R E P U B L I C OF B U L G A R I A
NATIONAL AIR, MARITIME AND RAILWAY ACCIDENTS INVESTIGATION BOARD

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FINAL REPORT

from

Investigation of railway accident – fire in electric locomotive № 44094.8, occurred while servicing fast train № 3621 between the stations Chernograd – Aytos on 28.09.2020

2021

OBJECTIVE OF THE REPORT AND EXTENT OF RESPONSIBILITY

The National Air, Maritime and Railway Accidents Investigation Board (NAMRAIB), which is an independent body performs the investigation of serious accidents and incidents. The National Board is within the Council of Ministers (CM) of the Republic of Bulgaria, and aims to find the circumstances and causes that led to the accidents and incidents occurrence in order to improve the safety and to avoid such in future, without **searching personal fault and responsibility.**

The investigation is performed in accordance with the requirements of Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety, Railway Transport Act (RTA), Ordinance № 59-dated 5.12.2006 on the rail transport safety management, as well as per Agreement dated 17.04.2018 on the interaction during investigation of accidents and incidents in the air, maritime and railway transport between the Prosecutor's Office of the Republic of Bulgaria, Ministry of Interior, and the Ministry of Transport, Information Technology and Communications.

The Report structure follows the requirements of Regulation (EU) 2020/572 of 24 April 2020 on the reporting structure for railway accident and incident investigation reports.

TABLE OF CONTENTS

ABBREVIATIONS, USED IN THE REPORT

BDZ PS Ltd. – "BDZ Passenger Services" Ltd.

SE NRIC – State Enterprise "National Railway Infrastructure Company"(railway infrastructure manager)

NAMRAIB – National Air, Maritime, and Railway Accidents Investigation Board (Independent National Investigation Body)

TOSARRT – Train Operation and Shunting Activity Rules in the Rail Transport

TF– Task Force

RAEA – Railway Administration Executive Agency

ECM – Entity in Charge of Maintenance

LPP – Locomotive Park Prescription

FT – Fast train

PSD – Passenger Services Division

RD FSCP – Regional Directorate Fire Safety and Civil Protection
ABS – Automatic block system
FAS – Fire alarm system
FES – Fire extinguishing system
TOS – Train operation schedule

1. Summary

1. Brief description of the event.

On 28. 09. 2020 at 06:55 a.m., FT № 3621 departed from Sofia station. The train was in composition of 4 wagons, 16 axles, 162 tons. Electric locomotive № 44094.8 serviced the train at Plovdiv Locomotive Depot, with locomotive driver and assistant locomotive driver from Sofia Locomotive Depot. Transport crew, train manager, and conductor from the Transport Service of Burgas to the PSD - Plovdiv. The railway undertaking "BDZ-Passenger Services" Ltd. carried out the transport and servicing of the train with vehicles and personnel.

FT № 3621, arrived in Karnobat station at 12:53 p.m., and departed at 12:55 p.m. During the operation between the stations Chernograd - Aytos on track № 1, the locomotive crew smelled smoke coming from the engine compartment. The locomotive driver stopped the train at 13:07 p.m., switched off the battery and activated the fire-extinguishing system from the two cabins of the locomotive, but it did not start. The locomotive crew tried to put out the fire with the portable fire extinguishers, but they failed due to the thick smoke. The locomotive driver called 112 for asking help from the fire services.

After the train stopping, the train manager saw that smoke was coming out of the locomotive and together with the conductor, evacuated the passengers from the first wagons to the last wagon of the train, they were 35 passengers in total.

At 13:30 p. m. a fire engine arrived on the spot with employees of RD FSCP - Aytos. The voltage of the catenary was switched off, and the locomotive was turned off at 15:20 p.m.

As a result, from the fire no passengers or staff were injured. There were no damages caused to the railway infrastructure, and the facilities. Damages were caused to the locomotive.

2. Location and time of the event occurrence.

The accident (ignition) of electric locomotive № 44094, which serviced FT № 3621 during movement, occurred between the stations Chernograd - Aytos on track № 1 at km 254 + 200 at 13:07 p.m. on 28.09.2020 (Fig. 1.1).

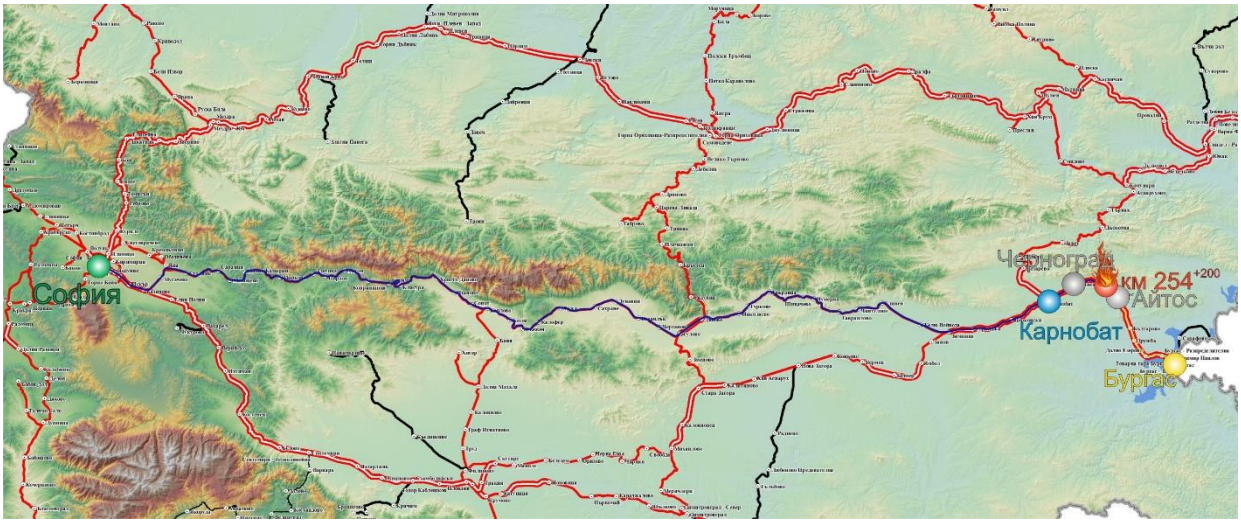

Fig. 1.1. Route of the movement of train № 3621

- Original station for the movement of the train;
- Final station, where the train stopped;
- Final destination for the train movement;
- Place, where the accident occurred;
- Route, which the train passed;
- Route, which the train did not succeed to pass.

3. Factors, defining the event.

Determining factor for the occurrence of the accident is explosion in the capacitors of the R-C groups of the first rectifier unit 220, supplying the compressor engine 234 of the locomotive.

Contributing factor for the occurrence of the accident are the low values of the average voltage in the catenary that the electric meter of locomotive 44094 registered before and at the time of ignition.

4. Immediate causes and consequences of the event.

Immediate cause for the accident occurrence is explosion in the capacitors of the R-C groups of the first rectifier unit 220. That increased the temperature in the rectifier unit due to reduced voltage in the catenary.

The main cause for ignition of the locomotive is the temperature increase in the rectifier unit of the first group due to poor cooling followed by a sharp decrease in voltage in the catenary, which led to increased currents and further increase in the heat load. The capacitors did not withstand the high temperature, they burst and the catalyst from them ignited the insulation of the wires and the whole rectifier cabinet.

The consequences of the event led to the burning of a large part of locomotive 44094 and the inability to service the further movement of FT № 3621.

5. Safety recommendations and addressees to which are directed.

The Investigation Commission suggests to RAEA the following safety recommendations:

By recommendation 1 it is suggested BDZ PS Ltd. to revise the control scheme of the fans in the locomotive in order to exclude interference of the subjective factor (the locomotive driver), observing the requirements of the Regulations for depot repair and maintenance of electric locomotives of BDZ (LS 0103/01.01.1979) - §13, and of the Regulations for factory repair of electric locomotives series 44.000 and 45.000 (PLS 127/05) -§13.

By recommendation 2 it is suggested BDZ PS Ltd. to restrict the access for forced "impact" of electronic relay for control of the voltage of fans Y3, by obligatory sealing and carrying out of periodic scheduled control for serviceability and functionality.

By recommendation 3 it is suggested SE NRIC to carry out inspections of the facilities and devices for the traction power supply, related to the establishment and elimination of damages, leading to low supply voltage in the catenary during the movement of the trains along Zimnitsa – Aytos section.

2. Investigation

2.1. Decision for starting the investigation.

The decision to initiate an investigation of the accident took into account the seriousness and its impact on the safety. The investigation aims to prevent this type of accidents (fires) in locomotives series 44.000, caused while servicing passenger trains, which in slightly different circumstances could lead to serious accidents.

2.2. Motives for the decision to initiate the investigation.

The Decision for starting the investigation is based on art. 20, comma 2, (a), art. 115к, paragraph 1, item 3 of RTA, art. 76, par. 1, item 3 of Ordinance No 59 was assigned a Commission for investigation of the railway accident – fire occurred in electric locomotive № 44094, serviced FT № 3621 during movement along Chernograd – Aytos interstation on 28.09.2020 running in Sofia-Burgas direction.

2.3. Scope and restrictions of the investigation.

The scope of the investigation will consider and analyse the violations of the regulations implemented by the entities (NRIC and BDZ PS Ltd.) in the repair and maintenance of the railway infrastructure and in carrying out scheduled repairs of locomotives series 44.000.

Previous similar accidents will be reviewed.

Given the realized minimal damages of non-subjective nature, the investigation will be limited to the circumstances that led to the causes for the ignition of locomotive No 44094 between the stations Chernograd-Aytos.

2.4. Competences of the persons, involved in the investigation.

The composition of the commission includes external independent experts - habilitated persons from the higher scientific circles with qualification and professional orientation in fields of activity – railway infrastructure and rolling stock.

2.5. Communication and consultations with the persons and entities, involved in the event.

During the investigation, the task force, which includes representatives of both entities, was consulted. The Task force collected all the books and samples, as well as other documents and materials downloaded records from the recording device of locomotive No 44094. They were handed over to the Chair of the Investigation Commission. Interviews were conducted with the persons, directly involved in the accident. The entities were requested and then provided information on the decoding of the data in the electric meter of the locomotive, as well as on the repair and maintenance of the locomotive. Interviews were conducted with the heads of the entities, and with their safety authorities.

2.6. Degree of cooperation from the participating entities.

During the investigation, the participating entities (BDZ PS Ltd. and SE NRIC), the Task Force and the persons involved in the accident fully cooperated with the Investigation Commission.

2.7. Methods and techniques of investigation and analysis.

The burned locomotive № 44094 was moved to Plovdiv locomotive depot by another locomotive, where it resided.

The Investigation Commission performed primary inspections of the burned locomotive at the Plovdiv Locomotive Depot. It conducted an interview with the staff from both railway entities, involved in the accident. There was required download of the records from the recording device of the locomotive. The Commission required the whole documentation on repair and maintenance of electric locomotive № 44094. A Statement of findings for the technical condition of locomotive № 44094 was prepared in the presence of the Commission. The Investigation Commission required the rectifier groups, the burnt cable connections and other auxiliary machines to be dismantled from the engine compartment of the locomotive.

- The two rectifier units were dismantled.

The inspections of the locomotive found the damages caused by the fire:

- Severely damaged insulation pads of the rectifier elements of rectifier group 020 (rectifier of the first traction group). Molten diode coolers at the bottom of the rectifier group (Fig. 2.1);
- Terminal board of the second traction motor (TM) - badly burnt, including the cable insulation of the second traction motor (Fig. 2.2);
- The connecting rubber pipe of motor pump 238 has been burnt but not destroyed. Most likely from a secondary fire flame in rectifier group 020;

Fig. 2.1

- Auxiliary rectifier 220 power supply engine compressor - badly destroyed. Most likely, the temperature there was the highest. It is very likely that the source of the fire was from the rectifier 220 (Fig. 2.3);
- Auxiliary rectifier 221 power supply engine fans is less affected. The power cables of the horizontal fan 230 are strong;

- The rectifier unit 022 - in good condition. After the inspection it was found that a wedge was placed on the relay U3 (relay for voltage control of the rectifier 221, supplying the fans (Fig. 2.4). There is a damaged lacquer insulation of the R-groups of the compressors rectifier (strongly blackened);
- Relays 491, 492, 493 and 494 – functioning;

Table 1

Date: 28.09.2020 12:00 - 28.09.2020 14:00		
	Average current value for a period of 5 min.	*Average voltage value for a period of 5 min.*
Time	44 094 Current Phase R A	44 094 Voltage Phase R V
12:05	12,0	26525,0
12:10	28,0	25850,0
12:15	20,0	26425,0
12:20	8,0	26725,0
12:25	40,0	26075,0
12:30	24,0	17525,0
12:35	36,0	26125,0
12:40	36,0	26300,0
12:45	36,0	26425,0
12:50	8,0	26575,0
12:55	48,0	24250,0
13:00	12,0	17125,0
13:05	0,0	0,0
13:10	0,0	0,0
13:15	0,0	0,0
13:20	0,0	0,0
13:25	0,0	0,0
13:30	0,0	0,0
13:35	0,0	0,0
13:40	0,0	0,0
13:45	0,0	0,0
13:50	0,0	0,0
13:55	0,0	0,0
14:00	0,0	0,0

- Check after disassembly of the resistances of the rectifier elements of the power rectifier 022- within the admissible norms;
- The C-groups have been dismantled and their capacity has been measured - in good condition;

Fig. 2.2

Fig. 2.3

- The check for the serviceability (by insulation resistance, for circular fire) of the horizontal fan - 230 - upright;
- Disassembly of the bogies, inspection of the body shell floor and inspection of traction engines 1-2. After drying the locomotive, the insulation resistance of the armature winding and the additional poles were measured - in good condition;
- Download and decoding of the locomotive tape information;
-The Commission received all the collected materials and the report from the Task force according to the requirements of art. 73 para. 3 and para. 4 of Ordinance № 59, reviewed and analysed in detail the collected documentation.

Fig. 2.4

- There was performed analysis of the data downloaded from the recording device of locomotive № 44094 to establish the speed of FT № 3621 in the area of the accident on 28.09.2020.
- There was downloaded information recorded in the electricity meter of locomotive № 44094 with records of voltages supplied and maintained by "Traction substation Karnobat" (Table 1);
- At the Plovdiv Locomotive Depot, several inspections of the burned machines and units in the locomotive were carried out to establish the cause of ignition.

2.8. Difficulties faced during the investigation.

During the investigation, the Commission did not encounter any difficulties or obstacles from the entities side in clarifying the circumstances and causes for the accident.

2.9. Interaction with the judicial authorities.

In accordance with the Agreement for the interaction with the judicial authorities, after their inspections of the burned locomotive № 44094, it was released from supervision and the Investigation Commission started its independent investigation.

2.10. Other important information for the investigation context.

There is no such.

3. Description of the event

a). Information on the event and the context.

3.1. Description of the event type

On 28.09.2020 FT № 3621, departed from Sofia station at 06:55 a.m. in the composition of: 4 wagons, 16 axles, 162 tons. The national railway undertaking BDZ-Passenger Services Ltd., with electric locomotive № 44094.8, with a locomotive crew - locomotive driver and assistant locomotive driver serviced the train. The locomotive and the transport crew of the train are employees of BDZ-Passenger Services Ltd. The train runs daily in the direction Sofia - Karlovo - Dabovo - Karnobat - Bourgas and vice versa.

At Karnobat station the train arrived at 12:53 p.m. and after a stay of two minutes, departed at 12:55 p. m. following the train operation schedule. During the movement of the train in the interstation Chernograd - Aytos on track № 1, the locomotive crew smelled smoke coming from the engine compartment. The locomotive driver took a quick stop and the train stopped at 13:07 p.m. at km 254 + 200, as can be seen from the records of the locomotive's recording device. The driver disconnected the battery and activated the fire protection system, but it did not start. The assistant locomotive driver and the locomotive driver tried to put out the fire with the portable fire extinguishers of the locomotive, but due to the thick smoke, they failed. The locomotive driver

called the national telephone number 112 to ask assistance from the fire services. The train was moving at a speed of 120 km / h, with a permissible speed of 130 km / h. During the movement of the train on the route from Sofia station to Chernograd station the operation of the locomotive was accident-free.

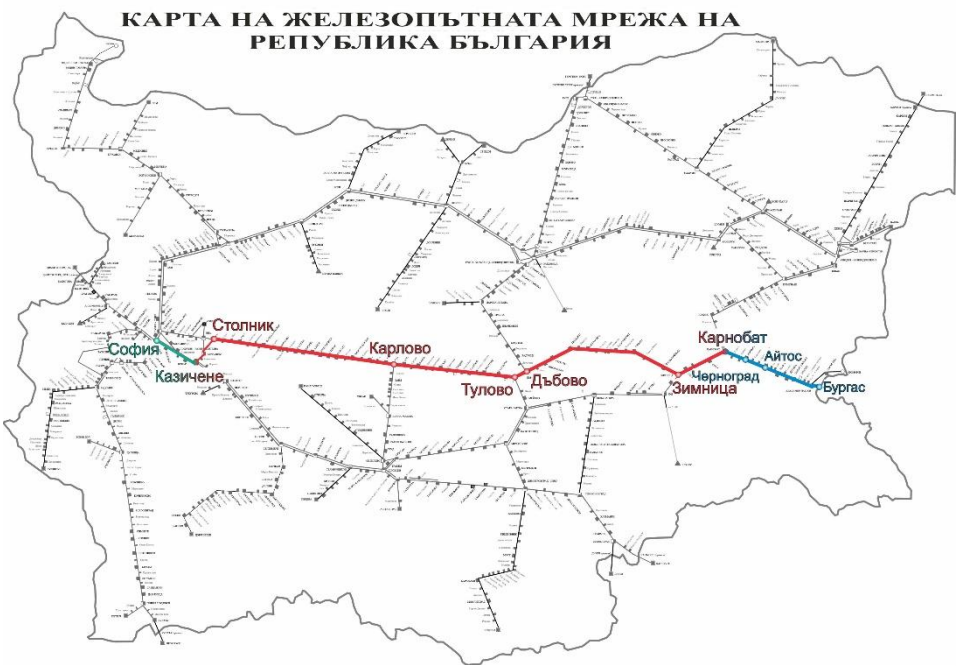

Fig. 3.1

3.2. Date, punctual time and location of the event

On 28.09.2020 at 13:10 p.m. between the stations Chernograd - Aytos at km 254 + 200 in a straight section of the rail track a fire broke out in locomotive № 44094 in motion.

3.3. Description of the event location.

Chernograd and Aytos stations are located on the eighth main railway line in the direction Plovdiv - Stara Zagora - Karnobat - Bourgas. The eighth main railway line is conventional with a speed of up to 130 km / h. The event occurred in a section of a double-track electrified railway line with a profile - 9.3 ‰ downhill (Fig. 3.1).

Meteorological and geographical condition at the time of the event.

- in the daylight hours – between 13:00 ÷ 13:30 p.m.;
- weather – partly cloudy, normal for accepting the signals;
- air temperature – 26ºC;
- wind speed – 20 km/h;
- air humidity – 42%;

Performance of construction activities on the site or in vicinity.

Not applicable.

3.4. Fatalities, injuries and material damages.

- *Employees of the railway infrastructure manager or railway undertaking.*

None.

- *Other persons officially connected with the location of the event.*

None.

- *Passengers.*

None.

- *External persons.*

None.

- *Cargo, luggage or other property.*

None.

- *Environment.*

None.

- *Rolling stock and railway infrastructure.*

The fire caused damages to locomotive №44094 as data on the suffered damages are presented.

- Burnt body shell of the locomotive;
- Burnt traction transformer;
- Burnt two oil radiators for cooling;
- Burnt auto-transformer switch;
- Burned two rectifier cabinets;
- Burnt fan motor;
- Burnt block resistors for rheostat brake;
- Burnt command cabinet;
- Burnt power cables;
- Burnt operating cables.

The damages caused to the locomotive amount to BGN 76,938.

- *Railway infrastructure.*

No damage was caused and no data on damages were presented.

Losses were incurred due to a change in the TOS and they amount to BGN 1431.00

3.5. Description of other consequences, including the event impact on the usual activity of the participants.

None.

3.6. Identity of the participants and their functions, as well as of the involved entities.

Railway infrastructure:

- Traffic manager on duty in Chernograd station – SE NRIC employee. The same has nothing to do with the accident;
- SE „National Railway Infrastructure Company" has;

- Safety Authorization No № BG 21/2018/0001 valid from 01.07.2018 until 30.06.2023.

Railway undertaking:

- Engine driver, locomotive of locomotive № 44094 – employee of BDZ PS Ltd.;
- Assistant engine-driver, locomotive of locomotive № 44094 employee of BDZ PS Ltd.;
- „BDZ Passenger Services" Ltd. has:

o License for performing of railway transport services № 151 dated 10.07.2008 lately amended on 08.01.2019 due to the expiration of a five-year period from the latest revision.;

- o Safety Certificate part A № BG 1120170009;
- o Safety Certificate part B № BG1220170009;

The Safety certificates are valid from 31.12.2017 to 30.12.2022.

3.7. Description and identifiers of the train and its composition, including the rolling stock and its registration numbers.

- Fast train № 3621, passenger;
- locomotive № 91520044094.8 – registered in the Vehicles Register;
- locomotive № 91520044094.8 is equipped with vigilance device active type, recording speedometer type „Hasler" RT9, and non-recording speedometer „Hasler" A16;
- passenger cars with №№ 51 52 1940 163-2 – A4, 50 52 2974 261-2 – B4, 50 52 2974 178-8 – B4, 50 52 2974 282-2 – B4 registered in the Vehicles Register;

3.8. Description of the respective parts of the railway infrastructure

Description of the signalling and interlocking:

- the interstation Chernograd - Aytos is equipped with Automatic Block System (ABS) with axle counters without pass signals – working.
- the indications of semaphores are by ordinary signalling.

Type of the track, rail switch etc. maint.

- the interstation Chernograd - Aytos is a double-track railway section with a profile of 9.3 ‰ downhill, in a straight line in the direction of traffic

Catenary.

- Chain/loop, fully compensated (the accident occurred at the end of the feeder zone of the TS) - technically sound;

Train protection systems.

The Karnobat - Burgas section was equipped with European Train Control System ETCS-L1 – ALTRACS Ver.1.2.0 – SE NRIC switched it off in 2017.

Other information referring the event.

None.

b). Factual description of the occurred.

1. <u>Immediate sequence of events that led to the accident, including:</u>

Actions that the involved in the event persons undertook.

After the departure of the train from Karnobat station at 12:55 p.m., it passesed without stopping at Chernograd station at 13:01 p.m. It was moving in the interstation Chernograd - Aytos on track № 1 with the admissible speed for the section 120 km/h, about 13:04 p.m., the locomotive crew smelled smoke in the cabin, coming from the engine compartment. The locomotive driver took a quick stop of the train. The train stopped in the interstation at km 254 + 200 at 13:07 p.m., as can be seen from the records of the locomotive's registration device. The locomotive driver disconnected the battery and activated the fire-fighting installation of the locomotive, but it did not activate. The assistant locomotive driver together with the locomotive driver tried to extinguish the ignition in the engine room with the portable fire extinguishers of the locomotive, but due to the thick suffocating smoke, they failed. The locomotive driver called the national telephone number 112 for help. The train manager and the conductor have evacuated the passengers from the first to the last car, the number of which is 35 passengers.

Rolling stock and technical facilities functioning.

The technical facilities between the stations Chernograd - Aytos were technically sound and functioned normally.

Operational system functioning.

The operational system is regular with proper functions.

2. <u>Sequence of events from the beginning of the accident to the end of the rescue services actions:</u>

- At 13:07 p.m. locomotive № 44094 self-ignites and stops at the interstation Chernograd-Aytos;
- The movement of trains in the interstation Chernograd - Aytos is interrupted in the period 14:17 ÷ 17:08 p.m. on track № 1;
- There was no immediate necessity of the rescue services actions;

Undertaken measures for protecting and guarding the event location.

From 13:30 p.m. to 17:00 p. m. the bodies of the Ministry of Interior have detached and secured the area of the accident for carrying out procedural-investigative actions, after which the locomotive has been released from supervision.

Actions of the emergency rescue services

- at 14:36 p.m. the voltage in the catenary of the interstation on track № 1 and 2 is switched off. The bodies of FSCP undertake extinguishing of the locomotive. A locomotive № 55137 left Chernograd station, which pulled the passenger cars of BV № 3621 back to Chernograd station;
- at 15:20 p.m. the fire in locomotive № 44094 was extinguished, the voltage on track № 2 was switched on and the traffic was restored;
- from 15:20 p.m. to 16:34 p.m. the locomotive is under the supervision of the bodies of FSCP. With the locomotive № 55137 the burned locomotive № 44094 was pulled back to Chernograd station;

- at 17:14 p.m. FT № 3621 with locomotive № 44126, departs from Chernograd station to Burgas station with a delay of 253 minutes;

An organization was established by BDZ-PS Ltd. to move the burnt locomotive № 44094.8 with another auxiliary locomotive to Plovdiv Locomotive Depot.

4. Analysis of the event when is necessary as it refers the individual facts

a). Roles and responsibilities

Participation and responsibilities of the entities, involved in the event

4.1. Railway undertaking

Analysis of the operation of FT № 3621 from Sofia station to km 254+200 between Chernograd – Aytos stations.

It should be noted that the registration of time lags behind that of the speed on the speedometer tape, and the marking of round hours by perforation on the tape lags behind the pen for recording time, which introduced some difficulties in performing the analysis of FT movement № 3621 (Fig. 4.1).

FT № 3621 departs from Sofia station at 06:55 a.m. with locomotive № 44-094. When moving to Karnobat station, the locomotive driver has no problems with train management, observes the section speeds and the train operation schedule.

FT № 3621 arrives at Karnobat station at 12:54 p.m. on the registration of the time line on the speedometer tape

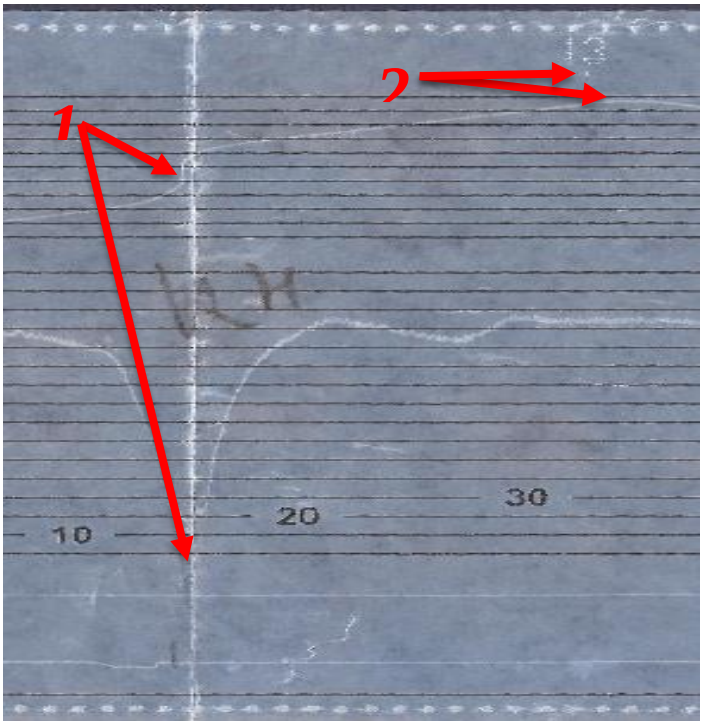

Fig. 4.1

(Fig. 4.1, pos. 1). After a standstill of about 1 minute and 10 seconds, the train departs, accelerates to 22 km/h, after which the speed stays at this value for about 40 seconds - a time during which it travels about 250 meters, then begins to accelerate again (Fig. 4.2, pos. 1). In this mode it travels 1900 meters in 1 minute and 20 seconds to reach a speed of 125 km/h at km 235^{+200} (Fig. 4.2, pos. 2). At this point, the locomotive driver switches off the traction mode of the locomotive and prepares it for the passage of the neutral insert. The train travels 1800 meters by inertia from km 235^{+200} to km 237^{+000} in 1 minute. In this interval, the speed decreases to 113 km/h (Fig. 4.2, pos. 3).

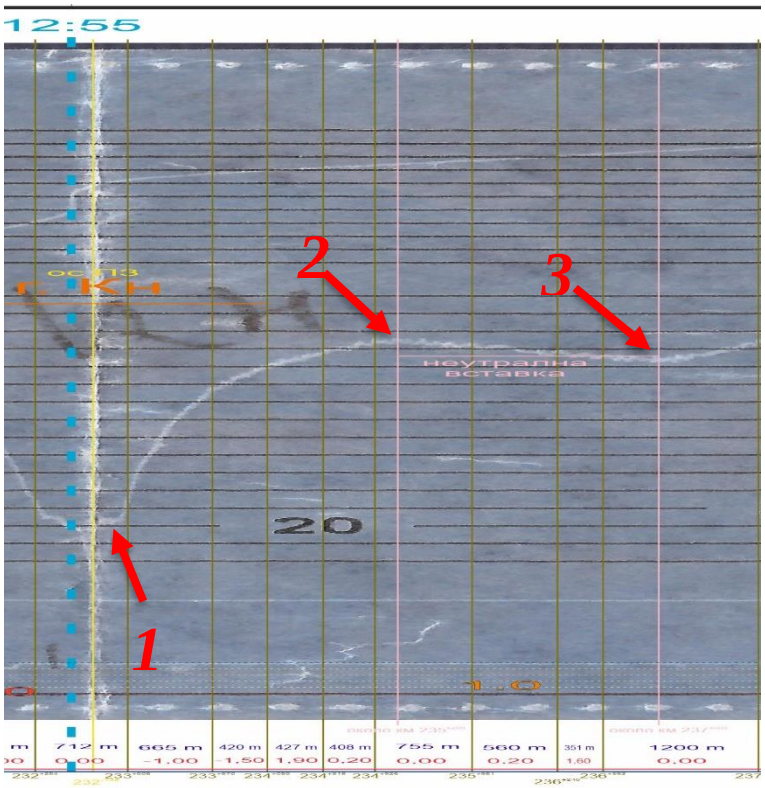

Fig. 4.2

After passing the neutral insert, the locomotive driver again puts the locomotive in traction mode and the speed begins to increase again, reaching a value of 128 km/h in 30 seconds, passing 900 meters, then decreases to 125 km/h and stays at this value for 2 minutes and 30 seconds, traveling 4.5 km from 238^{+100} to km 242^{+600}. At this point, the locomotive driver switches off the traction mode of the locomotive and the train begins to move by inertia. The speed gradually begins to decrease and from km 242^{+600} to km 243^{+348} for 750 meters in 30 seconds it reaches a value of 120-122 km/h.

During the movement in this interval of km 242^{+815} the train enters in Chernograd station at a speed of 120 km/h at 13:02 p.m. At this speed, the train moves for 1985 meters from km 243^{+348} to km 245^{+333} for 1 minute (Fig. 4.3).

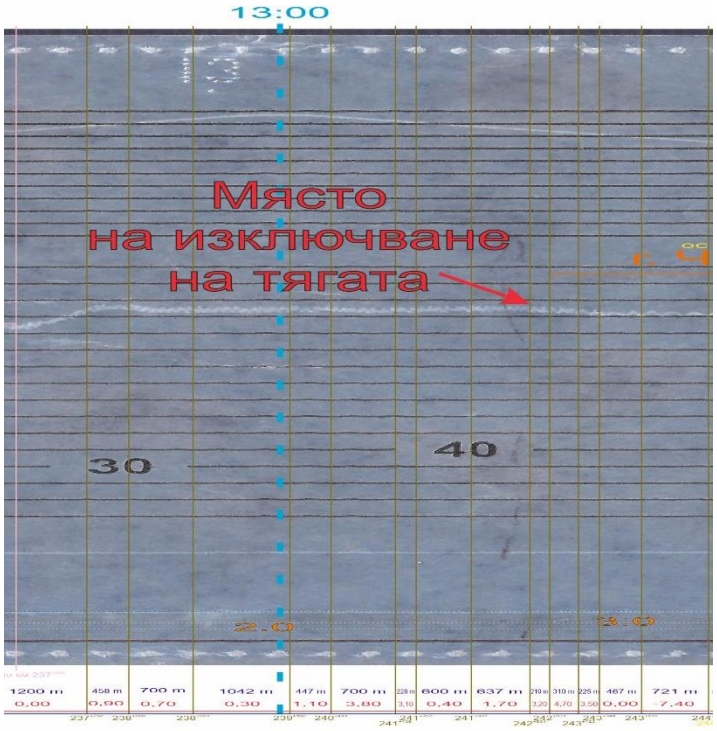

Fig. 4.3

From km 245^{+333} at 13:02:50 p. m. the train moves by inertia, but the speed starts to increase due to the increase of the longitudinal slope of the road. The speed reaches 128 km/h at km 246^{+512} at 13:03:30 p.m. At this point, the locomotive driver applies the automatic train brake to prevent the section from exceeding the maximum permissible speed by reducing the pressure in the main air conduct by 0.4 bar to 4.6 bar for about 10 seconds, then loosens the brake and restores it up to 5.0 bar (Fig. 4.4). The speed starts to decrease, reaching a value of 117 km/h at 13:05 p.m. from km 246^{+512} to km $250^{+000}$for 3.5 km in 1 minute and 40 seconds. From km 249^{+660} to km 252^{+800} the speed fluctuates between 117 and 120 km/h when driving by inertia, traveling about 660 meters

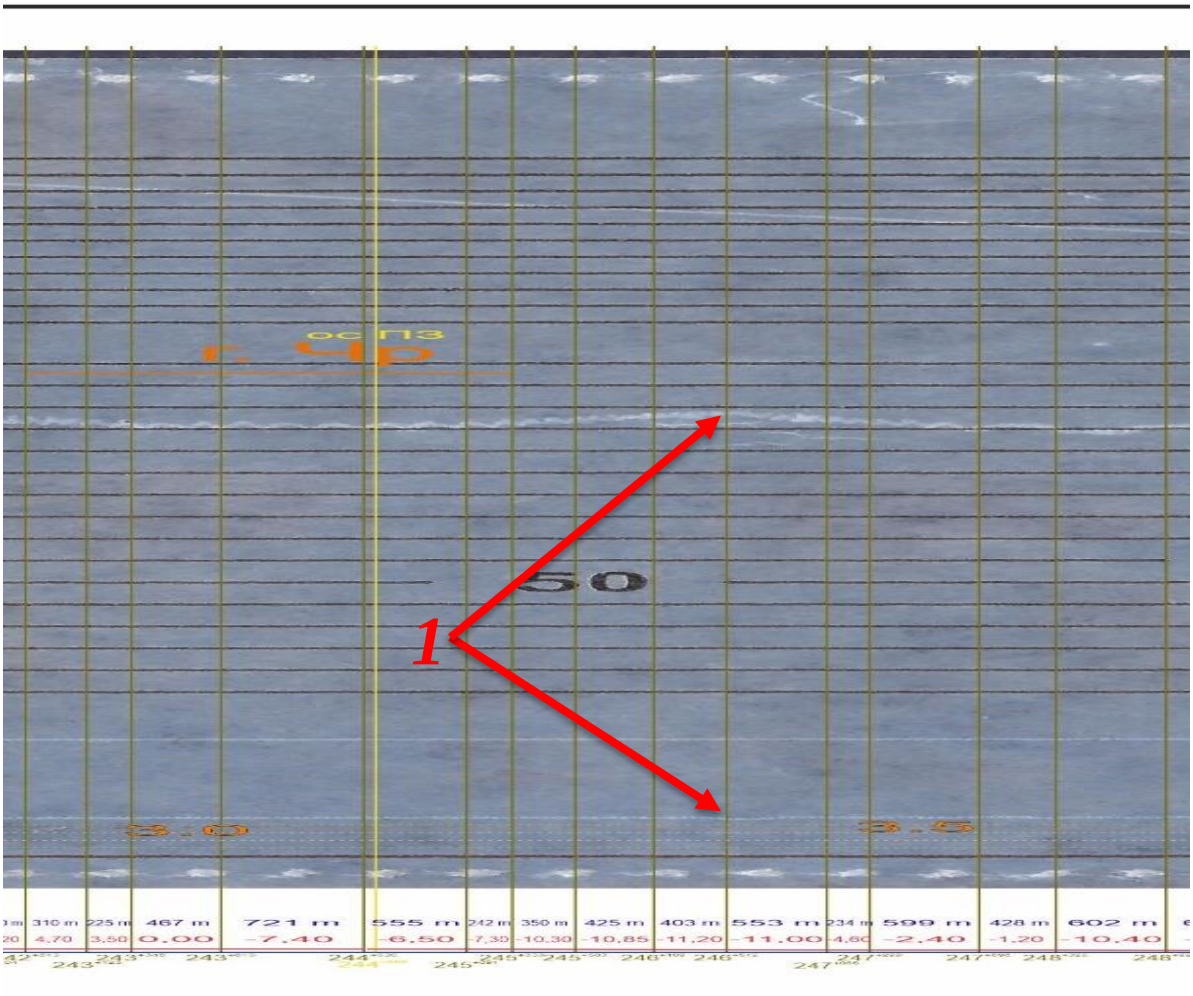

Fig. 4.4

in 1 minute and 20 seconds (Fig. 4.4, pos.1).

At 13:06 p.m. at km 252^{+800} the locomotive driver applies the automatic train brake, reducing the pressure in the main air duct by 0.4 bar (Fig. 4.5, pos. 1). After traveling 250 meters for about 5 seconds, the pressure was restored to 5.0 bar. Almost immediately afterwards, the brake was applied again, reducing the pressure in the main air conduct by 1 bar and reaching 4.0 bar in 500 meters and 10 seconds. After another 10 seconds, the holding rate with the automatic train brake is increased by reducing the pressure in the main air conduct to 3.5 bar, i.e. complete detention has taken place. The speed starts to decrease steeply and the train stops at km 254^{+200} after traveling 1200 meters in 1 minute and 30 seconds.

Most of the time the **average** values of the voltage in the catenary vary between 26 725 V and 24 250 V, with the exception of two values of 17 525 V, measured at 12:30 p.m. (Fig. 4.6, pos. 1) and 17 125 V, measured at 13:00 p.m. (Fig. 4.6, pos. 2).

The second value was measured in the area of TS Karnobat, exit Chernograd, track № 1, after the locomotive has passed the neutral insert. The conclusion that can be made is that the voltage in the area of TS Karnobat was much lower than the nominal one.

The maximum measured **average** value of the current consumed by the locomotive is 48.0 A at 12:55 p.m. (Fig. 4.6, pos. 3), which corresponds to the moment of departure of the train from Karnobat station. Then the second lowest **average** current value of 12.0 A was measured for the second time (Fig. 4.6, item 4) when the train is already in the area of TS Karnobat, terminal Chernograd, track № 1. This can be explained by the fact that the train is moving at high speed and the values of the traction current are low, after which it switches to inertia mode and logically the traction current decreases even more. At the same time, the auxiliary machines (especially the compressors) continue to operate and load the rectifier units. Reduced voltage values lead to increased current during the operation of auxiliary machines, which increases their operating time, combined with the lack of cooling. This mode of operation has led to an increase in the temperature in the rectifiers of the auxiliary machines and to their ignition. At the end of the

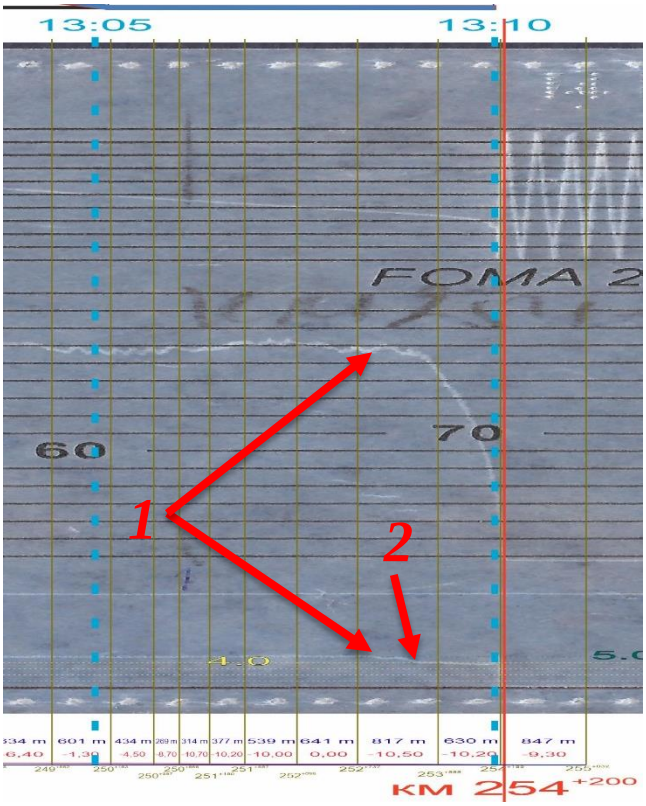

Fig. 4.5

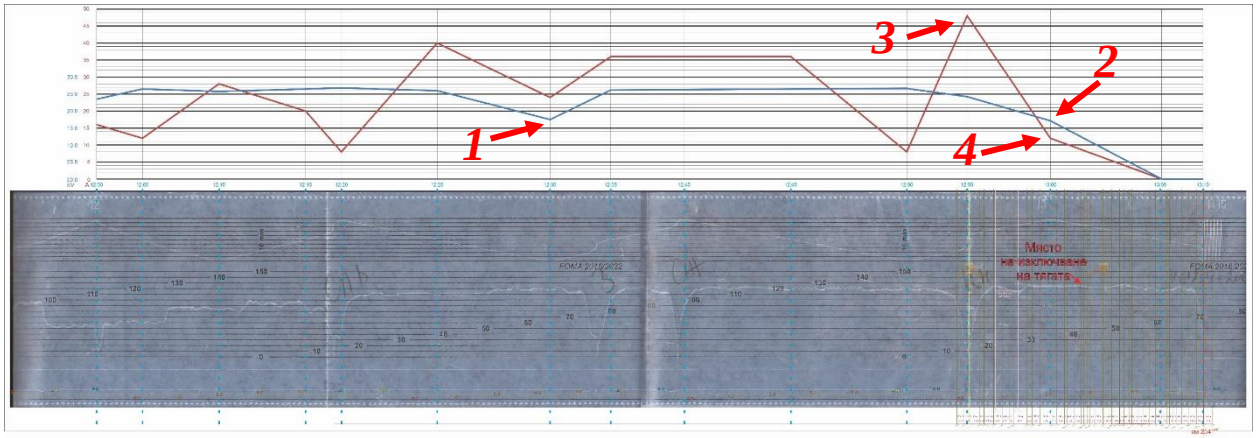

Fig. 4.6

movement, the voltage in the catenary decreases to zero, as does the current consumed by the locomotive, as the pantograph is lowered and the locomotive is switched off.

Railway infrastructure.

The change of the **average** values of the voltage in the catenary and the current consumed by locomotive 44094 are registered in the electricity meter of the locomotive and are presented in Table 1. The values of the **average** voltage in the catenary change from 26 525 V at 12:05 p.m. to 26 075 V at 12:25 p.m., and all the time the values do not fall below the nominal for the catenary

- 25 kV (Fig. 4.6). At 12:30 p.m. an **average** value of 17 525 V was registered, which is slightly above the minimum value to be supplied to the network (Fig. 4.6, pos. 1). From 12:35 p.m. to 12:50 p. m., again the **average** voltage values are above the nominal. At 12:55 p. m. an **average** value of 24 250 V was registered, which can be explained by the high consumption of traction current at this time, when the locomotive is in traction mode and accelerates (Fig. 4.6, pos. 3). In the next registration period - 13:00 p. m., the registered average value of the voltage in the catenary is again reduced to the possible minimum - 17 125 V, again without exceeding its minimum value (Fig. 4.6, pos. 2). However, this reported **average** value has an impact on the operation of the locomotive and in particular on the operation of the auxiliary machines, which are forced to operate in more severe conditions at reduced voltage, which leads to an increase in operating current and increase of their operating time, as the whole process is accompanied by an increase in the temperature of the rectifier units and rectifiers of the auxiliary machines without cooling.

The **average** values of the current consumed by the locomotive are directly dependent on the operation of the locomotive itself and the voltage in the catenary. The highest **average** value registered by the locomotive's electricity meter is 48 A, reported in a period when the locomotive is in the process of acceleration when starting from Karnobat station (Fig. 4.6, pos. 3). After passing the neutral insert in the period from 12:55 p.m. to 13:00 p.m. an average value of the consumed current of 12 A was registered (Fig. 4.6, pos. 4), which is a result of the movement of the locomotive in traction mode (acceleration after the neutral insertion and maintenance of a speed of 125 km/h), and after 13:00 p.m. the **average** value of the consumed current is 0 A.

The lack of voltage and current in the period from 13:00 p.m. to 13:05 p.m. is an indicator that the locomotive was not connected to the catenary at that time.

4.2.Entities in charge of the technical maintenance.

Railway undertaking.

BDZ-Passenger Services Ltd. is a certified ECM for traction and non-traction rolling stock. The Investigation Commission requested from the railway undertaking documents for the repairs and technical inspections of locomotive № 44094 and analysed its technical condition. The planned repairs and technical inspections of the locomotive were carried out in accordance with the requirements for realized operational runs and time -periods.

Railway infrastructure.

SE NRIC carries out the technical maintenance and repair of the railway infrastructure in particular the facilities of the catenary and the ongoing voltage on it, supplied by the Karnobat Traction Substation, as well as the track circuits.

4.3. Manufacturers or providers of rolling stock and railway products.

Not applicable.

4.4. National Safety Authority.

Railway Administration Executive Agency is a National safety authority in the rail transport of the Republic of Bulgaria.

4.5. *Notified bodies or Risk assessment bodies.*

Not applicable.

4.6. Certifying bodies of the entities in charge of maintenance.

The Railway Administration Executive Agency as the National Safety Authority for railway transport performs certification of the entities in charge of the vehicles maintenance (ECM) in accordance with Directive 2004/49/EC and Regulation (EU) 445/2011, as per Ordinance No 59 on the railway transport safety management and on the maintenance functions in accordance with Directive 2004/49/EC and Regulation (EU) 445/2011.

From June 16, 2020 the RAEA performs certification of the ECM as per the Commission Implementing Regulation (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a

system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011.

4.7. Persons or entities involved in the event, documented or not in the respective safety management systems or indicated in register.

Railway undertaking.

BDZ-Passenger Services Ltd. is a railway company with a license for transportation of passengers on the railway infrastructure of the Republic of Bulgaria with a safety management system. The railway undertaking is a member of the International Rail Transport Committee (CIT), which provides international passenger and/or freight services. CIT is based in Bern - Switzerland.

Railway infrastructure.

The State Enterprise "National Railway Infrastructure Company" participates and is responsible for the database, which it submits to the Register of Railway Infrastructure (RINF), as required by Directive (EU) 2016/797 for the EU Member States with the seat of the European Union Agency for Railways (EUR), Valenciennes – France.

b). Rolling stock and technical facilities.

1. Factors, deriving from the design of the rolling stock, railway infrastructure or technical facilities.

Rolling stock.

Locomotive № 44094 is a four-axle electric locomotive for alternating current 25 kV, 50 Hz, manufactured in the locomotive plant "Škoda" - Pilsen, Czechoslovakia (now the Czech Republic) in 1987.

Railway infrastructure.

In the section Tserkovski - Karnobat - Burgas the railway has been renewed, aiming to reach the design speeds. The scope of work also includes the related activities for maintenance of the signalling, telecommunications and catenary facilities. The funds are provided under the Operational Program on Transport of the European Union. The construction of the section was completed and put into operation in 2017. The track superstructure was renewed with rails type UIC 60, fastening type SKL-14 and concrete sleepers type B-70. Two traction substations have been built in the section at the stations Karnobat and Burgas for power supply of the catenary, put into operation in 2018.

2. Factors deriving from the installation and placing into service of the rolling stock, railway infrastructure and technical facilities.

Not applicable.

3. Factors deriving from manufacturers or another provider of railway products.

Not applicable.

4. Factors, deriving from the technical maintenance and/or modification of the rolling stock or the technical facilities.

Not applicable.

5. Factors due to the entity in charge of the technical maintenance, workshops for technical maintenance and other technical maintenance service providers.

Not applicable.

6. Other factors or consequences considered as involved within the inspection objectives.

Do not refer.

c). Human factor.

1. Individual human characteristics:

a). Training and development, including skills and experience.

Railway undertaking:

- Locomotive driver – Diploma № 18344/16.06.1980 for obtaining professional qualification „Operation and repair of electric locomotives“, issued by Transport College at HMTU „Todor Kableshkov“.
- Assistant locomotive driver – Diploma № 20673/08.08.1984 for obtaining professional qualification „Operation and repair of electric locomotives“, issued by Transport College at HMTU „Todor Kableshkov“.

Railway Infrastructure:

- Traffic manager – License № 486/17.10.2002, obtained license for traffic manager and commercial operation, issued by Professional Training Center (PTC) at NRIC.

b). Medical and personal circumstances, which influence the event, including the presence of physical and psychological stress.

Railway undertaking:

- Locomotive driver:

o Medical exam card dated № 945/10.06.2020, issued by Multi-profile Transport Hospital Plovdiv. Conclusion: suitable for engine driver.

o Physiological exam № 814/11.09.2020, issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for engine driver – conclusion: accepted for one-year period.

- Assistant locomotive driver:

o Medical exam card dated 14.05.2020, issued by Multi-profile Transport Hospital Plovdiv. Conclusion: suitable for assistant locomotive driver.

o Physiological exam № 438/08.04.2019, issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for assistant engine driver – conclusion: accepted for a 3-year period.

Railway infrastructure:

- Traffic manager Chernograd station:

o Medical exam card № 163/01.06.2020 for periodic preventive examinations for traffic manager at SE NRIC, issued by National Multi-profile Transport Hospital Plovdiv, conclusion – suitable.

o Physiological exam № 260/10.03.2020 issued by Laboratory for physiological expertise at National Multi-profile Transport Hospital Plovdiv – accepted for traffic manager at SE NRIC for a 5-year period.

c). *Fatigue.*

Railway undertaking:

- Locomotive driver:

o Break/rest: from 22:05 p.m. on 27.09.2020 until 06:05 a.m. on 28.09.2020 (08 hours and 00 minutes).

- Assistant locomotive driver:

o Break/rest: from 22:05 p.m. on 27.09.2020 until 06:05 a.m. on 28.09.2020 (08 hours and 00 minutes).

Railway infrastructure:

- Traffic manager Chernograd station:

o Break/rest: from 07:00 a.m. on 26.09.2020 until 07:00 a.m. on 28.09.2020 (48 hours and 00 minutes).

d). Motivation and attitudes.

Do not refer.

2. Work related factor

a). Tasks planning.

BDZ-Passenger Services Ltd. is a licensed national railway undertaking, which performs passenger transport in accordance with the Train Operation Schedule on the national railway infrastructure. The railway undertaking has its own fleet of locomotives and wagons with which it provides passenger transport services.

b). Constructive particularities of the facilities that influence the connection human-machine.

Not applicable.

c). Communication means.

Not applicable.

d). Practices and processes.

Not applicable.

e). Operation rules, local instructions, staff requirements, prescriptions for technical maintenance and applicable standards.

Application of the European national normative acts that refer the safety operation within the performance of passenger transport service along the national railway infrastructure!

f). Working time of the involved personnel.

As per the requirements of the normative acts. Working regime on shifts in 12 hours working shift.

g). Risk treatment practices.

Railway undertaking.

BDZ-PS Ltd. applies a procedure „Procedure and methods for defining the risk level“ and „Order № 76/23.02.2012 „Methods of analysis and assessment of the safety risk within BDZ-PS Ltd” as part of the SMS.

Railway infrastructure.

SE NRIC applies safety procedure SP 2.09 „Methods of evaluation, assessment and management of the risk „version 05 effective from 01.03.2019, which is part of the SMS.

h). Context, machinery, equipment and indications for shaping the working practices

Not applicable.

3. Organizational factors and tasks.

a). Planning of the working force and the working load.

As per the requirements of the normative documents and best practices.

b). Communications, information and teamwork.

Not applicable.

c). Recruitment, staffing requirements, resources.

Not applicable.

d). Implementation management and supervision.

Not applicable.

e). Compensation (remuneration).

Not applicable.

f). Leadership, powers related issues.

Not applicable.

g). Organizational structure.

Not applicable.

h). Legal issues (including the respective European and national rules and provisions).
Not applicable.

i). Regulatory framework conditions and safety management system application.
Railway undertaking.

- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety;
- Commission Delegated Regulation (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulations (EU) No 1158/2010 and (EU) No 1169/2010.
- COMMISSION IMPLEMENTING REGULATION (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011;
- COMMISSION IMPLEMENTING REGULATION (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No 352/2009;
- Railway Transport Act;
- ORDINANCE No 59 dated 5.12.2006 on the railway transport safety management.

Railway infrastructure.

- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety;
- Commission Delegated Regulation (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulations (EU) No 1158/2010 and (EU) No 1169/2010;
- COMMISSION IMPLEMENTING REGULATION (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011;
- Commission Implementing Regulation (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No 352/2009;
- Railway Transport Act;
- Ordinance No 59 of 5.12.2006 on the railway transport safety management.

4. Environmental factors.

a). Labour conditions (noise, illumination, vibrations).
Not applicable.

b). Meteorological and geographic conditions.
The event occurred in the daylight hours, around 13:10 p.m., partly cloudy, air temperature 26ºC, humidity 42%, wind speed 20 km/h, with good visibility for the signals acceptance

c). Construction works, performed on the spot or in very proximity.
In the area of the event have not been performed any construction works.

5. Any other significant factor for the investigation objectives.
None.

d). Feedback and control mechanisms, including risk and safety management, as well as monitoring processes:

1. Regulatory framework conditions.

- Commission Delegated Regulation (EU) 2018/761 of 16 February 2018 establishing common safety methods for supervision by national safety authorities after the issue of a single safety certificate or a safety authorisation pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 1077/2012;
- ORDINANCE No 59 of 5.12.2006 on the railway transport safety management.

2. Processes, methods and results from the activities on the risk assessment and monitoring that the involved entities performed:

Railway undertaking.

BDZ-PS Ltd. applies a procedure „Procedure and methods for defining the risk level" and „Order № 76/23.02.2012 „Methods of analysis and assessment of the safety risk within BDZ-PS Ltd" as part of the SMS.

Railway infrastructure.

SE NRIC applies safety procedure SP 2.09 „Methods of evaluation, assessment and management of the risk „version 05 effective from 01.03.2019, which is part of the SMS.

Entities in charge of the technical maintenance.

SE NRIC and BDZ PS Ltd. are certified ECM.

SE NRIC applies safety procedure SP 2.09 „Methods of evaluation, assessment and management of the risk „version 05 effective from 01.03.2019, which is part of the SMS.

BDZ-PS Ltd. applies a procedure „Procedure and methods for defining the risk level" and „Order № 76/23.02.2012 „Methods of analysis and assessment of the safety risk within BDZ-PS Ltd" as part of the SMS.

Manufacturers and all other participants.

Not applicable.

Reports on independent risk assessment.

There has not been performed an assessment by independent Assessment Body (AsBo) on changes/modifications performed in operational conditions and factors that refer to the occurred accident.

3. Safety Management System of the involved:

Railway undertaking.

The last annual planned supervision of the SMS of "BDZ-Cargo" Ltd. was performed in the period from 10.02.2020 to 21.02.2020.

Railway infrastructure.

The last annual planned supervision of the SMS of SE NRIC was performed in the period from 19.10.2020 to 31.10.2020.

4. Safety Management System of the entities in charge of the technical maintenance.

The entities are certified ECM and in 2020 have had performed planned audits.

5. Results from the supervision, performed by the National Safety Authority.

The results from the performed audits and inspections referring the functionality of the Safety Management System of SE NRIC and "BDZ-PS" Ltd. as per the requirements of Regulation (EU) 2018/761, Regulation (EU) No 1169/2010, Ordinance No 56 and Ordinance No 59 on respect of the specific requirements of the European legislation and national rules for design, maintenance

and operation of the managed railway infrastructure demonstrate that the entities maintain SMS and are able to respect the requirements, envisaged in the respective normative documents;

6. Permits, certificates and assessment reports, provided by the National Safety Authority or other Conformity Assessment Bodies

6a. Safety certificates of the involved railway infrastructure managers.

- Safety Authorization № BG 21/2018/0001 valid from 01.07.2018 until 30.06.2023.

6b. Safety certificates of the involved railway undertakings.

- Safety Certificate part A № BG 1120170009;
- Safety Certificate part B № BG1220170009;

The Safety Certificates are valid from 31.12.2017 until 30.12.2022.

6c. Authorizations for placing in service of permanently fixed equipment and permits for placing on the market of vehicles.

Not applicable.

6d. Entities in charge of the technical maintenance.

„BDZ-Passenger Services“ Ltd. has an ECM Certificate for railway vehicles BGRA/2017/0004 valid until 30.12.2022;

SE NRIC is in charge of the repair, maintenance and operation of the national railway infrastructure.

7. Other system factors.

There are no.

e). Previous similar cases.

Similar cases of the same locomotive series within similar or identical circumstances were investigated, and were inspected and analysed

5. Conclusions

The conclusions include:

a). Summaries and conclusions based on findings and analysis

Railway undertaking.

The Investigation Commission at the Plovdiv Locomotive Depot carried out several detailed inspections of locomotive № 44094. In the presence of the Commission, the burned units and aggregates were dismantled. Their condition was analyzed and the relevant conclusions were made.

It was found that the rectifier unit of the first group was almost completely burned, as the traction rectifier has fused diodes and cooling radiators to them. The Commission also found that the initial ignition source was located at the lower end of the rectifier cabinet, where the rectifiers of the auxiliary machines are located, and more precisely on the rectifier side of the compressor motor of the same group (Fig. 5.1). The conductors were with burnt insulation and in a brittle condition, proving the presence of temperatures of 800÷900°C (Fig. 5.2). The condensers had swollen and broken housings, apparently due to high pressure inside them, caused by self-ignition due to the developed high temperature (Fig. 5.3). It was obvious that the fire occurred and developed in the lower part of the rectifier unit, on the rectifier side of the motor-compressor.

Fig. 5.1

Fig. 5.2

Fig. 5.3

The construction of the rectifier units is such that in one cabinet are located the traction rectifiers and under them - the rectifiers of the auxiliary machines - fans and compressors. The whole cabinet is cooled by one fan, located horizontally under the frame of the locomotive (horizontal hopper fan), which in addition to the rectifier unit cools another of the radiators for cooling the oil for the traction transformer, traction smoothing reactor and smoothing reactor of auxiliary machines (fig. 5.4) of the respective traction group. Thus, the cooling air is first sucked in from the engine compartment, whose temperature is high, especially in warm weather. The air entering in the rectifier unit is heated and polluted, cools the diodes of the rectifier of the traction motors and, already at a high temperature, is directed to cool the rectifiers of the auxiliary machines - fans and compressors.

At the same time, the cabinets of the rectifier units are closed with solid walls, which does not allow air circulation through the R-C groups,

Fig. 5.4

which remain insulated in the side compartment without any cooling. All this, accompanied by the harmful practice of switching off the ventilation by the locomotive driver immediately after switching off the traction mode, leads to extremely severe thermal modes of operation of the rectifiers, and especially the rectifiers of the auxiliary machines.

The Commission also carried out in-depth inspections of the other units of the locomotive's engine compartment. It was found that the engine-compressor of the first group is unusable, but recoverable, with a smoky manifold/collector. The compressor was removed from the locomotive for further inspections. During the additional inspections performed on this unit, it was found that the damage was due to the high temperature during combustion and due to the water, by

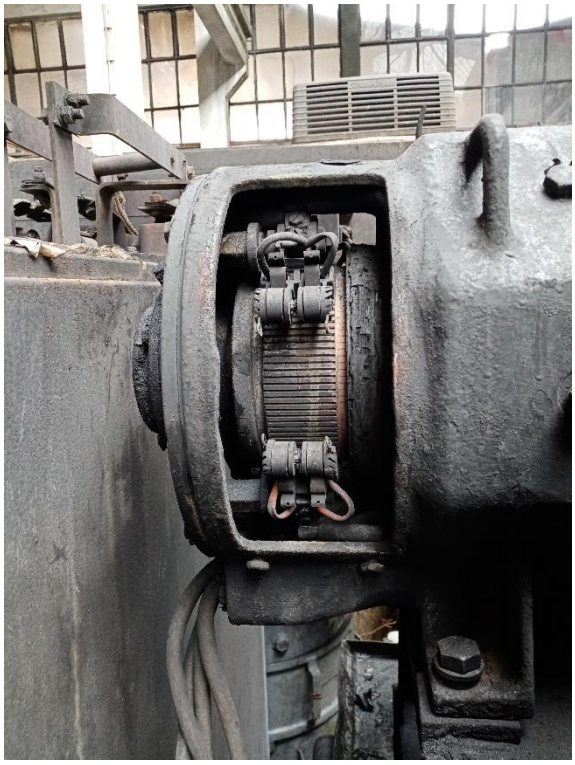

Fig. 5.5

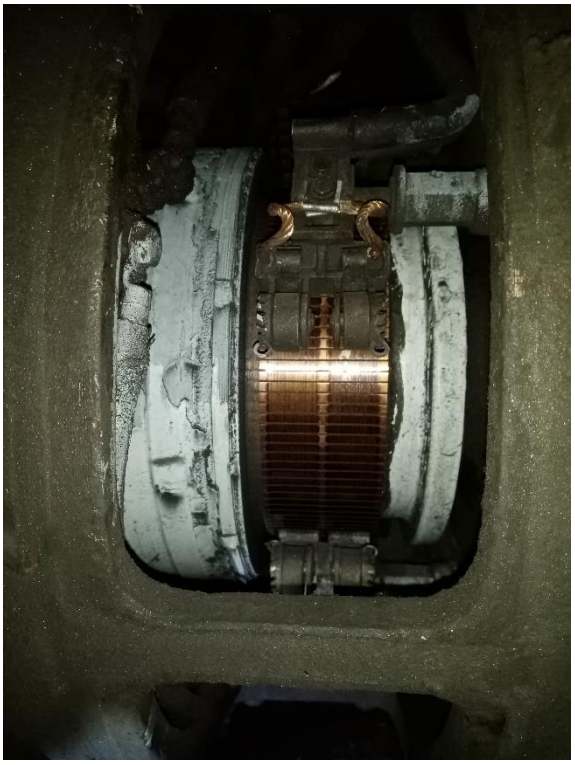

Fig. 5.6

which was put out the fire. There were no signs of a short circuit or ignition source on the compressor motor (Fig. 5.5). The commission also inspected the horizontal hopper fan cooling the rectifier unit of the first traction group and found that it was also undamaged due to the timely actions of the locomotive crew and the impossibility the fire to spread on this unit (Fig. 5.6).

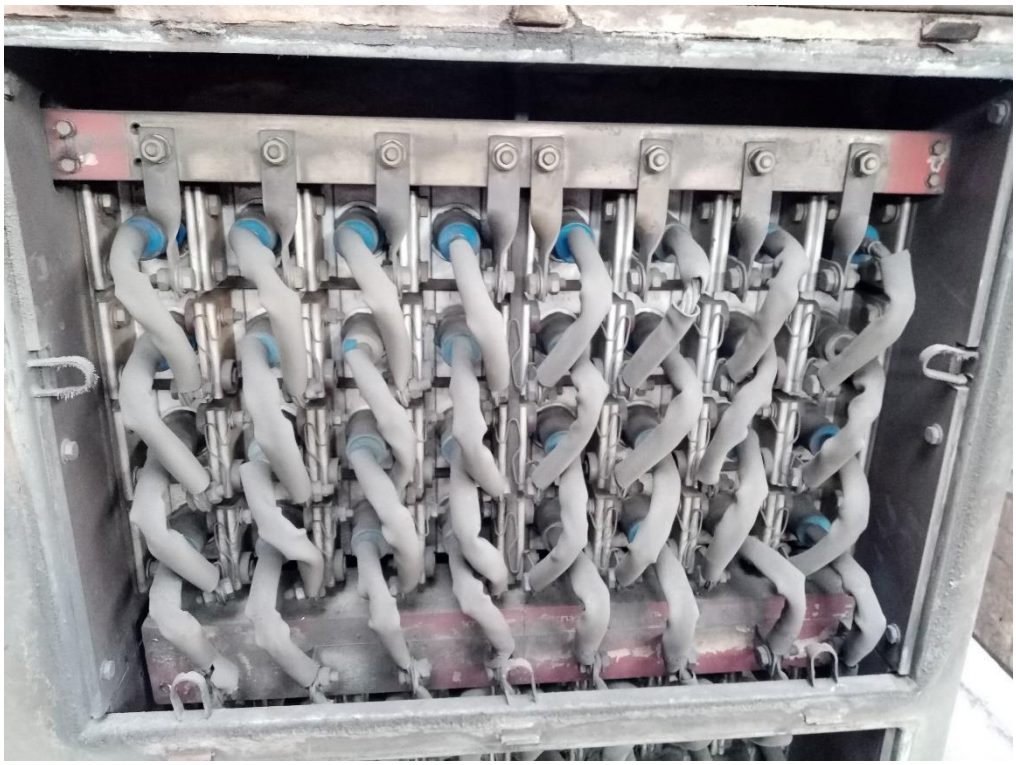

Fig. 5.7

The Investigation Commission carried out a detailed and in-depth inspection of the rectifier unit of the second traction group. It was established that there were no damages on this rectifier unit - the locomotive crew found the fire that occurred early and took measures to limit it, thus preventing even greater damage to the locomotive. At the same time, keeping in good condition the rectifier unit of the second group allowed the Commission to inspect and analyse its condition and the causes that led to the ignition of the locomotive (Fig. 5.7 and 5.8).

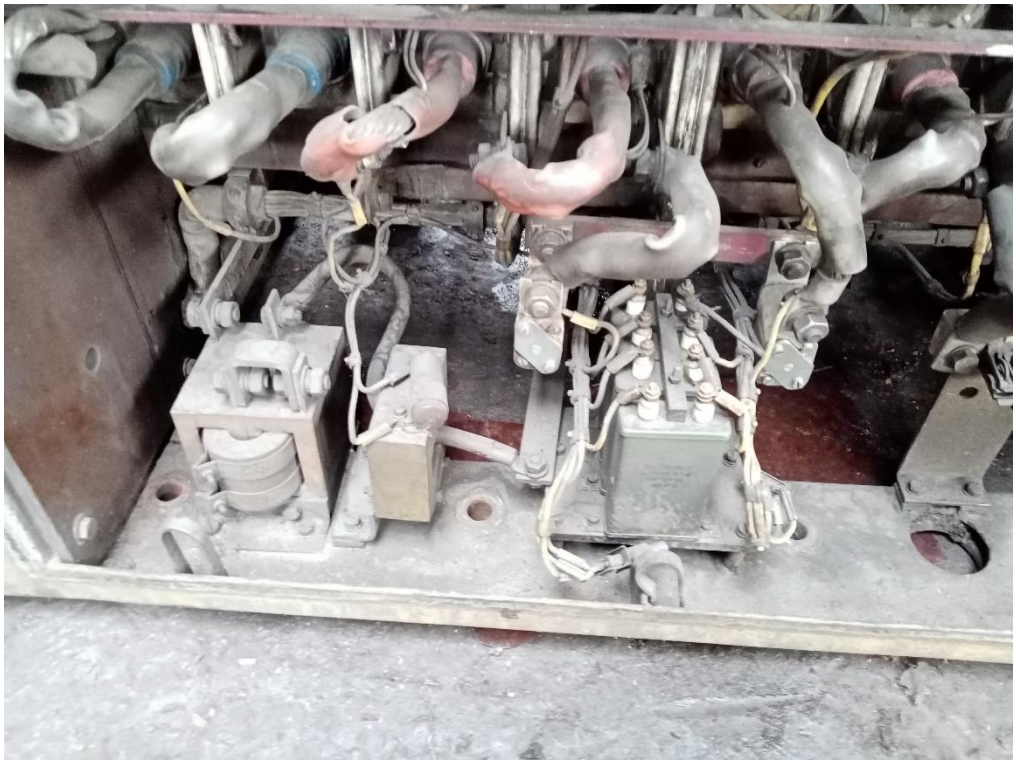

Fig. 5.8

In the course of the investigation, the Commission also found a breach of the safe operation of the locomotive - the exclusion of important protection, which ensures that the locomotive does not remain without cooling during operation. It was found that on the coil of the control relay Y3 is placed an object - which keeps the relay on, regardless of the signals it receives. Relay Y3 is a control relay that receives voltage from the auxiliary rectifiers of the fans. It turns off the traction mode of the locomotive below (143V) and participates in the cooling control circuits of electrical machines and rectifier groups (Fig. 5.9). In this way, the relay remains switched on continuously, regardless of whether the cooling is normal, and this creates a precondition for the locomotive to operate without sufficient or even without any cooling of electrical machines and apparatus. The operation of the locomotive without the necessary cooling leads to an excessive increase in temperature in the individual units and in the engine compartment as a whole, which leads to melting of the cable insulation, damage to the capacitors, leakage of their electrolyte, which in turn becomes a catalyst for ignition of the rectifier unit.

In this regard, it is necessary to emphasize that in this series of locomotives the cooling fans of the electric machines are switched on automatically during the traction mode of the locomotive, but are switched off manually by means of a button on the control panel, i.e. the subjective factor (the locomotive driver) is the one that assesses

the degree of cooling and whether further operation of the fans is necessary when switching off the traction mode.

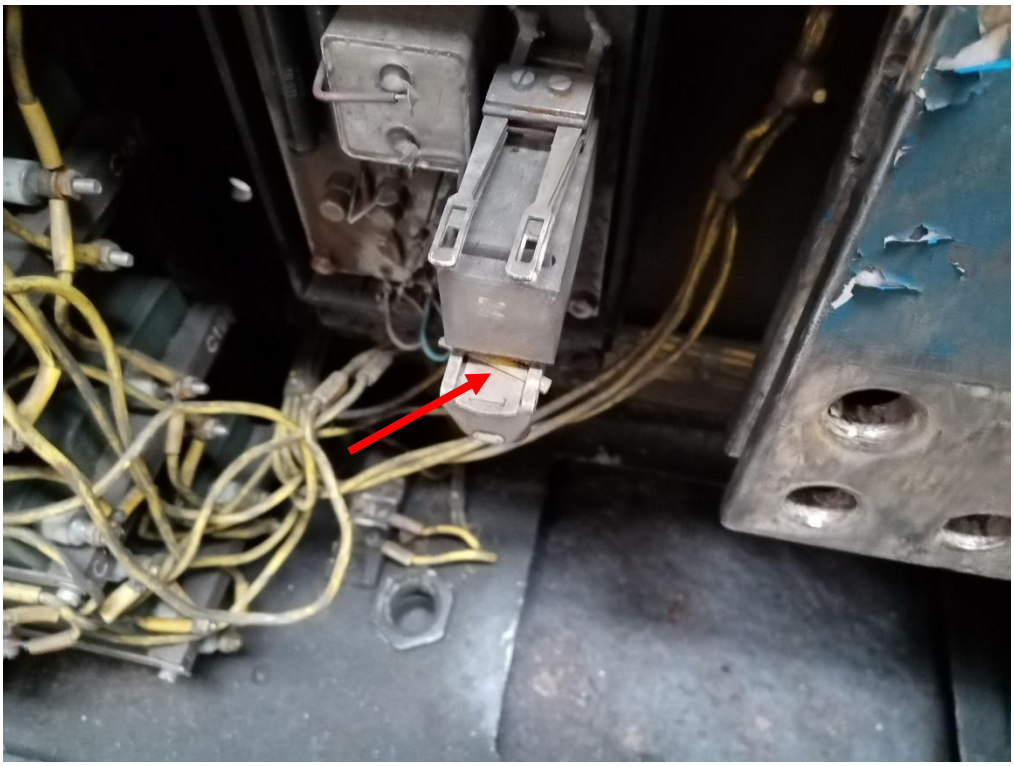

Fig. 5.9

It is very common practice for locomotive drivers to switch off the fans immediately after switching off the traction mode of the locomotive in order to prevent the gust of strong air current and increase the noise level in the control cabin. Violation of the working conditions of locomotive drivers is a precondition for the deterioration of their health, which is the main reason for their actions. However, this shutdown is accompanied by a further increase in temperature in the cooled machines and appliances, and especially in the rectifier units, which have so far operated at full capacity, their heating is very intense and at the time of shutdown they continue to radiate heat. This heat is distributed in the closed cabinet of the rectifier unit, including the rectifiers of the auxiliary machines. The above leads to intense heating of the rectifiers of auxiliary machines and the rectifier unit as a whole and in certain circumstances the capacitors do not withstand the high temperatures, burst and the spilled electrolyte ignites from the heated surfaces of the cabinet walls, igniting the wire insulation, which is in it.

The switching on of the compressor in operating mode additionally loaded the rectifier, which led to a further increase in the temperature in this part of the rectifier unit and accelerated the whole ignition process.

The scenario in which the ignition of locomotive № 44094 developed coincides very much with the reasons described above.

During the departure from Karnobat station, the locomotive driver loads seriously the locomotive to accelerate and reach a speed that is close to the allowable (remember that the train was late and this delay should have be recovered as much as possible). Immediately after Karnobat station there is a neutral insert, in which the driver switches off the locomotive completely and removes the current collector. Thus, for 1 minute the locomotive moves by inertia, without any cooling, having previously been loaded with high current, i.e. the electrical machines and appliances were severely heated. After passing the neutral insert, the driver switches on the locomotive again and immediately loads it in heavy traction mode to maintain the required speed (130 km/h).

This mode of movement continues until entering in station Chernograd, where the driver turns off the traction mode, the ventilation and then the locomotive continues its movement by inertia. The temperature of the rectifier unit is high due to the high load until recently and continues to rise because the ventilation is turned off.

When entering the downhill, the speed of movement increases and approaches the maximum allowable. At this point, in order to prevent the speed limit from being exceeded, the locomotive driver takes a short stop with the automatic train brake, restoring the pressure in the main air conduct after a few seconds. This causes the compressor to be switched on in a work mode and provokes new loading (mostly thermal due to the high currents) on the motor-compressor rectifier. Due to the high temperature that has developed in the lower part of the rectifier unit, the capacitors of the rectifier of the motor-compressor do not withstand, they crack and their electrolyte becomes a catalyst for ignition of the whole cabinet.

Railway infrastructure.

An important factor for raising the temperature is the operation of the locomotive with reduced voltage in the catenary (Fig. 4.6), which leads to increased operating currents, which are known to cause intense heating of the wires and devices through which they flow and worsen the conditions for operation of auxiliary machines and devices, in other words, the parameters of the voltage in the catenary at 13:00 p. m. at the time of the fire in the locomotive were violated.

c) Additional findings.

On 12.02.2021 an experimental trip was made along the route of FT № 3621 with a locomotive № 44198. In the locomotive were installed devices measuring the voltage in the catenary and the current consumed by the locomotive during its movement, all data were recorded after which were analysed in depth and detail. The measurement of the values of the alternating voltage in the catenary was performed with a certified multifunction device "Fluke 430 Series SN": DM9311111, which also performs harmonic analysis of voltage and current in one phase, scanning with a frequency of 4 kHz, applying a computational algorithm - fast conversion of Fourier. The device allows digital recording of current and voltage curves with a scanning frequency of 2.5 Hz, which is determined by high accuracy (<0.5%). The recordings made by the devices are at every 5 seconds and give a clear and detailed picture of the change of the above-mentioned parameters. The data were taken and recorded using the software product Power Log Classic 4.6, after which they were processed and compared with the speedometer tape of the locomotive, which provides accurate information about current and voltage data both in time and in location and speed of FT № 3621. Due to the large volume of data, only the data from 12:40 p. m. to 13:35 p. m. were analysed - time during which the train is in the same section where the accident with locomotive 44094 was realized on 28.09.20202, namely the section of Zimnitsa station to Vladimir Pavlov station (Fig. 5.10).

In the interval from 12:00 p. m. to 12:25 p. m. the average values of the voltage in the catenary is over 26 000 V at **average** values of the consumed current for the same interval from 4 to 28 A (Table 2). At 12:30 p. m. the **average** value of the consumed current is 24 A at an average value of the voltage in the catenary 25 950 V. In the next moment of measurement at 12:35 p. m. was reported the lowest one.

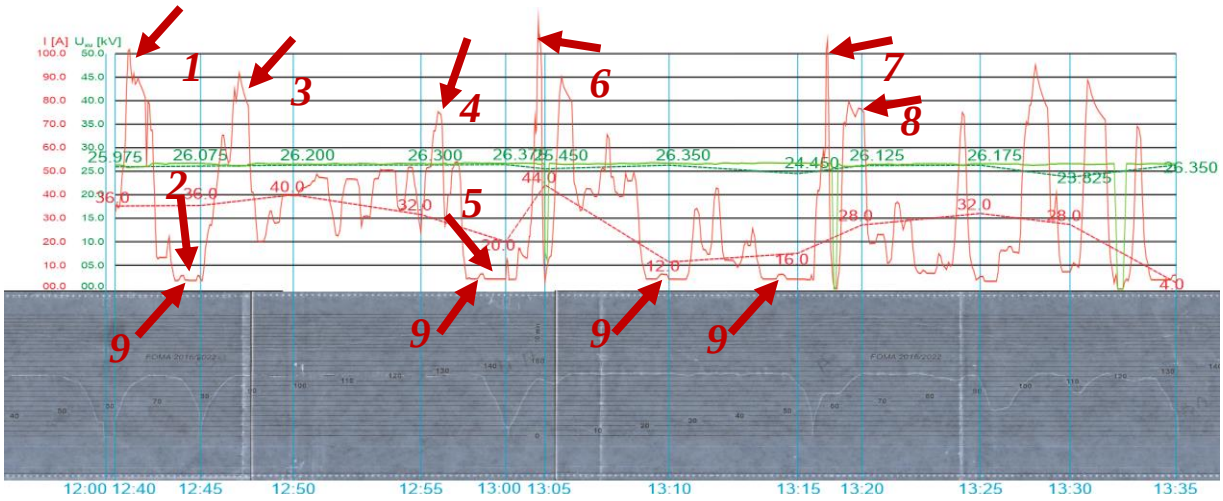

Fig. 5.10

Instantaneous current value measured by the multifunction device;

Instantaneous value of the voltage in the catenary, measured by the multifunction device;

Average current value for a five-minute interval, measured by the locomotive electricity meter;

Average value of the voltage in the catenary for a five-minute interval, measured by the locomotive electricity meter;

Time intervals.

A graphics shows the average values of current and voltage measured by the locomotive electricity meter for the five-minute intervals.

At 12:40 p. m. FT № 3621 with locomotive 44198 departs from Zimnitsa station, as the values of the consumed current reach 102 A at 12:40:45 p. m., which is logical in view of the fact that in this interval the train accelerates after departure from station (Fr. Fig. 5.10, pos. 1). After reaching the nominal speed, the consumption decreases, as the train moves by inertia and in braking mode for stopping at Straldzha station (Fig. 5.10, pos. 2). At 12:40 p.m. the **average** value of the voltage measured by the locomotive electricity meter in the catenary is 25 975 V, and the current - 36 A (Table 2). At 12:45 p. m. the values measured by the electricity meter are respectively 26 075 V and again 36 A.

When leaving Straldzha station, the picture repeats itself - initially high consumption up to 92 A, which then decreases and is maintained between 20 and 50 A for maintenance of the required train speed and in order to comply with the TOS (Fig. 5.10, pos. 3). For the interval from 12:45 p. m. to 12:50 p. m. the **average** value of the voltage supplied to the catenary is 26 200 V and the current consumption is 40 A. For the interval from 12:50 p.m. to 12:55 p. m. the **average** values are: current 32 A and 26,300 V (Table 2).

At 12:56 p .m. the current briefly increases to 75 A again to maintain the required speed - in this case 120 km/h (Fig. 5.10, pos. 4). From 12:57 p. m. until its stop at 13:02 p. m. at Karnobat station, the current is maintained in minimum values between 4 and 6 A, which is due to the included heating of the train (Fig. 5.10, pos. 5). When departing from Karnobat station at 13:04 p. m. the current rises sharply and reaches its maximum value for the studied section - 114.5 A (Fig. 5.10, pos. 6). During this interval, the locomotive consumes a large amount of electricity because it accelerates its movement - on the one hand, to reach the required speed for the interstation, and on the other to be able to pass the neutral insert located immediately after the station area. When the neutral insert is passed, the current and voltage decrease to almost zero, after which the voltage returns to its nominal value, and the current increases until it reaches 90 A in order to reach the required speed in the interstation. After passing Chernograd station, the current decreases again to 4 A, as the train moves downhill. The next peak of the current is at 13:08 p. m. after the departure of the train from Aytos station (Fig. 5.10, pos. 7). Again, the current and voltage are reduced to

pass to a neutral insert, after which the voltage returns to its nominal value, and the current increases to 80 A to accelerate the train (Fig. 5.10, pos. 8).

During further movement, the peaks of current consumption again coincide with the moments of acceleration of the train until its establishment at Vladimir Pavlov station, when the measurement is stopped.

During the movement of the train in some places local current peaks are observed, caused by the operation of the motor-compressors, and the consumption does not fall to zero value due to the fact that the train heating is constantly switched on (Fig. 5.10, pos. 9).

Throughout the movement in the observed section, the voltage in the catenary is maintained in the range of 26 to 27 kV, except for the values measured at 12:35 p. m. (15 350 V) and at 13:45 p. m. (2 625 V) (Table 2). The average values of current and voltage read by the locomotive electricity meter for intervals of 5 minutes generally show the same trend with voltage values slightly lower than those measured with the help of the device.

Table 2

Hour	Average values of the consumed current from locomotive 44-198 with train 3621 on 12.02.2021, reported by the locomotive electricity meter	Average values of the voltage in the catenary, reported by the locomotive electricity meter of locomotive 44-198 with train 3621 on 12.02.2021.
12:00	4,0	26225,0
12:05	16,0	24475,0
12:10	16,0	26200,0
12:15	28,0	26125,0
12:20	20,0	24975,0
12:25	16,0	26100,0
12:30	24,0	25950,0
12:35	16,0	15350,0
12:40	36,0	25975,0
12:45	36,0	26075,0
12:50	40,0	26200,0
12:55	32,0	26300,0
13:00	20,0	26375,0
13:05	44,0	25450,0
13:10	12,0	26350,0
13:15	16,0	24450,0
13:20	28,0	26125,0
13:25	32,0	26175,0
13:30	28,0	23825,0
13:35	4,0	26350,0
13:40	8,0	26325,0
13:45	0,0	2625,0

6. Safety recommendations.

In order to improve the rail transport safety, the Investigation Commission suggests to the Railway Administration Executive Agency the following safety recommendations that refer to „BDZ-Passenger Services“ Ltd. and SE NRIC.

Recommendation 1 proposes that BDZ PS Ltd. revise the control scheme of the fans in the locomotive in order to exclude interference of the subjective factor (the locomotive driver), observing the requirements of the Regulations for depot repair and maintenance of electric locomotives of BDZ (LS 0103 / 01.01 .1979) - §13 and of the Regulations for factory repair of electric locomotives series 44.000 and 45.000 (PLS 127/05) -§13.

Recommendation 2 proposes that BDZ PS Ltd. limit the access for forced "impact" of an electronic relay for voltage control of the Y3 fans, by obligatory sealing and performing periodic scheduled control for serviceability and functionality.

Recommendation 3 proposes SE NRIC to inspect the facilities and devices for traction power supply, related to the detection and elimination of faults leading to low supply voltage in the catenary during the movement of trains in the section Zimnitsa - Aytos.

With reference to the requirements of art. 94, paragraph 2 of Ordinance No 59 of 5.12.2006. The NAMRAIB Investigation Commission proposes a final report. The Report's Addressees shall inform in written the member of the NAMRAIB Administrative Board (President of the Commission) on the undertaken measures under the presented recommendations.

The NAMRAIB Commission prepared a final report dated 20.04.2021.

President:

……**(Dr. Eng. Boycho Skrobanski)**
Deputy President of the NAMRAIB AB

Members:

1.....(S).....(External expert)

2.....(S).....(External expert)

I, the undersigned Giulietta Marinova Marinova-Popova, certify that this is a true and accurate translation done by me from Bulgarian into English of the attached document.
The translation consists of 32 pages
Translator: Giulietta Marinova-Popova