UNITED STATES DEPARTMENT OF LABOR
Mine Safety and Health Administration

EVALUATION OF THE DYNO-NOBEL DIGISHOT™ ELECTRONIC BLAST INITIATION SYSTEM--- REQUIREMENTS FOR SHUNTING AND CIRCUIT TESTING

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By

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Purpose

Inquiries from manufacturers have been received by MSHA about how the requirements for shunting and circuit testing are applied to electronic detonators for use in mine blast initiation systems. The purpose of this report is to discuss the technical and field evaluations of the Dyno-Nobel Digishot™ electronic detonator initiation system and its aspects of meeting "shunting" and "circuit testing" with regard to the intended MSHA standards.

Introduction

The coal and metal-nonmetal mine requirements for shunting and circuit testing **electric** detonators are specified in 30 CFR 77.1303(y)(1),(2),(3) and 77.1303(z); 56.6401(a),(b),(c); 56.6407(a),(b),(c),(d) and 57.6401(a),(b),(c) and 57.6407 (a) and 57.6407 (b). **Electric** blasting systems are designed differently than electronic detonator initiation systems and the design features are not the same. Each electronic detonator initiation system differs in design, construction, operation and testing features. To resolve the issue of "shunting and "circuit testing", technical information was evaluated and a mine site examination was made on the Dyno-Nobel Digishot™ electronic detonator system. This report presents the findings of an evaluation of the Dyno-Nobel Digishot™ electronic blast initiation system regarding the shunting and circuit testing requirements as required by Mine Safety and Health Administration (MSHA) regulations for electrically initiated detonators. The Digishot™ electronic blast initiation system consists of the Digishot™ electronic detonator with down-hole wire with two-wire connector for connecting surface wires, the Digishot™ Tagger which is the circuit testing and logging device, and the Digishot™ Blaster for functions such as checking the blast layout, programming and arming the electronic detonators, and arming and firing the electronic detonators. An evaluation of the Dyno-Nobel Digishot™ electronic detonation system was necessary to determine its intrinsic shunting and circuit testing capabilities. Both a technical review and an examination of use in the field were performed on the Digishot™ system to ensure the design of this electronic detonation system meets or exceeds the intended MSHA safety standards. The design and operational aspects of the Digishot™ system were reviewed and evaluated from technical information supplied from Dyno Nobel. Subsequently, a field visit was made to examine and witness the use of the Digishot™ electronic blast initiation system at a surface mine site near Strasburg, Virginia.

Electric Detonators

Electric detonator systems for performing blasting operations have been in use in the mining industry for many decades. They are used in both series and parallel blasting circuits. An electric detonator consists of two leg wires embedded in a metal shell which contains a high explosive base charge designed to initiate other explosives. Electric detonators are typically designed with an ignition mixture, a pyrotechnic fuse train (for the delay element) and a base charge, respectively (See Figure 1). A thin metal filament, known as a bridgewire, is attached between each end of the leg wire and is embedded in an ignition mixture. The pyrotechnic delay element is designed to burn at an approximated rate. The length and composition of the pyrotechnic train control the approximate rate of burn and thus the timing of when the detonator fires. Electric detonators are supplied with a distinctive, numbered tag to facilitate easy identification of the delay period. Since the approximate rate of burn is subject to variation, the firing time accuracy of the electric detonator is affected. When sufficient electrical current passes through the bridge wire, it becomes hot enough to ignite the ignition mixture. This event initiates the pyrotechnic element in the delay train which then initiates the base charge.

All electric detonators produced in the USA have shunts on the free ends of the leg wires. The shunt provides a low resistance path to prevent current from flowing through the bridge wire of the electric detonator. With a shunt, both of the leg wires are at the same potential to prevent extraneous current flow into the detonator. In addition, some designs completely enclose the ends of the wires in order to prevent corrosion and to prevent bare wires from contacting extraneous electrical current sources. The shunt is removed when an electric detonator is connected into the blasting circuit.

Electric detonators are designed to fire when a certain level of electrical energy is supplied. If electrical energy is applied too early or applied at too low of a level, the likely result is premature detonation or a failed detonation which is also known as a misfire. An extraneous source of electric current represents a potential source for initiation of an electric detonator. Sources such as lightning, high voltage power lines, radio transmitters, and static electricity must be avoided when preparing a blast site. There are also occurrences where the energy from lightning has traveled several miles along pipes or cables into an underground mine and can represent an unsuspected source for initiation of electric detonators.

When electric detonators are initiated, current leakage from the blasting circuit must also be prevented. If bare wires are allowed to come into contact with another conductor or even a conductive portion of the ground, some of the electric energy may leak out of the circuit causing misfires. Other events that affect the amount of current reaching electric detonators occur when either too many electric detonators are connected into the circuit and the increased resistance causes a greater voltage drop than intended or if there is a failure to connect all the intended electric detonators into the circuit.

When using electric detonators, the continuity and resistance of the individual detonator as well as the entire circuit needs to be tested with a blasting galvanometer. A blasting galvanometer is used to check the individual detonators prior to making the primer and again prior to stemming the borehole. Care should be taken when stemming a borehole to prevent any possible damage to the detonator leg wires. Once the circuit is completely wired, it should be checked again. When the blast line is connected to the circuit, the resistance needs to be checked prior to connecting the blasting unit.

Electronic Detonators

Electronic detonator systems are new technology advancements for the initiation of blasts in mining operations. Their introduction for use in mine blasting operations continues to advance. Several advantages for using electronic detonators are precise timing, reduced vibrations, a reduced sensitivity to stray electrical currents and radio frequencies, and a great reduction in misfires through more precise circuit testing.

Electronic detonators have been designed to eliminate the pyrotechnic fuse train that is a component of electric detonators, thus improving timing accuracy and safety. For the electronic detonators, typically an integrated circuit and a capacitor system internal to each detonator separate the leg wires from the base charge. Depending on the design features of the electronic detonator, the safety and timing accuracy can be greatly improved. An example of the constructional features of an electronic detonator is shown in Figure 2. The electronic detonator is obviously a more complex design compared to a conventional electric detonator. A specially designed blast controller unique to each manufactured system transmits a selectable digital signal to each wired electronic detonator. The signal is identified by each electronic detonator and the detonation firing sequence is accurately assigned. The manufacturer's control unit will show any incomplete circuits during hookup prior to initiation of the explosive round. The wired round won't fire until all detonators in the circuit are properly accounted for with respect to the current blasting plan layout.

Using electronic detonators as designed and recommended by the manufacturer require specialized devices to identify, program and arm the blasting circuit. The detonators, connecting wires and accompanying items such as taggers, loggers, circuit testers and blast controllers are typically referred to as electronic blasting systems or electronic initiation systems.

Technical Discussion

As part of the resolution of the "shunting" and "circuit testing" issues, MSHA conducted a technical evaluation of the Digishot™ electronic blast initiation system. The Digishot™ electronic detonator system is a fully programmable blasting system. The system includes the Digishot™ electronic detonator with connecting wires, the Digishot™ Tagger which is a circuit testing and detonator tagging device, and the Digishot™ Blaster for setting the electronic detonator delay times, programming the detonators, arming the electronic detonators and firing the blast. The system can accommodate up to 300 electronic detonators per blast. The Digishot™ electronic detonator with downhole wire and two wire connector is shown in Figure 3. The Digishot™ Tagger is shown in Figure 4 and the Digishot™ Blaster is shown in Figure 5.

In preparing a round to be blasted, the Digishot™ electronic detonator with down-hole wire (Figure 6) is inserted into a booster to form a primer to be positioned in a blast hole powder column (Figure 7). Once the primers are positioned and the powder charge added, the condition of each detonator is tested using the Digishot™ Tagger at the borehole before the hole is stemmed. The detonator wire is plugged into the receptacle on the Tagger, as shown in Figure 8 and the detonator circuitry is tested for short circuits, open circuits, and operational integrity. Once these tests have been made, the steps are repeated for each electronic detonator in the blast hole powder column before stemming.

The electronic detonators are checked for operational integrity and assigned a location with the Tagger before stemming. After stemming, all detonators are clipped on to a 22 gauge twisted pair lead line. The entire circuit is then checked with the Tagger for current leakage, the correct number of detonators, and assigned position of detonators. Any discrepancies between the blast plan and the Tagger data are corrected at this time. The lead line or firing line is then run to the firing point. Again, the Tagger is used to check for operational status and current leakage. The firing line is attached to the Blaster (Figure 9). The Blaster is turned on, and a password is entered. Desired delay times are entered into the Blaster, and the detonators are programmed. The delay times are verified by checking the displayed firing times for each detonator against the shot plan. Modifications in assigned firing times can be made at this point if needed.

The blast site must be cleared prior to arming the round. The "arm" program is selected, the Smart Key is inserted into the Blaster (Figure 10), and the authorization PIN is entered. After 30 seconds for arming, the Blaster is ready to fire. The "fire" buttons are pressed within 90 seconds of arming completion, and the shot is fired.

Mine Field Trip

A trial shot of the Dyno Digishot™ electronic blasting system was conducted at the O-N Minerals Middletown quarry near Strasburg,VA on January 3, 2008. The field trial was observed for MSHA by personnel from the Commonwealth of Virginia, Department of Mines, Minerals and Energy.

The trial was conducted by Mr. Sandy Tavelli, Product Manager - Electronics, Dyno Nobel, Inc., and Mr. Stuart Brashear of Dyno Consult. Mr. Danny Shrout of Dyno Nobel, Inc. was the Certified Blaster. Other Dyno Nobel, Inc. personnel assisted with loading the shot. The trial was observed by Mr. David Benner, Eastern Mine Inspector Supervisor, Mr. Thomas Bibb, Engineering Manager, and Mr. John Guth, Mine Inspector, all of the VA Department of Mines, Minerals, and Energy.

The weather conditions were cold, clear, and calm, with a temperature of 27 degrees Fahrenheit at the time of firing. The shot consisted of 26 holes in 3 rows. The holes were 5 inches in diameter, and were 33 feet deep, except for the left hand hole at the end of each row, which was 9 feet deep to accommodate a natural bedding plane. The holes were variously loaded with ANFO/emulsion blend and/or bulk ANFO. Cast boosters weighing one pound were used for priming. Three (3) holes contained two detonators each.

The Digishot™ electronic detonator system consisted of the Digishot™ electronic detonators, the Digishot™ Tagger unit, and the Digishot™ Blaster unit.
The detonators consisted of a detonator assembly containing the electronic timing circuit capable of timing delays from 0 to 20,000 milliseconds, a 2-conductor lead wire of varying lengths up to 40 meters, and an insulation displacement connector.

The Digishot™ Tagger unit is a 9 volt battery powered handheld unit used to assign an individual detonator its location in the blast pattern, assign "special"(out of sequence) individual detonators, test individual detonators, test strings of connected detonators, and view a list of "tagged" detonator locations.

The Digishot™ Blaster unit is a portable rechargeable battery powered unit used to check the blast layout and detonator connections, set the detonator time delays, program the individual detonators with the appropriate time delay, arm the detonators, and fire the detonators. The Digishot™ Blaster unit is capable of firing up to 300 detonators from a maximum distance of 2.5 kilometers, and multiple units can be utilized in a master and slave format.

Personnel from the Commonwealth of Virginia, Department of Mines, Minerals and Energy observed the loading of last 3 holes, and the tagging, hook up, testing, programming, and firing of the shot. One hole was purposefully left out of the hook up, and the system provided information to indicate its absence. Also, 3 holes were loaded with 2 detonators in each hole, and a tagging mistake was made, identified, and corrected.

Each detonator was tagged with its relative location in the shot by reference to its hole number in each row as ordered by the designed firing sequence. The detonators were connected in parallel to a 22-gauge twisted pair lead line by clipping the insulation displacement connector from the detonator on to the lead line. The connector is also packed with a dielectric grease to minimize current leakage.

After hook up, the whole shot was successfully tested for continuity and current leakage. After completion of hook up and testing, the lead line was connected to an 18-gauge duplex firing line, which was coupled to the firing point approximately 800 feet to the rear of the shot. At the firing point, the firing line was connected to the Digishot™ Blaster unit. A delay time of 25 milliseconds between holes in each row was assigned, and a delay of 92 milliseconds between rows was assigned. Again, the circuit was tested for continuity and current leakage. After programming, a representation of all detonators and their assigned firing times was available on the LCD screen of the Digishot™ Blaster unit. The shot was successfully armed and detonated at approximately 12:06 PM. Figure 11 shows the results of the blast.

In summary, the Dyno Digishot™ electronic detonator system performed in the field test as designed.

Acknowledgement

The field test examination, report information used in the Mine Field Trip section and review of the Dyno Digishot™ electronic detonator system for MSHA was provided by personnel of the Commonwealth of Virginia, Department of Mines, Minerals and Energy and is gratefully acknowledged. Their assistance was significant to completion of this evaluation and report.

Conclusions

The Digishot™ electronic detonator is provided with an internal means of shunting that is at least as effective as the external shunting required for conventional electric detonators. The Digishot™ electronic blast initiation system using the dedicated Digishot™ Tagger has its own integral testing and verification procedures that meet the intended MSHA requirements for circuit testing. Therefore, the Digishot™ electronic blast initiation system does not need to be physically shunted and circuit tested by using a blaster's galvanometer as would be performed for conventional electric detonators. Because of the unique design and construction of this system, it must be used according to the manufacturer's instructions.

Summary

Electronic detonator systems are one of the newer technologies being introduced into the mining industry. Their advantage is thorough pre-blast circuit testing and very precise detonator firing time. The design and operational features of the Digishot™ electronic blast initiation system have been technically reviewed and the field use of the system has been observed at a surface mine site. The Digishot™ electronic blast initiation system has its own proprietary electronic design for shunting and circuit testing that meets the intended MSHA requirements. This system provides thorough pre-blast circuit testing and precise detonator firing times. The Digishot™ electronic detonator safety features are obtained by the use of integrated circuit chips, internal capacitors, and other proprietary electronic features. The Digishot™ electronic blast initiation system cannot be initiated by a conventional blasting unit, nor can it be activated without entering security codes. However, electronic detonators can still be initiated by lightning, fire, and impact of sufficient strength. Their added safety features do not preclude proper transportation, storage and handling as an explosive product.

This report is posted on MSHA's web site and may be accessed under Technical Reports at http://www.msha.gov/S&HINFO/TECHRPT/TECHRPTS.asp. Also, an MSHA Program Information Bulletin (PIB 04-20) on electronic detonators and requirements regarding shunting and circuit testing is available on MSHA's web site. The PIB 04-20 may be accessed at http://www.msha.gov/regs/complian/PIB/2004/pib04-20.htm.

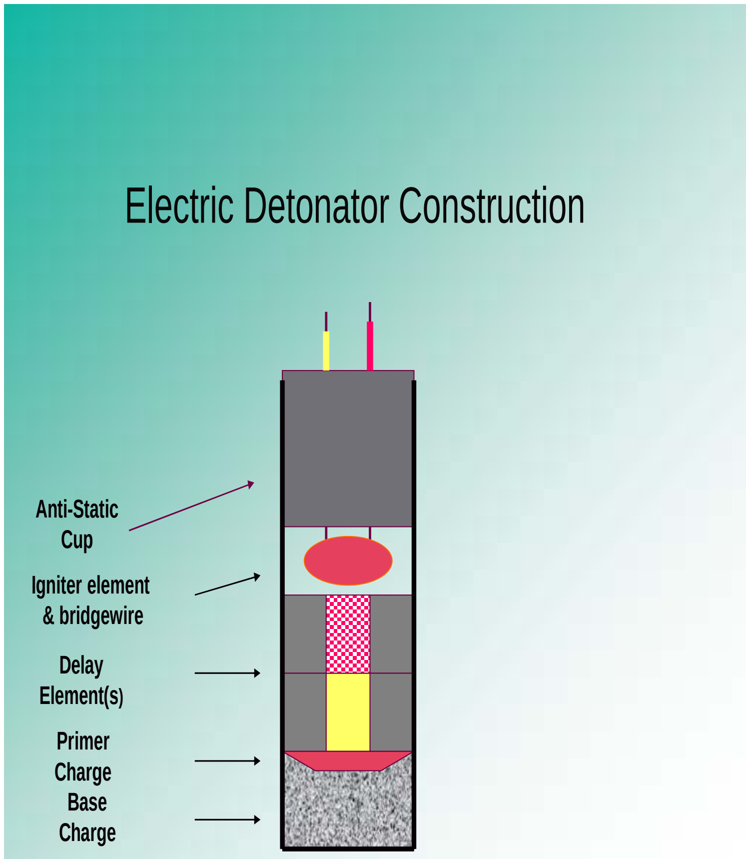

Figure 1 - Electric detonator design (generic)

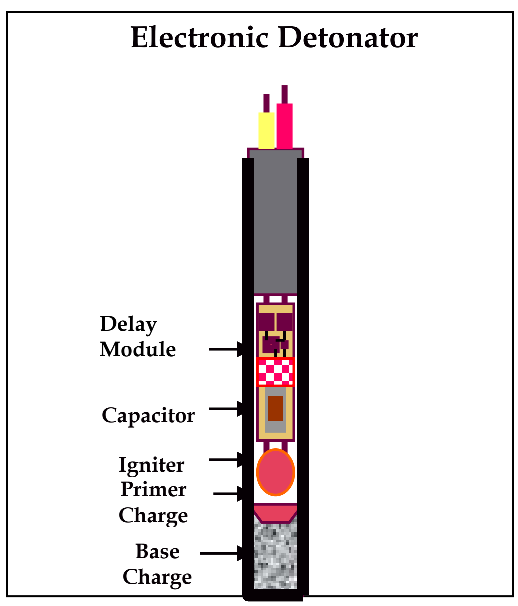

Figure 2 – Electronic detonator design (generic)

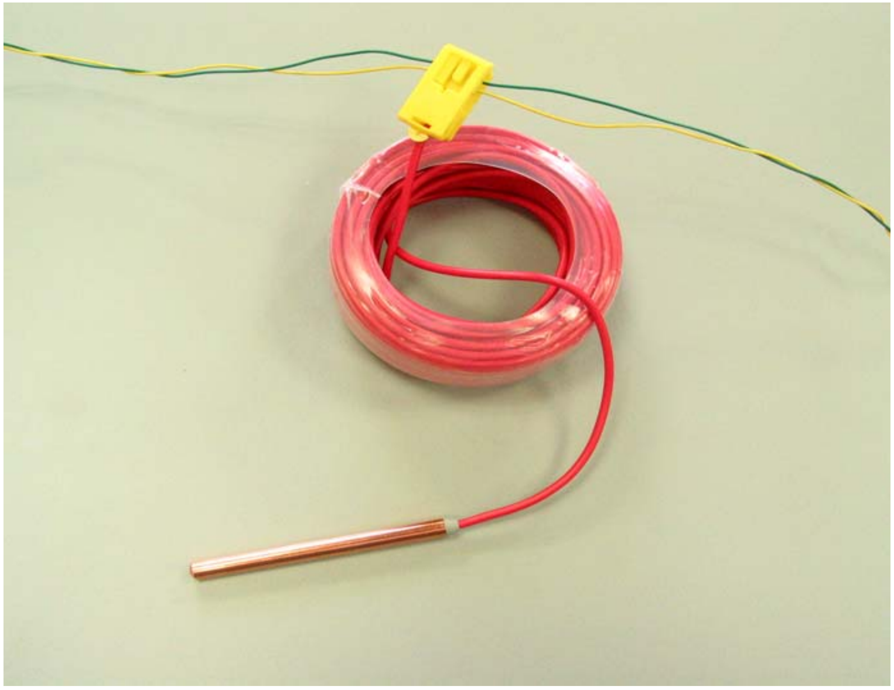

Figure 3 – Electronic detonator with down-hole wire coil and 2-wire connector

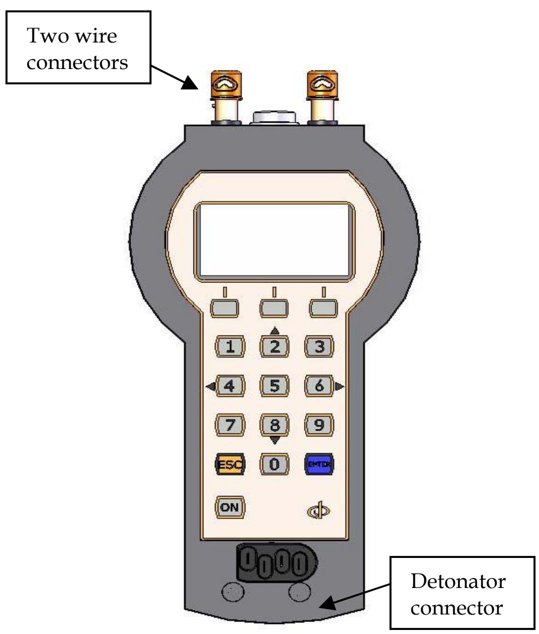

Figure 4 - Digishot™ Tagger

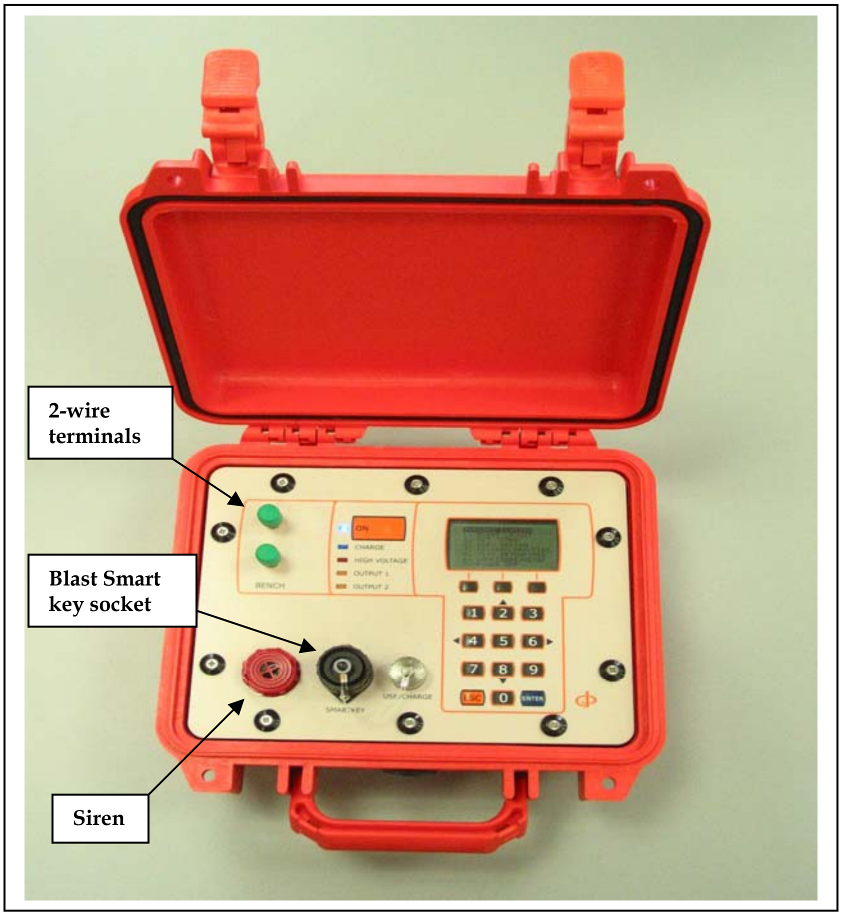

Figure 5 - Digishot™ Blaster

Figure 6 – Electronic detonators & down-hole wire coil for connection & tagging

Figure 7 – Placement of Digishot™ electronic detonator into a booster

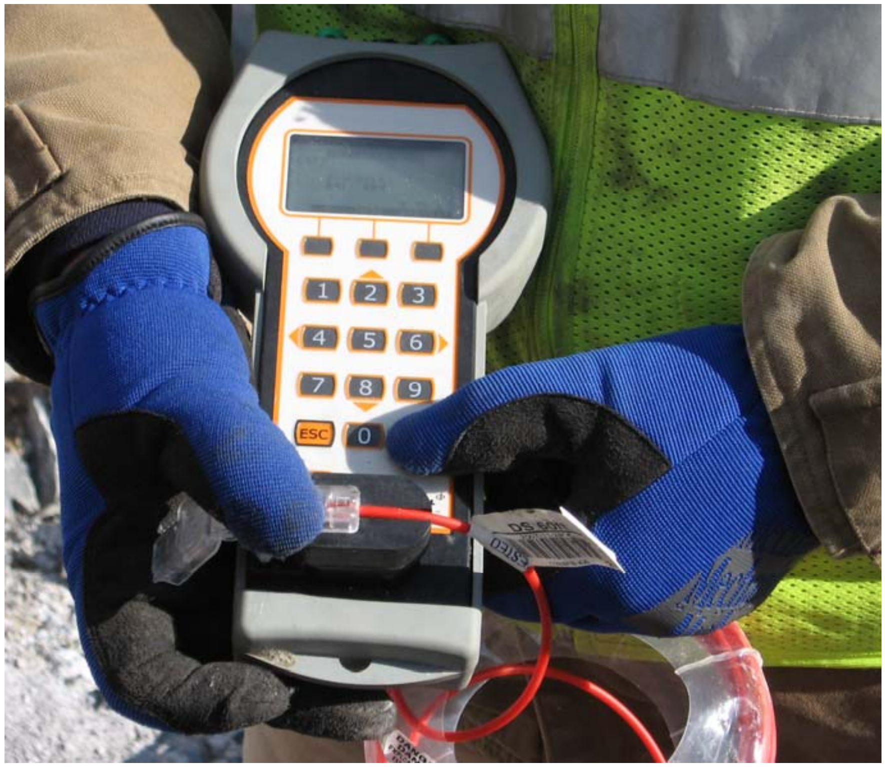

Figure 8 – Inserting the electronic detonator wire into the Digishot™ Tagger

Figure 9 – Connection into the Digishot™ Blaster for checking the blast layout and programming of the blast

Figure 10 – The Digishot™ Smart key for initiation of the blast inserted into the Blaster

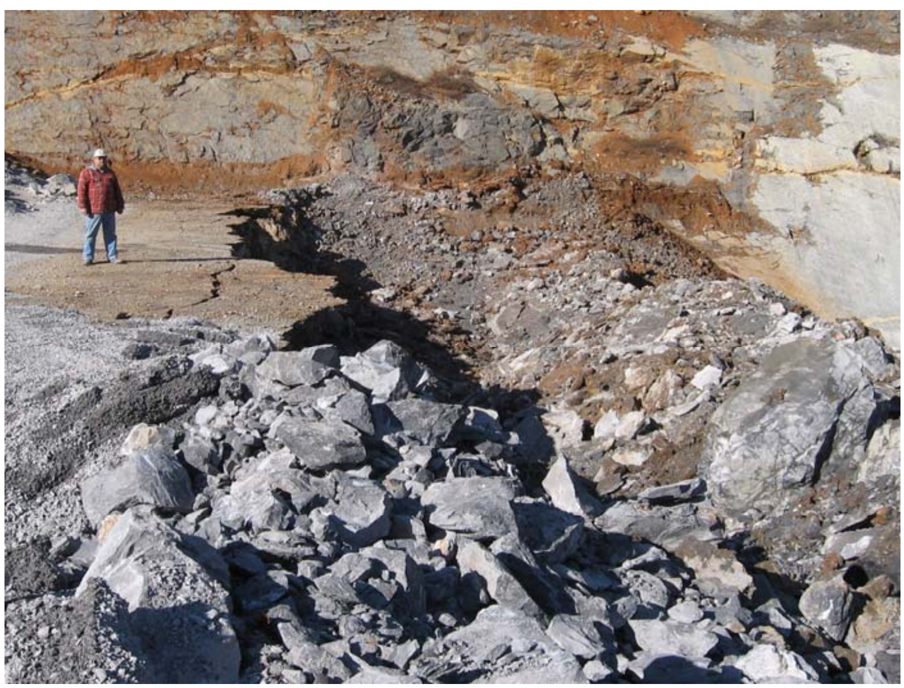

Figure 11 – Muck pile of the blasted material