

TOMASZ BUDNIOK
RAFAŁ KONSEK
BERNARD KRAKOWCZYK
ANDRZEJ TOR
WOJCIECH ZASADNI
LESZEK ŻYREK

An innovative CA-190 monorail battery locomotive powered by a VOLTER lithium battery

The article describes the CA-190 battery locomotive powered by a VOLTER lithium battery, intended for the suspended transport of machine parts, materials and people. The CA-190 battery locomotive with a VOLTER lithium battery is an innovative construction tailored to the current development trends in transport in the global mining industry. Having its own power source eliminates the use of electrical power cables or hydraulic hoses which typically limit the use of locomotives. The method of charging the battery directly from the mine's power grid with a three-phase voltage of 500 V, 1000 V during standstill is an innovative solution. The use of batteries as a source of energy reduces the negative impact on the mine environment due to the elimination of exhaust emissions and significant reduction of noise and heat. The implementation of CA-190 locomotives results in increased efficiency of works and improves the safety of personnel and work ergonomics.

Key words: *suspended transport, battery-powered locomotive, lithium battery, battery charging, work safety*

1. INTRODUCTION

In recent years, battery-powered transport systems have been one of the key production areas of Becker-Warkop Sp. z o.o. In 2014, the first suspended battery manoeuvring locomotive of the CMA-190 type was designed and manufactured by the company, before being approved and introduced in mines.

2. DESIGN DESCRIPTION

The subject of the article is the improved innovative CA-190 battery locomotive powered by a VOLTER lithium battery, which consists of lithium cells placed in an explosion-proof casing in a flameproof enclosure and meets the current requirements of the

ATEX directive and harmonized standards. Other elements of the electric equipment of the CA-190 locomotive, such as the electric drive, headlamp, etc., are placed in flameproof enclosures. Other devices such as a methane detector, radio remote control etc. are intrinsically safe. The above electrical devices have their own ATEX certificates. In 2020, the CA-190 locomotive powered by a VOLTER lithium battery was approved by the President of the State Mining Authority (WUG) to be operated in underground mining workings in non-methane and methane fields, in workings included in 'a', 'b' or 'c' degree of methane explosion hazard and in workings included in 'A' or 'B' class of coal dust explosion hazard. This locomotive is another solution in the whole family of suspended battery-powered locomotives of CA-190/X/Y/Z type (where: X – number of drives, Y – number of opera-

tor's cabins, Z – type of battery used) and is a driving unit for transport sets of suspended monorails used for transporting machine elements, materials and people. These locomotives can travel on tracks of the I155 (I140E), I140V95 and I250 profiles or other compatible of approved type. The maximum longitudinal track inclination is $\pm 30^\circ$ (Fig. 1) [1].

Figure 1 shows the basic design of the CA-190 locomotive with operator's cabins. The locomotive can also work without cabins as a manoeuvring locomotive (Fig. 2) [2]. Then it is controlled by a wired control box or a radio remote control.

A full preview of the locomotive's operating parameters is presented on the operating parameters display located on the housing of the battery unit and in the operator's cabins.

A novelty used in the CA-190 locomotive with a VOLTER lithium battery is the option of an alternative operator login, instead of entering a PIN code, via an RFID electronic key and a built-in reader in

the locomotive hydraulic module. The keys are assigned to each of the authorized operators. The advantage of the CA-190 locomotive drive system is the full integration of the motor with the inverter, enabling the rapid reconfiguration of the number of locomotive drives, adapted to the current operating needs. Figure 3 shows a single BWNE electric drive.

An innovative solution used in the CA-190 locomotive with a VOLTER lithium battery is the use of mobile lighting, which enables the replacement of stationary lighting of passenger and material stations by using lamps installed in passenger cabins and transport sets (Figs. 4 and 5). The use of this lighting method and the option of its use both at stations and along the entire length of the railway route improves the safety, economic and energy efficiency of the mining plant. Standard stationary lighting for material and passenger stations requires constant reconstruction as the works advance [2].

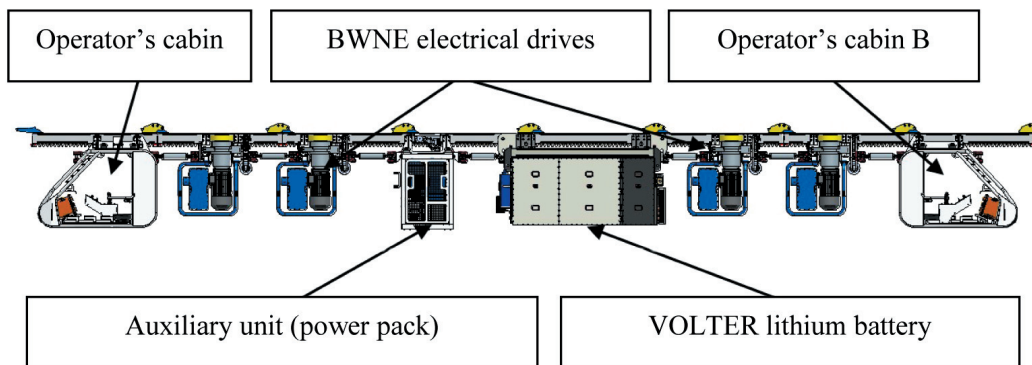


Fig. 1. Basic configuration of the CA-190/4/2/2 locomotive [1]

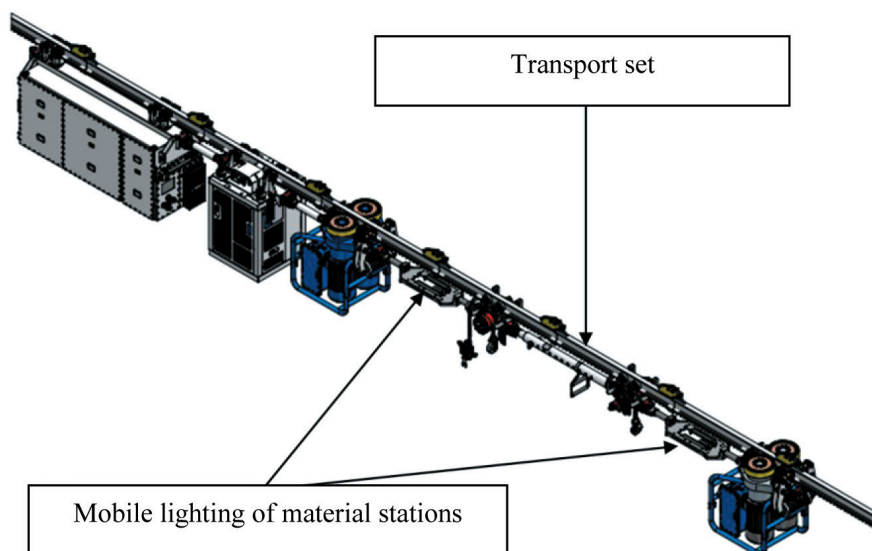


Fig. 2. CA-190 manoeuvring locomotive (CA-190/2/0/2 version) powered by a VOLTER lithium battery with a double-locomotive transport set and mobile lighting for material stations [1]

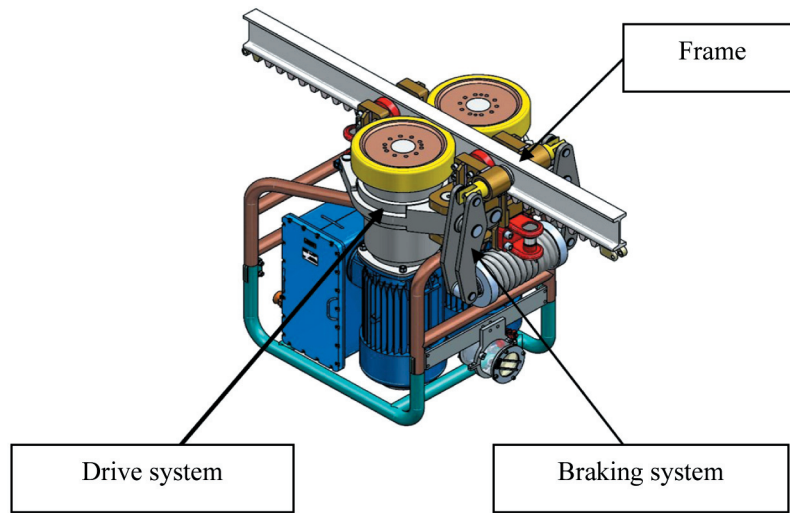


Fig. 3. BWNE electric drive



Fig. 4. Mobile lighting of passenger stations from the CA-190 battery-powered suspended locomotive (white light – the locomotive is at the passenger station)

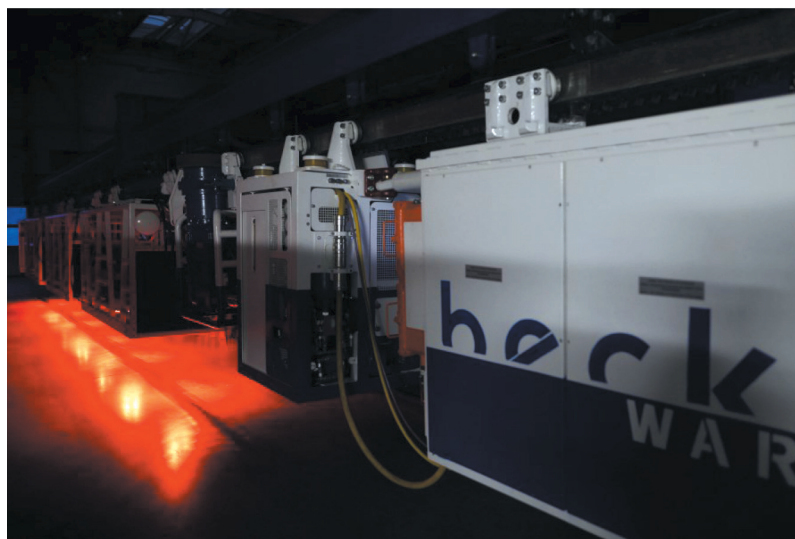


Fig. 5. Mobile lighting from the CA-190 battery-powered suspended locomotive (red light – locomotive in operation)

The VOLTER lithium battery used in the CA-190 locomotive is used to power the locomotive's drive motors. The battery unit also includes the systems intended for checking, protection, monitoring and control of the locomotive's individual devices. The whole system is built in a two-chamber flameproof enclosure. The battery compartment contains lithium cells grouped in 20 assemblies. There are 8 cells in each assembly, which are voltage and temperature monitored by individual check modules. The check modules communicate with the monitoring part located in the apparatus chamber and are also

responsible for charging the cells and for transmitting the operating parameters to the control system. The apparatus compartment (the compartment of electrical, control apparatus and measurement devices) includes elements responsible for the monitoring and proper operation of the battery. The use of lithium cells enables their charging at any time and place, including in mine workings with a methane and/or coal dust explosion hazard, so there is no need to place the locomotive in a special battery charging compartment ventilated with an independent airflow.



Fig. 6. Basic configuration of the CA-190/4/2/2 locomotive on a test track – the track inclination is 30 degrees

An unquestionable advantage of the VOLTER battery is its integrated charger (built in the dedicated compartment of the battery housing), enabling the charging of the cells directly from the mine's power grid with a three-phase voltage of 500 V, 1000 V. The mine grid is connected through the quick connector in a flameproof enclosure – which significantly speeds up the connection/disconnection process. The charging time is significantly reduced compared to the previously used batteries and is up to a maximum of 4 hours. The drive system of the CA-190 locomotive with a VOLTER battery enables operation with energy recuperation, i.e. energy recovery back to the battery while travelling on dips or during braking. In special cases, the CA-190 locomotive can be additionally equipped with a BWMRE energy dissipation module devel-

oped and implemented at Becker-Warkop Sp. z o.o. The BWMRE module enables the CA-190 locomotive to travel on dips with a VOLTER battery fully charged. The electricity generated from kinetic energy is then dissipated in the form of heat.

The design of a VOLTER battery includes innovations based on Industry 4.0 solutions. Due to the use of a data recorder and communication modules, it is possible to establish communication between the locomotive and an intrinsically safe tablet/smartphone through Wi-Fi transmission using a special application (the so-called Internet of Things) [3]. After establishing the connection between the locomotive and a tablet/smartphone, the locomotive operating parameters are also displayed on the screen of the mobile device (Fig. 7).



Fig. 7. Becker-Warkop Sp. z o.o. tablet

This solution is justified when the CA-190 locomotive is in a manoeuvring version (Fig. 2) and the operator cannot view the parameters on the locomotive's display, e.g. when the locomotive is located on a high section of the route. Another Industry 4.0 solution is predictive maintenance of the locomotive. All data from sensors, check modules, events etc. are saved on a memory card. These data can be sent on an ongoing basis or copied and transferred to Becker-Warkop Sp. z o.o., where, using a database, the user can be informed about current inspections and necessary component replacements. The predictive maintenance strategy enables the reduction of breakdown and service costs as well as the reduction of downtime. At the same time, the operating time of the devices is extended, and safety is improved. The basic technical parameters of the CA-190 battery locomotive powered by a VOLTER lithium battery [1] are presented below.

Table 1

Basic technical parameters of the CA-190 battery locomotive powered by a VOLTER lithium battery

Parameter	Value
Pulling force	80 kN – frictional drives
Maximum speed	2.0 m/s
Minimum horizontal turning radius	4 m
Minimum vertical turning radius	8 m
Maximum track inclination	$\pm 30^\circ$
Nominal charging voltage (directly from power grid)	500 V, 1000 V
Battery type (VOLTER)	lithium
Battery energy	142 kWh
Power of one drive motor	11 kW
Locomotive power with 4 frictional drives (two-motor)	88 kW
Locomotive dimensions with 4 drives (height \times width \times length)	1275 \times 800 \times 15,340 mm
Kerb weight of locomotive with 4 drives	11,110 kg

3. SUMMARY

The CA-190 monorail battery locomotive powered by a VOLTER lithium battery is an innovative construction. An own power source in the form of a lithium battery eliminates the use of power electric cables or hydraulic hoses, which limit the use of locomotives. The method of charging the battery directly from the mine's power grid with a three-phase voltage of 500 V, 1000 V during standstill is an innovative solution. The use of batteries as a source of ener-

gy reduces the negative impact on the mine environment due to the elimination of exhaust emissions and a significant reduction of noise and heat. The implementation of CA-190 locomotives with a VOLTER lithium battery will contribute to increasing the efficiency of works and improving the safety of personnel and work ergonomics. The CA-190 battery locomotive with a VOLTER battery has been offered by Becker-Warkop sp. z o.o. since the second half of 2020.

To date, three locomotives of this type have been put into operation in Polish mines. The locomotives,

due to their qualities, have received favourable reviews from the users. The CA-190 locomotive powered by a VOLTER battery is also attracting considerable interest in foreign markets.

References

- [1] Operation Manual – Operations and Maintenance Manuals of the CA-190 battery-powered locomotive.
- [2] Data sheet for mobile lighting of passenger and material stations.
- [3] Data sheet of the IS910.M1 intrinsically safe tablet.

TOMASZ BUDNIOK, M.Sc, Eng.
RAFAŁ KONSEK, Ph.D., Eng.
BERNARD KRAKOWCZYK, M.Sc., Eng
ANDRZEJ TOR, Ph.D., Eng.
WOJCIECH ZASADNI, Ph.D., Eng.
LESZEK ŻYREK, Eng.
Becker-Warkop Sp. z o.o.
ul. Przemysłowa 11, 44-266 Świerklany, Poland
{t.budniok, r.konsek, b.krakowczyk, a.tor,w.zasadni,
l.zyrek}@becker-mining.com.pl