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TECHNICAL SOLUTIONS FOR CATASTROPHIC EXTENT OF THE HUMAN FACTOR IN DRIVERS TRAINING AND STRUCTURAL SAFETY OF BUSES AND HEAVY VEHICLES

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RESEARCH ARTICLE

ABSTRACT: The concept of “human factor” is actively used in determining the guilt of pilots in plane crashes and drivers in railway accidents, as well as from a historical perspective, in economics and management of organizations, but surprisingly rarely when it comes to road transport. In addition, the human factor usually means the driver’s fault, which is the main misconception. Other causes of road accidents include weather conditions, the state of the road infrastructure, and technical malfunctions, hiding the true cause, which in the vast majority of cases is also a consequence of human factors of various levels. An analysis of incidents with buses and trucks that regularly occur in Russia shows that it is possible to distinguish such levels of human factor as driver, managerial, political, legal, technological, production, system, and commercial. A bus or heavy truck accident is always fraught with particularly serious consequences and public outcry. However, public outcry does not yet mean that the authorities will take the necessary steps in this direction in terms of organizing transportation processes and monitoring motor transport enterprises. Therefore, it is necessary to invent technical solutions, including an integral brake valve, a driver monitoring system and a post-accident braking system.

KEY WORDS: *road safety, preventive motion control method, secondary braking system, driver monitoring system, secondary collision brake system*

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TEHNIČKA REŠENJA ZA KATASTROFALNU OBIM LJUDSKOG FAKTORA U OBUCI VOZAČA I KONSTRUKCIJSKA BEZBEDNOST AUTOBUSA I TEŠKIH VOZILA

REZIME: Koncept „ljudskog faktora“ se aktivno koristi u utvrđivanju krivice pilota u avionskim nesrećama i vozača u železničkim nesrećama, kao i iz istorijske perspektive, u ekonomiji i upravljanju organizacijama, ali iznenađujuće retko kada je u pitanju drumski saobraćaj. Pored toga, ljudski faktor obično znači grešku vozača, što je glavna zabluda. Drugi uzroci saobraćajnih nezgoda su vremenske prilike, stanje putne infrastrukture i tehnički kvarovi, koji prikrivaju pravi uzrok, koji je u velikoj većini slučajeva i posledica ljudskih faktora različitih nivoa. Analiza incidenata sa autobusima i kamionima koji se redovno dešavaju u Rusiji pokazuje da je moguće razlikovati nivoe ljudskog faktora kao što su vozački, menadžerski, politički, pravni, tehnološki, proizvodni, sistemski i komercijalni. Nesreća autobusa ili teškog kamiona uvek je prepuna posebno ozbiljnih posledica i negodovanja javnosti. Međutim, negodovanje javnosti još ne znači da će vlasti preduzeti neophodne korake u tom pravcu u smislu organizovanja transportnih procesa i praćenja autotransportnih preduzeća. Zbog toga je neophodno izmisliti tehnička rešenja, uključujući integralni kočni ventil, sistem za nadzor vozača i sistem kočenja nakon udesa.

KLJUČNE REČI: *bezbednost na putu, preventivni metod kontrole kretanja, sistem sekundarnog kočenja, sistem za nadzor vozača, sistem kočnice pri sekundarnom sudaru*

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INTRODUCTION

The term “human factor” recently celebrated its centenary – it was first mentioned in a book by the British economist Benjamin Seebohm Rowntree in relation to entrepreneurship [1]. By the middle of the 20th century, it was increasingly used in technical fields [2–3]. Gradually, the concept of the “human factor” began to be associated with a set of human abilities and qualities in a wide variety of areas of human activity, for example, in economics [4–7], management [8–9], medicine [10–16], industry [17–22], pedagogy [23–25], sociology [26–27], ecology [28–30], resource use [31–32], agriculture [33–34], astronautics [35], logistics [36–37], safety management [38–39], mining [40] and oil and gas [41–42] industries, operator training [43–44], as well as in such modern areas as artificial intelligence [45] and cybersecurity [46–50]. But in technology, the concept of the “human factor” is most often associated with negligence, inattention, erroneous decisions made by a person and actions taken or, conversely, not taken by him in a critical situation [51-54], which entail significant damage and loss of life, including both natural [55-57] and man-made [58-63] disasters, especially at thermal and nuclear power plants [64-69] and, of course, in transport [70-74]. The term "human factor" is widely used in rail [75-83], sea [84-90] and especially air [91-100] transport, but much less often when it comes to road transport [101-104], although its influence in the area of road safety is difficult to overestimate. The phrase "catastrophic scale" in this case is not a metaphor or hyperbole, since the consequences of the human factor in road transport, as a rule, are the loss of life.

1 RESONANT ACCIDENTS

An accident involving a bus or a heavy truck is always fraught with particularly serious consequences and public resonance.

On June 20, 2012, at 21:43 (19:43 Moscow time), on the 1644th kilometer of the M5 Ural highway near the city of Yuryuzan (Chelyabinsk region), the brakes of a Volvo road train failed on a small descent. The road in this section is two-lane and has steep slopes on both sides. The driver, a Dagestani, a resident of Stavropol Krai born in 1981, tried to squeeze through along the center line, drove into the oncoming traffic lane and at high speed rammed a Kia Jess and VAZ-2106 passenger cars, a Gazelle minibus, a Scania road train, and then crashed into an oncoming KamAZ, the driver of which heard a warning on the radio and slowed down to the side of the road to let the out-of-control road train pass (Figure 1). The impact sent the KamAZ trailer flying into a ditch, and the tractor turned over on its side across the road. Several cars caught fire. The 61-year-old driver of the Kia Jess and the 58-year-old passenger of the Gazelle died in the accident. Nine more people received various injuries, three of whom had to be hospitalized. The Volvo driver fled the scene immediately after the tragedy, but was detained by police officers in the woods near the highway in the early morning of June 21. He was charged under Article 264 of the Criminal Code of the Russian Federation (violation of traffic rules and operation of vehicles, resulting through negligence in the death of two or more persons).

Figure 1 Yuryuzan accident, 20.06.2012

Eight years later, on June 16, 2020, at 1:09 p.m., another car accident occurred in almost the same area of the M5 highway on the bridge over the Silga River. The driver of a Shacman dump truck loaded with 15 tons of crushed stone with faulty brakes failed to slow down before the narrowing due to repair work being carried out on the bridge and rammed into the following cars that had slowed down: Lada Granta, Audi Q7, Renault Sandero, VAZ-2114 and a Hino truck (Figure 2). The driver could have turned right into a free space, but panicked and did not do so. As a result of the collision, the driver and passenger of the Lada Granta died on the spot. Other participants in the accident received less serious injuries. Later, the driver said that the air in the service brake system ran out on a long descent. As part of the criminal investigation, the children of the deceased couple have filed claims for six million rubles. The property of Gorod LLC, where the truck driver works, has been seized. The Katav-Ivanovo City Prosecutor approved the indictment in the criminal case against the dump truck driver, accused of committing a crime under Part 5 of Article 264 of the Criminal Code of the Russian Federation ("Violation by a person driving a car or other mechanical vehicle of traffic rules and the operation of vehicles, resulting through negligence in the death of two persons").

Figure 2 Silga river bridge accident, 16.06.2020

The worst thing happens when a bus gets in the way of a truck with failed brakes. On July 13, 2013, at about 1 p.m. (the incident report was received by the Ministry of Emergency Situations at 12:54 p.m.) in the village of Oznobishino (New Moscow, Novotroitsky District) at the intersection of the Kaluga Highway and a secondary road leading from the village of Shchapovo, a KamAZ-65115 dump truck overloaded with crushed stone and with failed brakes, driven by 46-year-old Armenian citizen Grachya Harutyunyan, who has been driving for over 20 years, accelerated to 70 km/h on a steep descent, while attempting to make a left turn, overturned onto its right side and rammed the rear of a LiAZ bus traveling with 64 passengers on route #1033 from the city of Podolsk to the village of Zhokhovo. The impact tore off the rear of the bus, and the passengers were buried alive under tons of rubble that spilled out of the dump truck into the passenger compartment. Fourteen people died on the spot (including the 66-year-old conductor), and four more died later in hospitals. Most of them were crushed by a pile of stones and suffocated. Those who were dug out suffered severe combined and compression injuries, fractures, bruises, and concussions. More than 30 passengers (16 of whom were in serious condition) were taken to medical facilities (with the participation of four helicopters) - the Podolsk Central Regional Hospital and the Sklifosovsky Institute.

The dump truck driver jumped out of the destroyed cabin without serious injuries (Figure 3). He was sober at the time of the collision. Immediately after the accident, the driver was put into a drug-induced coma, but the next day he came to and was immediately questioned by an investigator, after which he was charged under Article 264 of the Criminal Code of the Russian Federation "Violation of traffic rules and operation of vehicles, resulting in the death of two or more persons through negligence." It became known that in the previous year alone, Grachya Harutyunyan was brought to administrative penalties nine times for violating traffic rules, including for driving into the oncoming traffic lane and crossing a railroad crossing at a red light.

As for traffic violations, the traffic police punish a specific driver for them, and his employer is not informed about it. But if a traffic police officer stops a truck and finds faults, then the owner - a company or an individual entrepreneur - is informed.

In case of a vehicle malfunction in an accident, there is Article 266 of the Criminal Code of the Russian Federation, "Poor-quality repair of vehicles and their release into operation with technical faults," which provides for up to 10 years in prison – even more than for the accident itself. However, it is unlikely that any lawyer will remember the last time this article was applied in practice.

As it turned out, the dump truck was deregistered in April 2013 and was used with transit numbers. The truck belonged to OOO Stroyavtoservis, which has been engaged in general construction work since 2003 and registered in Moscow to Gamlet Gulakyan, who owned two more companies: OOO Avtoservis-09, created in 2009, is engaged in wholesale and retail trade in motorcycles, car parts, car repair and maintenance, and OOO MMS, founded in 2000 in the Tambov Region, produces soft drinks, vegetable and animal oils and fats, processes and preserves fruits and vegetables, along with architectural design development and construction. Grachya Arutyanyun was hired by the company Stroyavtoservis to transport goods several years earlier.

Figure 3 Oznobishino accident, 13.07.2013

As always, not before, but after the tragedy, the acting governor of the Moscow region Andrei Vorobyov, at an emergency meeting, which he held right in the building of the Podolsk hospital after going around the wards with the wounded, set the task for law enforcement agencies to provide additional inspections of all rolling stock of the Moscow region (about six thousand buses), conduct medical examination of drivers before going on a trip, pay attention to dangerous intersections of the Moscow region, take punitive measures against cars that are used with transit numbers and are not registered with the state, and also toughen the punishment for drivers after repeated violations of traffic rules, especially on high-tonnage vehicles. However, the public outcry does not mean that the authorities will take the necessary measures in the sphere of organizing transportation processes and monitoring motor transport enterprises.

The issue of registering drivers who systematically violate traffic rules has been raised many times: it has long been necessary to supplement the administrative code and forcibly deprive them of their driving licenses. But in this case, it would not have helped: the dump truck driver worked in Russia with an Armenian license!

On August 4, 2014, the Trotsky Court of Moscow found Grachya Arutyunyan guilty of causing an accident with 18 victims and sentenced him to 6 years and 9 months in prison. During the investigation, it was discovered that the truck had not been properly maintained, and as a result, its brakes were malfunctioning. Arutyunyan, according to the investigation, should have known about this. Seven years in prison is the maximum sentence in Russia for an accident with more than two fatalities, if the culprit was sober at the time of the accident.

On June 3, 2014, at 8:42 p.m. in St. Petersburg on Nevsky Prospekt near house No. 64, not far from the Anichkov Bridge, the driver of a city LiAZ bus felt unwell and lost consciousness. The out-of-control bus smoothly crossed the solid line separating the lane for public transport vehicles and, without braking, drove onto the corner of the sidewalk and, knocking down an advertising board, crashed into a lamppost (Figure 4). As a result of the accident, 26 people were injured, including passersby who were hit by the fallen advertising board. 8 people were hospitalized, two of them (including the bus driver) are in serious condition.

The passenger bus belonged to a large private transport company, Piteravto, which serviced dozens of routes in St. Petersburg and neighboring regions. In total, Piteravto's fleet consisted of about 2,700 buses and minibuses. The next day, representatives of the St. Petersburg administration's transport committee came to the company to check compliance with transportation rules, the correctness of the waybill and its availability, what shift the driver spent behind the wheel, and in what condition he left for the route.

The accident on Nevsky Prospekt showed that the main reason for the low efficiency of active safety systems is a fragmented approach to considering processes in a car. A single lane keeping system, if installed on a bus, would be deactivated when the turn signal was turned on. Therefore, buses should be equipped with an active safety system that includes a promising driver fatigue monitoring system [105–106], which would record the driver’s loss of consciousness [107–109] and take measures to stop using a collision avoidance system, while the lane keeping system would help keep the vehicle within the occupied lane.

On December 25, 2017, at 14:46 in Moscow on Kutuzovsky Prospekt near the Slavyansky Bulvar metro station, a LiAZ-5292.60 bus equipped with an automatic transmission spontaneously started moving from a stop, drove onto the sidewalk, went into an underground pedestrian crossing and stopped only when it hit the ramp of the crossing (Figure 5). As a result of the accident, 4 people died, more than 10 received various injuries.

Figure 4 Nevsky prospect accident, 03.06.2014

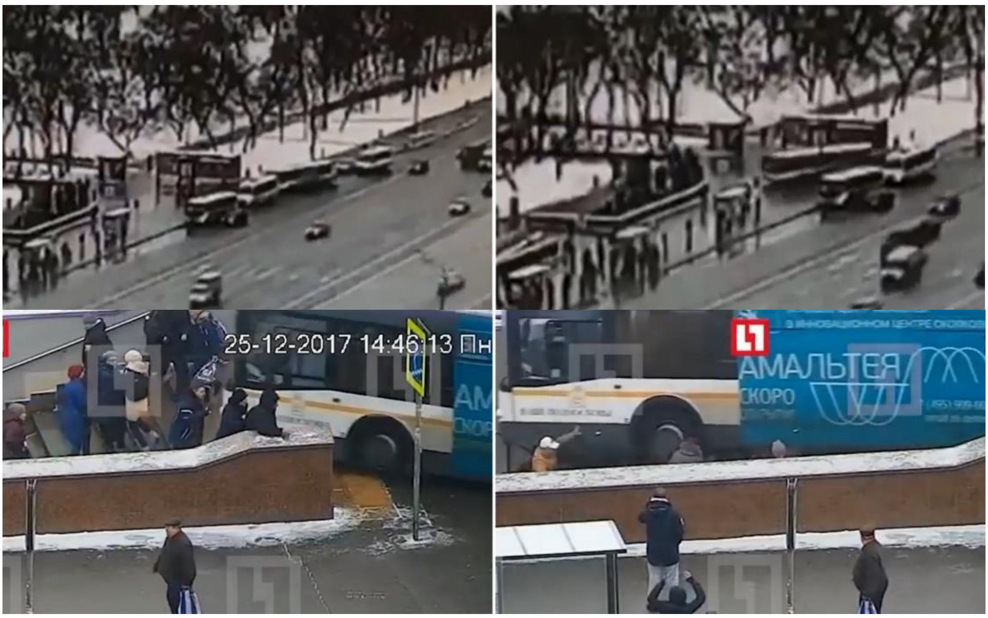

Figure 5 Slavyansky boulevard accident, 25.12.2017

Experienced driver Viktor Tikhonov could not give a clear explanation of what happened. The bus had a video recorder that was supposed to record all the driver's actions, and this recording could have become key evidence in a criminal case, providing an answer to the question about the driver's behavior. However, the video recorder was badly damaged, so only a few seconds could be restored. The recording captured the moment the car drove onto the sidewalk, and the driver's obscene language can be heard in the background.

According to the driver Viktor Tikhonov, he pulled up to the final stop, Slavyansky Bulvar. There were three people in the bus, and he had to wait another 15 minutes to board. Another bus pulled up behind him, and he decided to move over to give it his seat. When he released the handbrake, the bus suddenly started moving on its own. Despite all his attempts to stop the bus, the brakes did not work, and the bus continued moving. The bus has an automatic transmission, so he could not do anything else. Later, he said that before the tragedy, a plastic bottle of water rolled under his pedal and prevented him from reacting adequately to the situation. In addition, it became known that Tikhonov regularly works on another Mostransavto route, and that Monday he went out unplanned to replace a colleague, was driving a bus of this type for the first time, and was unable to make the right decision in a critical situation.

According to the manufacturer of the GAZ Group bus, the driver did not even try to brake. The bus was manufactured in 2016, transferred to the State Unitary Enterprise Mostransavto for work on regular routes in the Moscow Region and was registered on January 4, 2017, that is, it was practically new. Buses of this model are equipped with a certified Wabco or Knorr-Bremse pneumatic brake system with an anti-lock system, two working circuits and a parking circuit that functions as a spare brake system.

According to an unofficial version, the cause of the tragedy could be hidden in the system of blocking the movement with open doors. The spontaneous movement of LiAZ buses occurred regularly and often led to accidents. The last time was just 5 days before, on December 20, 2017, in Zelenograd on Kryukovskaya Square, where the bus almost rammed a flower stall. It was stopped by anti-ram bollards, which were installed in this place after buses of the same brand unexpectedly drove onto the sidewalk twice in 2016, and in both cases the driver was not in the cabin. Such incidents are far from uncommon. In Moscow, there were a number of episodes when new LiAZ buses drove away from drivers, leaving them outside. They left the car with an automatic transmission in the DRIVE position, and blocked the movement with open doors. The doors were closed, and the bus drove away. In 2012, in St. Petersburg, a LiAZ without a driver spontaneously started moving. The female conductor climbed into the cabin for some reason and accidentally switched the selector to DRIVE mode. Despite the fact that the parking brake was activated, the bus started moving and went towards the bus in front. The conductor tried to stop the multi-ton vehicle herself and ended up dying.

The State Duma deputies were in no hurry to draw conclusions and no statements were made on the topic of possible legislative initiatives. By December 30, about 800 concrete barrier blocks were urgently installed at the entrances to the busiest metro stations and in places of mass gatherings of people in Moscow. Incidentally, a similar practice appeared in Europe after the terrorist attack in Nice on July 14, 2016.

On May 10, 2024, at 1:03 p.m. in Saint Petersburg, the driver of the Volgabus 4298 city bus, route #262, 44-year-old native of Dagestan Rakhmatshok Kurbonov, despite the “Dangerous Turn” and “Maximum Speed Limit” signs of up to 20 km/h installed on Bolshaya Morskaya Street, entered the turn at a speed of 35 km/h and lost control. The bus drove onto the sidewalk, jumped over the anchors near the Naval Museum, knocked down the fence, drove into the oncoming lane, where it hit a Chery Tiggo, and, having overcome a high curb (the traction force, given the automatic transmission, was greater than the resistance force), fell from the Potseluyev Bridge into the Moika River (Figure 6). The most tragic thing is that 5 (!) seconds after falling into the water, the bus sank to the level of the roof. The first to come to the rescue were eyewitnesses driving across the bridge and two passing boats, one of which the bus almost fell into. Rescuers arrived seven minutes after the incident. Only two people, including the driver, managed to get out of the water-filled cabin. Three passengers died (drowned, not from injuries!) on the spot, another four were hospitalized in a state of clinical death, but they could not be saved.

At first, Rakhmatshoh Kurbonov reported faulty brakes. However, the video recorder installed inside the cabin showed that the driver had been driving in a panic for 15 seconds without ever attempting to press the brake pedal. A criminal case was opened against the driver under Part 5 of Article 264 of the Criminal Code of the Russian Federation, “Violation of traffic rules resulting in the death of more than two persons,” which provides for up to 7 years in prison. In addition, another case was opened against Kurbonov for fictitious registration of foreigners – according to the Investigative Committee, he registered 10 migrants in his apartment.

The driver was not the only person involved. A criminal case was also opened against the carrier under the article on providing services that do not meet safety requirements. Over the previous two years, the company was fined 23 times for gross violations of license conditions for a total of 3.6 million rubles. The head of the motorcade of the company OOO Taxi, where Kurbonov worked, 28-year-old Dzhakhangir Khalilov, violated the working conditions of the driver and set him an inconvenient schedule, which is why he came to work on the fateful day without getting enough sleep. Kurbonov's wife testified that her husband was forced to go on a trip the next morning after a 20-hour shift. Kurbonov arrived at about 2 a.m., having worked since 5 a.m., and at 7:30 he was woken up and told to go to work again. The operating director of the Taxi Company, Roman Yurenev, tried to refute this information. At the same time, the Investigative Committee studied the question of why for a year and a half the transport company was nominally headed by 49-year-old businessman Pavel Kuznetsov, who did not participate in the life of the enterprise in any way and received his salary for nothing. He was released on his own recognizance not to leave.

2 IN A NORMAL COUNTRY, AFTER ONE SUCH DISASTER, THE MINISTER OF TRANSPORT AND THE LEADERSHIP OF THE TRANSPORT HUMAN FACTOR LEVELS

The analysis of the above-mentioned accidents shows that the human factor should be considered not only from the perspective of driver errors, but in the broadest sense. The following levels of the human factor can be distinguished in driver training and operational safety:

- driver - driving errors, overestimation of one's own skills, low level of training;
- managerial or organizational - the motor transport enterprise does not conduct driver inspection or conducts it fictitiously, releases faulty vehicles on the road;
- political - the transport department does not monitor the situation or there is corruption in the inspection of motor transport enterprises, the minister is busy extorting money from drivers instead of safety, migrants with purchased licenses of the appropriate category without proper driving experience and training get behind the wheel of buses and heavy trucks;
- legal - the wrong person is judged, there is a constant search for a scapegoat and the concealment of responsible persons.

Committee would resign, but not in Russia.

Figure 6 Mojka river accident, 10.05.2024

Levels of the CF in design safety:

- technological – errors in the choice of technology, materials, suppliers (cheaper);
- production – defects in the work of plant employees;
- systemic – inertia of the standardization system when adopting new requirements and rules;
- commercial, or ideological – the established stereotype that the buyer allegedly does not want to pay for safety allows the management of automobile plants to save on the implementation of expensive active and passive safety systems.

Currently, there are no ways to fully solve the problem of the human factor, so it is necessary to offer technical solutions. The automotive community hopes for the introduction of unmanned technologies, but even with their introduction, as a number of fatal accidents have shown, the negative influence of the human factor is inevitable [110–112]. Autonomous vehicles will not help to overcome many of the listed levels, especially in Russia.

3 INTEGRAL BRAKING VALVE

A more detailed investigation into the circumstances of the Oznobishino accident showed that the dump truck driver did not even try to activate the backup brake system. The experience of specialists from the KamAZ driver training center shows that only 1 driver out of 10 remembers about the backup brake system in an emergency, and the reaction time increases to at least 3 seconds. An integral brake valve in two versions was proposed as a technical solution.

The technical task of the inventions consists in creating the possibility of emergency braking of a wheeled vehicle in the event of a pressure drop in the receivers of both working circuits of the brake system below the permissible limit without activating an additional control element. The solution to the technical task becomes possible due to the supply of the main two-section brake valve with a third section, which allows in the emergency braking mode in the event of failure of all circuits of the working brake system, i.e. in the event of a pressure drop in the receivers of the working brake system, to use the possibility of automatically activating the parking brake system when the driver presses the brake pedal due to the combination of the control element of the working brake system and the circuit of the parking brake system.

Figure 7 shows an integral brake valve with a parallel additional section [113]. In the initial position, when the brake pedal 7 is released, the receivers 3, 4, 5 are discharged, the upper follower piston 48 of the main two-section brake valve 6 under the action of the spring 49 and the lower follower piston 55 under the action of the spring 56 occupy the extreme upper position. The valve seats 50 and 57 are made as a single unit with the pistons 48 and 55, therefore the outlet ports of the valves 50 and 57 are open, and the brake chambers 8 and 9 of the tractor are connected to the atmosphere through the openings 64 and 65 and the hollow rod 53. Under the action of springs 52 and 59, valves 50 and 57 are pressed against fixed seats located in housing 38, and openings 60 and 61 are disconnected from openings 64 and 65, respectively. At the same time, control pistons 21 and 22 of the third section 12 of the integrated brake valve 13, under the action of springs 32 and 33, are in the extreme upper position, rubber seat 29 of atmospheric valve 28 is pressed against the movable seat in the lower control piston 21 by spring 31.

As receivers 3 and 4 are filled with compressed air from compressor 1 after the tractor engine is started, the pressure increases at inlet openings 60 and 61 of the main two-section brake valve 6, as well as at inlet openings 23 and 24 of the third section 12 of the integrated brake valve 13 and, accordingly, in cavities 17 and 18 above control pistons 21 and 22. When the force from the compressed air pressure exceeds the force of springs 32 and 33, control pistons 21 and 22 move to the extreme lower position, as a result of which the seat of the bypass valve 27 sits on the fixed seat in the housing 14, the cavity 19 connecting openings 25 and 26 is isolated from the auxiliary cavity 20 of the third section 12 of the integral brake valve 13, and the pusher 44 and the atmospheric valve 28 are lowered down. Thus, the lever 43 does not transmit force to the pusher 44 when turning, and the integral brake valve 13 does not affect the operation of the parking brake system of the tractor.

If the compressed air reserve in receivers 3 and 4 of the service brake system is sufficient, then during braking the force from pedal 7 through lever 41, pusher 42 and elastic rubber bushing 46 is transmitted to the upper follower piston 48 of the main two-section brake valve 6. The movable valve seat 50, moving together with piston 48, closes the outlet window of valve 50 and blocks communication through outlet 65 of brake chambers 9 with the atmosphere, and then tears valve 50 away from the fixed seat. Compressed air from receiver 4 through inlet 61, open valve 50 and outlet 65 enters the rear brake chambers 9, braking the tractor in the normal mode.

The pressure in the upper section 51 of the main two-section brake valve 6 increases until the force of pressure on the rubber bushing 46 is balanced by the force acting on the upper follower piston 48. Then the valve 50 sits on the fixed seat, and compressed air stops flowing into the brake chambers 9.

When the pressure in the cavity 69 of the upper section 51 increases, air enters the cavity 70 above the large piston 54 through the internal opening 68, which moves downwards together with the lower follower piston 55 and opens the valve 57. The compressed air enters the front brake chambers 8 through the inlet opening 60, the open valve 57 and then through the outlet opening 64. The pressure of the compressed air located in the space under the pistons

54 and 55 balances the force acting on the piston 54 from above. In the lower section 58 of the main two-section brake valve in the front brake chambers 8, a pressure is established corresponding to the force of pressing on the rubber bushing 46.

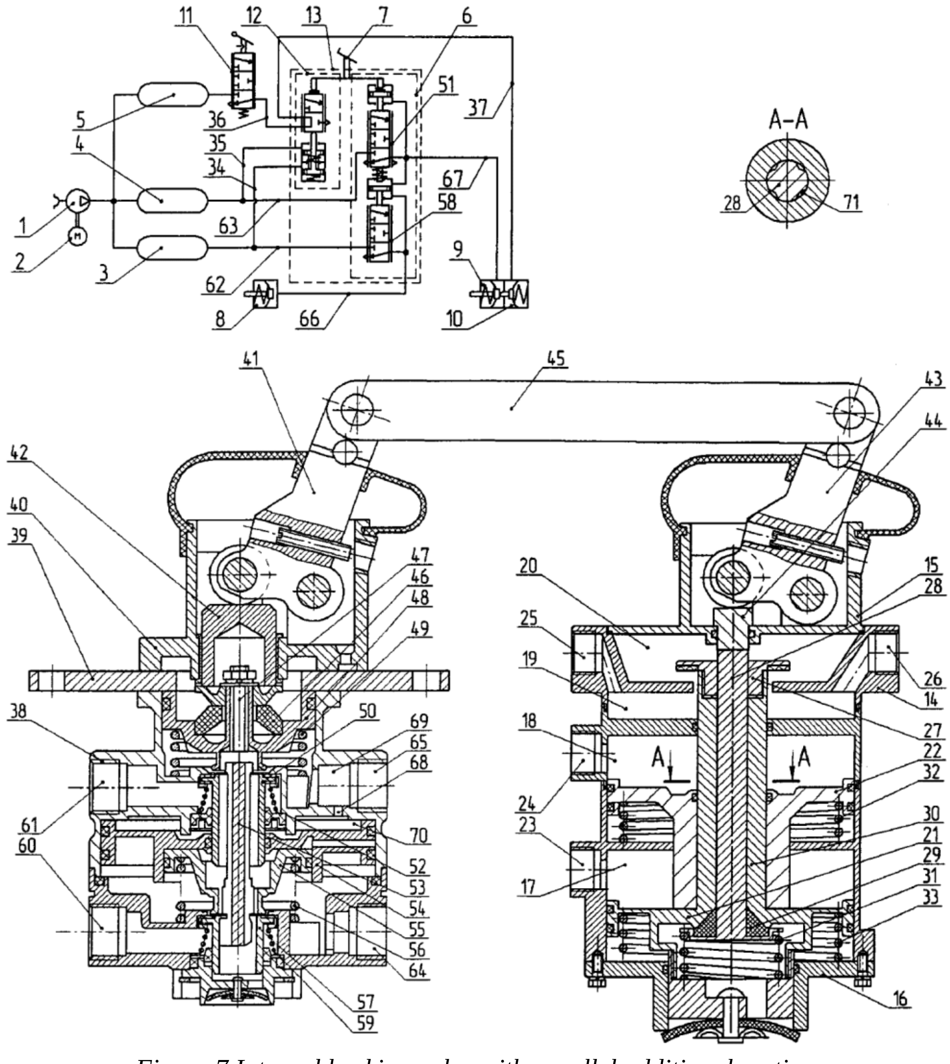

Figure 7 Integral braking valve with parallel additional section:
1 - compressor; 2 - engine; 3, 4, 5 - receiver; 6 - two-section main brake valve; 7 - brake pedal; 8, 9 - brake chambers; 10 - spring energy accumulators; 11 - parking brake valve; 12 - third parallel section; 13 - integral brake valve; 14, 38 - housing; 15, 16, 39, 40 - cover; 17, 18, 19 - working cavity; 20 - auxiliary cavity; 21, 22 - control piston; 23, 24, 25, 26, 60, 61 - inlet; 27 - bypass valve; 28 - atmospheric valve; 29 - rubber seat; 30, 53 - hollow rod; 31, 32, 33, 49, 52, 56, 59 - spring; 34, 35, 36, 37, 62, 63, 66, 67 - pipeline; 41, 43 - lever; 42, 44 - pusher; 45 - earring; 46 - rubber bushing; 47 - thrust bolt; 48, 55 - follower piston; 50, 57 - valve; 51 - upper section; 54 - piston; 58 - lower section; 64, 65 - outlet holes; 68 - inner hole; 69, 70 - cavity; 71 - grooves

When the force is removed from the lever 41, the piston 48 moves upward, the valve 50 is pressed against the fixed seat, and the outlet 65 communicates with the atmosphere through the outlet window of the valve and the hollow rod 53. The decrease in pressure in the upper section 51 causes the piston 54 to move upward, as a result of which the valve 57 also sits on the seat in the housing 38, and the outlet 64 communicates with the atmosphere, as a result of which the tractor is released.

During operation of the brake system, damage to the front and/or rear working circuit is possible, for example, in the event of a leak in the communication line, as well as in the event of a complete failure of compressor 1. In the event of a pressure drop in the upper section 51 of the main two-section brake valve 6 as a result of damage to the rear circuit, the force from the lever 41 through the stop bolt 47 is transmitted to the hollow rod 53, rigidly connected to the lower follower piston 55, and opens the valve 57. Thus, the lower section 58 will be controlled mechanically. In this case, its follower action will be preserved, since the force acting from above on the piston 55 will be balanced by the force on the piston, arising as a result of an increase in pressure in the lower section 58. When the pressure in the lower section 58 drops as a result of damage to the front circuit, the piston 54 sits on the lower stop in the body 38 of the valve 6, and the upper section 51 operates in the usual way.

The control pistons 21 and 22 of the third section 12 of the integrated brake valve 13 operate independently of each other. When the air pressure in the receiver 4 of the rear circuit of the service brake system drops (for example, as a result of a leak), the pressure also drops at the inlet opening 24 and in the cavity 18 above the upper control piston 22, which is displaced upward under the action of the spring 32. However, the bypass valve 27 is still closed, since the lower control piston 21 remains in the lower position.

When the pressure in the receiver 3 of the front circuit of the working brake system drops, the pressure also drops at the inlet 23 and in the cavity 17 above the lower control piston 21. However, the force from the compressed air pressure in the cavity 18 above the upper control piston 22 exceeds the total force of the springs 31 and 32, the control pistons 21 and 22 remain in the lower position, and the bypass valve 27 remains closed. If the compressed air pressure in receivers 3 and 4 simultaneously falls below the permissible limit, control pistons 21 and 22, under the action of springs 32 and 33, respectively, return to the extreme upper position, while the seat of the bypass valve 27 breaks away from the fixed seat in the housing 14. The atmospheric valve 28 moves upward, but its rubber seat 29 remains pressed against the movable seat in the lower control piston 21 by spring 31. Together with the atmospheric valve 28, the pusher 44 also rises upward until it stops against the roller of the lever 43.

Now, when there is a need to brake, when pressing pedal 7, the force from the lever 41 is transmitted through the earring 45 to the lever 43, which turns and moves the pusher 44 downward with the roller. The lower control piston 21 remains in the extreme upper position under the action of the spring 33, therefore the atmospheric valve 28, when acted upon by the pusher 44, moves downwards, overcoming the force of the spring 31, and the rubber seat 29 breaks away from the movable seat in the lower control piston 21. Compressed air from the spring energy accumulators 10 through the inlet opening 26, the open bypass valve 27, then through the grooves 71 in the atmospheric valve 28 goes out into the atmosphere. The tractor is braked by the spring energy accumulators 10, and the driver does not need to manually operate the parking valve 11.

As a result, equipping the tractor brake system with an integrated brake valve 13, having a third section 12, makes it possible to use the line of the spare parking brake system in the event of failure of both circuits of the vehicle's service brake system using only the brake pedal, which makes it possible to reduce the driver's reaction time and reduce the braking distance.

Figure 8 shows an integral brake valve with a sequential additional section [114]. The hollow rod 18 is designed to transmit mechanical force from the brake pedal 7 in emergency mode through the following movable elements of the main two-section brake valve 6: lever 27, stop bolt 30 and rod 36. A limit switch 58 is installed in flange 22 to transmit a signal to the driver's control panel about activation of the emergency mode.

In the initial position, when the brake pedal 7 is released, the receivers 3 and 4 are discharged, the upper follower piston 31 of the main two-section brake valve 6 under the action of the spring 32 and the lower follower piston 38 under the action of the spring 39 occupy the extreme upper position. The valve seats 33 and 40 are made as a single unit with the pistons 31 and 38, respectively, therefore the valves 33 and 40 are open, the brake chambers 8, 9 are connected to the atmosphere through the corresponding outlet openings 49, 50 and grooves in the rod 36 through the hollow rod 18 in the control piston 17. When the valves 33 and 40 are pressed under the action of the springs 35 and 42 to the fixed seats located in the housing 24, then the inlet openings 46 and 45 are disconnected from the outlet openings 49 and 50, respectively. At the same time, the control piston 17 in the additional, sequentially installed section 12, under the action of the spring 23, is in the extreme upper position and closes the outlet openings 56.

If the compressed air reserve in receivers 3 and 4 of the service brake system is sufficient, then during braking the force from pedal 7 is transmitted to lever 27, pusher 28 and elastic rubber bushing 29 on the upper follower piston 31 of the main two-section brake valve 6. The movable valve seat 33, moving together with piston 31, closes the outlet window of valve 33 and blocks the communication of the rear brake chambers 9 with the atmosphere, and then tears valve 33 away from the fixed seat. Compressed air from receiver 4 through inlet 46, open valve 33 and outlet 49 enters the rear brake chambers 9, performing braking in the normal mode.

The pressure in the upper section 34 of the main two-section brake valve 6 increases until the force of pressing on the rubber bushing 29 is balanced by the force acting on the upper follower piston 31. Then the valve 33 sits on the fixed seat, and the compressed air stops entering the brake chambers 9. When the pressure in the cavity of the upper section 34 increases, air enters the cavity above the large piston 37 through the internal opening 53, which, together with the lower follower piston 38, moves downwards and opens the valve 40. The compressed air enters the front brake chambers 8 through the inlet opening 45, the open valve 40 and then through the outlet opening 50. The pressure of the compressed air located in the space below the pistons 37 and 38 balances the force acting on the piston 37 from above. In the lower section 41 of the main two-section brake valve, in the front brake chambers 8, a pressure is established corresponding to the force of pressing on the rubber bushing 29.

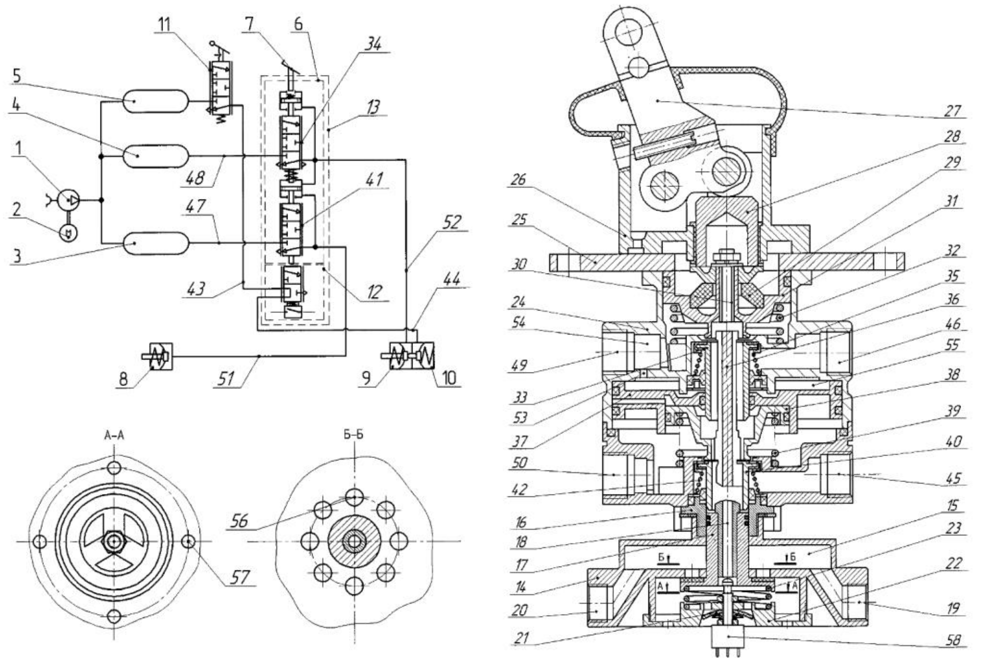

Figure 8 Integral braking valve with a sequential additional section:
1 - compressor; 2 - engine; 3, 4, 5 - receiver; 6 - two-section main brake valve; 7 - brake pedal; 8, 9 - brake chambers; 10 - spring energy accumulators; 11 - parking brake valve; 12 - third sequential section; 13 - integral brake valve; 14, 24 - housing; 15 - working cavity; 16 - sleeve; 17 - control piston; 18 - hollow rod; 19, 20, 45, 46 - inlet; 21 - atmospheric valve; 22 - flange; 23, 32, 35, 39, 42 - spring; 25, 26 - cover; 27 - lever; 28 - pusher; 29 - rubber bushing; 30 - stop bolt; 31, 38 - follower piston; 33, 40 - valve; 34 - upper section; 36 - rod with longitudinal grooves; 37 - large piston; 41 - lower section; 43, 44, 47, 48, 51, 52 - pipeline; 49, 50 - outlet; 53, 56, 57 - inner hole; 54, 55 - cavity; 58 - limit switch

When the force is removed from the lever 27, the piston 31 moves upward, the valve 33 is pressed against the fixed seat, and the inlet 49 communicates with the atmosphere through the open valve 33 and the grooves in the rod 36. The decrease in pressure in the upper section 34 causes the piston 37 to move upward, as a result of which the valve 40 also sits on the seat in the housing 24, and the outlet 50 communicates with the atmosphere, as a result of which the vehicle is released. During operation, there are cases of simultaneous failure of both working brake circuits, for example, when compressed air leaks occur along communication lines in the form of pipelines 47, 48, 51, 52, as well as when compressor 1 fails. In the event of a pressure drop in the upper section 34 of the main two-section brake valve 6 as a result of damage to the pipeline 52 of the rear working circuit, the force from the lever 27 through the stop bolt 30 is transmitted to the rod 36, rigidly connected to the lower follower piston 38, as a result of which the valve 40 opens. Thus, the lower section 41 will be controlled mechanically. In this case, its tracking action will be maintained, since the force acting from above on piston 38 will be balanced by the force arising as a result of the increase in pressure in the lower section 41. When the pressure in the lower section 41 drops as a result of damage to the pipeline 51 of the front working circuit, the large piston 37 sits on the lower stop in the housing 24, and the upper section 34 operates in the usual way.

If the compressed air pressure in receivers 3 and 4 simultaneously drops below the permissible limit, the force from lever 27 is transmitted through stop bolt 30 to rod 36, which transmits the force mechanically to hollow rod 18. Hollow rod 18, pressed against body 14 by means of spring 23 mounted on flange 22, lowers control piston 17, and compressed air from spring energy accumulators 10 exits into the atmosphere through openings 56 in body 14 and openings 57 on flange 22. Automatic braking of the vehicle is performed by the parking brake system, which performs a reserve function, while the driver does not need to additionally manually activate parking valve 11. Hollow rod 18 acts on limit switch 58, from which a signal is sent to the control panel about the emergency operation of the parking brake system of the vehicle.

Thus, equipping the main two-section brake valve with an additional, sequentially installed section makes it possible to reduce the stopping distance of a wheeled vehicle during emergency braking in the event of a decrease in pressure in the receivers of both working circuits of the brake system below the permissible limit by reducing the driver's reaction time by eliminating the need to activate an additional control element with informing the driver about the emergency mode of operation of the parking brake system.

4 SECONDARY COLLISION BRAKE ASSIST

Scientists estimate that about a quarter of all crashes involve multiple collisions. Secondary collisions can be especially dangerous because many safety systems, such as airbags and seat belt pretensioners, have already been deployed in the initial collision and cannot provide subsequent assistance. In addition, the vehicle’s structure is compromised by the initial impact and may be less able to absorb the energy of secondary collisions. Secondary collision brake assist (SCBA) reduces the likelihood and severity of secondary impacts (Figure 9).

Figure 9 Secondary collision brake assist

It is estimated that if all cars were equipped with SCBA, about 8 percent of fatalities and 4 percent of serious injuries could be prevented each year. The track tests included electronic simulations of airbag deployment and compliance checks in both high- and low-grip conditions. Testers covered almost a million kilometers to ensure there were no false alarms. SCBA has been independently tested by EuroNCAP and has been standard equipment on new Audi A3s since 2012.

If the airbag deploys in the initial collision, a signal is sent to the electronic stability control to automatically apply the brakes. If the vehicle is capable of safely and effectively braking, it automatically applies the brakes at a rate of 6 m/s2 to a speed of 10 km/h (6 mph) to prevent or at least mitigate a secondary impact with another vehicle or object on the road. During braking, the brake lights and hazard warning lights are turned on and remain on after stopping. In the event of a severe initial collision, there is a risk that the driver will be unable to steer, and SCBA will act automatically. If the driver detects that braking after the initial impact increases the risk, SCBA can be deactivated by pressing the accelerator pedal.

If the car is seriously damaged by the initial impact, SCBA will not act, as safe braking cannot be guaranteed. However, the electronic control unit is located in a well-protected area, so it is likely that SCBA will be able to help even if there is significant damage. On low-friction surfaces, the 6 m/s2 deceleration is not achieved, so the full benefit of SCBA cannot be realized.

The accident on the Moika River demonstrated the need to introduce a similar system on regular city buses.

5 CONCLUSIONS

The developments listed above have not yet been implemented in Russia, since the legislative system is very inert, especially in the area of standardization, and the commercial interests of the management of automobile plants diverge from the interests of society in the area of improving safety. Therefore, high-profile accidents with buses occur and will continue to occur. And the worst thing is that in any case, innocent victims are passengers who are not active participants in the traffic and are not able to influence the course of the disaster.

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