REPUBLIC OF SERBIA
CENTER FOR INVESTIGATION OF ACCIDENTS IN TRANSPORT
SECTOR FOR INVESTIGATION OF ACCIDENTS IN RAILWAY TRAFFIC AND INTERNATIONAL COOPERATION
Nemanjina 11, 11000 Belgrade

No.: ŽS - 01/18
33 No.: 340-00-3336/2018-10
Date: 06.03.2019.

FINAL REPORT ON ACCIDENT INVESTIGATION

Type of accident:	Fire on the train
Train No.:	2746
Place:	Hadžićevo, open track between stations Matejevac and Svrljig
Date:	30.03.2018.
Time:	17:50

This report presents the results of investigation of accident, fire on the train No. 2746 (DMK 710-004), which occurred 30.03.2018. at 17:50 on the regional route Crveni krst - Zaječar-Prahovo Pristanište, between the stations Matejevac and Svrljig.

Director of the Center for Investigation of Accidents in Transport of the Republic of Serbia established the Working Group for the investigation of this accident by the Decision 33 No. 02-02-3335/2018 of 05.04.2018.

In accordance with the Article 33 of the Law on Investigation of Air, Rail and Water Traffic Accidents (*"Official Gazette of the RS" No. 66/15 and 83/18*) and the Article 23 of the Directive 2004/49/EC of the European Parliament and of the Council of EU (Directive on Railway Safety), Center for Investigation of Accidents in Transport drafted and published the Final Report.

In this report, all sizes and measurements are expressed in accordance with the International System of Units (*SI*).

The meaning of abbreviations used in the text is explained in the Glossary.

CINS has been established in accordance with the Law on Investigation of Air, Rail and Water Traffic Accidents (*"Official Gazette of the RS" No. 66/15*). The founder is the Republic of Serbia and the holder of founding rights is the Government of the Republic of Serbia.

Department for investigations of railway traffic accidents and international cooperation carries out tasks within the competence of the Centre for investigation of accidents in traffic in relation to rail traffic with the aim of possible improvement of safety on the railways by issuing safety recommendations. The investigation procedure in the field of railway traffic is conducted on the basis of the provisions of the Law on Investigation of Air, Rail and Water Traffic Accidents (*"Official Gazette of the RS" No. 66/15 and 83/18*).

CINS conducts investigations after serious accidents on the railway system with a view to possible improvement of railway safety and the prevention of new accidents caused by the same or similar causes. Serious accident in railway traffic means any train collision or derailment of trains, resulting in the death of at least one person or serious injuries to five or more persons or extensive damage to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety.

In addition to serious accidents, CINS may also investigate other accidents and incidents that could lead to a serious accident, including the technical failure of structural subsystems or interoperability constituents.

CINS has the discretion to decide whether to open an investigation of other accidents and incidents.

CINS is independent in its work and performs independent accident investigations. The aim of an investigation is to identify the causes and the possibility of improving safety on the railways and to prevent accidents by issuing safety recommendations.

Professional activities related to safety investigations are independent of judicial inquiry or any other parallel investigations which objective is to determine responsibility or the degree of guilt.

Glossary:

CINS	.....	Center for Investigation of Accidents in Transport
IŽS	.....	Serbian Railways Infrastructure
RS	.....	Republic of Serbia
a.d.	.....	Joint Stock Company
OJ	.....	Organizational Unit
ZOVS	.....	For the maintenance of rolling stock
DMK	.....	Diesel Motor Vehicle
PP	.....	Against Fire
SKP	.....	Traffic Commercial jobs
JP	.....	Public Enterprise
ŽS	.....	Railways Serbia
PS	.....	Police Station
MUP	.....	Ministry of Interior
DM	.....	Diesel engine
DMV	.....	Diesel Motor Train
TSI	.....	Technical Specifications for Interoperability
VO	.....	Major Repair
SO	.....	Medium Repair

C O N T E N T :

1. Summary

1.1. Short description of the accident

On 30.03.2018. at 17:50 at the regional track Crveni Krst - Zaječar - Prahovo Pristanište, between the stations Matejevac and Svrljig, it came to fire at the train No. 2746. In the train composition No. 2746 there was one DMK of inventory No. 710-004. During the drive through the tunnel "Gramada" it came to fire. As it was not safe to stop the train in the tunnel, upon exiting the tunnel, the train driver had stopped the train at km 32+500, at approximate distance of 100 m before the stop Hadžićevo. The accident occurred in the area of the village Grbavče, municipiality Svrljig, in the uninhabited area.

1.2. The causes of the accident determined by investigation

Due to the increasing load of DM "A" because the DM "B" could not due to the failure join in the joint traction during climbing, there has been an increase in the temperature and flow of larger amounts of exhaust gases through the exhaust manifold - exhaust pipe, which passes through the vertical shielding canal and goes out onto the roof of DMK. As a consequence of heating the exhaust gases of the exhaust pipe to a temperature above the temperature of the work -warmed operating engines, and due to the non-existence of seals on the coupling with the continuation of the exhaust manifold, the hot products were directly affecting on the protective shielding pipe, which then heated and due to its warming there came to inflammation of upholstery, plastic and wooden parts, which in this part of the canal it touches. The fire started in the upper part of the canal, and then continued to expand in the lower part after which the parts of the burned lining began to fall to the bottom of the canal and to melt aluminum parts of air intakes.

Based on the submitted Request EV-63 by "Srbija Voz" a.d. it can be concluded that the same are recorded and to act upon them, but the measures to be implemented on the basis of data from the Request cannot be noted. Namely, it is evident that the work carried out/repairs to eliminate the consequences and not to determine the causes of failure are determined to eliminate the causes of failure so that they would not be repeated in a short period of time.

1.3. Main recommendations and information on subjects to which the report is submitted

Aiming to achieve the possible improvement of railway safety and to prevent occurrence of new accidents, CINS issued the following safety recommendations:

"Srbija voz" a.d.:

SR_01/19 "Srbija voz" a.d. to review the constructive design of the end of the exhaust manifold on the DMK series 710, and to perform the modification of solution (installment of the convenient seal), with the aim to prevent breakthrough of hot exhaust gasses, which could lead to occurrence of new fires on this segment.

SR_02/19 "Srbija voz" a.d. that on the basis of quality control in the course of repair and final review of the DMK series 710, determine whether repairs were made in the required quality and scope of work, with the aim of adequate execution of the repairs in accordance with Article 8 of the Rulebook on the Maintenance of railway vehicles.

SR_03/19 "Srbija voz" a.d. to perform the checks and tests, not only of the parts on the DMK series 710 that are relevant to safety, but also those parts of the fault frequency higher than the ones that are defined by the manufacturer that can affect the availability of the vehicle.

SR_04/19 "Srbija voz" a.d. that, given the long exploitation period of DMK series 710, carry out technological research related to the joint work of the diesel engine - hydrodynamic transmitter - the cooling system in order to identify lacks and on the basis of them implement appropriate improvements of the drive system (replacement of the kind of coolant, check the capacity of the heat exchanger - cooler, etc.) in order to prevent failures that could lead to occurrence of the new accidents.

SR_05/19 "Srbija voz" a.d. that due to the frequency of failures in the operating system DMK series 710 and accidents occurred - fires, conduct analysis and consider the possibility of shortening the period up to the execution of regular repairs.

SR_06/19 "Srbija voz" a.d. that at the next regular repair DMK Series 710, during the reconstruction of the interior applies materials in accordance with *EN 45545-1* and *EN 45545-2:2013+A1*, that is *SRPS EN 45545-1:2013* and *SRPS EN 45545-2:2017*.

Directorate for Railways:

SR_07/19 Directorate for Railways to check the license for use of DMK series 710 in terms of improvement of technical solutions of the drive system and the application of appropriate materials in terms of controlling the fulfillment of conditions for issuing safety certificates for transport.

2. Direct facts of the accident

2.1. Basic facts about the accident

2.1.1. Date, time and place of the accident

The accident occurred on 30.03.2018. at 17:50 in the area of the municipality Svrljig, in the area of the village Grbavče, where the railway stop Hadžićevo is located, on the regional track Crveni Krst - Zaječar - Prahovo Pristanište, between the stations Matejevac and Svrljig, on the part of the open track which is placed in the tunnel "Gramada". The area where the respective accident occurred is not populated.

The view of the place of the accident is shown in Fig. 2.1.1.1.

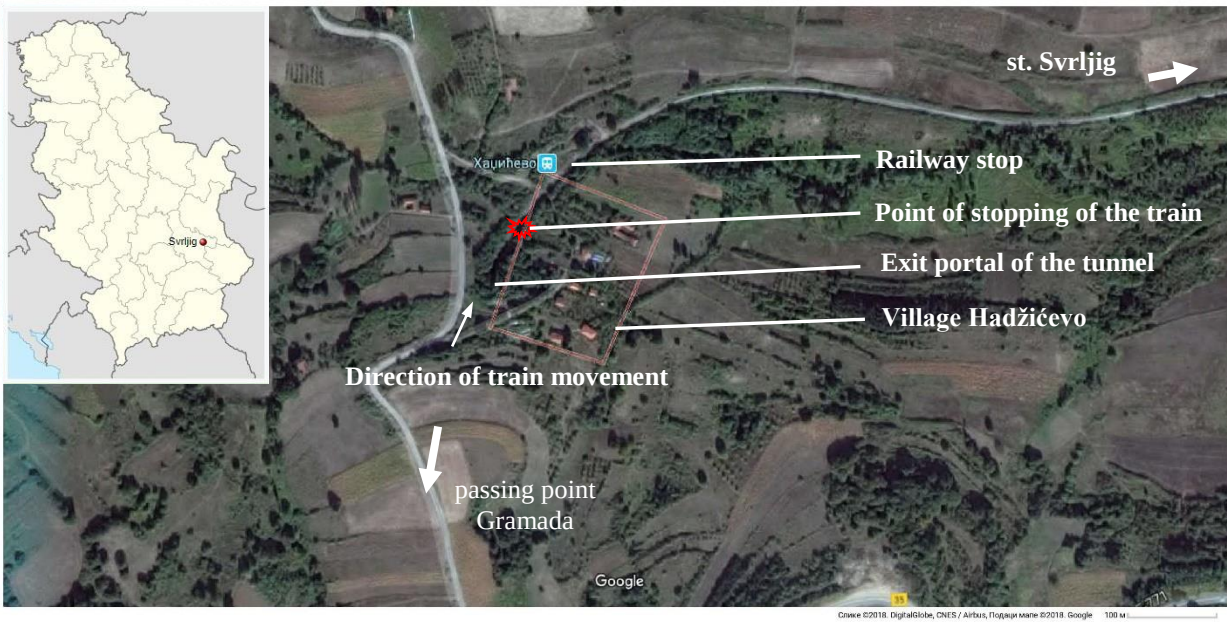

Fig. 2.1.1.1: The area of the accident site (source: *Google maps*)

2.1.2. Description of the accident and the accident site and work of rescue and emergency services

On the regional track Crveni Krst - Zaječar - Prahovo Pristanište, between the station Matejevac and Svrljig, during the drive in the direction from the station Matejevac to the station Svrljig, on the open track, in the tunnel "Gramada" (entrance portal - km 30+708.05 and exit portal - km 32+409.32) it came to the fire on the train No. 2746 (DMK 710-004).

Since the smoke appeared in the mere tunnel, which the train driver has felt, from safety reasons he carried on with the drive and upon exiting the tunnel at km 32+500 he stopped the train so that the passengers would be timely and safely evacuated. Upon stopping the train, the train driver has started extinguishing the fire by using the three manual fire extinguishers from the vehicle, but since the source of the fire was unknown, it was insufficient. Additional locomotive 661-112 arrived to help, with three more fire extinguishers, and then the team of the Fire-Rescue Department of Svrljig, after which the fire has been extinguished.

The train driver has primarily noted the fire from the outside on the roof of the vehicle, after which he took the fire extinguishers and he climbed on the roof to extinguish the fire. Trying to localize the fire, he noted that the access to the center of fire was unavailable because the fire was under sheathing of the vehicle and that he could not localize the fire himself.

For remediation of the accident (fire), it was necessary to engage the fire-rescue department from Svrljig. There was no need to engage the emergency medical sevice, beacuse there were no injured nor dead in this accident. Remediating the consequences occurred in this accident was made by hiring the expert services and resources of "Srbija Voz" a.d.

Due to this accident, it came to rail traffic interruption between the stations Crveni Krst and Svrljig. The traffic interruption lasted until 30.03.2018. at 21:00.

The schematic review of the place of the fire is shown in Fig. 2.1.1.2.

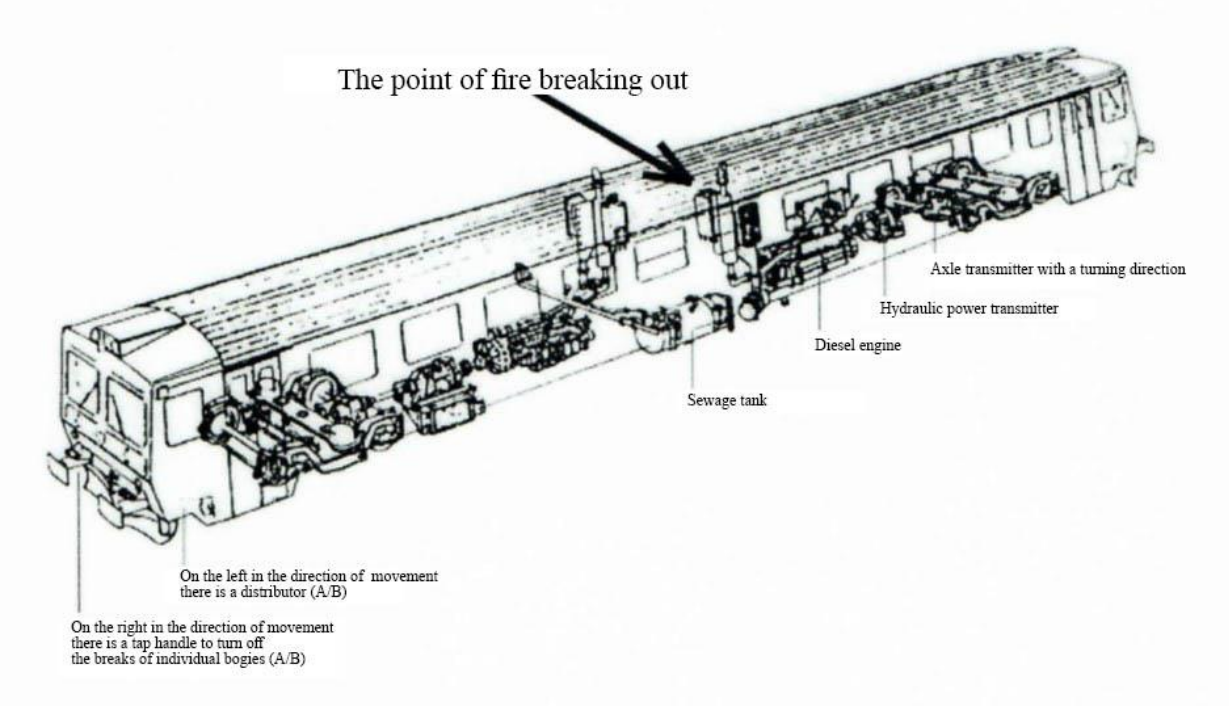

Fig. 2.1.1.2: The schematic review of the place of the fire on DMK 710-004 (source "Srbija Voz" a.d.)

2.1.3. Decision to launch the investigation, composition of the investigation team and conducting of the investigation

The first notification on the accident occurred the Main Investigator for Railway Traffic received on 30.03.2018. at 18:19 via telephone by the traffic dispatcher of the Central dispatching office of "Srbija Voz" a.d., and then at 18:42 by Assisstant Director of Setor for Operations of "IŽS" a.d. Based on the data and facts received, which the investigative team of CINS has established in the workshop of "Srbija Voz" a.d. in Zaječar, where DMK 710-004 was set after the accident occurred, CINS has launched the investigation of the respective accident in accordance with the Law on Investigation of Accidents in Air, Rail and Water Traffic ("Official Gazette RS" No. 66/15).

Composition of the Working Group for investigation of the respective accident is determined by Decision 33 No. 02-02-3335/2018 from 05.04.2018. of Director of CINS based on the Articles 6 and 32 of the Law on Investigation of Accidents in Air, Rail and Water Traffic Traffic ("Official Gazette RS" No. 66/15).

2.2. Accident background

2.2.1. Involved railway staff, contractors, other persons and witnesses

Train driver of the train No. 2746 (DMK 710-004), employed by the railway undertaking "Srbija Voz" a.d., OJ for traction, Zaječar, and conductor, who was following the train No. 2746, employed by the railway undertaking "Srbija Voz" a.d., OJ for SKP, Zaječar.

At the time of occurrence of the respective accident in the driver's cab of the train No. 2746 (DMK 710-004) apart from the train drive, there was also a third person - a train driver under supervision, employed by the railway undertaking "Srbija Voz" a.d., which at the time of the accident was driving the train No. 2746.

The other staff was not involved in the respective accident as well as contractors, other persons and witnesses.

2.2.2. Trains involved in the accident and their composition

In the respective accident the train No. 2746 was involved. The train No. 2746 operated, regularly, on the route Niš - Zaječar. The trains composition consisted of DMK of inventory number 710-004.

The abovementioned DMK, for the needs of JP "Železnice Srbije" (the name of the enterprise dates from 2006) were bought as second-hand from Swdish railways and for them the license No. 80/60 was obtained on 18.04.2006, when they were set to expolitation on the railway network ŽS.

Swedish railways have, the abovementioned vehicle of the type ALN 668 manufactured by Fiat from Turin, ordered it from the Italian State Railways (FS) and adapted it to Swedish operating conditions (quite extensive changes have been carried out). Workshop Kalmar Verkstad Sweden was determined to be subcontractor of FIAT. DMK 710-004 was released for traffic on the Swedish railways on 08.07.1981. Many structural elements were completed to correspond to the Swedish standard, climate and operating conditions.

According to data obtained with a letter of "Srbija Voz" a.d. No. 1/2018-689 from 16.05.2018., for the needs of exploitation on the network in RS on the motors, power transmitters and exhausts of DMK series 710 modifications, relative to the version purchased from Swedish railways, have not been made.

Technical data (some characteristics):

Overall lenghth via bumpers	24,4 *m*
Mass with full inventory without passengers and goods	46 *t*
Maximum speed	100 *km/h*
Engine power by 2000 *o/min* (engine Fiat)	2x147 *kW*
The number of seats	69

Fig. 2.2.2.1: View of DMK series 710

Motor vehicle has been constructed so that one person drives the vehicle, due to what, driver cabs, compared to the basic type, are set at the ends.

Side doors in entrances are two-winged folding doors which are controlled by electro pneumatics. Free door width is 780 mm.

The floor is lined with PVC coating. Parts of the walls in the level of the windows are made of polyester reinforced with glass fibers. Other wall and ceiling coverings are made of laminate panels. All motor vehicles have only second class. The seats have a textile coating. Ventilation is carried out with the static air intakes (valid for the basic version).

Power plant (diesel engines and transmission components) is located under the vehicle body and is divided into two separate units, one for each bogie.

DM is a lying six-cylinder in-line engine that was not supercharged. Nominal effect is at 2000 rpm (according to UIC) 147 kW (200 hp). Bogies on the motor vehicles Y1 have mainly been made as Fiat's original bogie for motor vehicle FS ALn 668.

The system for management and control functions on the principle of electro pneumatics and in general is built by Fiat's original decision. Those devices that are necessary to operate the vehicle, as well as the control instruments and signaling lights, are located on desks or panels in separate blocks in the driving cab's.

2.2.3. Infrastructure and safety signaling system

Regional track Crveni Krst - Zaječar - Prahovo Pristanište is one-track unelectrified track. By its characteristics, the respective track is mainly hilly.

The maximum slope on the track is 22,56‰ and is located between the stations Prahovo and Prahovo Pristanište from km 183+000 to km 183+250.

Section of the respective regional track from the station Crveni Krst to km 31+600 (interstation distance Gramada - Svrljig, the tunnel "Gramada") the track is in constant rise, as viewed in the direction Crveni Krst -Svrljig, in the direction of movement of the train No. 2746. The maximum rise on this section is 13‰ (from km 29+400 to km 29+560). On this section, the rise is greater than 10‰ in the overall length of 14.2 km.

The section of the respective regional track between the stations Matejevac and Svrljig is designed for speeds up to 65 *km/h*.

The maximum speed, according to the Timetable Booklet 7.1 (that was valid at the time of occurrence of the respective accident), on the section between the stations Matejevac and Svrljig is 40 *km/h* for passenger trains and 30 *km/h* for freight trains.

On the section between the stations Matejevac and Svrljig, from km 30+700 to km 32+410 there is a limited speed with 30 *km/h*, and there are no "restricted speed runnigs".

Traffic on the abovementioned section is regulated in station departments, by asking allowance for traffic of trains, notifying and checking out (verbally, with phonograms).

Between the stations Matejevac and Svrljig there is no safety signalling sytem that is operating, as well as devices for control, management and signalling. In the passing point Gramada there is bulit-in safety signalling device that for couple of years has not been in function.

2.2.4. Communication tools

On the section Crveni Krst - Zaječar - Prahovo Pristanište between the stations Matejevac and Svrljig, communication between personnel in charge of traffic regulation is performed via local radio network for traffic management Crveni Krst - Zaječar - Vražogrnac. The line of communication involves all the train dispatchers in all the station on the section between Crveni Krst and Vražogrnac. Communication on this radio network is recorded on the register device, located in TT section Niš. This type of communication is considered as evidence-based communication. At the time of occurrence of the respective accident, the radio network for traffic management was operating and functional at all the stations.

On this section of the abovementioned regional track there is no mean of communication between the staff that regulates the traffic and the train staff that is provided by TT service of "IŽS"a.d. To this end, only the lines of mobile operators are available.

2.2.5. Works at or near the accident site

Near the site of the accident there were no works performed.

2.2.6. Activation of the emergency plan for railways and the sequence of events

Railway undertaking "Srbija Voz" a.d. and infrastrcture manager "IŽS" a.d. have noted CINS on the accident occurred, that is, the Main Investigator for Rail Traffic. Railway undertaking "Srbija Voz" a.d. and infrastrcture manager "IŽS" a.d. have established a joint investigation committee that has conducted the investigation of the respective accident, in accordance with applicable regulations. Upon completion of the investigation, the Investigation Report U-109/18 was drafted.

According to the judgemenet of the train conductor, in the train No. 2746 (DMK 710-004) there were about 30 (thirty) passengers.

After exiting the tunnel, the train No. 2746 stopped, the passengers had, with the help of the train staff, safely left DMK and moved away to a safe distance.

After evacuation of the passengers, the train staff of the train No. 2746 has started initial fire extinguishing by using manual fire extinguishers with DMK.

From the station Svrljig at 18:02 the extra locomotive 661-112 was dispatched with additional manual fire extinguishers to assist in extinguishing the fire at the DMK 710-004, after which the DMK would be retracted in the station Svrljig.

Until the arrival of fire crews, employees at "Srbija Voz"a.d. had used 6 (six) manual fire extinguishers (three Co2 devices of 5 kg which were located on the DMK 710-004, and upon arrival of extra locomotive 661-112 three more manual fire extinguishers, one S-6 and two Co2 devices of 5 kg). It was attempted to extinguish the fire on the inside and the outside of the vehicle. Until the arrival of the additional locomotive 661-112, an attempt was made of fire extinguishing with water from a nearby stream, but all actions undertaken were insufficient to extinguish the fire.

The view of the used manual fire extinguishers is shown in Fig. 2.2.6.1. and 2.2.6.2.

Fig. 2.2.6.1: View of PP device type *S-6*

Fig. 2.2.6.2: View of PP device type *Co2*

By intervention of Fire rescue Department of Svljig, the fire was localized at 19:00.

After the fire had been localized, from the station Svrljig, for the acceptance of passengers from the train No. 2746 at 19:20 at the site the assisting DMV 711-039/040 was dispacthed, which

after the acceptance of the passengers returned to the station Svrljig at 20:16, from where at 20:45 as the train No. 2746 was dispatched to the station Zajecar.

DMK 710-004 had, with an assisting loc. 661-112, from the site been retracted to the station Svrljig at 21:00, and at 22:00 were dispatched for the station Zaječar as the train No. 32746.

The interruption of traffic on the respective section between the stations Matejevac and Svrljig lasted until 21:00.

2.2.7. Activation of emergency plan of public rescue services, police and medical services and sequence of events

Based on the data from the Letter of MUP, Emergency Management Sector, Administration for Emergency Management in Niš 09/20 No. 217-287/18 from 23.04.2018., at 18:04 the notification from the worker in charge of PS Svrljig via telephone has been made, that a passenger train is on fire on the railway stop Hadžićevo. Upon received notification that on the track Niš - Svrljig the passenger train is on fire, the team of Fire rescue Department of Svrljig at 18:15 came to do the intervention and arrived on site at 18:30 (two operators with a car tanker).

At the moment of arrival of the team on the site the fire on the traffic mean - DMK had been noted, in the middle part where DM "A" is located and exhaust manifold, where the electro installations and isolation were on fire, which is made of easily inflamable material (hardboard and canvas), in the motor and roof part.

Upon arrival of the car tanker-vehicle, due to inability of approaching with the firerescue car to the accident site, the push track of lenght over 200 m has been set and the review of DMK started, if any of the passenger remained with protection of water jet, and fire extinguishing. The fire was localized at 19:00 on the area od 3.5 m^2. Upon extinguishment of the fire on the site arrived committee in charge of rail traffic and, together with the members of the Fire rescue Department Svrljig has checked the vehicle. Due to driving DMK to Zaječar, DMK in the station Svrljig has been checked again by the members of Fire rescue Department Svrljig and committee and it has been concluded that everything had been extuinguished and secure for the continued drive, upon which at 21:45 extuinguishment of fire has been marked in the area of 4 m^2.

Intervention lasted from 18:15 to 22:00 (225 minutes). Two operators and one car tank were involved in the intervention. A total of 1 m^3 of water and 45 kg of powder had been spent. During the intervention there was no need to refill the extuinguishing means.

The aggravating circumstance was inability to nearly approach with the fire rescue vehicle to DMK on fire, due to the narrow field road for fire car tanker.

Intervention is considered as successful, having in mind that complete part of the vehicle for transport of passengers was saved in front and behind DM "A", as well as the drivers cab.

In this accident there was no need to hire the medical services.

2.3. Dead, injured and material damage

2.3.1. Passengers, third parties and railway staff, including contractors

In this accident there were no dead nor injured.

2.3.2. Goods, luggage and other assets

In this accident there were no damages to the goods and other assets.

2.3.3. Railway vehicles, infrastruictre and the environment

In the respective accident the railway vehicle was damaged. On the infrastructure and the assets of third parties there was no material damage.

The structure of the material damage is given accoridng to the following.

On DMK 710-004	1 000 000.00	RSD
Overall direct material damage:	**1 000 000.00**	**RSD**

The damage is stated in the official nomination of the RS (Dinar - *RSD*).

According to the official middle exchange rate of the National Bank of Serbia on the day 30.03.2018., which amounts to 1 EUR (Euro) = 118.3853 RSD (Dinars), overall material damage occurred in the respective accident amounts to 8 446.99 Euros (EUR).

The material damage in this report is shown based on the evaluation in the Record of determined scope of damage No. 2.33.3A/2018-554 from 23.04.2018., delivered by “Srbija Voz“ a.d.

2.3.4. External conditions - weather conditions and geographic characteristics

The place of occurence of the respective accident is located in the municipality of Svrljig, in the uninhabited area of the village of Grbavče, near the railway stop Hadžićevo. The terrain between the stations Matejevac and Svrljig is hilly. At the point where the train No. 2746 stopped, the track was in the cutting. The height of the embankment is 0.5 m.

The geographical coordinates of the accident site are: 43º 23' 51,3" N и 22º 2' 59,2" E.

At the time of the accident, the weather was clear and with no wind. The air temperature was 10°C.

The tunnel, where the accident occurred, was dark.

3. Minutes on the investigation and interviews

Data, facts and evidence regarding the respective accident have been collected and determined based on:

- a subsequent check of DMK in the workshop ZOVS Zaječar which was carried out by investigative team of CINS in the presence of the representatives of ”Srbija Voz” a.d.
- materials supplied by Infrastructure Manager “IŽS”a.d,
- materials supplied by Undertaking “Srbija Voz”a.d.
- materials supplied by MUP RS, Emergency Management Sector, Administration for Emergency Management in Niš.

For the respective accident, investigation on site and investigation were carried out by joint investigative committee of infrastructure manager “IŽS“ a.d. and railway undertaking “Srbija Voz“ a.d.

Police and judicial - investigative authorities did not conduct an investigation on the site.

3.1. Summary of testimonies

From “Srbija Voz“a.d. minutes from hearings of train driver, employed at railway undertaking “Srbija Voz“ a.d., OJ for traction Zaječar, conductor who was following the train No. 2746, employed at railway undertaking “ Srbija Voz“ a.d., OJ for SKP Zaječar and third person - train driver under supervision, employed at railway undertaking “Srbija Voz“ a.d., were delivered.

From “Srbija Voz“a.d. the Report on irregularities - disorders *K-91* was submitted by condcutor of train No. 2746 and Report on irregularities in work *EV-38* was submitted by the train driver of the train No. 2746.

3.1.1. Railway staff

The train driver stated (excerpt): „upon leaving the station Gramada we entered the tunnel and at about half of the tunnel I felt the scent of burns. Since the scent was strong, I thought it was coming from the electro compartment in the hall of DMK, and given the fact that I was going through the side “A“ forward, I first checked that. Once I made sure that in the electro compartment everything was ok, I started checking the vehicle and I noticed the certain amount of smoke in the passenger area. Since the motors were operating, I ordered to third person that was driving the vehicle, to speed up so that we could leave the tunnel as soon as possible. The train was stopped immediately upon exiting the tunnel to safely evacuate the passengers. Conductor, third person and me were in charge of the evacuation. Upon evacuation, I immediately stopped the engines, clamped on the parking brake, set the brake shoe and switched off the battery disconnecter. While I was trying to localize the fire, the first notification via mobile phone I sent to dispatcher of the station Svrljig and traction supervisor in Zaječar. In that momemt the fire appeared from the outside, on the roof of the vehicle, after which I grabbed the fire extuingishers and climed to the roof of the vehcile, in order to extuinguish the fire, but the access to the mere centre of the fire was unavailable (below the sheath of the vehicle). While I was on the roof of the vehicle, since I evaluated that I cannot extuinguish the fire alone, I recalled the dispatcher in the station Svrljig and informed him on the need for the fire rescue team. We extuinguished the fire from the outter and inner part of the vehicle by using the three fire extinguishers CO_2 of 5 kg, as

well as water from the nearby stream, and upon arrival of the extra loc. 661-112 we used three more fire extinguishers (one *S-6* and two *CO_2 of 5 kg).* The assisting locomotive and the fire rescue team arrived on site simultaneously. From the station Crveni Krst we had a problem with the gear "B", that was losing the traction during the drive and in the stop Pantelej I turned off the gear "B" while the motor "B" remained in function. In the station Matejevac, upon finished review of the vehicle, I reswitched on the gear "B". Upon exiting the station Matejevac, due to repeated problems with the gear "B", I turned it off completely and I contiuned to drive with two motors on and one gear. It happened before that I drive the vehcile with one gear turned off with no consequences, beacuse the vehicle is foreseen to return home with one gear. Upon extuinguishing the fire, we clutched DMK 710-004 for the loc. 661-112 and dragged it to the station Svrljig, where once again we examined it with the team of fire rescue department. During the drive I was in the drivers cab all the time, supervised and giving orders to the third person , and the third person helped me with securing the vehicle from self-rolling, evacuation of passengers and fire extuingishment."

Conductor stated (excerpt): „I felt the scent of smoke in the tunnel between the offical positions Gramada and Hadžićevo due to which I went to the middle part of the train set, and saw that the smoke is coming from between WC and the water compartment. The train was stopped upon exiting the tunnel. I secured the train from self-rolling by putting the brake shoes in front of the vehicle due to the fall of the track and with a handbrake. I told the passengers not to panic, that the train will stop as soon we exit the tunnel. Upon exiting the tunnel, I helped the passnegers evacuate and distanced them from the set for their safety. After extuinguishing the fire, in she stop Hadžićevo the train No. 2747 arrived and drove the passengers to the station Svrljig, and then to Zaječar. After the exit of the passnegers, which were about 30 by my judgement, we started extuinguishing the fire with the fire extuinguishers...".

The third person - the train driver under supervision stated (excerpt): „I was the third person with the train No. 2746, DMK 710-004 with the train driver. I was driving the vehicle from the station Niš to the point of stopping the train by instruction of the train driver. Upon leaving the station Crveni Krst, during the drive I had a problem with a gear "B", which the train driver switched off in the stop Pantelej, in the station Matejevac we switched on again the gear "B", but immediately upon departure of the train the same problems occurred, where the train driver completely switched off the gear "B" and so we continued with the drive until the accident site. During the drive in the tunnel Gramada I felt the scent of burns after which the train driver went out from the drivers cab to see what was going on, and I contiuned with the drive. Soon the train driver returned and told me to speed up exiting the tunnel and to stop the train due to the appearance of the smoke in the passenger area of DMK. Together with the train driver and conductor I help the passenger safely evacuate the vehicle and remained to help with the fire extuinguishment."

Report on irregularities- disorders K- 91 was submitted by the conductor of the train No. 2746 and Report on irregularities in work EV-38 was submitted by the train driver of the train No 2746 and reports on hearings drafted after the occurrence of the respective accident coincide in all the relevant facts.

3.1.2. Other witnesses

The witnesses of this accident (passengers of the train 2746) were not interrogated and the statements were not taken from them.

3.2. Safety management system

3.2.1. Organizational frame and manner of issuing and executing orders

In accordance with the Rulebook of Safety Management System of "IŽS"a.d. and with the Rulebook of Safety Management System of "Srbija Voz" a.d., infrastructure manager "IŽS" a.d. and railway undertaking "Srbija Voz" a.d. informed CINS on this accident.

Infrastructure manager "IŽS" a.d. and railway undertaking "Srbija Voz" a.d. have, in accordance with the Law on Railway Safety and Interoperability ("Official Gazette RS" No. 104/13, 66/15 - other laws and 92/15), formed the joint investigative committee that conducted the investigation of the respective accident. Upon finishing the investigation, Report on investigation U-109/18 was drafted.

3.2.2. Requirements that must be fulfilled by railway staff and the way they are applied

"Srbija Voz"a.d. through Safety Management System Rulebook (SMS) has provided the competence management, i.e. processes that all employees who are directly involved in the performance of rail transport are trained and competent for planning the workload.

Regarding the respective accident, involving the train driver and conductor, employed at "Srbija Voz"a.d, all activities related to professional training, competence and planning of office hours are conducted in accordance with applicable regulations.

3.2.3. Procedures for internal audits and controls and their results

"Srbija Voz" a.d., as railway undertaking, has established Rulebook of Safety Management System. The general purpose of Safety Management System (SMS) is to provide that "Srbija Voz" a.d. achieves its business goals in the safe manner.

The purpose of establishing the Safety Management System (SMS) in the joint stock company "Srbija Voz" a.d. is securing safe management of their own activities in accordance with the Law on Railway Safety and Interoperability ("Official Gazette RS" No. 104/13, 66/15 - other laws and 92/15) and Statute of the joint stock company for rail transport of passengers "Srbija Voz" a.d., Belgrade ("Official Gazette RS", No. 60/15)

Planning in the safety management process in certain elements that are relevant to the safety management process, is done by adopting other plans: Maintenance plans for rolling stock in order to increase technical safety and achieve greater safety in the traffic of rolling stock, the Framework plan and the program for teaching the executives in the joint stock company "Srbija Voz" a.d. and their proficiency expert check, Plans for checking the health ability of executive officers and operative workers.

Rolling stock must maintain the prescribed technical level of accuracy and must follow maintenance plans (EV-62) and their cycles of inspection and execution of scheduled repairs, in order to be as reliable as possible in traffic, in accordance with the Regulation on the Maintenance of Railway Vehicles and other legal acts and bylaw acts which are the integral part of the Rulebook of the Safety Management System of "Srbija Voz" a.d.

Within the joint stock company "Srbija Voz" a.d. internal control is organized in all organizational parts, which is especially expressed in the field of maintenance of rolling stock during the execution of regular repairs, in the control and technical examinations, in the case of rolling stock, and especially the control of the executive service officers in the application of

regulations, the use of alcohol, rest between the two services, and other. In addition to this type of control, control is also carried out through the Center for Internal Control, which has a task of controlling at all levels in all organizational parts of the joint stock company, on all relevant issues.

All mentioned activities and business processes of "Srbija Voz" a.d. are a risk generator in traffic conduction. These risks have been identified and quantified through the definition of operational business processes. In the work processes, instructions, rules, technical documentation and legal regulations are applied, which implements instructions, as well as the management of defined records and business documentation.

3.3. Relevant international and national regulations

3.3.1. Law on Railway Safety and Interoperability (*"Official Gazette RS" No. 104/2013, 66/2015 - other laws and 92/2015*) repealed on 08.06.2018.

Important note: at the time of occurrence of the respective accident, the Law was applicable.

2. Vehicle maintenenace

The person in charge of the vehicle maintenenace

Article 80 (excerpt):

The owner of the vehicle is obliged that for every vehicle that he uses determine the person in charge of its maintenance.

The person in charge of its maintenance can be also railway undertaking, infrastructure manager or owner of the vehicle.

...

In addition to the responsibility of the railway undertaking and the manager for the safe transport of trains, the person in charge of maintenance, with the use of maintenance system, is responsible for ensuring that the vehicles, for which maintenance he is in charge, are in a state that enables their safe movement.

The person in charge of maintenance shall ensure that vehicles are maintained in accordance with this Law, the vehicle maintenance file and the provisions of the TSI.

The maintenance files of each vehicle are collected and maintained by the person in charge of maintenance. The elements of the file of maintenance and management of the maintenance file are prescribed by the Directorate.

...

3.3.2. Rulebook on Maintenance of railway vehicles No. 340-382-7/2015 од 04.12.2015. (*"Official Gazette RS", No. 101/15, 24/16 and 36/2017*)

D) Regular repairs of the railway vehicles, cicles and deadlines of regular repairs

Article 16. (excerpt):

...

Cicles, deadlines and the scope of works of regular repairs are determined with the File on maintenance.

...

4. The maintenance file

Creation of the maintenance file

Artcile 34. (excerpt):

...

The creation of the maintenance file is based on the initial technical documentation produced by the manufacturer of the railway vehicle and which is enclosed with the application for the issuance of a license for the use of a railway vehicle.

...

The elements of the maintenance file

Article 35. (excerpt):

The maintenance file consists of the following elements:

...

3) documentation that consist of the description of mainetnance and the manner of execution of mainetnance and especially consists of:

...

(4) limit values for components that can not be exceeded during the exploitation of the railway vehicle,...

...

(6) the plan of maintenance that consists of:

...

- criteria and maintenance deadlines,

...

Management of maintenance file

Artcile 36. (excerpt):

...

2) Proposal of changes to the maintenance system of the railway vehicle, including maintenance deadlines, taking into account the results of evaluation and risk assessment and execution of changes in the maintenance file.

Upon updating the maintenance file the following should be taken into account:

1) limit values that should be maintained with the aim of securing the vehicle interoperability, and that are stated in the inital technical documentation and each possible change to documenatation;

...

3.3.3. Instruction for Maintenance of traction vehicles "Srbija Voz" a.d., No. 4/2016-16-4 from 23.02.2016

3. Periodic inspection

Article 4. (excerpt):

...

Depending on the series of traction vehicles, the types of periodic inspections and their order for a particular traction vehicle are determined, and their deadlines can not be longer than the deadlines prescribed in this Instruction.

On periodical inspections, in addition to the works prescribed by the manufacturer for a particular vehicle, it is mandatory to perform:

- checking the functional correctness of parts and assemblies,
- replacement of worn and damaged parts and assemblies,
- checking and measuring the parameters of certain parts, assemblies and devices and bringing them within the prescribed values,
- amendment and refillment of lubricants,
- dyeing of damaged points of internal sheath, bodies and frameworks.

Periods for carrying out the periodic inspections may be extended for the total period of the traction vehicle out of use, if it has not been used uninterruptedly for more than 2 months. In the event of an extension, before the release of the vehicle into traffic there must be a periodic inspection of the higher ranking from the order of inspection.

The order for referral of vehicles to periodical inspections is determined by the criteria of kilometers traveled or during the previous calendar days, and upon this the criteria being the one that was first fulfilled is applicable.

The periodic inspection criteria may be reduced or increased by 15%.

Depending on the traction vehicle series, the periodic inspection criteria is:

...

Series 710

The type of inspection	P1	P3	P6	P12	VPR
Time criteria (days)	30	90	180	360	-
km criteria (km)	-	-	-	-	400.000

...

4. Regular repair

Article 5. (excerpt):

Regular repair of traction vehicles manufactured before 2010 can be:

- Medium repair (SO),
- Major repair (VO).

Under the medium repair (SO) of a traction vehicle, inspection, control and repair or replacement of parts and assemblies on the vehicle shall be understood to bring it into a technically correct condition for that type of repair.

…

Under the major repair (VO) of a traction vehicle refers to repairing or replacing all the parts and assemblies on the vehicle to bring it into a technically correct condition for many years of use.

…

Criteria for carrying out the regular repair of traction vehicles are kilometers traveled or the time elapsed since the last regular repair depending on which criteria is first fulfilled. On subassemblies of traction vehicles, the criteria for referral to repair may be: time, distance traveled (km), hours of work or number of working cycles. The criteria according to this basis is defined by the manufacturer's instructions.

- The measure in kilometers traveled between two regular repairs for vehicles produced before 2010 is:

…

- Series 710 800 000 *km*

…

The person in charge of maintenance may decide that the distance traveled between two regular repairs may be lower or higher depending on the technical condition of the vehicle, with the time limit between the two consecutive regular repairs of traction vehicle can not be longer than 15 years.

...

3.3.4. Law on Railway Traffic Safety (*"Official Gazette RS" No. 41/2018*)

2. Vehicle maintenance

The person in charge of maintenance

Article 53 (excerpt):

The owner of the vehicle is obliged to, for each vehicle that he uses, determine the person in charge of its maintenance.

The person in charge of maintenance can be a railway undertaking, infrastructure manager and the owner of the vehicle.

...

In addition to the responsibility of the railway undertaking and the manager for the safe transport of trains, the person in charge of maintenance, with the maintenance system, is

responsible for ensuring that the vehicles, for which the maintenance he is in charge of, are in a state that enables their safe movement.

The person in charge of maintenance ensures that vehicles are maintained in accordance with this Law, the vehicle maintenance file and the provisions of the TSI.

The maintenance files of each vehicle are collected and maintained by the person in charge of maintenance. The Directorate prescribes the elements of the maintenance file and the keeping of the maintenance file.

...

3.4. Functioning of railway vehicles and technical installations

3.4.1. Control, command and signalling

The traffic on the abovementioned section is regulated in station departments, by asking allowance for the traffic of trains, notifying and checking out (verbally, via phonograms).

Between the stations Matejevac and Svrljig there is no safety-signalling system that is in function, as well as control, management and signalling devices. In the passing point Gramada there is a built-in the station safety-signalling device that for years has not been in function.

3.4.2. Infrastructure

The site of the accident is located in the tunnel, on a slope between 1.62 and 4.86 ‰ (from km 30+600 to km 31+400 rise from 5.1 ‰, from km 31+400 to km 31+600 rise from 3.34 ‰, from km 31+600 to km 32+050 fall from 1.62 ‰ and from km 32+050 to km 32+415 fall of 2.52 ‰, viewed in the direction of driving the train) and up to km 32+280 in the direction of movement of the train, after which there is a curve (right curve, as viewed from the direction of driving the train, radius R=300 m and total length l=288.79 m). The place where the train stopped after leaving the tunnel “Gramada” is located, in direction of driving the train, at a fall of 8,83 ‰ and in the right curve of radius R = 300 m and the total length l=288,79 m.

Part of the respective regional railway track from Crveni Krst station to km 31+600 (section that the train 2746 was operating on before the occurrence of the fire) is constantly rising, looking in the direction of driving the train. On that section, the rise is greater than 10‰ in a total length of 14.2 km. The maximum rise on that section is 13‰. (from km 29+400 to km 29+560).

The maximum speed, according to the Timetable Booklet 7.1 (which was valid at the time of the accident), is 40 km/h on the section between the Matejevac and Svrljig for passenger trains and 30 km / h for freight trains.

At the section between the stations Matejevac and Svrljig from km 30+700 to km 32+410 there is a limited speed of 30 km/h and there are no “speed restricted runnings”.

3.4.3. Means of communication

At the time of occurrence of the respective accident, the means of communication were operating and functional. On the means of communiciation no faults or interferences have been recorded.

3.4.4. Railway vehicles

At the time of occurrence of the respective accident, the train No. 2746 was moving from the Matejevac station to the Svrljig station (from the beginning to the end of the line, towards the direction of the rising mileage). During the train drive, when passing through the tunnel "Gramada", there appeared the scent of burns and smoke in the passenger compartment DMK 710-004.

Taking into account the fact that there was no interruption of the operation of the drive group on the DMK and that the tunnel was not a suitable place for the safe evacuation of passengers and extinguishing of the resulting fire, the train driver issued an order to a person who was driving the DMK to increase the speed in order to leave the tunnel as soon as possible, and upon leaving the tunnel to stop the train in a place suitable for the evacuation of passengers.

Fig. 3.4.4.1: View of DMK 710-004 on fire (middle part from the outside)

Fig. 3.4.4.2: View of passenger compartment DMK 710-004 on fire

The DMK 710-004 has built-in speeding devices manufactured by Hasler: registering speeding device type RT12, serial number C12.208 and indicating speeding devices type R12, serial number C10.186. Both speeding devices have been certified, with a validity of attestation until 03.07.2018.

By processing the data recorded on the speeding device strip taken from the registering speeding device DMK 710-004, (Data from the speeding strip No.2.33.3A/2018-521-1 dated 23.04.2018.) it was determined that the train No. 2746, starting from the station Matejevac at 16:55 until stopping at the stop Jasenovik was moving at speeds of up to 30 km/h. After being in the Jasenovik stop for 1 minute, the train restarts and moves at a speed of 28 to 35 km/h, after which it stops at the Gramada passing point.

After being in the Gramada passing point for 2 minutes, the train restarts and moves up to 30 km/h until entering the Gramada tunnel, where the speed falls below 20 km/h, after which it suddenly begins to grow and reach 40 km/h. After leaving the tunnel, a sudden stop was registered at the stop Hadžićevo at 17:38. Times are given according to the clock of the speeding device.

3.5. Traffic operation and management

3.5.1. Actions taken by the staff that manages traffic regulation, control and signaling

Traffic of the train No. 2746 on the Matejevac - Svrljig route took place at station departments. Prior to the delivery of the train No. 2746, it was duly requested and received for the train the permission in accordance with applicable regulations and in that sense, there were no irregularities.

The driving staff, through the accompanying documents, received orders and notices on train traffic on that section.

3.5.2. Exchange of voice messages in relation to the accident

Shortly before and during the course of the accident, there was no communication between the train driver and the staff that regulates the traffic.

The communication between the staff that regulates the traffic and train driver was realized after the respective accident in order to inform of the accident occurred, in that manner that the driver of the train No. 2746, through the line of the mobile operator, informed the dispatcher of the station Svrljig, and then supervisor of traction Zaječar.

3.5.3. Measures taken to protect and secure the place of accident

After the accident, section of the respective regional track between the stations Crveni Krst and Svrljig was closed for traffic.

Immediately after the train stopped, passengers were evacuated from the DMK, and the train driver, in his own statement, turned off the DM and battery disconnector.

Considering the fact that the train No. 2746 after the respective accident, stopped on a section of the track, which is on a slope of 8,83 ‰, for the purpose of securing the train from self-rolling, the train driver braked the train with a parking brake and carried out the installation of brake shoes.

Other measures to secure the site of the accident have not been undertaken.

3.6. Interface between man, machine and organisation

3.6.1. Working hours of the staff involved

For the railway staff, data was provided showing that the train driver and the conductor who were in service at the train No. 2746 had a legally stipulated rest before commencing their work and that at work they did not spend time longer than the maximum stipulated by the law.

3.6.2. Health-related and personal circumstances that had an effect on the accident, including the presence of physical or psycological stress

For railway staff, data from which it can be seen that the train driver and the conductor who were in service at train No. 2746 were professionally trained and medically able to perform the service. From the undertaking "Srbija Voz" a.d. for the train driver a photo copy of the license to operate the traction vehicle No. RS 71 2017 0529 issued by the Directorate for Railways on 01.01.2017 has been delivered, with validity until 18.09.2022.

3.6.3. Design of the equipment that has influence on the interface between user and machine

According to its characteristics, the respective track is predominantly hilly with pronounced slopes.

The DMK is managed by a train driver by means of controls from the drivers cab, designed with the production of DMK. The DMK includes two drive groups (diesel engine and power transmission). It is envisaged that DMK in regular conditions of exploitation operates with both drive groups on. DMK is designed in that manner that the drive groups can work independently, so in case of failure of one drive group (diesel engine or transmission), DMK can be independently returned to the home station with only one drive group.

3.7. Previous accidents of similar nature

Based on data obtained from "IŽS" a.d, for the period from 01.01.2006 until 30.03.2018. on the DMK series 710, a total of 5 (five) accidents, fires, occurred. An overview of the resulting fires is given in Table 3.7.1.

Table 3.7.1: An overview of fires occurred on DMK series 710 in the period from 01.01.2006 to 30.03.2018.

number	date	time	Short description	cause
1	11.09.2007.	19:39	At *km* 84+400 of the track Stalać-Kraljevo - Požega, at the station Samaila, the fire broke out on DMK 710-009 at the train No. 4844. The fire broke out on the motor of the side "B".	Technical fault on DMK 710-009, caused by the collision of the DMK on the rock on 31.08.2007. at km 153+360 when they were used for the train No. 3833. At that time, there was no damage to the electrical instalation, which later caused the fire.
2	10.10.2008.	15:20	At *km* 85+240 of the track Stalać - Kraljevo - Požega, the engine ignition on the side "A" at the train No. 4836. Upon departure from the station Samaila (*km* 84+400), visible traces of oil in the track up until *km* 85+240.	Electrical installation fault DMK 710-007 due to the age of the vehicle, as the vehicle is 28 years old in operation.
3	19.06.2013.	11:35	On the track Niš- Zaječar - Crveni Krst - Prahovo Pristanište, at the passing point Gramada at the train No. 2744 the smoke was noted in the passenger compartment at DMK 710-003. The fire broke out at the engine on the "A" side.	Technical fault of a traction vehicle, a fire on a compressor of a turbocharger.
4	15.11.2013.	13:35	At km 194+000 of the track Požarevac - Bor - Junction 2 between the stations Majdanpek and Vlaole on DMK 710-005 at the train No. 2775 the fire broke out during which DMK was compeltely burnt and ruined.	Technical fault of a traction vehicle, a fire on a compressor of a turbocharger.
5	21.04.2015.	08:30	On the track Požarevac - Bor - Junction 2 between the stations Bor and Vlaole, at the tunnel No. 33, during the drive of train No. 2752 (DMK 710-001), it came to appearance of the smoke in the passenger compartment, the train driver in the rear window spotted the flame on the "A" side.	Technical fault of the traction vehicle, semering failure on the DMK 710-001 turbocharger.

In all the accidents occurred there were no dead nor injured.

4. Analyses and conclusions

4.1. Final overview of sequence of events and adoption of conclusions about the occurrence of event based on the facts determined during investigation and interviews

4.1.1. Overview of DMK after the fire

A fire on DMK 710-004, which were operating as a train No. 2746, happened in the central part, with traces of burning above the engine compartment DM "A", Figure 4.1.1.1.

Fig. 4.1.1.1: View of the middle compartment of DMK 710-004 above DM "A"

On the outer surfaces, above DM "B", no traces of burning have been noted, Fig. 4.1.1.2.

Fig. 4.1.1.2: Review of the middle compartment of DMK 710-004 above DM "B"

Traces of burning were not also noted on DM "A", while above the same compartment they have been, Fig. 4.1.1.3.

Fig. 4.1.1.3: Review of DM "A"

The metallic enclosure of the air filter DM "A" shows the change of the color of the metal housing part as a result of the development of high temperature, as well as the thermal degradation of the paint, Figure 4.1.1.4.

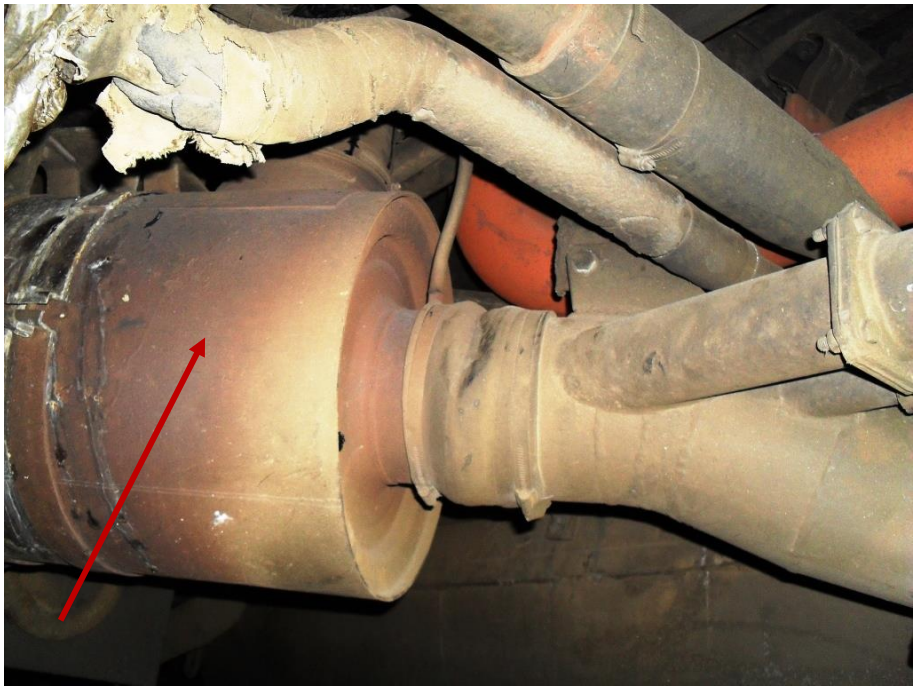

Fig. 4.1.1.4: View of the enclosure of theair filter DM "A"

Also, it was noted that the internal inflammable elements of the air filters, except the metal ones, were thermally degraded, Fig. 4.1.1.5.

Fig. 4.1.1.5: Review of the internal parts of air filter DM "A"

The traces of burning on the outer surfaces of the air intake DM "A" and the surfaces of the outer sheath DMK expressed in the upper part, Figure 4.1.1.6.

Fig. 4.1.1.6: Review of the air intake DM "A"

Tracks of burning in the inner part of DMK, where the passengers are placed, were expressed on the side above DM "A", on the surfaces in the upper part of the vehicle, Fig.4.1.1.7.

Fig. 4.1.1.7: Traces of fire in the inner part of DMK

Textile upholstery is thermally degraded while the aluminum parts are melted as a result of the presence of a temperature above the melting point of aluminum, that is approximately 650°C. It was noted that on other metal parts, the paint is thermally degraded as a result of the presence of high temperature, Figure 4.1.1.8.

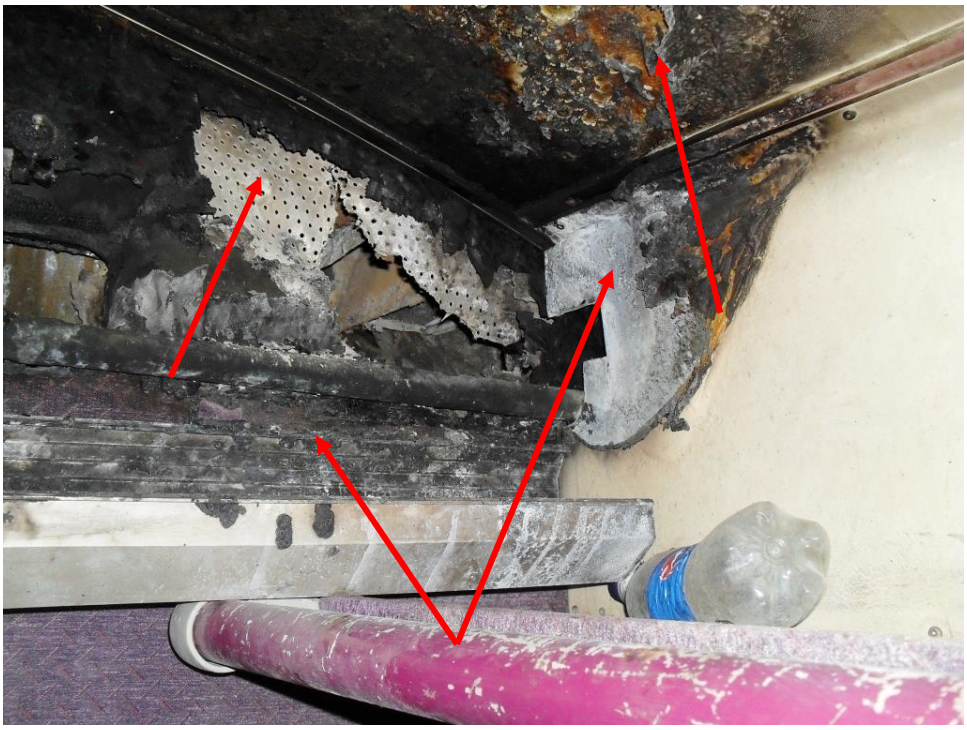

Fig. 4.1.1.8: View of other metal parts on fire

Traces of burning on the installation that is located in the roof construction are of a greater intensity, Fig. 4.1.1.9.

Fig. 4.1.1.9: Review of the traces of burning on the installation in the roof construction

The aluminum air intake on the outer part, which is located in front of the metal channel through which the exhaust pipe passes, with the traces of combustion expressed in the lower part, Figure 4.1.1.10. and the rear side of the air intake with the traces of melting expressed on the under side as a result of the fall of the burnt wooden and textile parts, Figure 4.1.1.11.

Fig. 4.1.1.10: View of the front part of aluminum intake

Fig. 4.1.1.11: View of the rear side of aluminum intake

Traces of burning on a metal pipe through which the exhaust pipe DM "A" passes are with the traces of burning of the greatest intensity on the surface in the upper part directly to the roof. The color is thermally degraded, and the aluminum parts on the left and right sides are melted as a result of the presence of high temperature. Parts of the isolation to the metal protective tube are thermally degraded, Figure 4.1.1.12.

Fig. 4.1.1.12: Parts of isolation to the metal protective tube

The floor on which the aluminum intake was located is with traces of burning of high intensity, which were caused as a result of falling of inflammable elements from the upper surfaces, Figure 4.1.1.13.

Fig. 4.1.1.13: The view of the floor on which the intake was found

During the inspection (disassembly operations) on the roof of the motor vehicle, it was concluded that the end of the exhaust pipe - the extension of the exhaust manifold DM "A" that comes out on the roof, was fitted with a flange connection without a seal (dichotung), that there are traces of contamination with the products of exhaust gases from DM to the inner wall of the metallic tube through which the exhaust pipe of DM passes through at the part with the connection with the exhaust pipe, Figures 4.1.1.14, 4.1.1.15, 4.1.1.16. and 4.1.1.17.

Fig. 4.1.1.14: View of the end of the exhaust pipe DM "A"

Fig. 4.1.1.15: View of the end of the exhaust pipe DM "A"

Fig. 4.1.1.16: View of the end of the exhaust pipe DM "A"

Fig. 4.1.1.17: The view of the seal of the protective pipe DM "A" with the traces of grime on the inner surface

4.1.2. Determining the centre of the fire

Based on the traces of burning and combustion products it was determined that the centre of the fire was located in the upper part, on the point of contact of the protective pipe through which the exhaust manifold DM "A" on the roof pipe passes.

4.1.3. Sources of energy in the centre of the fire

From stable sources of energy in the center of the fire, there was an engine exhaust temperature, which, in the case of the work-warmed operating engines and depending on the different load factors, could range from 300 to 600°C, and can also be increased above these values under certain conditions (eg irregular combustion or if the stoichiometric relationship is not correct). The main parameter is the load of the engine because the temperature of the exhaust gases depends on the released energy, i.e. the amount of fuel combusted in the unit of time. Apart from that, the temperature can not be constant for all the points/parts of the exhaust manifold and depends on the location/length of the exhaust pipe, or from the distance from the engine, so that the temperature decreases due to the cooling of the exhaust gases due to the heat transfer from them to the walls of the exhaust system, i.e. by moving away from the engine, the gases are colder, and with it the walls of the exhaust manifold.

4.1.4. Inflammable material in the fire zone

On the request of CINS for delivery of data on materials from which the interior of DMK has been made, the thermal isolation of the exhaust manifold and the level of fire protection, from "Srbija Voz" a.d. in the item 31 of the Supplement Annex of the Letter No. 1/2018-689 dated 16.05.2018. the answer was given that the data on the materials from which the DMK interior was made and the level of fire protection and thermal isolation "Srbija Voz" a.d. does not possess,

and that the thermal isolation is installed on the pipe through which the exhaust manifold passes, but it is very inaccessible for visual control (it is visible with one quarter of its surface).

In the ZOVS workshop, Zaječar, it was determined by visual inspection of DMK 710-004 that from the inflammable materials, wooden, plastic and textile parts are located in the center of the fire.

The specified materials according to the standard with mandatory application SRPS Z.C0.005 have the following characteristics:

W o o d (Hazard class FxIVC)

The degree of inflammability of wood depends on many factors (type of wood, surface treatment, degree of humidity, etc.). Wood burning temperature in ^{o}C:

1. the wood spruce 200
2. the wood beech 295
3. the wood oak 340

Plastic masses (Hazard class FxIIIC Fu)

Plastic masses are highly molecular organic compounds. The basic characteristic of these masses is that they are flammable and when burning they develop a considerable amount of heat. They are decompounded at relatively low temperatures. On that occasion, gas, liquid and solid products are formed which are flammable, and most of them are poisonous.

PVC-Polyvinyl chloride

When heating PVC materials of 100 ^{o}C, begin to separate the gases of hydrogen chloride, and at higher temperatures also phosgens, which are very poisonous.

In the presence of other flammable materies of wood, paper, paperboard and the like they burn at far greater intensity.

The ignition temperature of the layer of dust is 400 ^{o}C and the corroded dust 600 ^{o}C, is caused by flame and does not burn explosively.

P a p e r b o a r d (Hazard Class FxIII-IVC)

T e x t i l e (FxIIE Hazard Class)

Cotton goods (Hazard class FxIIIC)

The issue of the application of materials on the railway from the aspect of fire protection is treated along with the standard EN 45545-2:2013+A1 (2015) (Requirements for fire behavior of materials and components) adopted as a national standard labeled SRPS EN 45545-2:2017 (Fire protection in railway vehicles - Part 2: Requirements relating to the behavior of materials and components during fire). In the respective standard, in Table 2, components, parts and materials used on railway vehicles are treated and the requirements that they must satisfy, which are designated with R1 to R26. The above requirements are defined in detail in Table 5 of the abovementioned standard.

The abovementioned standard is only one of the series of standards EN 45545 (Railway applications - Fire protection) that treat the problem of fire protection of railway vehicles. TSI regulations, refer to the application of EN standards for new vehicles, while in section 4.6.1. of

the abovementioned standard predicts that materials in accordance with that standard are used in the maintenance and/or reconstruction process.

4.2. Analyses of facts determined during the investigation

4.2.1. Analyses based on the record of the speeding device

Analyzing the data from the speeding device strip DMK 710-004, it was found that during passing through the tunnel "Gramada", located from km 30+708.05 (entrance portal) to km 32+409.32 (exit portal), somewhere around the central part it came to exceeding of the limited speed on this section of the track (according to the Timetable Booklet 7.1, limited speed: 30 km/h, the reason: tunnel). Speed exceeding was done consciously (the train driver ordered an increase in the speed of the person who was driving the train) for the purpose of faster leaving the tunnel after the detected fire.

4.2.2. Review of maintenance documentation DMK 710-004

In accordance with the Law of Railway Safety and Interoperability (see point 3.3.1), “Srbija Voz“ a.d, as the owner of a vehicle, is registered in the National Register of Railway Vehicles as a person for the maintenance of the DMV Series 710 and is therefore authorized to maintain their vehicles.

“Srbija Voz“ a.d. with its Instructions on the maintenance of traction vehicles (see point 3.3.3) prescribed the manner of maintaining the DMV series 710.

From the submitted documentation “Srbija Voz“ a.d. it can be seen that periodic inspections of DMK 710-004 were executed in the deadlines according to Table 4.2.2.1.

Table 4.2.2.1: Review of the carried out periodic inspections of DMK 710-004

Type of inspection	Date of entrance	Date of exit	Note
П1	05.04.2017.	06.04.2017.	
П12	10.05.2017.	12.05.2017.	
П1	12.06.2017.	12.06.2017.	
П1	19.06.2017.	25.07.2017.	
П1	03.08.2017.	03.08.2017.	
П3	06.09.2017.	07.09.2017.	
П1	09.10.2017.	10.10.2017.	
П1	09.11.2017.	18.11.2017.	
П6	12.12.2017.	13.12.2017.	
П1	07.01.2018.	08.01.2018.	
П1	05.02.2018.	05.02.2018.	
П3	05.03.2018.	05.03.2018.	

From the submitted documentation for the process of mainetnance it was determined:

- that the maintenance of the DMK 710-004 was carried out within the deadlines prescribed in the Instructions for the Maintenance of Traction Vehicles “Srbija Voz” a.d. No. 4/2016-16-4 dated 23.02.2016.;
- last regular repair of DMK 710-004 was executed in the period from 20.10.2008. to 14.11.2008. The repair was done at the ZOVS Workshop in Zaječar, according to the scope of works foreseen for the middle repair of the car body. From the mentioned repair (according to the report of the Information and Communication Technologies Sector, mentioned in item 15 of the Annex Letter No. 1/2018-689 dated 16.05.2018. “Srbija Voz” a.d.) DMK ran 751,824 km. In 2018, no regular repair was planned. It can be concluded that there was no extension of the validity of the existing regular repair on the vehicle;
- last daily inspection on DMK 710-004 was done on 28.03.2018. in the period from 14:10 to 16:00. Before entering the daily inspection at DMK 710-004, a coolant hose cracked at DM “B” (Request EV-63 No. 118929). Data submitted from “Srbija Voz” a.d. in the table Condition of the traction vehicle 710-004 for the period 01.04.2017. until 01.04.2018. cites that in item 24 of Annexes Letter 1/2018-689 of 16.05.2018. “Srbija Voz” a.d. are contrary to the supplied EV-63 and EV-75i forms. This is just one of the examples of inconsistencies in keeping records submitted by “Srbija Voz” a.d. After that, the vehicle was in reserve (28.03.2018. from 16:00 to 30.03.2018. to 11:00) and was used for trains No. 2745/2746 of 30.03.2018., when the respective fire occurred;
- according to the submitted table “Srbija Voz” a.d. condition of traction vehicle 710-004 for the period 01.04.2017. until 01.04.2018., as well as the submitted EV-63 requirements, a relatively high frequency of failures on the drive system (diesel engine, cooling system and transmission) can be noted, as shown in Table 4.2.2.2.

Table 4.2.2.2: Review of failures on the drive system DMK 710-004

Date	Description of the failure
07.04.2017.	Cracked water hose on the hydraulic transmitter, DM "A" loses water, (repair of the water hose DM "A")
18.04.2017.	Leakage of coolant in the passenger compartment
02.05.2017.	The DM "B" shuts down, (the relay repair)
13.05.2017.	DM "A" lost water, (replacement of the rubber coupling on the cooling system)
16.05.2017.	DM "A" lost water, (replacement of the rubber coupling on the cooling system)
20.05.2017.	The DM "A" shuts off (replacement of the fuel pump)
29.05.2017.	Replacing the coolant hose on the DM "A"
04.08.2017.	**DM "A" overheats and drains cooling water, (replaced water pump)**
07.08.2017.	**DM "B" is turned off, DM "A" overheats, (replacement of the low pressure pump)**
09.08.2017.	**DM "B" is heated and loses water, (replacement of the water pump)**
14.08.2017.	**Overheating of "A" transmitter and ejects during driving**
15.08.2017.	**Overheating of DM "A", eject the transmitter "A"**
28.08.2017.	**DM "A", turned off**
30.08.2017.	**The DM "A" is heating up, the "A" transmitter is ejected, (washing the cooler and transmitter "A")**
31.08.2017.	**The DM "A" is overheated, the "A" transmitter is released, (the cooling system DM "A" is washed out)**
02.09.2017.	**Overheating DM "A" , ejects water, (cleaning and washing of cooler at DM "A")**
04.09.2017.	**DM "A" loses water**
05.09.2017.	**DM "A" loses water, (replacement of rubber connection for water at DM "A")**
20.09.2017.	DM "B" switches off, **transmitter** "B" not activated
02.10.2017.	The DM "A" switches off (replacement of the coolant hose on the DM "A", the "A" transmitter)
23.10.2017.	Cardan for **transmitter** "A", ("replacement")
17.12.2017.	(Replacing the sealant on the "B" **transmitter**)
17.01.2018.	**DM "B" loses water, (partially remediated)**
18.01.2018.	**DM "B" loses water, (the joints tightened)**
23.01.2018.	**DM "A" loses water**
26.02.2018.	**DM "A" loses water, ("repair")**
27.02.2018.	**Transmitter "A" ejects, low oil pressure, ("replacement")**
16.03.2018.	Starting DM "B"
28.03.2018.	DM "B" loses water and switches off, DM "A" does not start, (replacement of the coolant hose)

4.3. Conclusion on the occurrence based on the facts determined during investigation and interviews

On the basis of everything determined by direct on-site investigation on motor vehicles and insight into the submitted documentation, regarding the fire on DMK 710-004, which operated as a train No. 2746, the following can be concluded:

- The fire started in a separate area located next to the aluminum air intake DM "A". In this space, a metal protective tube is installed through which the exhaust manifold DM "A" passes, which then enters the roof where with the flange connection is connected to the end of the exhaust manifold. The fire was formed in the upper part of the roof in the part where the flange connection is set.
- Due to the major load of DM "A" because DM "B" could not be connected to a joint traction due to a failure, during the overcoming of the rise, there happens an increase in the temperature and flow of a higher amount of exhaust gases through the exhaust manifold - exhaust, passing through the vertical protective channel and goes to the roof of the train. As a consequence of the heating of the exhaust gases of the exhaust manifold to the temperatures above the temperature of the work-warmed operating engines, and due to non existance of seal on the flange connection at the extension of the exhaust manifold, the hot products directly act on the protective tube which is then heated and due to its heating comes to inflammation of the upholstery, plastic and wooden parts in that part where the channel touches. The fire started in the upper part of the channel, and then it continued to the lower part when the parts of the burning lining fall to the bottom of the channel and melt the aluminum parts of the air intake.

4.4. Conclusions

4.4.1. Direct cause of the accident

Due to the major load of DM "A" because DM "B" could not be connected to a joint traction due to a failure, during the overcoming of the rise, there happens an increase in the temperature and flow of a higher amount of exhaust gases through the exhaust manifold - exhaust, passing through the vertical protective channel and goes to the roof of the train. As a consequence of the heating of the exhaust gases of the exhaust manifold to the temperatures above the temperature of the work -warmed operating engines, and due to the non existance of seal on the flange connection at the extension of the exhaust manifold, the hot products directly act on the protective tube which is then heated and due to its heating comes to inflammation of the upholstery, plastic and wooden parts in that part where the channel touches. The fire started in the upper part of the channel, and then it continued to the lower part when the parts of the burning lining fall to the bottom of the channel and melt the aluminum parts of the air intake.

4.4.2. Basic causes deriving from skills, procedures and maintenance

Based on the submitted EV-63 Request by "Srbija Voz" a.d. it can be stated that they are recorded and treated accordingly, but the measures that are implemented on the database from the Request can not be noted. Namely, it is noted that works/repairs are being carried out to eliminate the consequences without determining the causes of failures in order to eliminate the causes of failure, so that they would not be not repeated in a short time interval.

4.4.3. Main causes deriving from conditions determined by legal framework and application of safety management system

N/A.

4.4.4. Additional remarks on failures determined during the investigation, but without relevance to conclusions about the causes

N/A

5. Measures taken

In letter No. 1/2018-689 of 16.05.2018. “Srbija Voz” a.d, after an accident from 21.04.2015. at 8:30 between the stations Bor and Vlaole, when a fire broke out on DMK 710-001, it was stated that it was concluded that the turbochargers at DM Volvo THD 102KB are being remodeled every year. Since then, there have been no fires on the DMK series 710 (until the respective accident where a fire occurred on DMK 710-004, which incorporates Fiat DM which do not have turbochargers). According to the information “Srbija Voz” a.d. even after the fourth case of fire occurrence on the DMK series 710, and prior to the occurrence of the respective accident, did not carry out the analyses and did not take any preventive measures.

6. Safety recommendations

Aiming to achieve the possible improvement of railway safety and to prevent occurrence of new accidents, CINS issued the following safety recommendations:

"Srbija voz" a.d.:

SR_01/19 "Srbija voz" a.d. to review the constructive design of the end of the exhaust manifold on the DMK series 710, and to perform the modification of solution (installment of the convenient seal), with the aim to prevent breakthrough of hot exhaust gasses, which could lead to occurrence of new fires on this segment.

SR_02/19 "Srbija voz" a.d. that on the basis of quality control in the course of repair and final review of the DMK series 710, determine whether repairs were made in the required quality and scope of work, with the aim of adequate execution of the repairs in accordance with Article 8 of the Rulebook on the Maintenance of railway vehicles.

SR_03/19 "Srbija voz" a.d. to perform the checks and tests, not only of the parts on the DMK series 710 that are relevant to safety, but also those parts of the fault frequency higher than the ones that are defined by the manufacturer that can affect the availability of the vehicle.

SR_04/19 "Srbija voz" a.d. that, given the long exploitation period of DMK series 710, carry out technological research related to the joint work of the diesel engine - hydrodynamic transmitter - the cooling system in order to identify lacks and on the basis of them implement appropriate improvements of the drive system (replacement of the kind of coolant, check the capacity of the heat exchanger - cooler, etc.) in order to prevent failures that could lead to occurrence of the new accidents.

SR_05/19 "Srbija voz" a.d. that due to the frequency of failures in the operating system DMK series 710 and accidents occurred - fires, conduct analysis and consider the possibility of shortening the period up to the execution of regular repairs.

SR_06/19 "Srbija voz" a.d. that at the next regular repair DMK Series 710, during the reconstruction of the interior applies materials in accordance with *EN 45545-1* and *EN 45545-2:2013+A1*, that is *SRPS EN 45545-1:2013* and *SRPS EN 45545-2:2017*.

Directorate for Railways:

SR_07/19 Directorate for Railways to check the license for use of DMK series 710 in terms of improvement of technical solutions of the drive system and the application of appropriate materials in terms of controlling the fulfillment of conditions for issuing safety certificates for transport.