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RESEARCH ON THE OPTIMIZATION OF THE SAW GIN'S ROLL BOX

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Abstract: The improvement of saw gin machines, particularly their roll boxes, plays a crucial role in increasing the efficiency of cotton processing in the textile industry. The density of the seed roll inside the roll box directly affects productivity, energy consumption, and the degree of fiber damage. Numerous studies indicate that when density exceeds the optimal range of 325-550 kg/m^3, the fiber quality deteriorates and machine productivity decreases. Therefore, modern engineering solutions, such as the introduction of accelerators, modified saw cylinders, and lifting mechanisms, have been proposed to regulate density and stabilize the ginning process. This paper presents a comprehensive analysis of structural modifications, operational parameters, and mechanisms applied in modern saw gin machines. Various types of accelerators – disk, blade, and elastic systems – are evaluated in terms of their contribution to fiber quality improvement and energy efficiency. Additionally, the role of automation, including pneumatic lifting devices and sensor-based control systems, is discussed as a means to optimize machine performance. The results demonstrate that the application of innovative accelerators, optimized saw parameters, and pneumatic mechanisms contributes to reducing fiber damage, stabilizing throughput, and increasing overall productivity. The research findings are expected to provide a theoretical and practical foundation for the development of advanced gin machine designs suitable for Uzbekistan's cotton industry.

Keywords: Cotton ginning, saw gin machine, roll box, seed roll density, accelerators, pneumatic lifting, automation, fiber quality, productivity, energy efficiency, saw cylinder, mechanical design, textile machinery, Uzbekistan, optimization.

Introduction. The cotton industry in Uzbekistan is a leading sector of the light industry and plays a significant role in the national economy. A key technological process in the primary processing of cotton is the separation of fiber from seeds using a saw gin. The efficiency of this process largely depends on the structural elements of the machine, specifically the technical parameters of the roll box, the saw cylinder, and the fiber removal devices.

As observed in practice, the density of the seed roll formed within the roll box directly affects the quality of the cotton fiber and the gin's productivity. When the optimal density (325-550 kg/m^3) is exceeded, fiber damage increases, energy consumption rises, and the machine's performance decreases. Consequently, various design solutions – accelerators, modified saw cylinders, lifting-lowering mechanisms, pneumatic actuators, and automated feeding systems – have been developed by scientists and engineers.

The relevance of the topic stems from the need to modernize the aging saw gins currently used in Uzbekistan's cotton cleaning industry. Modern design solutions can improve not only machine productivity but also fiber quality. This scientific article aims to analyze scientific developments related to the improvement of the saw gin's roll box, identify existing problems, and outline promising approaches to their resolution.

Methods. The productivity of saw gins is of paramount importance in the operation of cotton processing enterprises. The density of the seed roll within the roll box is a crucial factor influencing productivity. While an increase in density generally enhances productivity, exceeding a specific threshold results in increased fiber damage [1, 2, 3].

Scientists and engineers have developed various design solutions to improve saw gins, including accelerators, modified saw cylinders, lifting-lowering mechanisms, and other structural innovations. B.I. Bekmirzaev [4] investigated the optimal density values for minimizing fiber damage.

Although issues such as energy consumption and fiber damage have not always received sufficient attention, the condition of the saw and the friction force are also significant factors. X.T. Akhmedkhodjaev [5] and N.M. Safarov [6] proposed methods to address these problems by improving the technological processes.

R. Muradov et al. [7] studied the impact of novel structural elements within the saw gin's roll box on fiber quality, as well as the forces and movement patterns of the seed roll's interaction with the saw cylinder.

A.U. Sarimsakov [8, 9] developed a method for controlling the rotational speed of the seed roll in the saw gin. This method utilized an additional torque to regulate the roll's rotational speed.

To address issues such as non-uniform seed roll density and the retention of seeds in the roll box, the installation of accelerators with various designs in the center of the roll box has been proposed [10].

Authors [11-17] have developed various designs for the saw gin's roll box, aimed at reducing the energy consumption for rotating the seed roll, increasing productivity, and improving fiber quality (Figure 1.1). Their designs utilized protrusions on the roll surface, inclined disks, or disks arranged in a staggered pattern.

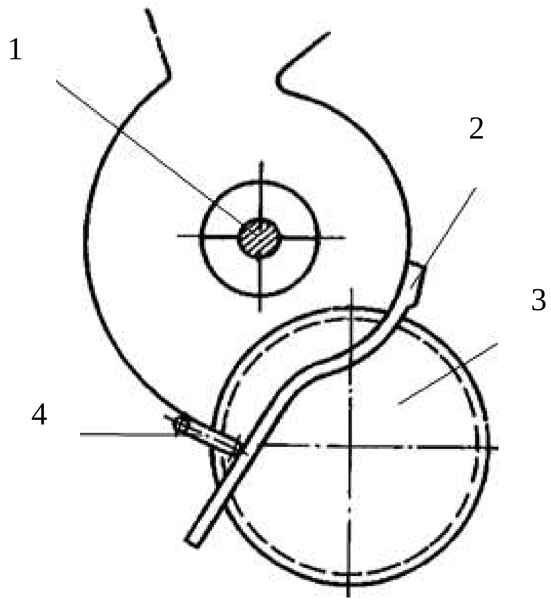

Figure 1.1. Roll box equipped with a disk-blade accelerator
1-disk-blade accelerator, 2-barrel grate, 3-saw disk, 4-seed comb

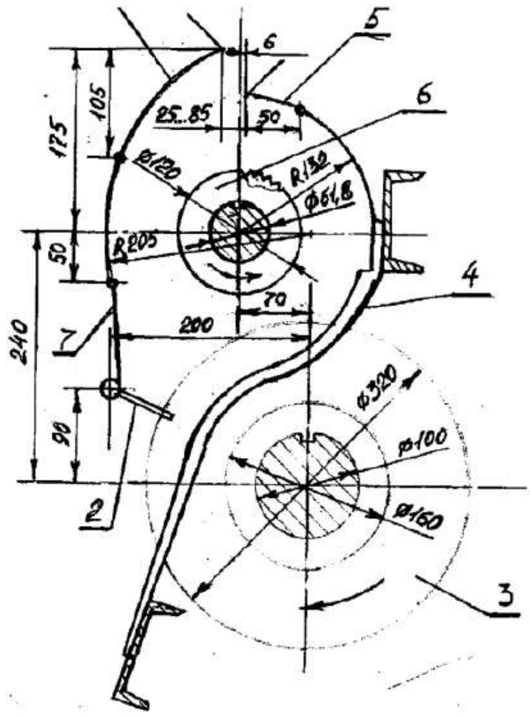

Figure 1.2. Roll box with accelerator
1 – inlet pipe, 2 – grain comb, 3 – saw cylinder, 4 – grate with grate, 5 – upper apron, 6 – working accelerator rotating the seed roll,
7 – lower apron

Various accelerator designs have been developed to improve the ginning process. S.Z. Yunusov [10] proposed a toothed disk accelerator installed through elastic bushings (Figure 1.2). R.F. Yunusov [18] attempted to increase the density and rotational speed of the seed roll by reducing the roll box dimensions and installing an accelerator.

N.Q. Safarov (Figure 1.3) [19] and J. Ergashev (Figure 1.4) [20] implemented mechanisms to aid in the removal of ginned seeds from the center of the roll box.

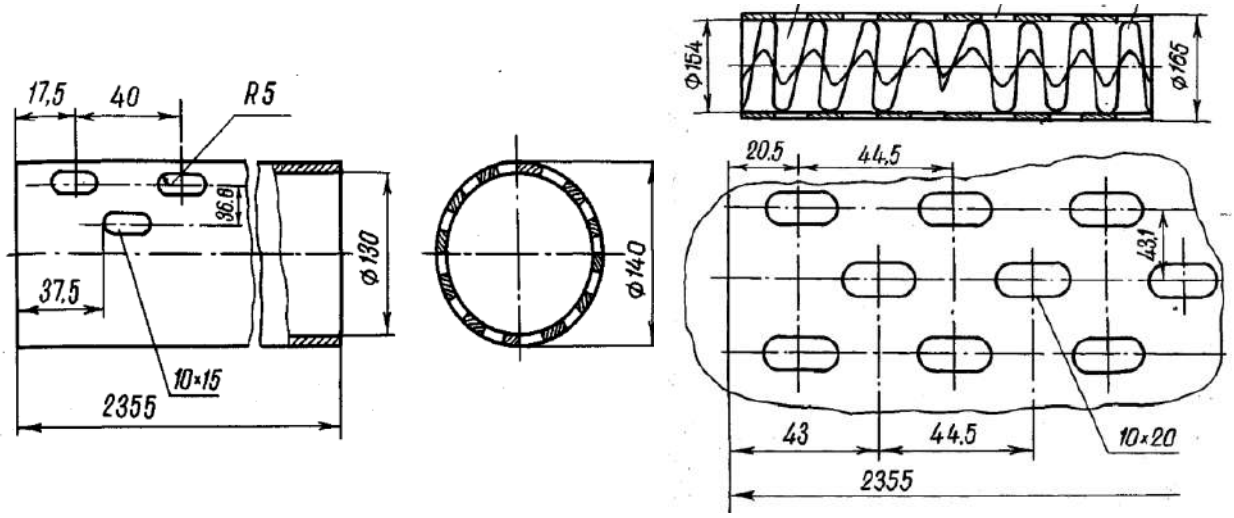

Figure 1.3. Mechanism that helps seed outlet

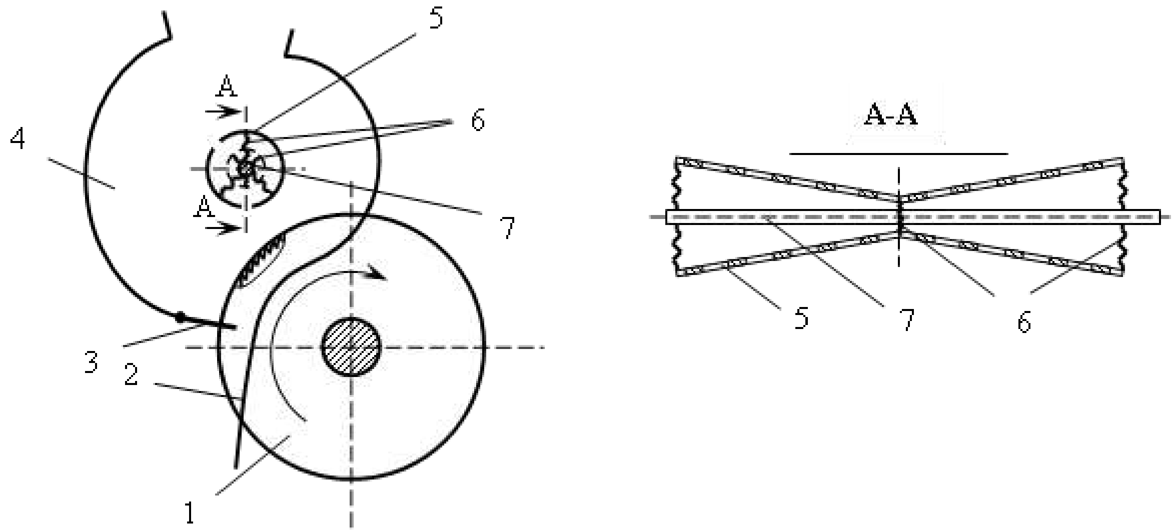

Figure 1.4. Conical mesh drum
1 – saw cylinder, 2 – comb, 3 – grain comb, 4 – roll box, 5 – conical mesh drum, 6 – springs, 7 – shaft

A review of the literature indicates that an increase in seed roll density leads to fiber damage [3]. Above a certain threshold (550-600 kg/m^3), the ginning process can cease altogether [22]. Research has also shown that by installing accelerators within the roll box, it is possible to ensure optimal seed roll density and to reduce the degree of fiber damage. Improvements in fiber separation and a reduction in waste can also be achieved through the use of air flow [20].

S. Fazildinov and R.M. Kattakhodjaev [22] investigated the causes of increased defects and impurities in fibers, as well as the effect of seed roll density. I.T. Maksudov [23] analyzed the impact of seed roll rotation speed and fiber damage on saw gin productivity.

The parameters of the saw disks, the main working components of the saw gin, directly affect the ginning process, machine productivity, and energy consumption. Therefore, the optimization of saw parameters is of considerable importance.

Research in the textile industry has focused on factors influencing fiber damage. N.M. Safarov [6] proposed a method for determining the contact pressure affecting individual fibers during the fiber separation process. S.Z. Yunusov [24] developed a design for an accelerator with elastic elements to reduce the seed roll density.

S. Aslam and N. Sumro [25] studied the effects of saw cylinder speed and seed roll density, while D.M. Mukhammadiev and F.K. Ibragimov [26] examined the critical angular speed of the saw cylinder, and S.E. Hughes and B. Carlos [27] investigated the impact of saw tooth shape on fiber quality. Research [28] indicated that the machine's operating speed should not exceed 0.7 of the critical speed.

Studies on improving the ginning process have revealed that the wear of saw teeth and their restoration affect machine productivity. Furthermore, productivity is dependent on the speed of the saw cylinder.

The impact factor, which affects the working efficiency of the saw disks, decreases with a reduction in the diameter of the saw disks (Table 1.1).

Table 1. Effect of the correction factor of saw blade diameter on performance

Saw blade condition	Saw blade diameter, mm	Productivity adjustment coefficient
New saw	320	1,00
	When a new tooth erupts	
First time	310	0,94
Second time	300	0,89

In pneumatic systems, the compressor power should be 50-70% greater than the power required by the system. The minimum pressure within the pneumatic drive must be higher than the operating pressure. A pneumatic cylinder (Figure 1.5) generates force on the rod by moving the piston 1 under the influence of compressed air. The cylinder consists of a cylinder 2, where the piston moves, seals 3, and a rod 4.

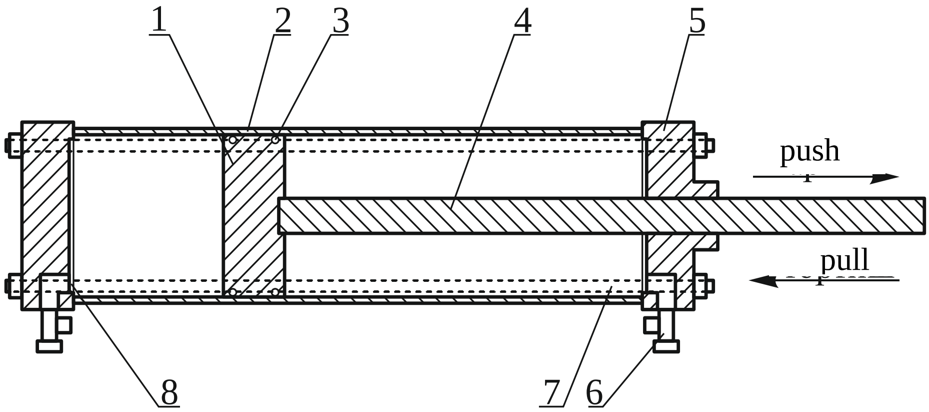

Figure 1.5. Structural diagram of a pneumatic cylinder

1 – piston, 2 – cylinder, 3 – seal, 4 – rod, 5 – cylinder cover, 6 – air vent, 7 – pin, 8 – dead volume

The rod transmits motion to the control object. Covers 5 are installed at both ends of the cylinder to limit the piston's movement and ensure hermeticity. The covers contain channels for the intake and exhaust of air. They are also equipped with screw-type air vents 6 to adjust the piston speed. The "dead volume" 8 between the covers maintains air pressure.

The force exerted on the rod is directly proportional to the air pressure within the pneumatic cylinder: the force increases as pressure increases [29]. The acting force depends on the piston diameter [29]:

$$F = P \cdot A, \tag{1.1}$$

here: F – force, N;

P – pressure, kPa;

A – piston area, mm^2

$$A = \frac{\pi D^2}{4}, \tag{1.2}$$

here: D – piston diameter, mm.

The force exerted by the rod during compression is greater than that during tension.

The internal surface of the piston (1.2) and the surface where the rod is fixed (1.3) are calculated as follows:

$$A = \frac{\pi\left(D^2 - d^2\right)}{4}, \tag{1.3}$$

here: d – rod diameter, mm.

Seals reduce the acting force due to frictional forces. A braking system is used to reduce the rod's speed at the end of its movement.

The utilization of airflows in cotton cleaning, including fiber separation in air-flow gins, is crucial for improving efficiency. This research analyzes the aerodynamic characteristics and design dimensions of the centrifugal-type VS-8M and VS-10M fans [30].

While P.T. Nizhnik [31] studied fiber separation using brush drums, he did not fully explain the principles of fiber separation in air-flow gins. Therefore, it is necessary to study the separation of fibers and the removal of impurities from the saws based on the laws of aerodynamics.

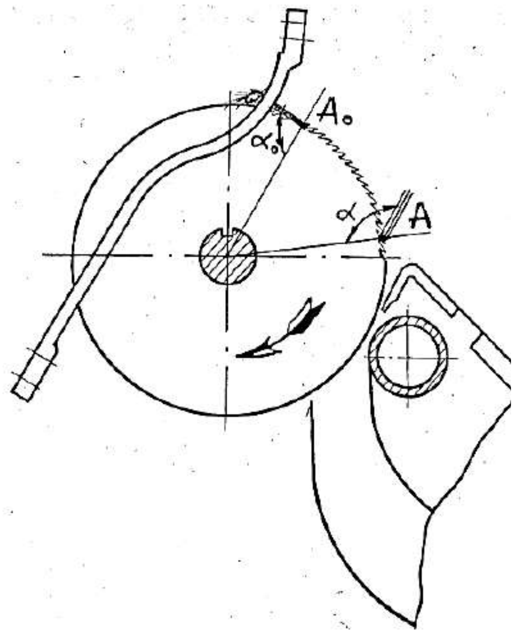

Figure 1.6. "Rod-fiber stripping device" area

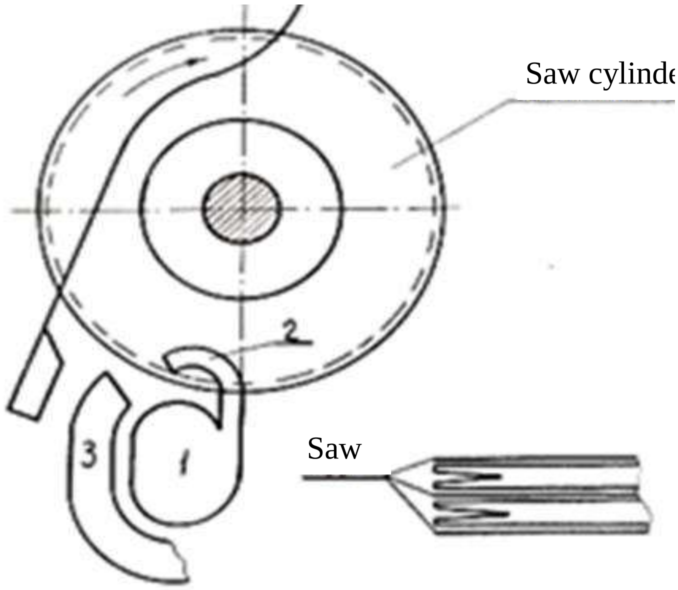

Figure 1.7. Air chamber for removing upper fibers with a separately directed nozzle, proposed by G.I. Boldinsky
1 – air nozzle; 2 – tube nozzle; 3 – inlet pipe

G.I. Boldinsky et al. [32; 33; 34; 35; 36] demonstrated that reducing the angle of inclination of the leading edge of the saw tooth leads to the "free fall" of the fiber from the saw teeth. Sh.T. Ergashev [37] showed that it is possible to facilitate fiber separation while preserving fiber and seed quality by optimizing the angle of contact between the saw tooth surface and the fibers (Figure 1.6).

E.L. Volovik [38] developed several models of devices that allow for fiber separation using various methods. This research focused on reducing the necessary airflow for fiber separation, as well as separating the linter, impurities, and foreign matter.

G.I. Boldinsky [39] at the Tashkent Institute of Textile and Light Industry developed a high-fiber separation chamber (Figure 1.7). I.T. Maksudov [40; 41] proposed a spiral-shaped air chamber, which was intended to ensure the efficient distribution of airflow. However, this device was not implemented in production due to the complexity of installation and maintenance.

Sh.A. Khusanova [42] proposed a design for a saw gin that was intended to provide a separate, directed airflow for each saw (Figure 1.8).

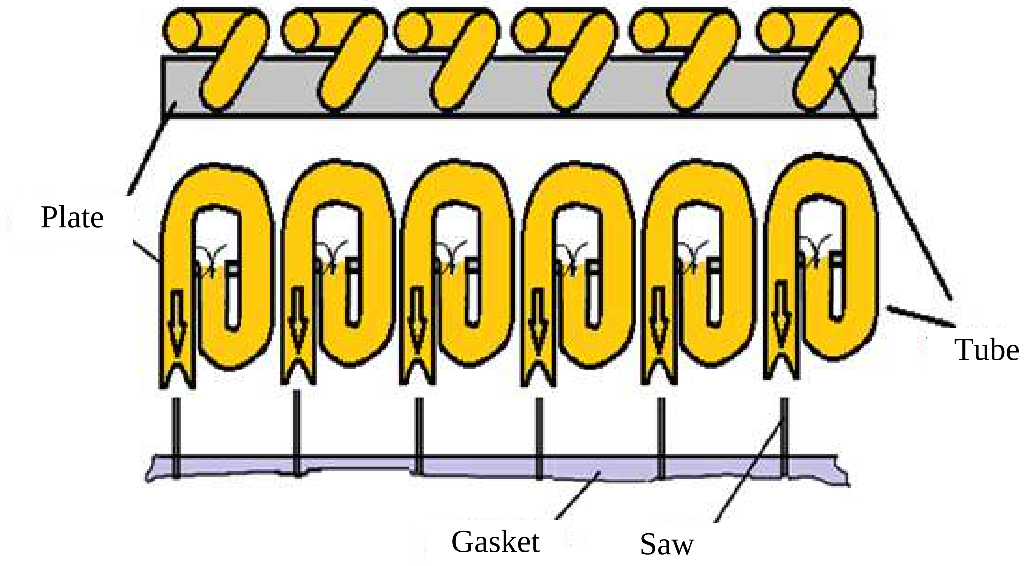

Figure 1.8. Schematic diagram of a device for targeted air flow to saws

The research object comprised saw gins, widely used in enterprises for the primary processing of cotton. Specifically, the roll box, saw cylinder, and fiber removal devices of the 4DP-130 and 5DP-130 model gins were selected as the main objects of analysis.

The methodological approach included several key methods:

1. Analytical analysis – scientific sources, patents, and technical solutions were studied.

2. Comparative method – the technical specifications of machines from Uzbekistan and the USA were compared.

3. Mathematical modeling – the dynamics of the seed roll and the effect of density were calculated.

4. Experimental observation – ginning tests were conducted at various densities (290-600 kg/m^3).

5. Technological experiments – the efficiency of different types of accelerators was investigated.

6. Practical experiments – pneumatic lifting-lowering mechanisms were tested.

Consequently, the research was conducted using a combination of theoretical, experimental, and practical methods.

III. Results. The following findings were obtained from the research:

- Fiber damage increases when the seed roll density exceeds the optimal range (290-325 kg/m^3).
- Accelerators reduced fiber damage by 12-15%.
- A decrease in the diameter of the saw cylinder and tooth wear reduces efficiency.
- The pneumatic lifting-lowering mechanism eased operator labor and increased safety.
- Complete fiber extraction is achievable in air flow devices at an optimal air velocity of 55-60 m/s.

- Automated control systems increased machine productivity by 8-10%.

Discussion. The results indicate that:

- The seed roll density has a decisive impact on fiber quality and process efficiency.
- The use of accelerators confirmed the ideas proposed in the scientific literature.
- The technical condition of the saw cylinder is a crucial factor for maintaining productivity.
- Pneumatic mechanisms eased operator labor while increasing safety.
- Air flow devices proved to be more effective than brush drums.
- Automation and sensor-based control systems are among the most promising directions and align with international experience.

IV. Conclusion and Recommendations:

1. The optimal seed roll density is 290-325 kg/m^3, which minimizes fiber damage.
2. Accelerators improve efficiency, with the elastic sleeve disc system yielding the best results.
3. Regular monitoring of the saw cylinder diameter and tooth condition is essential.
4. Pneumatic mechanisms reduce manual labor and increase efficiency.
5. Air flow devices are the most suitable for fiber extraction.
6. Automated control systems increase machine efficiency by 8-10%.

Recommendations: Accelerators, pneumatic mechanisms, and automated control systems should be implemented during the modernization of existing gin machines.

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