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Factors Determining the Size and Norms for Securing Barrier Wagon Groups

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ABSTRACT

Currently, barrier wagon groups are used on the sorting tracks of railway stations as means to prevent rolling stock from moving beyond their useful length to the opposite side from the hump yard. The reasons to use barrier wagon groups are explained by some factors that are present at most Russian railway marshalling stations and comprise elements of longitudinal profile with accelerating grade on the tracks of hump yards, significant length of sets of uncoupled wagons, unfavorable weather and climatic conditions.

Following use of the empirical method for determining the size of barrier wagon groups and cases of traffic safety violation it was necessary to develop a scientifically sound method for determining the need for formation of barrier wagon groups.

The objective of the study is to identify patterns and factors affecting the decision-making on formation of a barrier wagon group on a particular classification track (classification-departure track), as well as on the size and securing of the barrier wagon groups. The research used methods of statistical analysis and mathematical modelling.

The results of the research were reflected in regulatory instruments of the JSC Russian Railways, particularly in the Procedure to determine the size of barrier wagon groups to be placed on the free tracks of classification yards before train disassembling and to calculate the norms for securing barrier wagon groups [1].

The article provides an analysis of the current technology for formation of barrier wagon groups on the tracks of classification and classification & departure yards, as well as the definition of the term of barrier wagon group. A phased model is proposed for determining the need for formation of barrier wagon groups on free classification tracks before train disassembling, as well as of calculation of the size and norms for securing barrier wagon groups. Calculation criteria are established considering the holding capacity of a barrier wagon group and the mass of rolling wagons. Examples of calculations for specific marshalling stations are given (using examples of JSC Russian Railway). The main factors influencing the size and norms for securing barrier wagon groups were determined. The dependences of the maximum allowable speed of leaving yard brake position on the average axial load of the wagons in the absence of wind and with a fair wind, as well as of the norms for securing barrier wagon group on the maximum mass of the classified set of wagons and grade rate.

A scientifically based calculation of the required size of the barrier wagon group and the norms of its securing with stop-blocks (brake shoes) will allow to increase traffic safety by preventing the exit of rolling stock outside the track useful length.

Keywords: railway, traffic safety, marshalling station, traffic control, classification process, blocking means, barrier wagon group, classification track, norms of securing, track profile, grade.

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At railway stations where the trains are formed, train formation and disassembling is carried out with the help of different sorting facilities using various principles of wagon braking with the use of wagon retarders and (or) brake shoes. The technical capacity of railway stations to form or disassemble trains largely depends on the track useful length of hump yards, their profile and plan, as well as on the characteristics and aerodynamic properties of rolling sets of wagons.

According to the requirements of the current regulatory and technical documents in Russia, tracks of the hump yard of gravity humps of large, medium, and low capacity should be equipped with blocking means [2–4]. However, the analysis of the current situation shows that at several marshalling stations, the profile of tracks of hump yard yards does not comply with regulatory requirements, and there are no blocking means on them. As a result, during disassembling of trains using the hump, especially under adverse weather conditions, there remains a risk of such dangerous events as wagons moving outside the track useful length, a shot of a switch, a collision, formation of one-side sliders. This resulted in constant buildup of excessive restrictions on operation of humps, which in turn leads to a decrease in their processing capacity and to a decrease in productivity.

Currently, barrier wagon groups[1] are used to prevent unauthorized exit of rolling stock beyond the track useful length of the classification (classification & departure track) track in the direction opposite to the hump. The disassembling of trains using the hump and shunting by pushing to free classification (classification and departure) tracks is prohibited until formation of barrier wagon groups on them.

The foreign experience of using barrier wagon groups at marshalling stations is missing. It is explained first by the conditions of maintenance of hump yards, and second by application of high-tech automated systems [5], minimizing the need to use barrier wagon groups.

In practice, the size and weight of the barrier wagon group, as well as the number of stop-blocks (brake shoes[2]) placed to secure it, are determined, as a rule, empirically based on observations and personal experience of the managers of a particular station, as well as on the analysis of cases of exit of wagons beyond the useful length of classification (classification and departure) tracks at other railway stations of JSC Russian Railways. However, the empirical path does not allow to consider all possible combinations of unfavorable factors, which can lead to the occurrence of events associated with a violation of traffic safety.

On the other hand, the use of barrier wagon groups of unreasonably overestimated size leads to additional downtime for hump yards, as well as to unproductive losses and to a decrease in their processing capacity.

The objective of the study is to identify patterns and factors affecting the decision-making on formation of a barrier wagon group on a particular classification track (classification-departure track), as well as on the size and securing of the barrier wagon groups. The research used methods of statistical analysis and mathematical modelling.

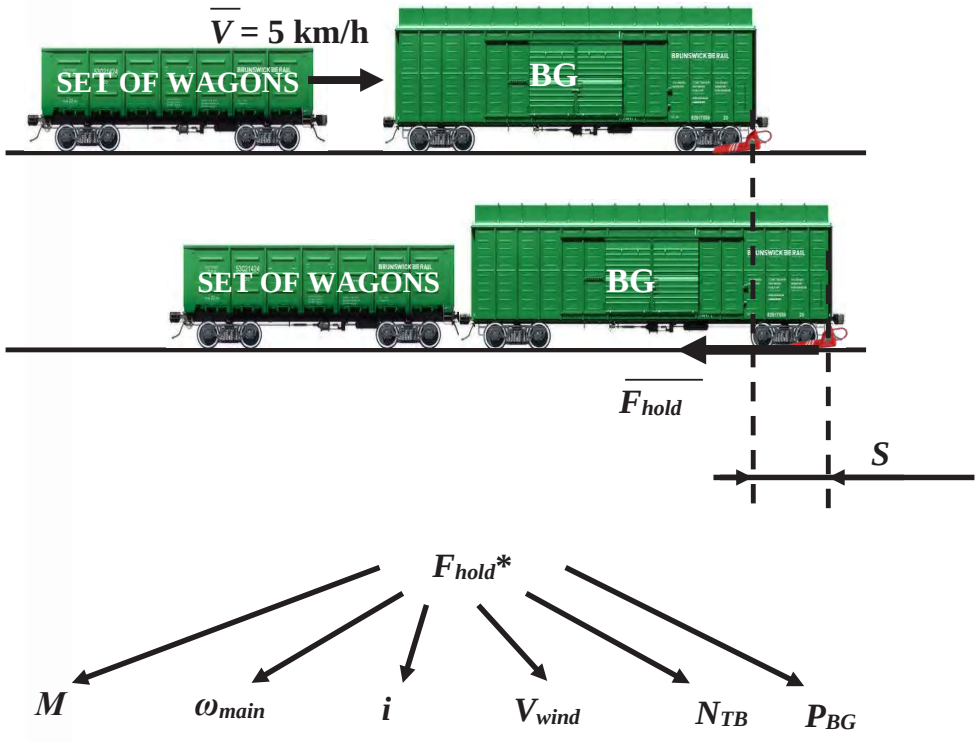
Results.

The department of Operational work and transport safety management of Russian University of Transport has developed a mathematical model to determine the size of the barrier wagon group and to calculate the norms for their securing.

The analysis of the current regulatory documents showed that the term barrier wagon group was not previously unambiguously defined, therefore the authors introduced the following definition of the concept of barrier wagon group: barrier wagon group is a group of wagons installed and secured by brake shoes before starting to disassemble the train on tracks of the classification (classification and departure) yard, designed to prevent spontaneous exit of rolling stock beyond the track useful length to the side opposite to the

[1] The term is specific and should not be confused with barrier wagon which means a wagon used mainly in dangerous goods trains to separate the wagons carrying dangerous goods from other parts of the train. The original Russian term literally reads as «barrier group» sometimes «barrier group of wagons» – *ed. note*.

[2] Stop-blocks mean in the context of the article brake shoes placed directly on the rail (not to be confused with brake shoe of the wheel) – *ed. note*.



Pic. 1. Scheme of interaction between the set of wagons being disassembled and barrier wagon group.

hump yard, or to the site of disassembling of wagons if shunting is made by single pushes.

The mathematical methods used in the developed model allow to solve the following main problems:

• to determine the conditions under which there is no need to use barrier wagon groups and place them on free classification (classification & departure) tracks before disassembling.

• to determine the minimum necessary size of the barrier wagon group to ensure its holding (blocking) capacity, which, when fused with the maximum set of wagons at a speed of not more than 5 km/h, ensures displacement («skidding») of the combined group of wagons by no more than a predetermined value [2].

• to determine the required number of brake shoes for securing the wagons of barrier wagon groups with a different combination of the main influencing factors (mass and composition of the barrier wagon group, its location, weather, and other conditions).

• when performing the calculations, to consider the climatic features of the railway station area and the following modes of its operation: normal and extreme (under adverse weather conditions), as well as special conditions (oil contamination, gale).

The calculation is carried out in two stages.

The first stage is determination of the need to form a barrier wagon group on a specific sorting track.

To perform mathematical modelling, the following initial data are used:

• elementwise profile of the classification (classification & departure) track.

• the maximum allowable number of wagons in a rolling set of wagons, determined according to the station documentation (Instructions for operation of the hump yard) [6; 7].

• maximum mass of the rolling set of wagons.

• average axial load of wagons in a rolling set of wagons.

Table 1

Calculation results of the maximum permissible exit speed of the maximum set of wagons from the yard brake position during normal operation of Agryz station

No. sectiona	Track No. 53				
	Slope, ‰	Length, m	Distance behind the yard BP, m	V_n, km/h	V_k, km/h
1	2,2	50	50	6,50	2,84
2	-1,8	50	100	2,84	4,85
3	-0,4	50	150	4,85	4,61
4	0,4	50	200	4,61	3,06
5	-0,4	50	250	3,06	2,67
6	-0,4	50	300	2,67	2,20
7	-0,8	50	350	2,20	2,73
8	-1,4	50	400	2,73	4,19
9	-0,6	50	450	4,19	4,23
10	-0,4	50	500	4,23	3,99
11	-0,8	50	550	3,99	4,35
12	-1,2	50	600	4,35	5,18
13	-1	50	650	5,18	5,70
14	-0,4	50	700	5,70	5,53
15	-0,2	50	750	5,53	5,11
16	0,2	50	800	5,11	4,09
17	0,8	50	850	4,09	0,00
18	0,2	50	900	–	–
19	-3,4	50	950	–	–

• the main specific resistance to movement and wind load on rolling stock, considering its aerodynamic properties.

According to the accepted calculation criteria, the use of barrier wagon groups on the accumulation track is not necessary if the following conditions are met:

• the set of wagons of a maximum mass, leaving the yard brake position at a speed not higher than the calculated one[3], will stop at the control point located at the place of laying the first restricting brake shoe or at a distance of at least $l_{OB2} \geq 95$ m from the border of the track useful length in the yard exit neck located towards the hump.

• the calculated value of the set of wagons exit speed from the yard brake position is not less than the value established taking into account the power of the brake devices (indicated in the passports of devices used on the hump yard and taken into account when calculating the maximum length of the set of wagons) [8].

If the specified requirements are not ensured, it is forbidden to carry out disassembling of wagons on the considered track until formation of the barrier wagon group on it.

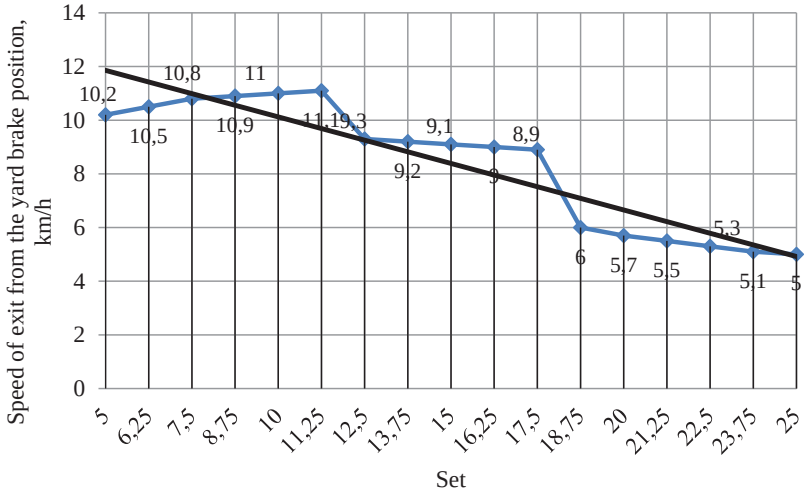
The second stage is determination of the size of the barrier wagon group of wagons and the norms for securing it with brake shoes on a particular track of the classification (classification & departure) yard.

The initial data use the parameters that have the greatest impact on the calculated values:

1) specialization of the yard (classification or classification & departure yard);

2) useful length of the classification (classification & departure) track;

[3] Calculated speed is the maximum allowable exit speed of the set of wagons of the maximum mass from yard brake position, in which its kinetic energy can be fully absorbed due to motion resistance forces [9; 10], as a result of which set of wagons will stop before the control point.



Pic. 2. Dependence of the maximum allowable speed of exit of the set of wagons from the yard brake position on the average axial load of the wagons in the set of wagons at a wind speed of V_w = 0 m/s.

3) maximum number of wagons in a rolling set of wagons;

4) ratio of loaded/empty wagons in the target formation accumulated on the considered sorting track (loaded and empty; only empty wagons);

5) maximum rate of securing of mixed rolling stock on the track in accordance with clause 3.9.1 TRA [6];

6) length of train formations accumulated on a given track.

Taking into account the fact that the barrier wagon group must keep the set of wagons of maximum weight within the useful length of the classification (classification & departure) track, its size is determined from the condition that the set of wagons when it is approaching the barrier wagon group located on the track and secured by brake shoes at a speed 5 km/h does not cause its displacement by more than a predetermined distance [2; 4; 11].

The developed mathematical apparatus allows us to determine the size of the barrier wagon group and the norm of its securing by brake shoes (with specification for weather conditions), taking into account the maximum mass of the set of wagons subject to disassembling, the main specific resistance to movement of wagons of the barrier wagon group, the grade in the location of the barrier wagon group, speed and direction of wind, the number of brake shoes that secure the barrier wagon group, as well as the average axial load of the secured wagons [12] (Pic. 1).

Let us suggest some examples of the use of the developed mathematical model both for solving practical problems and for carrying out scientific research.

Example 1. Justification of the conditions under which there is no need to use barrier wagon groups (sorting track No. 53 of Agryz station).

Initial data:

1) an element-by-element profile of the sorting track from the yard brake position to the limit column located in the outbound neck of the classification yard (see Table 1);

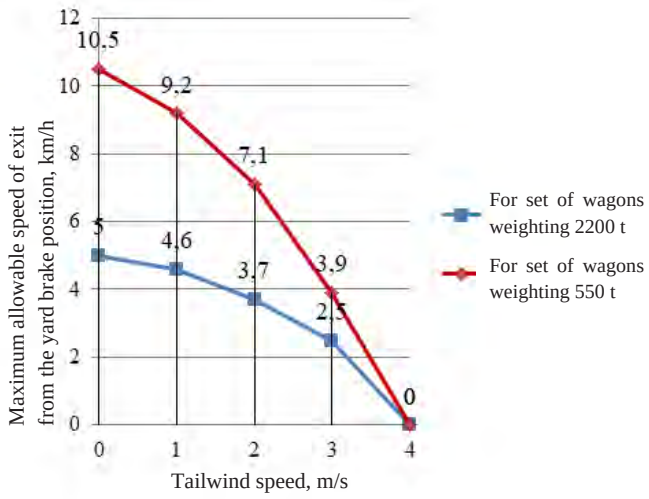
2) maximum length of set of wagons established in the Operating Instructions for the hump yard is 28 wagons for Agryz station (mechanized hump yard);

3) weight of maximum set of wagons is 2800 t;

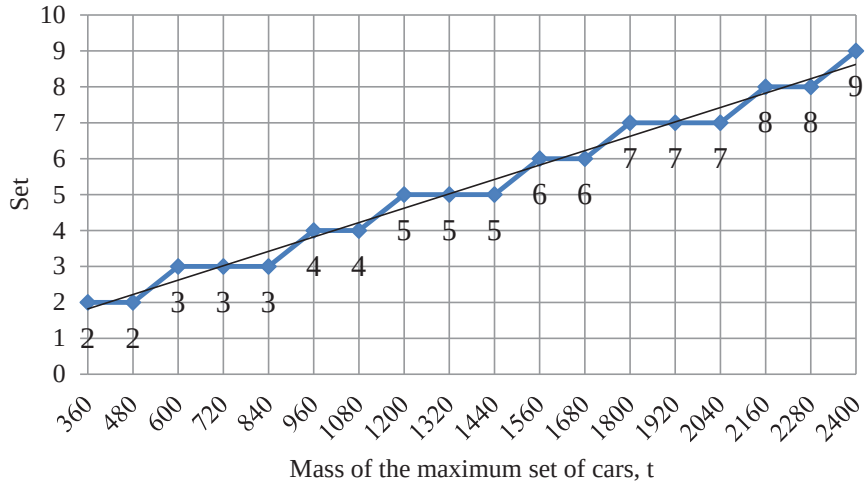
4) the control point is located at 95 m from the limit column in the outbound neck of the yard towards the hump, that is, at the end of section No. 17.

As a result of the calculations, it was found that during normal operation of Agryz station, there is no need to create a barrier wagon group on sorting track No. 53, provided that the speed of exit from the yard braking position of the first set of wagons directed to the specified track does not exceed 6,5 km/h

Example 2. Evaluation of the need to use the barrier wagon group with the calculation of its size and securing norm (sorting track No. 23 of the station Yekaterinburg-Sortirovochny).



Pic. 3. Dependence of the maximum allowable speed of exit of a set of wagons from the yard brake position on tailwind speed. Note: 550 t is estimated weight of the set of 22 empty wagons; 2200 t is estimated weight of 22 loaded wagons.



Pic. 4. Dependence of the norm of securing wagons of the barrier wagon group on mass of the maximum set of wagons.

When performing the calculations, the element-wise track profile and the following initial data were used:

1) the maximum size of the set of wagons, disassembled onto a free track: 22 cond. wagons;

2) the maximum mass of the rolling set of wagons: 2200 t;

3) the average grade of the sorting tracks from the yard brake position to the location of the barrier wagon group: 0,7‰;

4) useful length of the sorting track No. 23: 948 m or 67 cond. wagons;

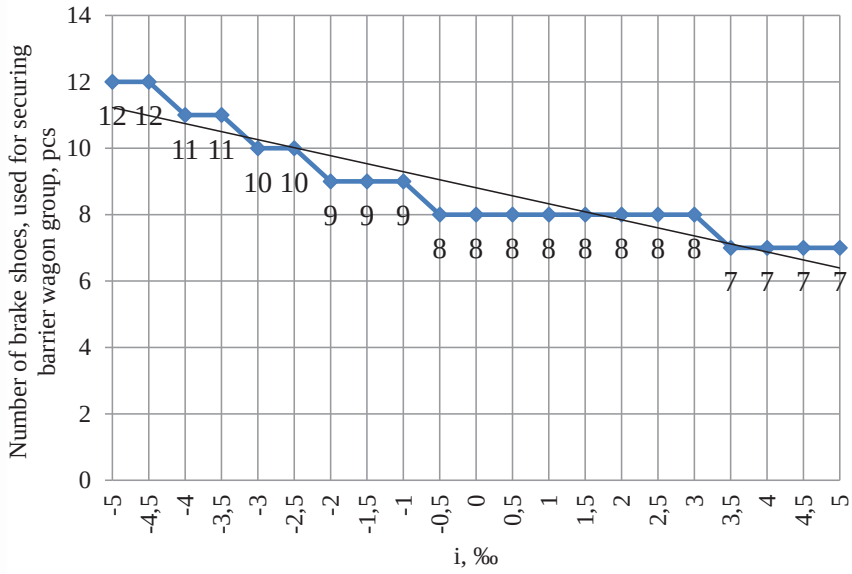
5) maximum permissible displacement of the barrier wagon group: 10 m.

Simulation results resulted in the dependencies shown in Pics. 2–6.

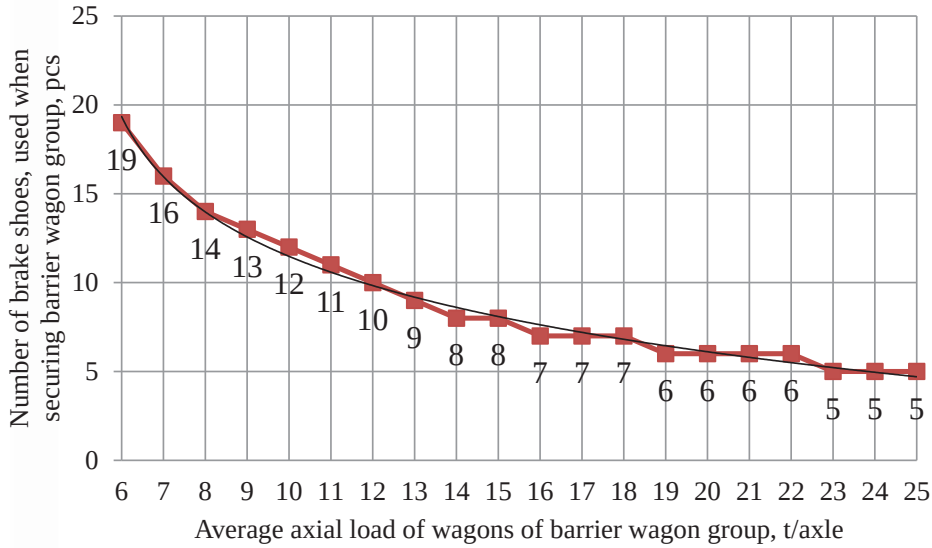
Pic. 2 shows the dependence of the maximum allowable exit speed of a set of 22 wagons from a yard brake position, at which there is no need to use a barrier wagon group, on the average axial load of wagons in a set of wagons.

Pic. 3 shows the dependence of the maximum allowable exit speed of the set of wagons from the yard brake position on the tail wind speed.

The analysis of the dependencies shown in Pic. 3, allows us to conclude that on the sorting track No. 23 of Yekaterinburg-Sortirovochny



Pic. 5. Dependence of the norm of securing barrier wagon group on the grade value (i), at the location of barrier wagon group (example for the set of 22 loaded wagons with axial load 25 t/axle).



Pic. 6. Dependence of the norm of securing barrier wagon group on the value of average axial load of wagons of barrier wagon group (for set of wagons weighting 2200 t).

station, both loaded and empty set of 22 wagons with a tail wind speed of more than 3 m/s will not be able to stop at the control point on their own. In this case, installation and securing of the barrier wagon group is required on the track.

According to the results of multivariate mathematical modelling, it was established that the following factors have the main influence on the size and norm if securing of the barrier wagon group:

- the maximum mass of the set of wagons, the value of which is established in the Instructions for operation of the hump yard [6; 7] (Pic. 4);
- the grade at the location of the barrier wagon group (Pic. 5);
- average axial load of wagons in the barrier wagon group (Pic. 6).

As a result of the calculations for the sorting track No. 23 of the station Yekaterinburg-Sortirovochny the following was established:

• before disassembling the train, a barrier wagon group of at least five loaded wagons must be formed on the track (when it is formed from loaded wagons with an axial load of at least 15 t/axle);

• barrier wagon group is located on the grade $i = 0{,}2$ ‰ at a distance of 100 m from the limit column in the outbound neck of the classification yard;

• to secure the barrier wagon group under favorable weather conditions, eight brake shoes are used, under adverse weather conditions (tail wind speed of more than 15 m/s), the barrier wagon group is secured by nine brake shoes;

• with a useful length of track No. 23 equal to 948 m (67 conv. wagons) and the size of the barrier group of up to five wagons on the track it is advisable to accumulate and form trains up to 58 conv. wagons. In this case, the barrier wagon group can be formed in the process of accumulation of the train and after it will be shunted barrier wagon group can remain on the sorting track, and that will not lead to a significant reduction in the processing capacity of the hump yard.

Conclusion

The scientific justification of the need to use barrier wagon groups before train disassembling on free classification (classification & departure) tracks of railway stations, followed by calculation of the required size of the barrier wagon group and the norm of its securing by brake shoes depending on the length and profile of specific tracks, weather conditions, weight and length of the set of wagons, will improve traffic safety during train and shunting operations by preventing cases of wagons go beyond the track useful length.

Formation of barrier wagon groups on the classification (classification and departure) tracks before train disassembling to ensure traffic safety will inevitably lead to decrease in processing capacity of classification yards. Optimization of some calculated criteria can help to reduce losses in processing capacity of marshalling yards when barrier wagon groups are formed [13].

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