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DEVELOPMENT OF CONSTRUCTIONS OF ELECTRICAL EQUIPMENT AND FUEL SYSTEMS FOR SPECIAL-PURPOSE VEHICLE BASED ON THE SOLUTIONS OF ZAKŁAD DOŚWIADCZALNY BISKUPIEC SP. Z O.O.

Roman Gąsior, Krystian Kucharewicz

Zakład Doświadczalny BISKUPIEC Sp. z o.o.
Czynu Społecznego Street 8, 11-300 Biskupiec, Poland
tel.: +48 89 7152641, fax: +48 89 7152043
e-mail: roman.gasior@zdbc.com.pl, krystian.kucharewicz@zdbc.com.pl

Abstract

The aim of this article is to describe the development of electrical equipment systems for military vehicles and fuel systems of these vehicles. Both electrical installations and fuel systems of military vehicles should meet strict quality requirements and resistance requirements to various exposure specified in the standards and other normative documents. This applies both to new vehicles and to the vehicles, which have been in service for many years. The article presents electrical components and fuel systems of military vehicles in which the fulfilment of quality and electromagnetic compatibility requirements and the use of innovative solutions constituted the leading targets in their construction. A great emphasis during the construction was placed not only on the fulfilment of functional requirements but also on the degree of reliability, maintainability, technical handling flexibility and the use of modern materials that can be recycled after the liquidation of the product.

The presented fuel systems meet strict modern requirements and are worth recommending for both the application in the equipment that has already been operated and in newly designed vehicles

Keywords: *dashboard, regulator, fuel system, on-board system*

1. Introduction

The Polish armed forces operate a large number of vehicles with different specifications and features as well as different technologies applied in their manufacturing process. Due to the fact that military technology is provided for use for even several dozen of years, currently one can find in the army the latest generation vehicles but there are also vehicles in which the technological solutions of the 60's and 70's were applied. Old technologies and design solutions often do not meet modern requirements set out in the Defence Standards or STANAG publications. They generate many problems in the process of repair of equipment due to the impossibility of obtaining obsolete, currently not used materials, spare parts and technology. The way to avoid problems is modernization of the equipment used and the introduction of new equipment for use manufactured in modern technology using the latest materials and components to meet modern requirements. The solutions of the essential components of electrical systems of military vehicles presented in the article, the next generation of dashboards for military wheeled and tracked vehicles and fuel systems dedicated to special-purpose vehicle have been designed and manufactured in Zakład Doświadczalny BISKUPIEC Sp. z o.o.

2. Driver's dashboards

2.1. PK-04 Driver's Control Panel

The need to construct a new driver's control panel for the PT-91 tank appeared during construction works aiming at developing the PT-91M version. It turned out that it was not possible to obtain analog gauges previously used in the device due to the cessation of their manufacture.

The indication accuracy of these devices far differed from the requirements set out by the PT-91M tank's contractor; what is more, the driver's board in the original form did not meet any of the modern requirements of electromagnetic compatibility (EMC). In 2004 after making arrangements with the manufacturer of the tank the PK-04 driver's control panel was proposed – Fig. 1. The control panel is dedicated to all vehicles using the T-72 chassis or constructed because of this vehicle.

Fig. 1. The PK-04 Control panel

The PK-04 Driver's Control Panel consist of:

- The PZ-04 Integrated Control Panel in the form of a box containing all the electronic systems of measurement chains, information visualisation systems and additional safety systems and event data recorder – „black box",
- The PW-04 Detachable Control Panel connected to the integrated panel,
- Bracket on which the Integrated Control Panel was mounted and switching components, fuses, switches.

The control panel is used to measure and illustrate the basic values needed for the driver - mechanic while driving:

- driving speed,
- engine revolutions,
- coolant temperature,
- oil pressure,
- oil temperature,
- the amount of fuel,
- voltage of the on-board system,
- battery charging current,
- service meter,
- clock.

The indicators are constructed in the form of lines of light (bar graph) consisting of tri-colour LEDs. The accuracy of the information visualization and resolution indicators are provided in table 1. The length of the luminous part of the bar graph is directly proportional to the measured value of the parameter and its colour is green when the measured size is within the assigned range agreed with the client or specified by the engine manufacturer. The colour of the bar graph is

yellow when the measured parameter goes out of range and reaches an alert value and finally when it reaches a critical value the colour of the bar graph turns red. Continuing driving at a critical value of any parameter may cause a serious hardware failure. This configuration of the information visualization is very ergonomic, allows a rapid orientation in the situation by the driver and speeds up the appropriate response. The values of all the parameters depicted on the bar graphs may be presented in a digital form on a seven-segment display. Brightness of light of indicators and displays is controlled manually and automatically depending on the light mounting location.

Tab. 1. The accuracy of the information visualization and resolution rates

No.	Indicator	Digital meter		Update frequency
		Indication accuracy	Resolution	
1	Temperature	±1%	0.1°C	2 Hz
2	Pressure	±1%	0.1 bar	2 Hz
3	Engine revolutions	±1,5%	1 RPM	3 Hz
4	Driving speed	±1%	0.1 km/h	2 Hz
5	Voltage	±1%	0.1 V	2 Hz
6	Current	±1%	1 A	2 Hz
7	Fuel level	±5%	10 dm^3	0.5 Hz
8	Moto hours	±1%	0.1 h	-
9	Main kilometre meter	±1%	0.1 km	-
10	Additional kilometre meter	±1%	0.01 km	-
11	Clock	±2min./year		1 Hz

The control panel has a system of auto testing and fulfils a number of additional functions, which makes it possible to simplify the on-board system and eliminate some devices such as the BOD-01, BA-1S and UA-200 blocks. However, the most innovative and extremely valuable additional feature of the control panel is an event data recorder, which is a kind of a „black box".

All inputs and outputs are short-circuit proof and can be operated with load current up to max 0.5 A. The control panel gives the opportunity to work with sensors located in the vehicle and engine via CAN (Control Area Network).

Basic technical parameters of the PK-04:

- rated supply voltage $27\ ^{+2}_{-5}$ V direct current,
- maximum power consumption 2A,
- working mode long-term,
- construction waterproof,
- service position vertical,
- weight of the set max. 5.2 kg.

Along with the PK-04 construction works, other works were carried out which aim was to make the control panel testing device that could be used on the equipment in field conditions. The result of these activities is the UT-04 automatic testing device – Fig. 2. The tester is made of the metal box with mechanical impact resistance. It automatically tests the control panel, calibrates measuring lines and in case of failure indicates the faulty measuring line providing additional information in the form of an error code specyfing the type of failure.

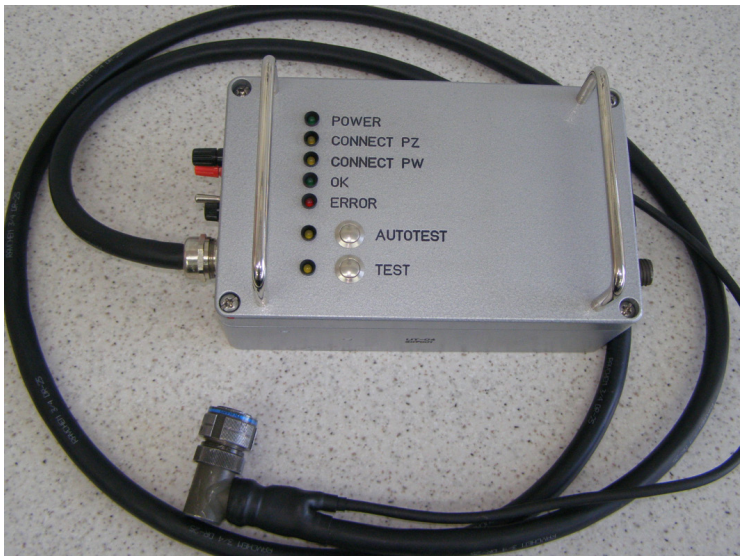

Fig. 2. The UT-04 testing device

2.2. Event data recorder

An event data recorder is a device, which records engine and vehicle motion parameters required by the client. Memory works on „a stack" in which after being filled up the oldest records are deleted and it is supplemented with the latest ones.

In the recorder's memory, the parameters are stored in accordance with table 2.

Tab. 2. Composition of the „record" logger memory

No.	Symbol in the recorder	Record	um	Purpose/function	Comments
1	RNO	Np.1111		Subsequent record number	
2	TYP	Param			
3	DAT	20.01.11		Date of recording	
4	TIM	10:33:25		Recording time	
5	SPD	0	Km/h	Vehicle speed	
6	RPM	0	RPM	Engine revolutions	
7	TEW	85	°C	Coolant temperature	
8	TEO	48	°C	Engine oil temperature	
9	THO	78	°C	Hydraulic oil temperature	
10	PEO	3,4	bar	Engine oil pressure	
11	PGO	3,1	bar	Gearbox oil pressure	
12	VLT	31,2	V	The mains voltage	
13	CUR	120	A	Current generator	
14	FUL	0,0		Fuel	
15	OH	0/1	-	Critical fall in the level of hydraulic oil	[0=no/1=yes]
16	AF	0/1	-	Pollution of the air filter	[0=no/1=yes]
17	UL	0/1	-	Unlocking the limiter	[0=no/1=yes]
18	HP	0/1	-	Activation of the emergency hydraulic pump	[0=no/1=yes]

19	WW	0/1	-	Winch operations	[0=no/1=yes]
20	WD	0/1	-	Bulldozer operations	[0=no/1=yes]
21	WC	0/1	-	Crane operations	[0=no/1=yes]
22	PE	0/1	-	Fall in engine oil pressure	[0=no/1=yes]
23	PG	0/1	-	Fall in oil pressure in meter box	[0=no/1=yes]
24	OV	0/1	-	Overloading of the main winch	[0=no/1=yes]
25	CA	0/1	-	Selection of the coolant- Antifreeze	[0=water/1=antyf.]
26	TW	0/1	-	Critical temperature of a cooling agent	[0=no/1=yes]
27	BL	0/1	-	Blocking the ventilator drive	[0=no/1=yes]
28	BR	0/1	-	Brake activation	[0=no/1=yes]

The recorder works in a mode of conditional record which records data from the moment of the fulfilment of even one of the conditions specified in table 3 and this process lasts until the condition disappears. The frequency of record (time interval between records) is 10 s.

Tab. 3. The list of necessary conditions of conditional record

	Parameter	Size
1	V	>60 km/h
2	n	>2175 RPM or <-100
3	Tchł-w	>112 °C – for water
4	Tchł-a	>107°C – for antifreeze
5	Tolsil	>120 °C
6	Polsil	< 2.4 bar while running the engine
7	Polsp	< 1,2 bar while running the engine
8	U	>29.6 V
9	U	<22.0 V
10	I	< – 100 A
11	Tolhyd	>72°C while operating a crane, bulldozer or winches
12	BlWent	The existence of the signal for Locking the ventilator drive while the engine is running
13	OFP	The existence of the signal for Pollution of the Air Filter while the engine is running
14	DebOgr	The existence of the signal for Unlocking the limiter while operating a crane
15	PmpAwar	Activation of the emergency hydraulic pump
16	<H hyd	Fall in the hydraulic oil level while operating a crane, bulldozer or winches
17	PrŻuraw	The existence of the signal Crane Operation
18	PrSpych	The existence of the signal Bulldozer Operation
19	PrWycig	The existence of the signal Winch Operation
20	OvrLoa	The existence of the signal for Overloading the main Winch while operating winches

If necessary, there is a possibility of turning on in the SERVICE MENU a mode of continuous record in which data are recorded at a frequency of 10 s regardless of the size of recorded parameters. The number for saving 64000 records gives the possibility to record in a continuous mode 178 hours of continuous operation. Recording parameters can be modified on request.

Viewing, copying from the record memory is possible after connection of the control panel to the computer. After saving data on your hard drive, they can be processed in a worksheet, presented in the form of tables, charts, etc. Properly processed data are the source of current information on the way of vehicle operation, engine condition and above all, they make it possible to identify clearly the cause of an engine failure.

2.3 The PK-08 Driver's Control Panel

The PK-08 Control Panel is an advanced version of the PK-04 Control Panel. It is designed for use in vehicles equipped with additional hydraulic devices (bulldozers, cranes, etc.) The PK-08 Control Panel being the part of the equipment of the armoured recovery vehicle WZT-3 is presented in Fig. 3.

It consists of:

- The PZ-08 Integrated control panel in the form of a box containing all the electronic systems of measuring lines, information visualisation systems and additional safety systems and event data recorder – „black box".
- The PW-08 Detachable Control Panel connected to the Integrated Control Panel.
- Bracket on which the Integrated Control Panel was mounted and switching components, fuses, switches.

Differences in the construction of the PK-08 as compared to the PK-04 are the use of newer electronic components of *„Automotive"* class, which ensure a proper operation of the device in compliance with the required ranges of temperature by Defence Standards. Moreover, the PK-08 has been adapted to work with different types of sensors measuring values (temperature, pressure, level). The selection of the type of the input signal from the sensor takes place by change in the software.

Switches and fuses used come from well-known global manufacturers and they meet military standards.

Fig. 3. The PK-08 Control Panel with the PW-08 version up to the WZT-3

2.4 The ON-13 Dashboard

The ON-13 dashboard is a fully independent management module of the electrical equipment of the vehicle. A classic panel of indicators and controls enables to visualise basic operating parameters of the engine and vehicle. The use of the Control Area Network CAN, operated

according to J1939 standard, significantly reduced the number of electrical connections between the ON-13 dashboard indicators and engine and gearbox controllers, increasing at the same time the reliability and scalability of the system.

Fig. 4. The ON-13 Driver's Dashboard

The dashboard also functions as an electrical energy distribution centre feeding the electrical components of the vehicle, among other things: gearbox, engine, lighting. Each of the circuits has fuses protecting the vehicle and dashboard system against short circuits and overloads. A unit of high-class switches depicted with clear pictograms provides an intuitive operation.

The component of the ON-13 equipment is a specialized controller managing the operation of the distribution box of the power transmission system that allows the control and supervision over the gear configuration panel and the lock of the central differential.

A mechanical design of the dashboard is based on lightweight aluminium components protected against corrosion by galvanic (electrolytic) coating and varnishing.

The ON-13 dashboard has passed the tests performed on the vehicle in the hot equatorial climate.

Basic parameters:

- rated supply voltage: 12 or 24 V DC,
- communication with engine and gearbox controllers via: CAN J1939,
- operating temperature range: –35°C-+70°C.

Fig. 5. The ON-13 Dashboard mounted in the vehicle

2.5 The DK-15 Dashboard

The DK-15 dashboard is a system constructed because of the 7-inch LCD display, a unit of mobile PLCs and video cameras.

A colour 7”display has two independent channels of CAN 2.0B interface working in the J1939 standard, 3 analog inputs with a resolution of 10 bits, 5 binary inputs, frequency input enabling work with the pulser, 10 programmable function keys and the function of variable adjustment of brightness. It is possible to implement the functionality of a „black box”, e.g. recording the data relating to incidents affecting the proper functioning of the vehicle.

The display allows you to communicate with the controllers of:

- vehicle's engine – ECU,
- automatic transmission – TCU,
- braking system – ABS,
- mobile controllers – PLC.

The central PLC is used to manage the functioning of the electrical equipment located in the front of the vehicle: exterior lights with the supervision over their efficiency, interior lighting, heating, connecting box of the power transmission system. The task of the rear controller is the operation of the exterior lighting of the vehicle and trailer, control over efficiency of the pneumatic system, steering of the camera. There is a possibility of expansion of the structure by other controllers and implementation of additional features according to customer requirements.

Additionally, the DK-15 dashboard being the centre of electricity distribution is equipped with the components protecting against the effects of overloads and short circuits in electrical systems. It also allows the cooperation with the additional accessories of the vehicle: vehicle central tyre inflation system, air conditioning, heating and other.

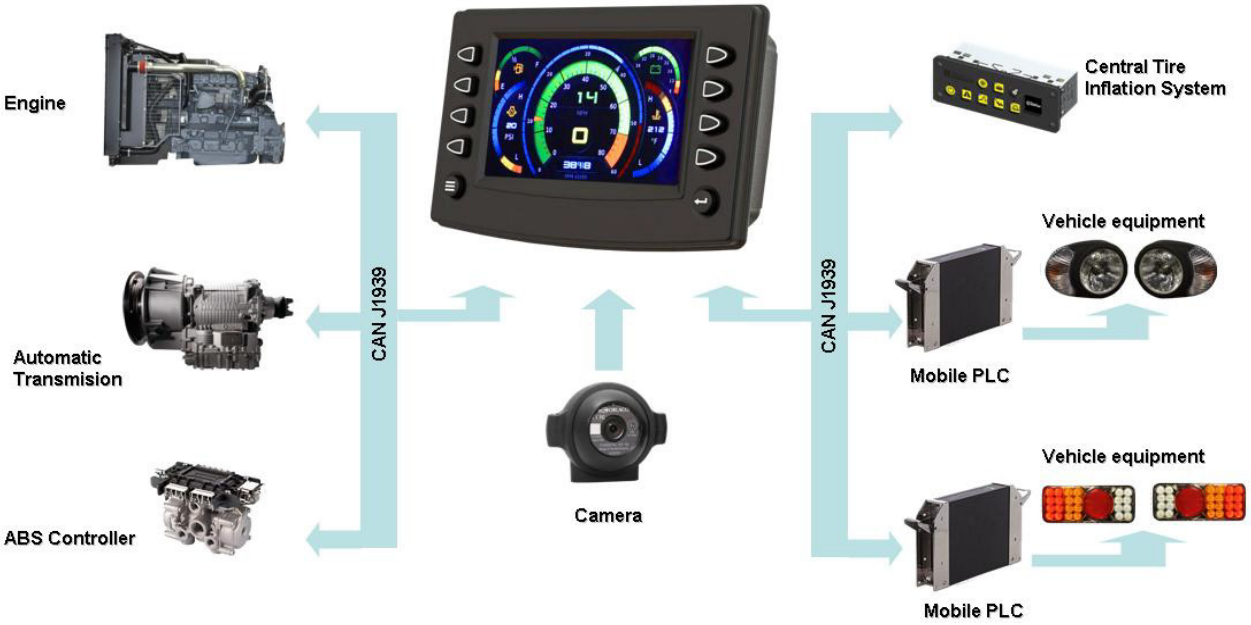

Fig. 6. Visualisation of the DK-15 Dashboard solution

3. Electric blocks dedicated to the T-72, PT-91

3.1. Voltage regulator RN-10U

Regulator RN-10U is electrically and mechanically interchangeable with technologically obsolete regulators R10-TMU, R10-TMU-1S, R10-TA occurring in the units installed in the T-72, PT-91 tanks and all other vehicles using the T-72 chassis. Specialized versions of the regulator are equipment of vehicles such as PT-91M, WZT-3, WZT-4 and KRAB.

The impulse to start works on the RN-10U regulator was the information about a bad cooperation of old types of regulators with modern batteries currently used, for example gel ones.

The regulator can work with the following current generators: SG10-1, 5S, G6 and their modifications and is designed to maintain automatically the generator voltage at a constant level and to disconnect or connect it to the on-board network. The level of the charging voltage takes into account the optimal temperature coefficient for a given type of batteries. The regulator is equipped with a measuring cable with a temperature sensor mounted on batteries and data transmission cable.

The regulator has been designed and manufactured in accordance with EMC Requirements.

Fig. 7. Voltage Regulator RN-10U2

3.2 Microprocessor starting device MUR-2

The MUR-2 device works with a starting system of the vehicles T-72, PT-91. WZT-3 and replaces the previously used 4 electronic blocks: PAS 15-2S, PUS15R, BSP-1M and SP-R.

Fig. 8. MUR-2 Microprocessor starting device

The device allows for engine starting-up in all possible modes, i.e. electrical, pneumatic and mixed ones. The use of one box instead of four blocks excellently simplifies the electric system and the service diagnostics system used in the device, informs the crew of the possible causes of engine start-up failure.

The regulator has been designed and manufactured in accordance with EMC requirements.

3.3 Indication box SSD-1

The SSD-1 box is electrically and mechanically interchangeable with KDS1-1S and KDS1-2S blocks. It is designed for controlling dimensional lights of the vehicle, signalling turning, braking and pulling up.

Fig. 9. Indication box SSD-1

The basic premise for beginning design works of SDD-1 was the necessity to eliminate major disturbances generated by the previously used KDS blocks. SSD-1 has the number of radio disturbance emissions at an acceptable level. It has a whole range of short circuit and overload safety devices and diagnostic system. It is the part of equipment of the PT-91M and WZT-4 systems.

4. Fuel systems

Fuel systems are seemingly simple constructions consisting of tanks, fuel pipes and fuel pumps. However, the fuel systems of military vehicles are often complex due to the large amount of tanks with irregular shapes located at different levels, which causes a problem of a precise fuel measurement. Another factor causing the complexity of the fuel system is the requirement of engine feed with extreme tilts of the vehicle and the minimum amount of fuel in the system. Additionally, the tanks must be protected against the fuel outflow in not only rollover accidents but also overshooting the tank.

Example requirements for the fuel system of a special- purpose vehicle:

- the system consists of two main tanks of 120l and one of the intermediate capacity of 10l,
- the intermediate tank is always full,
- the system reliably supplies the engine with fuel at an inclination up to 45° in each direction with a minimum fuel level of 0.25 of the tanks' capacity,
- the difference of fuel level between main tanks cannot be greater than 5%,
- fuel is drawn from the tank, which has a greater level during a side tilt,
- in case of fuel overheating, fuel should be drawn from the tank in which there is fuel of lower temperature,

- fuel pumps should have adequate capacity to meet the above requirements and they must be protected against interference emissions and have a required resistance to disturbances,
- the system continuously measures the amount of fuel with an accuracy up to a few percent and it visualises this information on the display,
- identification of the critical fuel level (reserve) in each of the tanks,
- identification of the critical fuel level in the intermediate tank,
- preventing fuel spills while overshooting with 7.62 calibre,
- fire protection,
- explosion protection.

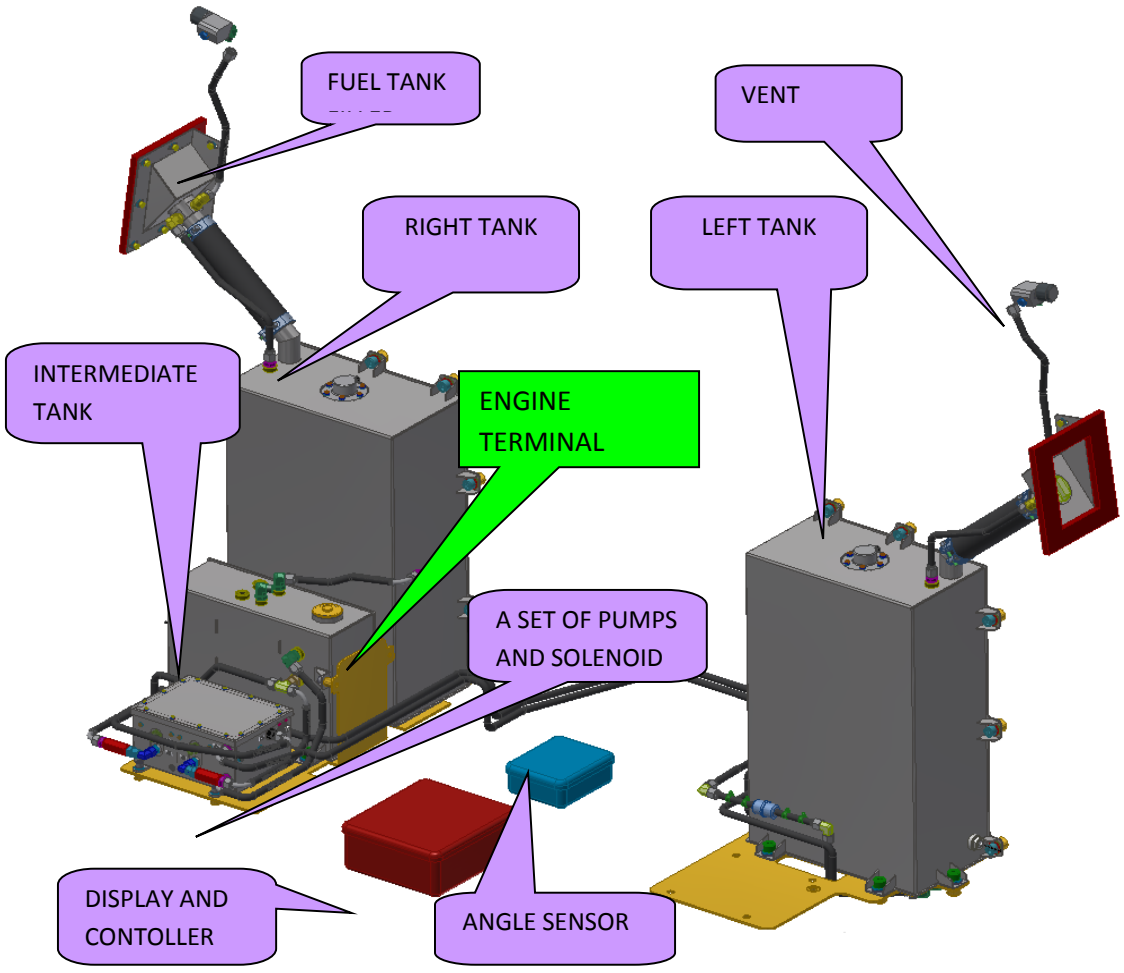

Fig. 10. Diagram of the fuel system

Additional requirements frequently occurring during contacts with business partners are protections of the tanks against fuel explosion and fuel leakage from the overshot tank. We offer such solutions. In Fig. 11, one can see the tank covered with a special coating, which seals itself after the 7.62 mm bullet passes through.

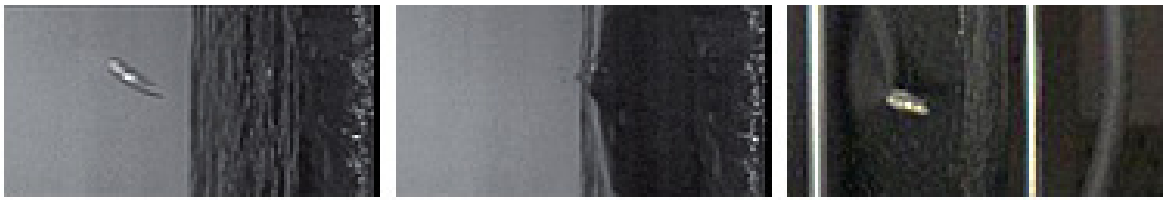

Fig. 11. Ballistic test on the tank covered with a special self-sealing coating

Fig. 12. Examples of tanks with ballistic protection

An important factor is also the explosion protection and the protection of the entire system against the fire.

Fig. 13. Elements used to fill tanks to protect against explosion

5. Summary

The design works on the presented solutions of the components and electrical systems of combat vehicles always took into account the use of the most advanced materials. A consideration was given to meet electromagnetic compatibility requirements specified in defence standards and interchangeability requirements of new or modernized solutions with the previously used ones. The result of such an approach to design works is products, which can be easily used in older generation vehicles, increasing their reliability, repair flexibility and electromagnetic compatibility.

The presented electrical components when used simplify and organize the electrical system, so their widespread use appears to be advisable for partial modernization of the tanks carried out during maintenance overhauls.

The presented fuel systems meet strict modern requirements and are worth recommending for both the application in the equipment that has already been operated and in newly designed vehicles.

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