UNITED STATES DEPARTMENT OF LABOR
Mine Safety and Health Administration

EVALUATION OF SPECIAL DEVICES INC./DAN-MAR ELECTRONIC DETONATOR BLAST INITIATION SYSTEM-- REQUIREMENTS FOR SHUNTING & CIRCUIT TESTING

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By

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CAPTIONS

1. **Purpose**

The purpose of this report is to present the technical findings and the evaluation of "shunting" and "circuit testing" for the Special Devices, Inc. electronic detonator ignition module used with the Dan-Mar digital logger and blasting machine with respect to the MSHA standards.

For e**lectric** detonators, the coal and metal-nonmetal mine requirements for shunting and circuit testing 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 systems and the operational features are not the same. Each electronic detonator system differs in design, construction, operation and testing features.

To resolve the issue of "shunting" and "circuit testing", technical information was provided by Special Devices, Inc. (SDI) on the details of their electronic detonator ignition module and the Dan-Mar Company digital logger and blasting machine that is used exclusively with the SDI electronic detonator. A trip was also made to examine the SDI electronic detonator system and Dan-Mar digital logger and blasting machine during use in the field at a surface coal mine blast site.

2. **Introduction—Using 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. 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. In other words, 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 supplied with a distinctive, numbered tag to facilitate easy identification of the delay period.

Since electric detonators are designed to fire when electrical energy is supplied to them, any extraneous source of electric current represents a potential source for initiation. Sources such as lightning, high voltage power lines, radio transmitters, and static electricity must be avoided. 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 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. If several circuits are wired in parallel, the total resistance of the firing circuit must be checked after each individual circuit is wired into the main circuit. When the blast line is connected to the circuit, the resistance needs to be checked prior to connecting the blasting machine.

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.

3. **Technical Discussion**

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 bridge-wire, 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. 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.

Electronic detonator systems are new technology advancements for the initiation of blasts in mining operations. Their introduction into mine blasting operations continues to advance. Several advantages for 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, and depending on the design features can greatly enhance safety and timing accuracy. The electronic detonator is obviously a more complex design compared to an electric detonator. Figure 2 is an illustration of the SDI electronic detonator.

In terms of the electronic blasting system, 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 according to the blasting plan layout. Figure 3 is an illustration of a blast layout incorporating the SDI electronic detonator and Dan-Mar digital logger and blasting machine.

SDI Electronic Detonator Ignition Module and Dan-Mar Blasting System

As part of the resolution of the "shunting" and "circuit testing" issues, a technical evaluation was made of the SDI electronic initiation module system which incorporates the Dan-Mar Company Model DLG1600-1-N Digital Logger and the Dan-Mar Model DBM1600-2-KN Digital Blasting Machine. A trip was also made to examine the SDI electronic detonator system and Dan-Mar digital logger and blasting machine during use in the field at a surface coal mine blast site.

Technical information for evaluation by MSHA Technical Support was provided by SDI. The SDI electronic detonator ignition module has an assigned ID number held on the internal chip. The SDI electronic detonator with leg wire for connections is provided on a spool. In setting up the round to be blasted, the SDI electronic detonator is inserted into the booster. This primer is then loaded into each borehole. Next, the borehole is loaded with the chosen blasting agent. Prior to stemming the borehole, the Dan-Mar digital logger is hooked onto each leg wire and digitally checked for short circuits, open circuits, and operational integrity. Once this check has been made, the SDI electronic detonator is assigned its timing value. All of this information is stored in the Dan-Mar digital logger while the timing value is permanently stored into the integrated circuitry of the SDI electronic detonator. After the programming procedure is completed, all of the electronic detonators are hooked together by connecting with in-line snap-type connectors. Once the wiring is completed the Dan-Mar digital logger is connected to the blasting circuit for verifying the functionality of wired round. The logger then checks for firing line continuity, extra detonators, and for detonators that have faulty connections or no connections at all. The functionality check of each electronic detonator and the round(s) to be blasted by use of the Dan-Mar digital logger serves as a circuit continuity check with respect to MSHA requirements. The information is then checked against the blast plan. The logger is then connected to the Dan-Mar blasting machine to download the blast information. The blasting machine software fully verifies the system hardware, software and the integrity of the wired round. This information is displayed on the blasting machine screen before the blast can be armed and fired. The Dan-Mar blasting machine will not arm the round until

the system operational check is completed and no errors are indicated. The blast site must be cleared prior to arming the round. Then the blaster can fire the round.

4. **Mine Field Trip**

A field trip was made to a surface coal mine operation in Alabama to examine and witness the use of the SDI electronic detonator system with the Dan-Mar Model DLG1600-1-N Digital Logger and the Dan-Mar Model DBM1600-2-KN Digital Blasting Machine. The system performed very well in the field. The system detected two open blasting circuits which enabled the blasting crew to specifically locate and correct the fault. This prevented misfires from occurring and causing a safety hazard.

The blast site at the surface coal mine operation contained 188 holes. The diameter of and depth of each hole was 7- 7/8 inches and 50-60 feet, respectively. The electronic detonators and boosters were laid out and assembled. Figure 4 shows the SDI electronic detonator module with the spooled connecting wire.

Figure 5 show a primer being prepared for blast hole loading. The primers were lowered into each blast hole prior to loading with ANFO-emulsion blend. The ANFO was pumped into each blast hole from several bulk loading trucks (Figure 6).

In setting up the blast initiation system the Dan-Mar digital logger was connected to the leg wires of each electronic detonator separately. The electronics, circuit continuity, and integrity were checked for each SDI electronic detonator module (Figure 7). Then each detonator was programmed with the desired delay. The delay time is stored in the internal chip of the electronic detonator and the digital logger. Each detonator has a separate unique ID number assigned. The blast holes are then stemmed. Once the whole round has been programmed, all the detonators are then connected to the main firing line by the use of snap-type in-line connectors (Figure 8). The data from the digital logger is then transferred to the Dan-Mar blasting machine (Figure 9). The Dan-Mar blasting machine (Figure 10) then checks the wired round for short circuits and unconnected firing lines, and missing or extra detonators. Then the SDI blasting machine checks all of the functions of each individual electronic detonator. This test showed two detonators were missing and indicated the blast hole numbers of where they should have been connected. This is an important feature, since it prevented the occurrence of a misfire. Also the Dan-Mar blasting machine acted as a blasting galvanometer by checking the continuity of the system.

A pre-blast diagnostic was performed after the detonators were connected into the wired round. The Dan-Mar blasting machine then indicated that the blast was ready to be armed and fired. The blast area was cleared. The wired round was then armed and fired as planned. All holes fired and there was little vibration, noise, and dust from the blast which is shown in Figure 11.

This field trip to examine the preparation of an actual blast showed that the SDI electronic detonators used with The Dan-Mar digital logger and blasting machine performed as intended. The diagnostic evaluation of the SDI electronic detonator modules with the Dan-Mar digital logger and the pre-blast diagnostic testing performed with the Dan-Mar blasting machine satisfied the MSHA requirement for circuit testing.

5. **Conclusions**

The shunting issue was evaluated in the technical review SDI electronic detonator module and the Dan-Mar digital logger and blasting machine system. The internal means of shunting for the SDI electronic detonator module is provided by its different design and constructional features than the conventional electric detonator. This system has gone through extensive testing which included sources of stray and extraneous electricity and performance is much safer than conventional electric detonators. The internal shunting via protective devices contained in the SDI electronic detonator replaces the need for a mechanical means of shunting. This system has its own integral elements for shunting within the SDI electronic detonator and circuit testing with the Dan-Mar digital logger and verification with the Dan-Mar digital blasting machine that meets the intended MSHA requirements. Therefore, from the detailed technical evaluation made by MSHA, this 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 design and construction of this system, it must be used according to the manufacturer's instructions.

6. **Summary**

Electronic detonator systems are one of the newest technologies being introduced into the mining industry. Their advantage is thorough pre-blast circuit testing and very precise detonator firing time. An integrated circuit chip and an internal capacitor system control the detonator initiation time. The electronic blasting systems observed have an unparalleled safety feature, since they cannot be initiated by a conventional blasting unit. However, electronic detonators can still be initiated by lightning, fire, and impact of sufficient strength. It is anticipated that a decrease in the number of pre-detonations, misfires, and other unintentional initiations should result from the use of electronic detonator systems.

The SDI electronic detonator ignition module used exclusively with the Dan-Mar Company Model DLG1600-1-N Digital Logger and the Dan-Mar Model DBM1600-2-KN Digital Blasting Machine has been technical reviewed and observed in actual operation at a mine site. This system has its own proprietary electronic design for shunting and circuit testing that meets the intended MSHA requirements.

Figure 1 – Electric Detonator Components

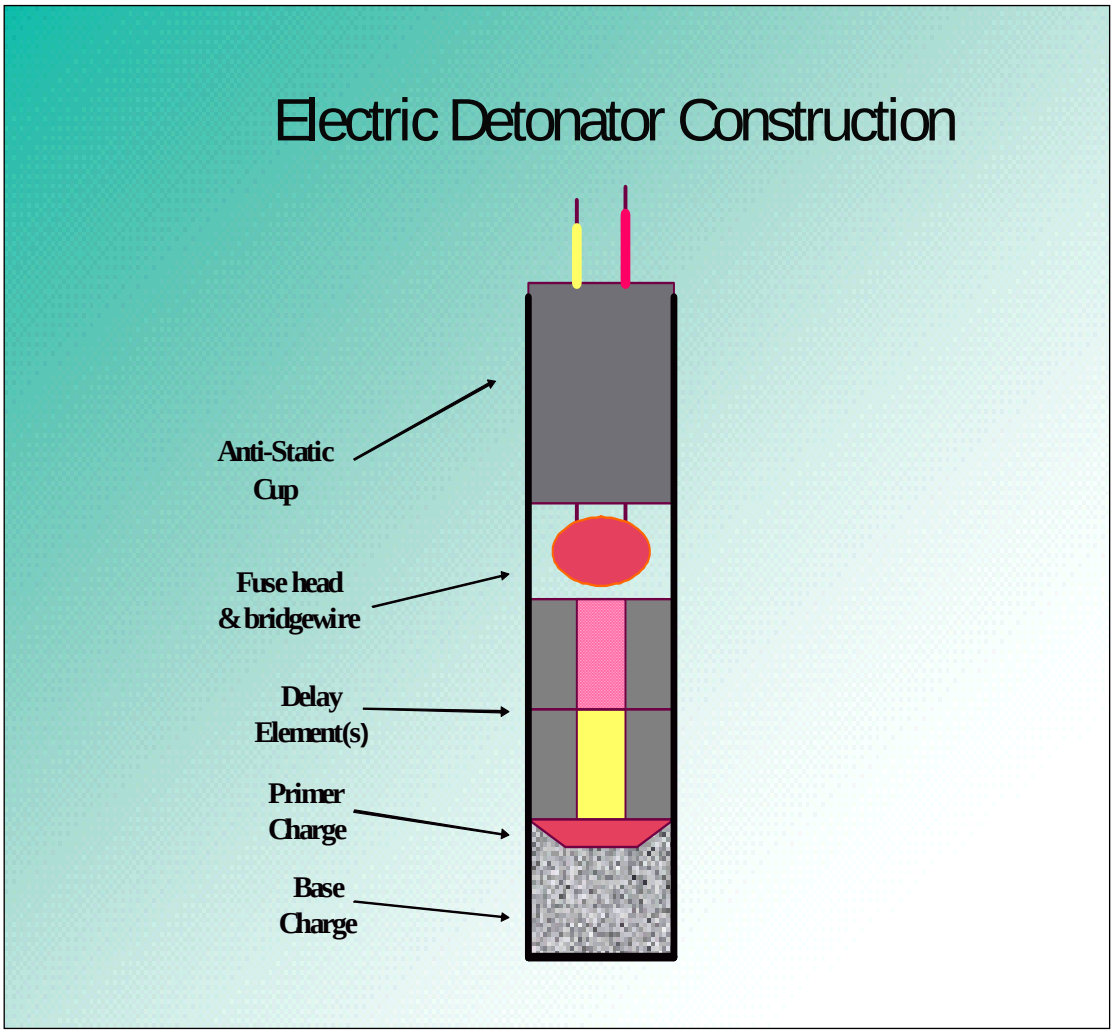

Figure 2 – SDI Electronic Detonator Components

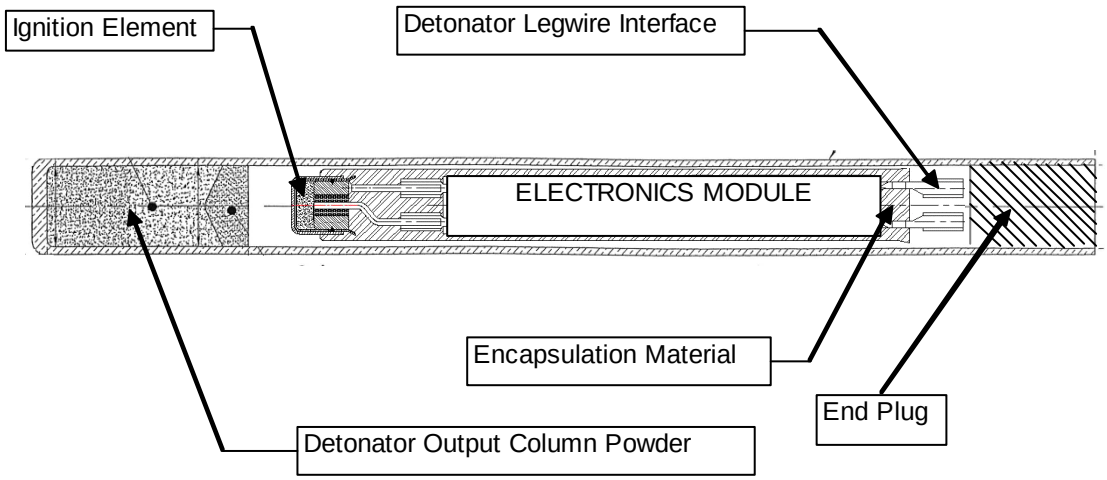

Figure 3 – Electronic Blasting System using SDI Electronic Detonators

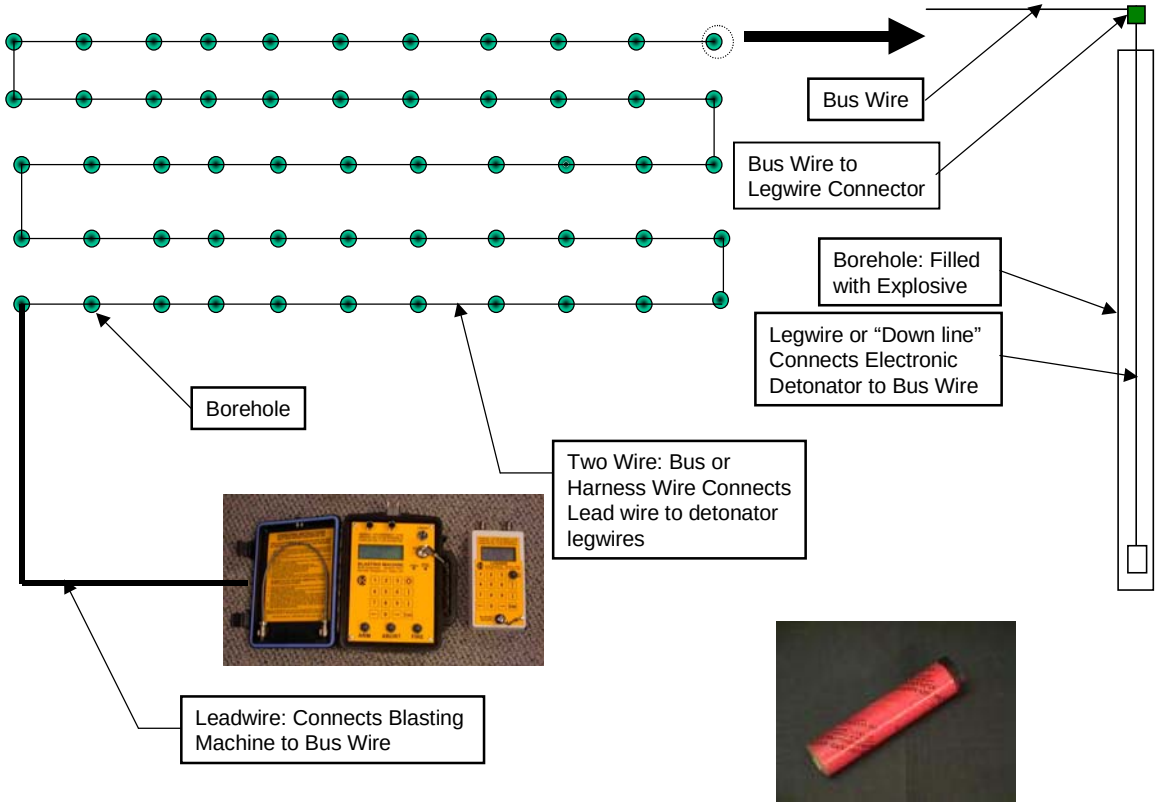

Figure 4 – An SDI Electronic Detonator Module with Spooled Leg Wire

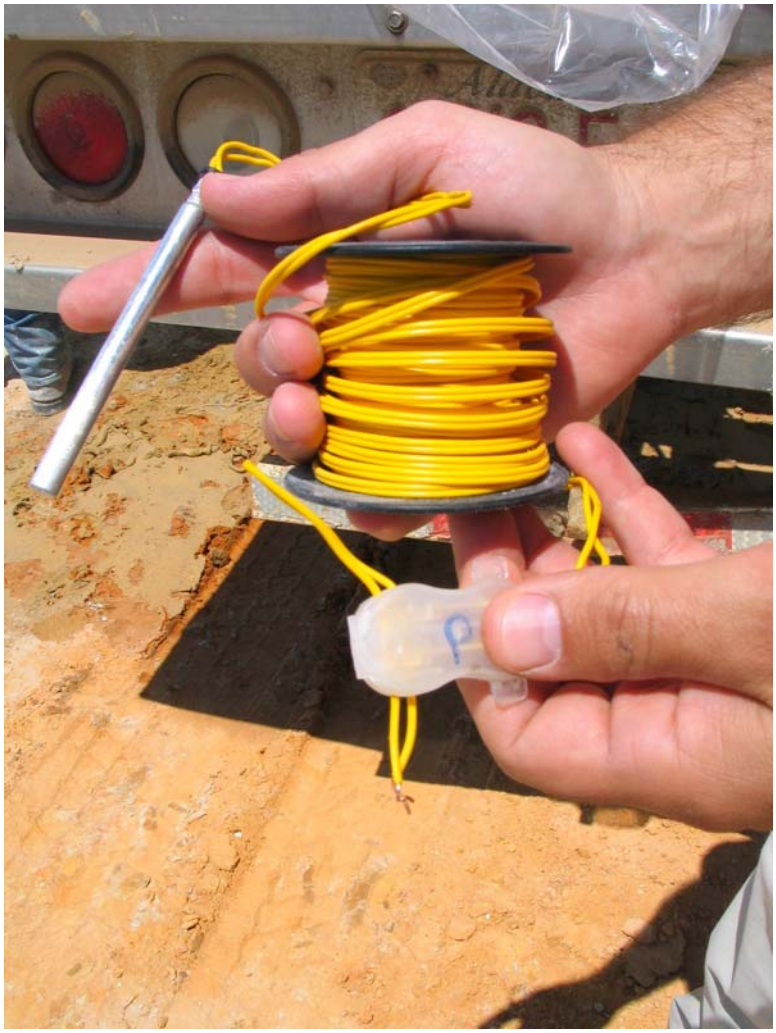

Figure 5 - Preparation of Primer for Blast Hole Loading

Figure 6 – Loading a Blast Hole with ANFO

Figure 7 – Dan-Mar Logger Check of SDI Electronic Detonator Hook Up

Figure 8 – Snap-Type In-line Connectors

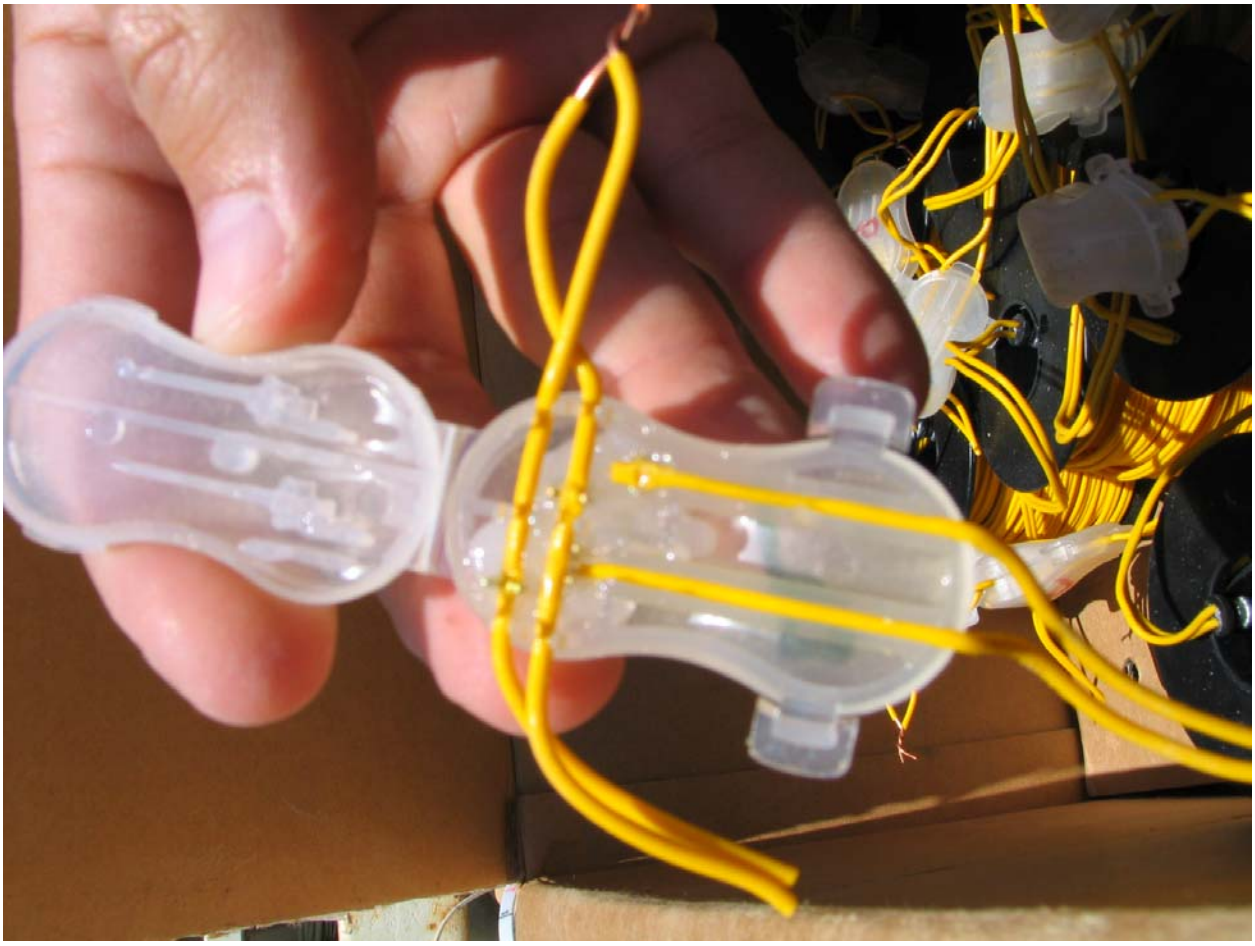

Figure 9 – Transfer of Logger Data to the Dan-Mar Blasting Machine

Figure 10 – Dan-Mar Blasting Machine

Figure 11 – Firing of the Blast