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RELIABILITY OF BLASTING MACHINES USED TO INITIATE ELECTRICAL DETONATORS

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Abstract: In underground or surface mining operations in Romania, blasting machines manufactured before 1990 are still used to initiate electric detonators. These blasting machines have a long or very long operating life and certain operating parameters have changed over time. On the basis of the data collected during the periodic inspections, the data contained in the test reports issued by the Laboratory of Non-Electrical Ex Equipment, Electrostatic Materials and Personal Protective Equipment of INCD Insemex Petroşani, an analysis was made in this paper of the parameters that change in a blasting machine over time, the possible causes and the consequences of these changes. Data from test reports from 2003 to 2023, i.e., over a period of 20 years, performed on blasting machines manufactured in Romania and the former German Democratic Republic was used for the analysis. According to the analysis carried out for the preparation of this paper, it was found that the blast machines with the longest service life were those produced in the former GDR, i.e., Vopil M514 blast machines, and that most of them were inductor and capacitor blast machines. The parameters that changed as a result of long use were the output voltage value, the pulse power and, in the case of blasting machines intended for coal mining, the pulse duration.

Key words: blasting machines, electric detonators, mining.

1. INTRODUCTION

Blasting machines, also known as blasting caps, detonators or initiators, are devices used to initiate explosive charges in mining operations. Advanced technologies in this field include the use of capacitors to provide the energy required to initiate explosions.

These devices are preferred for their accuracy and reliability, as they are capable of delivering highly controlled pulses of energy. These devices are vital in various applications including mining, construction and demolition.

Here's an overview of blasting machines for initiating electrical detonators:

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1.1. Types of Blasting Machines

1.1.1. Hand-Operated Blasting Machines

- These are manual devices that generate an electric charge when a handle is turned or a plunger is pushed.
- They are typically used in smaller operations where portability and simplicity are important.
- Example: Crank-operated or push-down blasting machines.

1.1.2 Battery-Powered Blasting Machines

- These machines use batteries to provide the necessary electrical current to initiate detonators.
- They offer greater convenience and reliability compared to manual devices.
- Example: Digital or electronic blasting machines with rechargeable batteries.

1.1.3 Capacitor-Discharge Blasting Machines

- These machines store electrical energy in capacitors and release it in a sudden, controlled burst to initiate detonators.
- They are known for their precision and ability to generate a high current pulse.
- Example: CD (capacitor discharge) blasting machines.

1.1.4 Electronic Blasting Systems

- Advanced systems that use microprocessors to control the initiation sequence.
- They offer features like programmable delay sequences and enhanced safety mechanisms.
- Example: Electronic detonators with programmable delay options.

1.2. Operation and Safety

1.2.1 Initiation Process

- The blasting machine generates an electric current.
- The current travels through wires to the detonators.
- The detonators then initiate the explosive material.

1.2.2 Safety Measures

- Ensuring all personnel are at a safe distance before initiation.
- Using proper insulation and handling techniques to avoid accidental discharge.
- Regular maintenance and testing of blasting machines to ensure reliability.

1.3. Applications

- Mining: Used for breaking rock and ore to access mineral deposits.
- Construction: Demolition of buildings, road construction, and tunnelling.
- Military: Controlled explosions for clearing obstacles or demolitions. [1]

Capacitors used in the manufacture of mining blasting machines are capable of storing large amounts of electrical energy and releasing it rapidly to initiate a controlled explosion. Types of capacitors used include:

- Electrolytic capacitors. Commonly used because of their large capacity and relatively low cost. They can store a large amount of energy and release it quickly. They have a fairly short lifetime (especially those produced in the past).

- Metallized polypropylene capacitors. These capacitors are used because of their stability and ability to withstand high voltages. They have a long life and are reliable in harsh conditions.

- Ceramic capacitors. They are used in applications that require high thermal stability and good reliability. Their capacitance is small and they are rarely used as energy storage capacitors in the production of mining blasters.

These types of capacitors are selected according to their working (operating) voltage, energy storage capacity, physical size and reliability under extreme environmental conditions.

The mining blasting machines that were analysed in this paper used high-voltage (1000 ... 2000V) electrolytic capacitors with a large electrical energy storage capacity (2 ... 20μF).

The reliability of capacitor-based blasting machines depends on several factors, including the type and quality of capacitors used, circuit design and operating conditions.

Four types of mining blasting machines from different manufacturers were chosen for the analysis. The analysis was carried out on a total of 775 blasters. Most were of the Vopil M514 type (614 pieces). Vopil M514 are mining blasting machines with capacitor, inductor and gas tube trigger and were produced in the former German Democratic Republic since the 1960s.

2. CAPACITOR-BASED BLASTING MACHINES

2.1. Principle of operation

Capacitor-based blasting machines work by storing electrical energy in a capacitor. When this capacitor is charged to the required capacity, the stored energy is suddenly discharged to an electrical detonator, triggering the blast. [2]

2.2. Advantages of using capacitors

- Accuracy and control: Capacitor-based blasting machines can deliver accurate and controlled electrical pulses, essential for the safe initiation of explosive charges.

- Reliability: Compared to other types of blasting equipment, these machines are less prone to failure.
- Safety: Because the energy is not permanently available in the circuit, the use of capacitors reduces the risk of inadvertent triggering of the explosion. [3]

2.3. Main components

- Capacitor: Energy storage device.
- Charging circuit: The mechanism that charges the capacitor. The capacitor can be charged by an inductor or by a voltage boosting electronic circuit.
- Detonator: The device activated by the electrical impulse supplied by the capacitor to trigger the explosion, in other words the electrical fuse. [4]

2.4. Applicability

These blasting machines are widely used in mining, quarrying and other industries where controlled explosions are required to fragment rock or other materials. [5]

3. RELIABILITY OF CAPACITOR-BASED BLASTING MACHINES

Their reliability depends on several factors, including the type and quality of capacitors used, circuit design and operating conditions. Here are some key points:

3.1. Capacitor quality

The use of high-quality capacitors from recognised manufacturers contributes significantly to the reliability of blasters. Capacitors must be able to store and release the required energy consistently and reliably. Poor quality capacitors can lead to major failures and risks in mining operations. [6]

4. THE LIFESPAN OF HIGH-VOLTAGE ELECTROLYTIC CAPACITORS

The lifespan of high-voltage electrolytic capacitors varies significantly based on several factors, including operating temperature, voltage, and ripple current. Typically, high-quality electrolytic capacitors have a base lifespan of around 5,000 to 10,000 hours at their maximum rated temperature, usually 105°C. However, this lifespan can be extended by operating the capacitor under less demanding conditions.

A common rule of thumb is that for every 10°C reduction in operating temperature, the lifespan of an electrolytic capacitor doubles. For instance, if a capacitor rated for 5,000 hours at 105°C is operated at 85°C, its lifespan could extend to around 20,000 hours. [7, 8]

Additionally, operating the capacitor at a lower voltage than its maximum rating can also improve its lifespan. For example, running a capacitor at 50% of its rated voltage can approximately double its lifespan. [9]

The ripple current also impacts the lifespan. High ripple currents generate more internal heat, which can shorten the capacitor's life. Operating at 50% of the rated ripple current can potentially increase the lifespan by about 23%. [9]

For a precise calculation of the expected lifespan under specific operating conditions, you can use the de-rating formula (Equations 1):

$$Lifeactual = lifebase \cdot temperatureFactor \cdot voltageFactor \cdot currentFactor \quad (1)$$

where each factor adjusts for operating conditions relative to rated conditions. [7, 8]

5. ANALYSIS OF DATA COLLECTED FOR THE STUDY OF RELIABILITY OF CAPACITOR-BASED BLASTING MACHINES

The data analysed and studied were taken from the certification reports issued after the periodic tests carried out at the Laboratory for Non-Electrical Ex Equipment, Electrostatics, Materials and PPE of INCD Insemex Petroşani. Data were collected from 775 certification reports over a period of 20 years (Table 1).

Table 1. ***Situation regarding the type of blasting machines and the number of inspections carried out at INCD Insemex Petroșani over a period of 20 years.***

Year	**Type and number of blasting machines checked**			
	VOPIL M514	AICmI	EI-200D	ECI-100
2003	169	1	-	8
2004	55	4	5	7
2005	9	4	5	10
2006	146	10	6	2
2007	26	6	3	2
2008	97	10	3	2
2009	77	8	4	3
2010	18	3	-	-
2011	-	3	2	-
2012	-	-	-	-
2013	-	1	2	-
2014	2	3	2	-

2015	4	3	-	2
2016	-	-	-	2
2017	2	1	2	-
2018	-	-	-	1
2019	4	-	8	-
2020	2	-	2	-
2021	-	1	-	1
2022	1	4	5	-
2023	2	4	5	1
TOTAL	614	66	54	41

As can be seen from Table 1, most of the periodically inspected blasting machines were of the Vopil M514 type (Figure 1), 614 certification reports.

Fig.1. Vopil M514 Blaster machine

The Vopil M 514 mining blaster is designed to trigger low-intensity electric detonators connected in series for carrying out blasting operations with explosives in mines with a risk of explosive atmosphere (coal mines).

The procedure for working with Vopil M 514 blasters is as follows:

- Connect the ends of the main ignition cable to the terminals on the blaster;
- Mount the operating crank and turn it clockwise at a speed of more than 4 revolutions per second until the "charged" signal lamp lights up and then until the explosion starts.

Technical data of Vopil M514:

- Rated voltage: 1800 V d.c.
- Capacity of the charging capacitor: 2 μF
- Maximum number of low-current electrical detonators connected in series: 100 pieces
- Maximum circuit resistance: 510 Ω
- Type of detonator: low-current electric detonator
- Detonators must be connected in series only.

Since the analysis followed the behaviour of a mining capacitor-based blasting machine over time, and the data on Vopil M514 blasters was much more extensive than that on other types of blasters (EI-200D and ECI-100), only the behaviour of Vopil M514-type blasters was followed.

The AICmI type mining blasters are of a different generation, they are electronically triggered blasters, with firing circuit control, etc. They were not included in this analysis.

The analysis was carried out on data from 18 blasting machines over a period of 7 years (2003 ... 2010). Of the 169 Vopil M514 blasters from 2003, only 18 were still undergoing verification in 2010.

In the year 2023 only two blasting machines that had not been verified at INCD Insemex Petroşani and therefore were not taken in the study, arrived to be verified.

Data were available for 6 repairs. Repairs were made by replacing the storage capacitors in all cases, replacing the discharge tubes in 2 cases and re-magnetising the inductor stator in one case.

It was also found that in 2 blasting machines the stored energy had increased at some point which implies that they were repaired.

The study period was limited to only 7 years and to a set of 18 Vopil M514 blasters. It was found that 8 blasters were repaired during this period and therefore these were also removed from the analysis. In the end, only 10 blasters were analysed over a period of 7 years (2003 ... 2010).

The aim of the analysis was to determine the existence of a decrease in energy output over the life of the blasting machines and the possible causes of this decrease.

Data was collected from test reports which included records of output voltage and output energy.

The blasting machine shall be capable of reliably delivering sufficient ignition energy (kRe) to reliably ignite the maximum number of electrical detonators with the permissible ignition lead resistance in the circuit. [10]

The value of the output pulse is plotted over the seven years for the 10 blasting machines. (Figure 2).

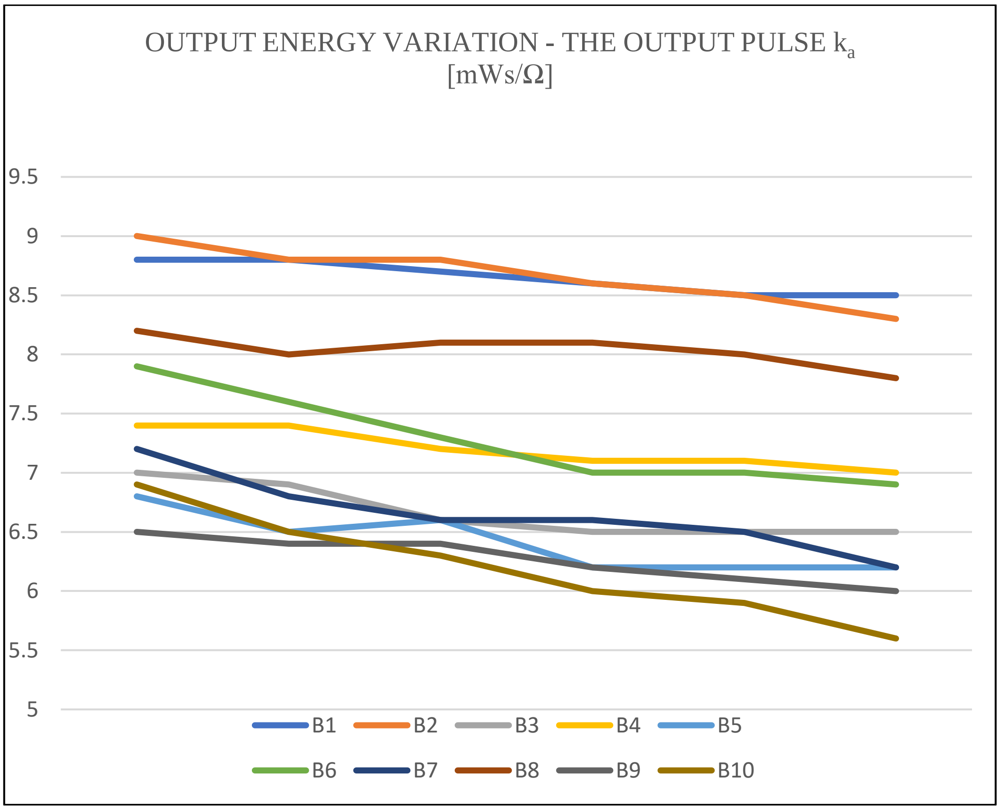

Fig.2. The output pulse variation

6. CONCLUSIONS

The analysis of the data collected over a period of 10 years from the certification reports issued by INCD Insemex Petroşani revealed the following:

- Table 1 shows a sharp decrease in the number of units inspected in 2010. This sharp reduction is due to the decline in the mining industry, particularly in the Jiu Valley. Financial problems and reduced production caused mining units to abandon many of the blasters they had previously used. Another explanation would be that they have started to carry out their own periodic checks.

- The longest-lived capacitor-based blasting machines were those produced in the GDR - Vopil M514.

- Vopil M514 blasters have electrolytic capacitors for energy storage, the required voltage is supplied by an electromagnetic inductor and the triggering is done by a gas tube.

- The graph in Figure 2 shows that there are variations in the energy released by the blaster, in the sense of a decrease, but the decrease is small and does not pose a problem, even though the blasters are very old (blasters produced from the 1960s to 1987 were studied).

- Reducing the output voltage and/or reducing the capacity of the energy storage capacitors can reduce the output energy.
- The drop in output voltage may be due to failure of the discharge tube (which sets the voltage at which the discharge occurs).
- The drop in energy may also be due to a reduction over time in the capacity of the capacitors that store electrical energy.
- A drop in the output voltage of the electromagnetic inductor causes the detonator to stop working as it is unable to charge the capacitor to a voltage sufficient to trigger it.
- Most repairs have been carried out by replacing the storage capacitors. The inductor stators were also re-magnetised and the gas discharge tubes replaced.
- It was found that users of Vopil M514 blasters were gradually replacing them with more modern, safer and more reliable electronic capacitor-based blasters, inductor-charged blasters or battery-charged blasters.
- Vopil blasters were very reliable blasters, simple in design, robust and well suited to the harsh working environment in which they were used.
- It was also found that the correct choice of components, robust circuit design and regular and careful maintenance are essential to ensure the reliability of mining blasters.
- The study would be more conclusive if data from more blasters could be collected. Many of the blasting machines verified at INCD Insemex in 2003, although still in use, have not been sent for verification and therefore traceability could not be achieved for them.
- A future comparative analysis of electronic and induction mining blasting machines can identify the advantages and disadvantages of the two types of mining blasting machines. Also, by collecting and analysing data from electronic mining blasting machines currently in use in mines, potential problems that may arise from long-term use can be identified.

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