

ANALYSIS OF AXIAL TESTS OF CONVEYOR BELT SAMPLES

ANALIZA AKSIJALNIH ISPITIVANJA UZORAKA TRAKA TRAKASTIH TRANSPORTERA

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REZIME

Kako trake trakastih transportera predstavljaju ključni element transportera, veoma je bitno da one budu proizvedene u skladu sa važećim standardima i kasnije ispitane kako bi se potvrdili nazivni parametri. U ovom radu su prikazane četiri vrste aksijalnog ispitivanja uzoraka trakastih transportera. Opisani su potrebni ambijentalni uslovi za ispitivanja i potreban ispitni uređaj. Dat je pregled ispitivanja, gde je navedeno kako se ispitivanje vrši i objašnjeno je kako da se tumače dobijeni rezultati.

Professional paper

SUMMARY

As conveyor belts are the key element of conveyors, it is very important that they are manufactured in accordance with applicable standards and later tested in order to confirm nominal parameters. In this paper, four types of axial testing of conveyor belt samples are presented. The required ambient test conditions and the required test device are described. An overview of tests is given where it is stated how tests are performed and it is explained how to interpret the obtained results.

1. INTRODUCTION

Conveying is a mean of continuous transport without stopping during loading and unloading of material. It has an important role in the industry - production lines in factories, transport of ore in mines, material feeding, etc. There is a large number of devices for continuous transport, and the most common among them is the belt conveyor. For this type of conveyor, the load bearing and pulling element is the belt, which is therefore the most responsible, but individually the most expensive element of the conveyor [1 - Živanić script]. The belt consists of three layers, Fig. 1, - the upper protective rubber layer (1), the middle bearing layer – the core which consists of plies (2), which can be made of textile fibers, synthetic fibers or can be made of steel ropes and the lower protective rubber layer (3).

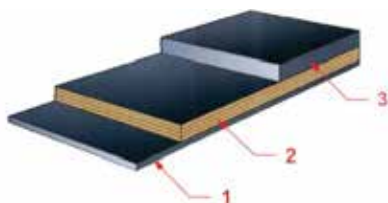


Figure 1. Sample of a conveyor belt

The basic parameter on the basis of which the design of belt conveyors is done is the required material transport capacity, which can be presented as the mass or volume capacity, according to [2].

After receiving the information about the required capacity of the conveyor, the first element that should be calculated is the conveyor belt. After completing the calculation of the belt conveyor, information is obtained about the necessary parameters of the belt - its width, number of plies, strength of plies to tear (tensile strength), material of plies, thickness of rubber layers, etc.

According to [3 - DIN 22102], manufacturers of conveyor belts are obliged to state on each belt the information about the manufacturer, material of plies, tensile strength of plies, number of plies, special features of the belt if it has one and the identification number of the belt.

In order for the data about the tensile strength of plies to be reliable, the manufacturers have to test samples of belts through a number of experiments.

The topic of this paper will be axial testing of conveyor belt samples.

2. BELT SAMPLING AND REQUIRED CONDITIONS FOR TESTING

Before it is possible to perform experimental tests, it is necessary to take proper samples of the belt. The sampling scheme is determined according to [3 - DIN 22102] which is shown in Fig. 2:



Figure 2. Sampling scheme on the conveyor belt

The number of samples depends on the length of the belt, which is determined according to [4 - ISO 282]. Table 1 shows the number of samples depending on the total length of the belt:

Table 1. Number of samples depending on the total length of the belt

Total length of the conveyor belt [m]	Number of samples
$L \leq 500$	1
$500 < L \leq 1000$	2
$1000 < L \leq 2000$	3
$2000 < L \leq 3500$	4
$3500 < L \leq 5000$	5
$5000 < L \leq 7000$	6
$7000 < L \leq 10\ 000$	7
Note: It is necessary to take one additional sample for each 5000 m if the length of the belt is over 10 000 m.	

In order for the tests to be valid, it is necessary to have a certain time interval between the production of the belt and the test itself. Also, it is necessary to respect atmospheric conditions that are required for the results to be adequate. These parameters are determined according to [5 - ISO 18573].

For all types of tests, it takes 24 hours between the production of the belt and sampling. On the

other hand, the time between production and testing should not exceed 3 months.

Regarding atmospheric conditions, there are 5 combinations that allow proper testing of samples and they are shown in Table 2:

Table 2. Required atmospheric conditions

		Temperature [°C]	Relative humidity [%]
1	Atmospheric conditions A	20 ± 2	65 ± 5
2	Atmospheric conditions B	23 ± 2	50 ± 5
3	Atmospheric conditions C (tropical)	27 ± 2	65 ± 5
4	Atmospheric conditions D (only temp. control)	23 ± 2 or 20 ± 2	/
5	Atmospheric conditions E (only temp. control, tropical)	27 ± 2	/

3. THE DEVICE FOR AXIAL TESTING OF CONVEYOR BELT SAMPLES

The device for axial testing of samples of conveyor belts should work on the principle of constant speed of elongation (CRE) of the sample, or on the principle of constant speed of movement (CRT) of the jaws. The device must be capable of stretching the belt sample at a speed of 100 ± 10 mm / min. It needs to be designed according to [6 - ISO 7500-1]. The drive of the device is usually electric, but it can be hydraulic and possibly manual for measurements of a lower accuracy class. The stretching of the belt sample can be performed in several ways, among which the stretching by means of a threaded spindle stands out.

In order to measure the force acting on the sample, the device should have a force sensor (loading cell), Fig. 3a. The loading cell must be mounted on the device so it transmits only the axial force. This is achieved by applying joint connections between the load cell and one of the jaws, as well as between the loading cell and the construction of the device. In order to measure the elongation of the belt sample, the device should have a displacement sensor, Fig. 3b, which must be in constant contact with the

belt sample. Also, the device should be able to graphically record the results during the test.

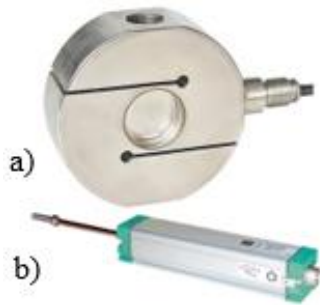


Figure 3. Examples of required sensors

Jaws of the device should be designed to prevent movement of the belt sample during the test and therefore it is necessary to use jaws with a serrated surface shown in Fig. 4.

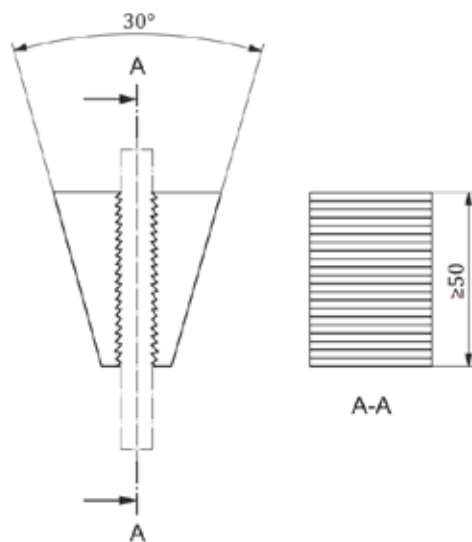


Figure 4. Recommended design of serrated jaws

Before using the device, it is necessary to calibrate the force and displacement measuring system for each force and displacement range which will be used. The calibration of the force and displacement measuring system is performed using instruments to confirm the specified values. Calibration of the displacement measuring system is performed using the etalon, while calibration of the force measuring system is performed according to [7 - ISO 376]. It is possible to use weights of known masses or instruments to exercise known forces. The class of the instrument for realizing the known force must be of a better accuracy class than the device being calibrated. An example of a device for testing samples of conveyor belts is given in Fig. 5, where 1

indicates the measuring force transmitter, 2 is the upper jaw, while 3 indicates the belt sample. The maximum force that the load cell can bear must be 25% greater than the maximum force that the load cell will be loaded with during the test, while the displacement sensor must be able to move at least 100 mm with an accuracy of at least 0.1 mm.



Figure 5. INSTRON 5960 series device

4. THE DEVICE FOR AXIAL TESTING OF CONVEYOR BELT SAMPLES

There are 4 types of axial tests of conveyor belts samples – determination of tensile strength and elongation of the belt sample; determination of elastic and permanent deformation of the belt sample and modulus of elasticity; determining the resistance to separation of the belt sample layers and determining the maximum force that can be withstood by the connection of the ends of the belt sample. It is possible to use the device described in the previous chapter for all tests.

4.1. Determination of tensile strength and elongation of the belt sample

The tensile strength and elongation of the belt sample are determined according to [8 - ISO 283].

This test is used to determine the tensile strength of the belt sample in the longitudinal and transverse direction of the sample and elongation of the sample under the action of the reference force - one tenth of the nominal tensile strength of the belt multiplied by the width of the belt sample in the narrowest part expressed in millimeters.

The tensile strength of the belt [N / mm] is a quantity that shows how much force the belt can withstand before it breaks. It is calculated by dividing the maximum force [N] recorded during the test by the width [mm] of the test sample in the narrowest part.

The elongation of the belt sample under the action of the reference force [%] is calculated according to the expression:

$$E_{Fr} = \frac{100(L_R - L_1)}{L_1} \quad (1)$$

where:

- L_2 – sample length under the action of the breaking force;
- L_1 – initial sample length.

The elongation of the belt sample under the action of the breaking force [%] is calculated according to the expression:

$$E_{Fb} = \frac{100(L_2 - L_1)}{L_1} \quad (2)$$

where:

- L_2 – sample length under the action of the breaking force;
- L_1 – initial sample length.

In order for the results to be valid, for all three types of experiments it is necessary to test three samples and express the mean value of the obtained results.

The test is performed by placing the belt sample in jaws of the testing device and stretching it to the desired limits depending on the type of test. An example of a belt sample elongation test at the breaking point is shown in Fig 6.



Figure 6. Belt sample test procedure

There are four types of samples that depend on the tensile strength of the belt, i.e. of the nominal tensile strength of the sample. Samples A, B and C are used arbitrarily when the tensile strength of the belt is less than 2000 N/mm, while sample D is used when the tensile strength of the belt is greater than 2000 N/mm.

The samples are shown in Figure 6. The reference lines marked in the figure (1) represent the lines between which the sample should be free, i.e. jaws should be placed up to those lines.

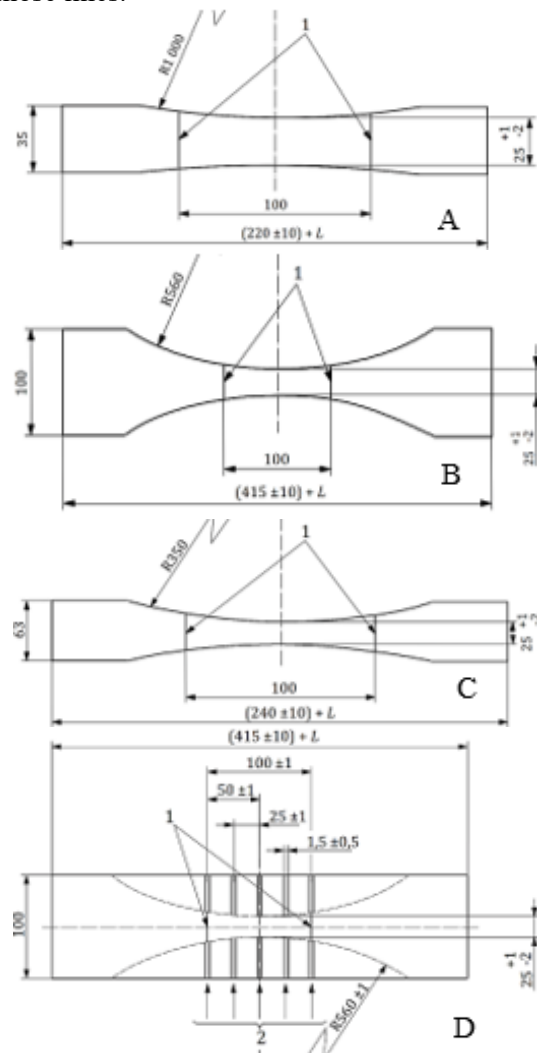


Figure 7. A, B, C and D belt samples

4.2. Determination of elastic and permanent deformation of the belt sample and modulus of elasticity

Testing of elastic and permanent deformation of the belt sample and modulus of elasticity is performed according to [9 - ISO 9856]. As for light conveyor belts, they are tested according to [10 - EN 873]. The test is performed by stretching the belt sample. The force with which the sample is stretched depends on the tensile strength of belt sample plies. Prior to the start of the test, the sample has to be loaded with a force of 0,5% (2) of the nominal tensile strength of the sample multiplied by the width at its narrowest point.

During the test, it is necessary for the test device to act on the sample in the range

between the upper and lower reference forces where the event changes with a frequency of 0.1 Hz. The upper reference force F_U [N] should be equal to 10% of the nominal tensile strength of the belt sample multiplied by the width at the narrowest part, while the lower reference force F_L [N] should be equal to 2%. It is necessary to perform a graphical recording of the 1st and 200th test cycle (1), as shown in Fig. 8.

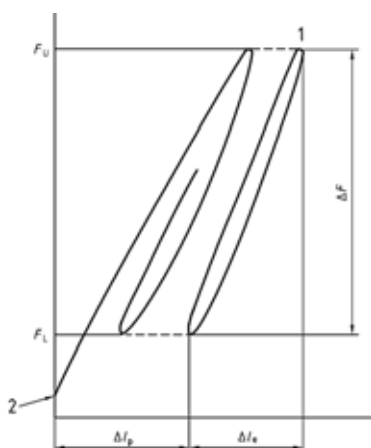


Figure 8. Graphic recording of the test result

From the obtained graph it is necessary to read the value ΔF - force range, as well as the values Δl_p - permanent elongation, and Δl_e - elastic elongation.

The percentage of permanent elongation of the belt sample is calculated according to:

$$\varepsilon_{perm} = \frac{\Delta l_p}{l_0} \cdot 100 \quad (3)$$

The percentage of elastic elongation of the belt sample is calculated according to:

$$\varepsilon_{elst} = \frac{\Delta l_e}{l_0} \cdot 100 \quad (4)$$

where:

- l_0 – initial sample length.

The modulus of elasticity of the belt sample is calculated according to:

$$M = \frac{\Delta F}{\varepsilon_{elst}} \cdot 100 \quad \text{or} \quad M = \frac{\Delta F \cdot l_0}{\Delta l_e} \quad (5)$$

In order for the results to be valid, it is necessary to test three samples and express the mean value of the obtained results. The elastic deformation test of a belt sample is shown in Fig. 10.



Figure 10. Elastic deformation test of a belt sample

4.3. Determining the resistance to separation of belt sample layers

Determination of the resistance of the belt sample to separation of belt layers is performed according to [11 - ISO 252]. It is not possible to use this test on light conveyor belts as described in [12 - ISO 21183].

There are two ways in which this test can be performed - methods A and B.

According to method A, it is necessary to separate the upper protective rubber layer (1) from the rest of the sample at one end of the sample so that the jaw can accept the sample, Figure 10. It is necessary for one jaw to grab the rubber layer and the other jaw to grab the rest of the sample. The sample is then stretched and the force required to separate the layers by an additional 100 mm is recorded. It is then necessary to repeat the procedure for each subsequent ply until the middle of the sample is reached. Next, it is necessary to put another sample in the jaw and start from the lower protective rubber layer (2) and repeat the procedure until the middle of the sample is reached. Separation of the layers should occur between them, if it happens that during the separation a layer begins to split inwards, such a phenomenon should be noted because it is an indicator of the inadequate connection between the layers. Method A is shown in Fig. 11.

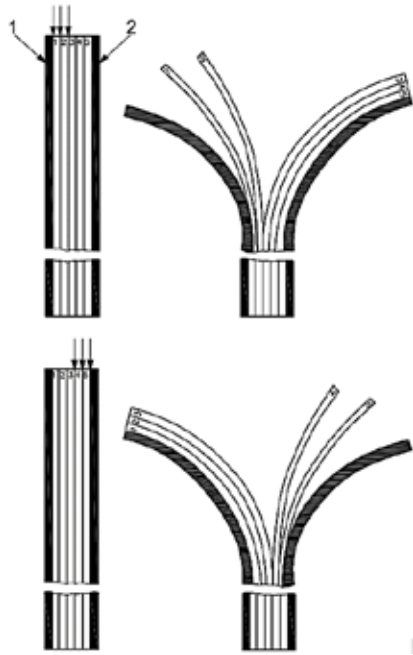


Figure 11. Method A shown on a sample of 5 plies

According to method B, the same steps are performed at the beginning as with method A. The difference is that the individual plies are not separated, but 2 by 2 plies are separated, Fig. 12.

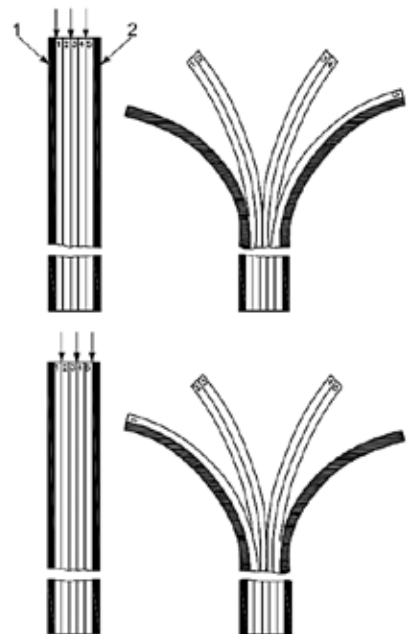


Figure 12. Method B shown on a sample of 5 plies

In both methods, it is necessary to find the mean value of the force at which layers separate. Also, it is necessary to note the minimum value of the force at which the separation occurs. Obtained results are evaluated according to [13 - ISO 6133]. The

mean adhesion [N / mm] is obtained as the quotient of the mean force [N] recorded and the sample width [mm]. The minimum adhesion is obtained as the quotient of the minimum value of the force [N] that was recorded and the width of the sample [mm].

According to [3 - DIN 22102], the value of adhesion (resistance to separation) should be close to the values shown in Table 3:

Table 3. Adhesion values

Adhesion [N/mm]		
Between plies	Between plies and rubber covers	
	Cover thickness [mm]	
	0,8 - 1,5	above 1,5
5	3,5	4,5

Adhesion values obtained by the test may be at most 1 N/mm less than values given in the table in order to be able to claim that the belt is adequately manufactured. Maximum adhesion values may be 16 N/mm for belts with a tensile strength less than or equal to 1250 N/mm and 20 N/mm for belts with a tensile strength greater than 1250 N/mm.

The testing procedure is shown in Fig. 13:



Figure 13. Test of resistance to layer separation of a belt sample

4.4. Determining the maximum force that can be withstood by the connection of ends of the belt sample

There are three ways to connect ends of the belt:

- vulcanization (hot joining) - used for belts with textile or synthetic plies, with

one, two or more plies, as well as for belts where steel ropes are used as plies;

- adhesive (cold bonding) - used for belts with textile or synthetic plies, with two or more plies;
- mechanical – it is considered as a temporary connection.

First two ways of connecting belt ends are tested according to [14 - PN-C-94147], while the third way of connecting belt ends is tested according to [15 - ISO 1120].

When testing connections formed by vulcanization and adhesion, the tensile strength of the joint, the delamination strength of an adhesive joint and the shear strength of an adhesive joint are examined. The belt sample is placed in jaws of the test device and the sample is stretched until the joint breaks. Then the tensile strength of the joint is calculated as the quotient of the measured force [N] and the width of the sample [mm]. It is not necessary to prepare a sample for this test, i.e. it is possible to test rectangular samples with a minimum width of 100 mm.

According to [3 - DIN 22102], the percentage of loss of tensile strength of joints in relation to the tensile strength of the belt is shown in Table 4.

Table 4. Percentage of loss of tensile strength of joints in relation to the tensile strength of the belt

Number of plies	The loss of tensile strength at joints of belt ends [%]
1	0,2
2	0,2 ¹⁾ 0,5 ²⁾
3	0,33
4	0,25
5	0,2
¹⁾ combination with reinforcement interlayer and 2-step joint	
²⁾ without reinforcement interlayer	

In order for results to be valid, it is necessary to test three samples and express the mean value of obtained results. Testing of the vulcanized joint of the belt sample is shown in Fig. 14.



Figure 14. Vulcanized belt joint test

When testing mechanical joints, the test differs in two cases - when testing joint where a pin is used and the joint where a pin is not used, Fig. 15.



Figure 15. Mechanical joints

In both cases, the test is performed by the testing device as it stretches the belt sample until the joint breaks. The difference is that when testing samples where a pin is used in the connection joint, one belt sample is used and its lower end is placed in the fixed jaw, while the upper end with a mechanical joint is placed in an attachment placed in the movable jaw, Fig. 16.

The sample has to be of full thickness and of minimum length of 100 mm plus the length required to accept the sample into the jaw. The width of the joint should be at least 100 mm. The width of the belt sample should be at least 150 mm.

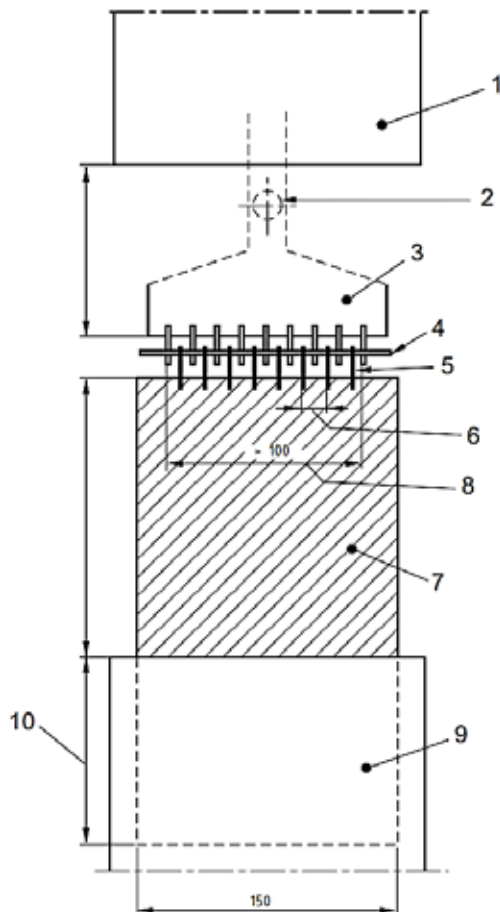


Figure 16. Test scheme of the sample with a pin in the joint: 1 – the movable jaw, 2 - jaw axis, 3 - attachment for accepting mechanical connections in the jaw, 4 - pin, 5 - half of the mechanical coupling, 6 - step of the mechanical coupling, 7 – the belt sample, 8 - joint width, 9 - the fixed jaw, 10 - belt sample width

When testing a sample where a pin is not used in the joint, two samples of the belt that are connected mechanically are used. The end of one sample is placed in the fixed jaw, while the end of the other sample is placed in the movable jaw. Both samples should be of full thickness, minimum length of 100 mm plus the length required to accept the sample into jaws and a width of 150 mm. The width of the joint should be at least 100 mm.

It is necessary to note the value of the force at which the joint is broken. After that, the tensile strength of the joint should be expressed as the quotient of the recorded value of the force [N] and the joint width [mm].

In order for the results to be valid, it is necessary to examine three samples and express the mean value of obtained results. Fig. 17 shows the test of the sample where the joint was made with a pin.

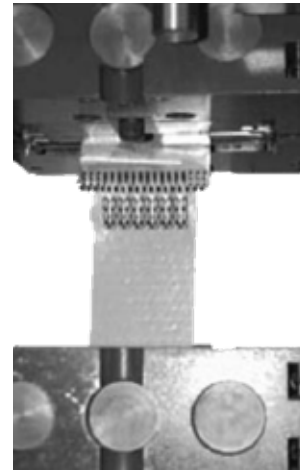


Figure 17. Test of the mechanical joint of conveyor belts where the pin is used

5. CONCLUSION

The role of the belt conveyor is to ensure continuous flow of material. The key element of the conveyor is the belt, which has a dual role - as a load bearing and as a pulling element. To be able to fulfill its role, the belt must be designed and manufactured in accordance with standards from that area. Also, belt samples should be tested in accordance with tests mentioned in previous chapters in order to confirm nominal characteristics or to find defects that occurred during manufacturing. This paper can serve as a basis for the design of the device for axial testing of conveyor belt samples. It has been shown that the testing device should be able to incessantly apply tension to the belt sample. The value of the tension depends on the type of testing that is conducted and the tensile strength of plies. The deformation of the sample has to be measured during the test. Also, the drive of the device should have a braking system that reacts when the testing sample breaks in order to prevent unwanted behavior of the device. Finally, all test values that are gathered during the test have to be displayed live, but also they have to be stored so they can be analyzed later.

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