în cel de exploatare. Studiul de faţă îşi propune sa analizeze proprietăţile funcţionale pentru trei variante de stofe de mobilă, cu scopul de a le ierarhiza din punct de vedere calitativ si al valorii de utilizare. Studiul cuprinde două părţi: in prima parte sunt determinate rezistenţa la întindere axială şi rezistenţa la forfecare, iar in partea a doua, rezistenţa la abraziune şi rezistenţa la foc. Ierarhizarea finală a celor trei articole s-a realizat pe baza unor coeficienţi de importanţă acordaţi fiecăreia dintre proprietăţile analizate.

Cuvinte chele: Textile de interior, Stofe de mobilă, Rezistenţa la abraziune, Rezistenţa la foc.

ABSTRACT. Woven upholstery fabrics are an important category of interior textiles which provide comfort and durability to the furnishings of both residential and commercial spaces. Besides their aesthetic qualities, woven upholsteries need to have properties which are beneficial to both the upholstery manufacturing process and their practical usage. This study aims to analyse the functional properties for three variants of woven upholstery fabric, with the intent of ranking them according to their quality and value of use. The study consists of two parts: the first part describes the testing method for tensile and shear resistance and the second describe the testing of abrasion resistance and resistance to fire and associated fire-retardant properties. The final ranking relies on setting some importance coefficients to the aforementioned properties and computing a global evaluation index.

Keywords: Interior textiles, Woven upholstery, Abrasion resistance, Flammability, Value of use.

1. INTRODUCTION

Woven upholstery fabrics are interior textiles and can be classified in two broad categories: for domestic and contract use. The areas of which the contract upholstery market is composed include the following categories: automotive (aircraft, cars, buses, trains etc.), commercial (offices, hotels, restaurants, cinemas, theatres etc.), educational (classrooms, sports and leisure complexes etc.), institutional (hospitals, nursing homes, clubs etc.).

Regardless of their purpose, upholstery fabrics have to be designed with certain properties in mind such as tensile resistance, abrasion resistance and flame resistance, which ensure their functionality, as well as appearance retention, resistance to seam slippage, colour-fastness to light and rubbing, stain repellence, easy clean etc., for easy maintenance and long operational life. For contract upholstery fabrics, the functional and aesthetic properties have to be ensured for at least 5 years [1].

This paper is part of a larger study that aimed evaluation and global ranking of woven fabrics upholstery for contract use, depending on their value of use. To this end, for three selected upholstery fabrics, 5 properties were analysed: 4 were aesthetic and functional properties (tensile/abrasion/flame resistance and appearance retention) and the last one pertains to processability (formability, defined by shear resistance).

In the first part of the study were presented the structural characteristics of the three woven fabrics (their structure, the type of yarn used, the nature of the fibres, the yarn fineness and density, the type of weaved structure used) and the results of the ranking based on the evaluation of tensile resistance and shear resistance [2].

This paper presents the results of ranking the same upholstery woven fabrics based on the

evaluation of other properties considered relevant for the intended use: abrasion resistance, appearance retention after abrasion and flame resistance.

Finally, considering all five characteristics analyzed, a global hierarchy of the three articles was established. Importance coefficients were set for each of the analyzed properties and a global evaluation index was calculated. This index allowed ranking the three upholstery fabrics according to their value of use.

2. ABRASION RESISTANCE OF UPHOLSTERY WOVEN FABRICS

One important aspect to be considered when assessing the quality of upholstery fabrics is their behavior at abrasion.

Abrasion is the process of wear or degradation of fibers, yarns and fabric, resulting from the rubbing of a textile surface over another surface. Abrasion resistance is a major factor in determining the lifetime of many textile products. It is influenced by various factors such as the type and the properties of fibers, the yarn structure, the fabric construction, the type and amount of finishing treatment etc. [3].

The abrasion tests are carried out on testing apparatus which perform a large number of friction cycles using abrading materials. The fabric behavior at abrasion can be assessed using various parameters such as: the number of abrasion cycles that lead to total degradation of the specimen, the number of abrasion cycles that cause a certain degree of wear, the mass loss, the changes of parameters characterizing the physical-mechanical or structural properties of fabric (thickness, air permeability, breaking strength, elongation at break, etc.).

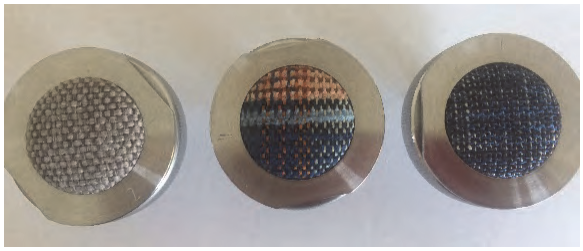
Abrasion tests of the upholstery woven fabrics were performed on Martindale Abrasion and Pilling Tester M235 - SDL ATLAS (Fig.1). The testing procedure was done in accordance with the SR EN ISO 12947-3 standard [4].

A circular specimen of woven fabric, with diameter of 38 mm was placed in support and was rubbed by an abrasive material. The relative movement between the abradant and sample describes a complex pattern - a Lissajous figure - that causes rubbing the sample in all directions. Standard worsted wool fabric with diameter of 140 mm was used as abrasive surface. During the abrasion test, the sample was subjected to a load of 12 kPa, as indicated for the upholstery fabrics. [4]

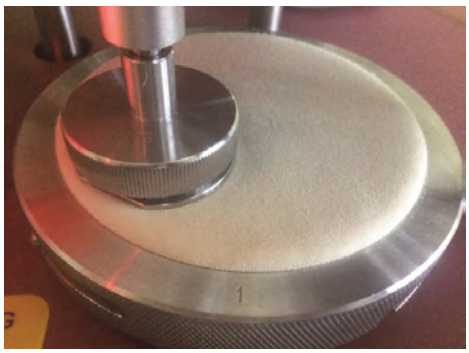
Figure 2 shows the fabric samples prepared for abrasion test: Fig.2 a) shows the upholstery woven fabric specimens mounted in the sample holders and in Fig.2 b) the abrasive worsted wool fabric can be observed.

The number of abrasion cycles was chosen according to estimated number of rubs that would lead to the specimen destruction. For upholstery woven fabrics, the selected test series includes following test intervals: 5,000, 7,500, 10,000, 15,000, 25,000 and 40,000 abrasion cycles [4].

Fig. 1. Martindale Abrasion and Pilling Tester M235-SDL Atlas used for testing the abrasion resistance of upholstery woven fabrics.



The three articles of upholstery woven fabric placed in the sample holders.



Standard woven worsted wool fabric

Fig. 2. The samples prepared for abrasion test.

The abrasion resistance was assessed by the loss of mass and the reduction in thickness of the samples after a certain number of abrasion cycles.

In order to determine the loss of mass, the specimens were carefully removed from the support, the abraded material (fiber debris) from both sides

was removed and the specimens were weighed by means of an electronic balance ABT 120 4M - KERN&SOHN GmbH. The mass of each sample was measured with a precision of 1 mg, at the beginning of the test and after completed each number of abrasion cycles in the chosen test series.

The mass loss was determined with the relationship (1):

$$\Delta_m = m_i - m_f \quad [\text{mg}] \qquad (1)$$

where: Δ_m – mass loss, m_i – the mass of the specimen before test and m_f – the mass of the specimen at the end of the abrasion test.

To evaluate the abrasion effect on the fabric thickness, this parameter was measured before test and after performing each number of abrasion cycles, by means of fabric thickness tester MESDAN.

The thickness reduction after abrasion was determined with the relationship (2):

$$\Delta_g = g_i - g_f \quad [\text{mm}] \qquad (2)$$

where: Δ_g – thickness reduction, g_i – specimen thickness before test and g_f – the specimen thickness at the end of the abrasion test.

Table 1 summarizes the results obtained in the abrasion test, i.e. the mass and the thickness of specimens before test and after each number of abrasion cycles in the test series.

Table 2 presents the calculated values of mass loss and thickness reduction following the abrasion wear, for each of the testing stage.

Figures 2.3 and 2.4 graphically show the evolution of mass and thickness changes of the three article of upholstery woven fabric.

Table 1. **The mass and thickness values of specimens before testing and after each number of abrasion cycles**

Number of abrasion cycles	Mass (mg)			Thickness (mm)		
	1st Article	2nd Article	3rd Article	1st Article	2nd Article	3rd Article
0	363	372	387	0,99	0.94	0.91
5,000	363	372	371	0,99	0.94	0.87
7,500	363	372	370	0,95	0.93	0.86
10,000	363	362	363	0,93	0.88	0.82
15,000	360	360	360	0,92	0.83	0.82
25,000	356	362	341	0,88	0.83	0.79
40,000	350	344	330	0,88	0.81	0.75

Table 2. **The mass loss and thickness reduction by abrasion**

Number of abrasion cycles	Mass loss (mg)			Thickness reduction (mm)		
	1st Article	2nd Article	3rd Article	1st Article	2nd Article	3rd Article
5,000	0	0	7	0	0	0.04
7,500	0	0	8	0.04	0.01	0.05
10,000	0	10	15	0.06	0.06	0.09
15,000	3	12	18	0.07	0.11	0.09
25,000	7	10	37	0.11	0.11	0.12
40,000	13	28	48	0.11	0.13	0.16

From the values presented in Table 2 and from graphical representations in Figure 3 and Figure 4, one can notice a similar trend, both in mass loss and thickness reduction, for the three studied woven fabrics.

For the 1st Article, mass loss occurs after 15,000 cycles of abrasion and is very low in value - only 3 mg. At the end of test, the total mass loss is 13 mg, which represents a percentage of 3.5% out of initial mass of the specimen. A slight reduction in specimen thickness (0.04 mm) occurs after 7,500 abrasion cycles; after 40,000 cycles the total thickness reduction is 0.11 mm, representing 11.1% percentage decrease.

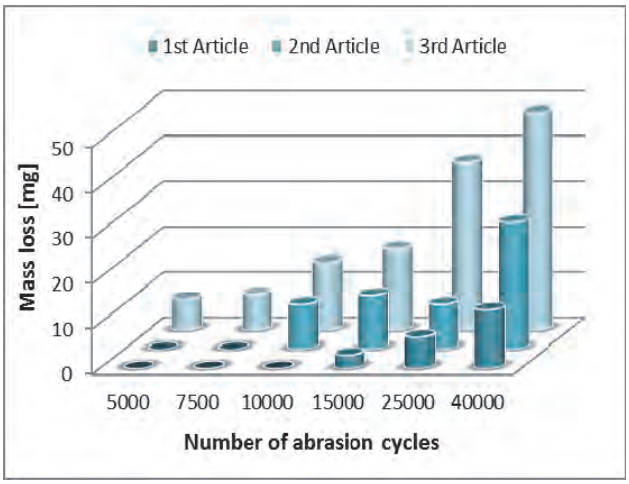


Fig. 3. Mass loss of the three articles after 5,000, 7,500, 10,000, 15,000, 25,000, and 40,000 cycles of abrasion

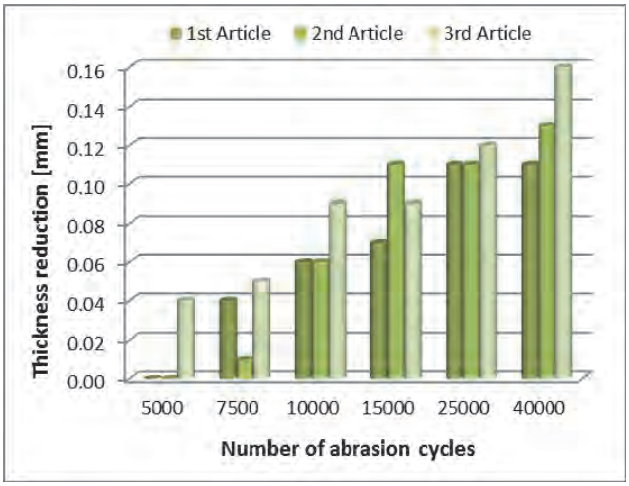


Fig. 4. Thickness reduction of the three articles after 5,000, 7,500, 10,000, 15,000, 25,000, and 40,000 cycles of abrasion

The 2nd Article behave similar, except that the change of mass occurs earlier and the final values of mass loss and thickness reduction at the end of test are higher than for the 1st Article, i.e. 7.5% and 13.8% respectively.

The 3rd Article shows the weakest performance: both the mass loss and thickness reduction occur at the very beginning of the test. After 5,000 abrasion cycles the specimen mass is already decreased by 7 mg and the thickness reduced by 0.04 mm. By the end of test, the 3rd Article lose 12,4% from mass and 17.6% of thickness.

The above observations allow ranking the studied upholstery articles, in terms of abrasion resistance, as follows:

I – 1st Article;
II – 2nd Article;
III – 3rd Article.

In addition to the evaluation of abrasion resistance by the loss of mass and the thickness reduction, also the appearance retention of upholstery woven fabrics was analyzed. After the completion of each number of abrasion cycles, pictures of the specimens were taken and were used to assess the abrasion process evolution.

Table 3 shows the pictures of the fabric specimens before abrasion test and after 7,500, 15,000, 25,000, and 40,000 abrasion cycles. The analysis of these images highlighted the following aspects:

After 7,500 abrasion cycles, one can observe that the 1st Article and the 3rd Article show only slight change in color due to the onset of the fiber dislocation process within the yarn systems, while the surface area of the 2nd Article remains unchanged.

After 15,000 abrasion cycles, the surface appearance of the 2nd Article still remains unchanged, while for the 1st Article and the 3rd Article the wear process become more visible. The 1st Article shows a color change - the fibers dislocated from the two yarn systems of different color are mixed on the worn surface, changing the shade of color. One can notice the thinning of the warp threads and the pilling formation on fabric surface. The 3rd Article is the most affected by abrasion wear and show color fading, pilling formation and broken warp threads.

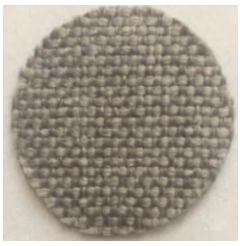
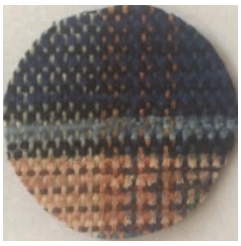
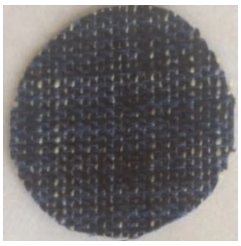
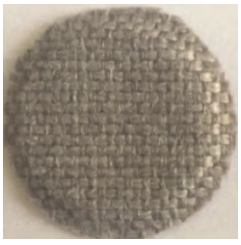
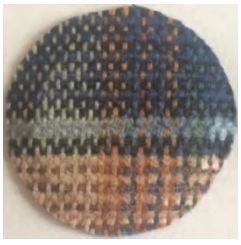
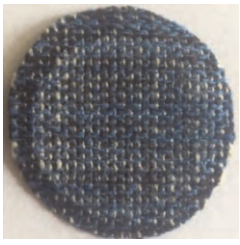
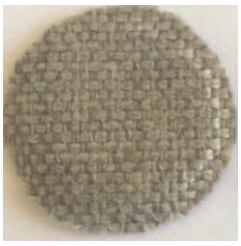
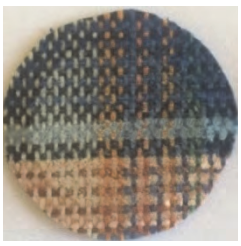
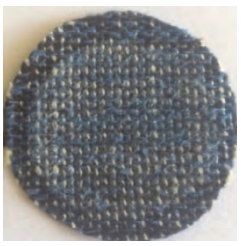
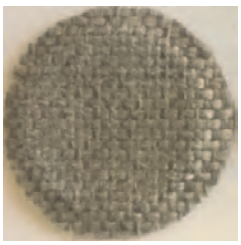
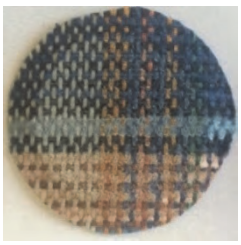
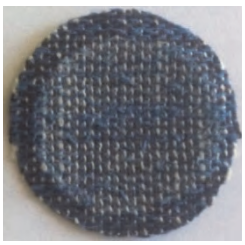
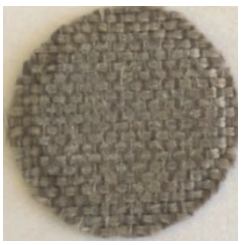
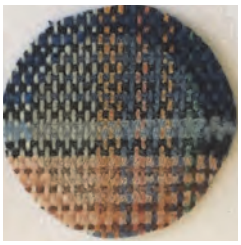
After 25,000 abrasion cycles, the wear is more pronounced for the 1st Article and the 3rd Article while for the 2nd Article the first surface changes occur.

At the end of the abrasion test - *after 40,000 abrasion cycles* - the hierarchy of the three variants of upholstery fabrics is maintained: the 2nd Article shows minimal changes in color (slight discoloration) without resulting the hairiness or formation the pilling effect. The 1stArticle continues to change its color - the surface becomes mat, with thinner warp threads and pilling effect. The 3rd Article exhibits the greatest degradation regarding both the surface appearance as well as the structure: pronounced discoloration, the disappearance of floating threads from upper warp system, broken warp threads, pilling effect.

Considering the above presented observations, it can be concluded that regarding the visual appearance preservation after abrasion, the three studied articles can be ranked as follow:

I – 2nd Article;
II – 1st Article;
III – 3rd Article.

Table 3. **Pictures of specimens surface before test and after 7,500, 15,000, 25,000 and 40,000 abrasion cycles**

Number of abrasion cycles	1st Article	2nd Article	3rd Article
0			
7,500			
15,000			
25,000			
40,000			

3. FLAMMABILITY OF UPHOLSTERY WOVEN FABRICS

Flammability is a major criterion for selection the upholstery fabric for contract use, because of the potential risk of ignites and propagates the fire. In this situation, it is desirable that the time interval between the moment of fabric contact with the flame and the moment of fabric ignition to be as large as possible in order to provide sufficient reaction time to the potential victims. Also, it is important to know the manner of material burning after ignition and the speed of flame propagation.

To assess the behavior of the three upholstery woven fabrics at the flame contact, the average time of ignition was determined and the burning mode of tested samples after the ignition and flame removal was observed.

The testing methodology was based on the standard EN ISO 6040: 2004 [5].

The surface of test specimen with size of 200 mm x 80 mm, placed in upright position was brought into contact with the flame from a special burner. The test specimens were oriented with the length on the vertical direction and the face toward to the ignition flame. Five tests were performed for each article.

The tests were recorded using a video camera with slow motion function. On the video films was possible to precisely establish the moment when the ignition flame come into contact with the specimen surface and the moment when the specimen lights up, which allowed to determine the ignition time.

The pictures in Fig. 5 show the typical moments for characterizing the fire behavior of the fabrics:

- the moment of contact with the flame,
- the moment when the specimen ignites,
- the manner of specimen's combustion at 2 seconds after ignition and flame removal.

The value of ignition time (seconds) for each article (the average of five tests) is also displayed in Fig. 5.

From the pictures shown in Fig. 5 one can observe that the three studied woven articles behave different at flame contact and also have a different burning mode. The 1st Article lights up after 4 seconds and burns very fast, with a strong flame while the 2ndArticle ignite after only 3 seconds, but it burns slower. The 3rd Article shows the best behavior: the ignition time is 6 seconds, and the burning manner is different: the material begins to melt first and then burns with flame.

Considering the above observations, from point of view of flammability, the three studied articles can be ranked as follow:

I – 3rd Article
II – 1st Article
III – 2nd Article.

	The contact of flame with fabric surface	**The moment of ignition**	**Burning behaviour at 2 seconds after ignition and flame removal**	**Ignition time [s]**
1st Article				4
2nd Article				3
3rd Article				6

Fig. 5. Typical images for fire behavior of the tested upholstery woven fabrics

4. GLOBAL ASSESSMENT OF UPHOLSTERY WOVEN FABRIC

The results presented in both the first part of the study [2] and in this second part, showed that the hierarchy of the three analyzed articles broadly differs depending on the considered property. For example, an article that ranks first in terms of flammability, ranks third in terms of abrasion resistance and second in terms of tensile resistance. Therefore, in order to decide which of the three articles is the most suitable as upholstery fabric, would be very helpful a global hierarchy of the three woven fabrics according to their value of use.

The value of use of a textile fabric is given by the degree to which it fulfils a number of functions that can be expressed by quality characteristics or exploitation properties. Each property has a certain level of importance in ensuring the products' value of use according to its intended destination.

In order to obtain an overall ranking of upholstery fabrics according to their value of use, a global evaluation index was used. It was calculated taking into account the importance level of each fabric property and the score attributed to each article after ranking according to the considered property.

The level of importance was set through *importance coefficients* which were determined as follow [6]: the five important properties that upholstery fabrics have to meet were listed and compare two by two. Following each comparison, a decision was granted: 1-0, 0.5-0.5, or 0-1.

The decision 1-0 or 0-1 is granted when one of the properties has a greater importance compared to the other one. The decision 0.5 - 0.5 is granted when the two compared properties have the same importance.

Total number of decisions depends on the number of properties considered and is determined with the relationship (3):

$$D = C_n^2 = \frac{n(n-1)}{2} \quad (3)$$

where: D – total number of decision, n – the number of considered properties.

The importance coefficient was calculated with the relationship (4):

$$IC = \frac{FD}{D} \quad (4)$$

where: IC – the importance coefficient, FD – the number of favorable decisions and D – total number of decisions.

Table 4 summarizes the calculus of the importance coefficients for the five considered properties of upholstery fabrics. These coefficients were further used to calculate the global evaluation index.

Depending on the place in the partial hierarchies obtained for the analyzed properties, the three articles were awarded points as follows:

Ist : 3 points,
IInd : 2 points,
IIIrd: 1 point.

Table 5 shows the number of points awarded to the three articles of upholstery fabrics.

Table 4. **Calculation of the importance coefficients for the considered properties of upholstery fabrics**

Fabric properties	Decisions										Favourable decisions	Importance Coefficient
	1	2	3	4	5	6	7	8	9	10		
Tensile resistance (maximum force)	0	0	0.5	0							0.5	0.050
Abrasion resistance (mass loss and thickness reduction)	1				0.5	1	1				3.5	0.350
Appearance retention		1			0.5			0.5	0		2	0.200
Shear resistance (formability)			0.5			0		0.5		0	1	0.100
Flammability (ignition time)				1			0		1	1	3	0.300

Table 5. **Calculation of the global evaluation index**

Fabric properties	Importance Coefficient	Number of points		
		1st Article	2nd Article	3rd Article
Abrasion resistance	0.35	3	2	1
Flammability	0.3	2	1	3
Appearance retention	0.2	2	3	1
Shear resistance	0.1	3	2	1
Tensile resistance	0.05	3	1	2
Global evaluation index		**2.5**	**1.85**	**1.65**

The fabric properties are listed in the table in descending order, according to the importance coefficients' values.

The global evaluation index was calculated with relationship (5):

$$GI = \frac{\sum_{i=1}^{5}(IC_i \cdot P_i)}{D} \quad (5)$$

where: GI – the global evaluation index, IC_i – the importance coefficient of the i^{th} fabric property and P_i – the number of points for the i^{th} fabric property.

Based on the values of global evaluation index, the overall ranking of three upholstery woven fabrics is as follows:

I – 1st Article
II – 2nd Article
III – 3rd Article.

5. CONCLUSIONS

This paper is the second part of a study that aims to find a method of ranking the quality of upholstery woven fabrics for contract use by analyzing five of the most desirable properties: tensile resistance shear resistance, abrasion resistance, flame resistance and appearance retention.

It presents the results of the upholstery fabrics ranking according to their performance regarding the abrasion resistance, appearance retention and flame resistance (flammability).

The results obtained in partial evaluation of the upholstery woven fabrics showed that the hierarchy of the three articles depends on the considered property.

The overall quality ranking of upholstery woven fabrics, achieved based on the global evaluation index is similar with the one resulted for the abrasion resistance and shear resistance and differs very little from the one regarding the appearance retention after abrasion.

These properties are very important features for the upholstery woven fabrics and the obtained results indicate a good correlation between the partial hierarchies and the overall ranking of fabrics.

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