

UNITED STATES DEPARTMENT OF LABOR
Mine Safety and Health Administration

**EVALUATION OF ELECTRONIC DETONATORS--
REQUIREMENTS FOR
SHUNTING & CIRCUIT TESTING**

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By

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Purpose

MSHA has received a number of inquiries concerning how to apply the MSHA requirements for shunting and circuit testing to electronic detonators. The purpose of this report is to discuss the technical findings and the issues of “shunting” and “circuit testing” for electronic detonators with regard to the MSHA standards.

With respect to **electric** 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 design features are not the same. Each electronic detonator system differs in design, construction, operation and testing features.

In order to resolve the issue of “shunting and “circuit testing”, technical information was needed on the details of the various electronic detonators systems. The manufacturers as well as the Institute of Makers of Explosives (IME) were queried for technical information that would be evaluated to resolve these issues. Difficulties arose in obtaining the necessary technical information. Some contacts were made, but only two companies responded with technical information to complete the evaluation.

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 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. 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 is beginning 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 (See Figure 2). This system is obviously a more complex design compared to an 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 according to the blasting plan layout.

As part of the resolution of the "shunting" and "circuit testing" issues, a technical evaluation was made of both the Daveytronics® Digital Blasting System marketed by Advanced Initiation Systems (AIS) and the I-KON™ Digital Energy Controlled System marketed by Orica. Where Daveytronics and I-KON are used throughout this report, they are trademark designations. In addition to the technical evaluations, two separate field trips were made to surface mining operations to examine and witness the use of the Daveytronics and the I-KON electronic detonator systems.

Daveytronics® Electronic Detonator System (Advanced Initiation Systems)

Technical information for evaluation of the Daveytronics electronic detonator system by MSHA Technical Support was provided by Advanced Initiation Systems. The components of the Daveytronic electronic detonator are shown in Figure 3. The Daveytronic electronic detonator is characterized by the use of bright orange duplex legwire and no delay tag. However, connected to the orange duplex leg wire is a white plastic tag embossed with Daveytronic and a capital "E." The duplex wire is pre-wound on a plastic spool with the electronic detonator inserted into the core of the spool. In the process of setting up the round to be blasted, the Daveytronic electronic detonator is inserted into the booster. This booster is then lowered into each borehole. Prior to the stemming of the borehole, the Daveytronic specially designed programming unit is hooked onto each leg wire, one at a time (See Figure 4). During this step, the Daveytronic electronic detonator is automatically checked for short circuits, open circuits, and operational integrity. Once this check has been made, the Daveytronic electronic detonator is assigned its final timing value. All of this information is stored in the Daveytronic specially designed programming unit while the timing value is permanently stored into the integrated circuitry of the electronic detonator. After the programming procedure is completed, all of the electronic detonators are hooked together by connecting their leg wires to duplex connecting wire using a special silicon filled waterproof plastic connector (See Figure 4). Once the wiring is completed and the blast site is cleared, the programming unit is inserted into the Daveytronic blast control unit (See Figure 4). The system then checks for firing line continuity, extra detonators, and for detonators that have faulty connections or no connections at all, and displays the number of blast holes in the wired round. The system can even tell if there are damaged detonators. The Daveytronic blasting controller will not arm the round until the system operational check is completed and no errors are indicated. At this point the blaster can fire the blast, otherwise the system disarms after a short time and the system check procedure must be started all over again.

I-KON™ Electronic Detonator System (Orica USA Inc.)

Technical information for evaluation by MSHA Technical Support was provided by Orica USA, Inc. The Orica I-KON digital electronic detonator system is characterized by having bright yellow duplex legwire with bright orange downline connectors and a unique ID tag for each detonator (See Figure 5). Each electronic detonator has an assigned traceable ID number held on the internal chip and printed on a tag. The turquoise paper tag is printed with a traceable ID number, a capital "E", the length of the wire and the manufacture date. The duplex wire is on a spool which has a pocket to hold the electronic detonator. In setting up the round to be blasted, the I-KON 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 I-KON specially designed programming logger is hooked onto each leg wire, one at a time (See Figure 6). During this step, the I-KON electronic detonator is automatically checked for short circuits, open circuits, and operational integrity. Once this check has been made, the I-KON electronic detonator is assigned its final timing value. All of this information is stored in the I-KON specially designed programming logger while the timing value is permanently stored into the integrated circuitry of the electronic detonator. After the programming procedure is completed, all of the electronic detonators are hooked together by connecting their snap-type downhole connector to twisted pair connecting wire. The order of connecting the electronic detonators to the twisted pair connecting wire is non-sequential. Once the wiring is completed the programming 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 information is then checked against the blast plan. The logger is then connected to the I-KON Blaster to download the blast information (See Figure 6). There are two sizes of blasters, a Blaster 400 and a Blaster 1600. The Blaster 400 can control two loggers giving a blasting system capacity of 400 electronic detonators. The Blaster 1600 can control eight loggers giving a blasting system capacity of 1600 detonators. The I-KON Blaster software fully verifies the system hardware, software and the integrity of the wired round. This information is displayed on the Blaster screen before the blast can be armed and fired. The I-KON Blaster will not arm the round, until the system operational check is completed and no errors are indicated. The blast site is cleared prior to arming the round. Then the blaster can fire the round.

4. Mine Field Trips

Two separate field trips were made to surface mining operations to examine and witness the use of the Daveytronics and the I-KON electronic detonator systems. The systems performed very well in the field. In both visits, the system detected 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.

Surface limestone mine visit. A visit was made to a surface limestone mine operation in Western Pennsylvania to view the Daveytronic digital blasting system in operation. The blast site contained 51 holes. The diameter of and depth of each hole was 6-1/2 inches and 68 feet, respectively. The electronic detonators (See Figure 7 and 8) and boosters were laid out and assembled. These primers were lowered into each blast hole prior to loading with ANFO from a bulk loading truck. The programming unit is connected to the leg wire of each electronic detonator separately. The electronics, circuit continuity, and integrity of electronic detonators in the blast plan were checked. Each detonator was programmed with the desired delay. The delay time is stored into the internal chip of the electronic detonator and programming unit. In preparation for blasting, each blast hole is loaded with ANFO from a bulk loading truck (See Figure 9) and 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 silicon filled waterproof plastic connectors. The data from the programming unit is then transferred to the Blast Controller which is show in Figure 10. The programming unit is visible on the left side of the Blast Controller in Figure 10. The Blast Controller is then used to check the wired round for short circuits and unconnected firing lines, and missing or extra detonators. Then the Blast Controller checks all of the functions of each individual electronic detonator. This test showed two detonators were missing and indicated the location of where they should have been connected. A pre-blast diagnostic was performed after the two detonators were connected into the wired round. The Blast Controller 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. Figure 11 shows the area of blasted limestone. This field trip to examine an actual blast showed that the Daveytronic digital electronic blasting system performed as intended. The diagnostic evaluation using the Daveytronic programming unit and the preblast diagnostic testing performed with the Daveytronic Blast Controller satisfied the MSHA requirement for circuit testing.

Surface coal mine visit. A visit was made to a surface coal mine operation in Western Indiana to view the Orica I-KON digital electronic detonator system in operation. The blast site contained 93 holes. The diameter of each hole was 9 inches and the depth was 50-60 feet. The electronic detonators and boosters were laid out and assembled. The I-KON electronic detonator with its unique ID tag is shown in Figure 12. A one pound booster primed with an Orica I-KON electronic detonator was lowered into each blast hole prior to loading with ANFO-emulsion blend from several bulk loading trucks (See Figure 13). The programming logger was connected to the leg wire of each electronic detonator separately. The electronics, circuit continuity, and integrity were checked. Then each detonator was programmed with the desired delay using the Orica Logger. The Orica Logger is shown in Figure 14. The delay time is stored in the internal chip of the electronic detonator and the programming logger. For tracking, each detonator has a separate unique ID number already assigned at the factory.

In preparation for blasting, each primed blast hole is loaded with ANFO from a bulk loading truck and then stemmed (See Figures 15 and 16). Once the whole round was programmed using the Orica Logger, all the detonators were then connected to the main firing line by the use of snap-type trunk line connectors. The orange colored snap-type connector is shown in Figure 17. The data from the programming logger is then transferred to the I-KON Blaster. The I-KON Blaster then checks the wired round for short circuits and unconnected firing lines, and missing or extra detonators. This test indicated that one hole, #92 was not registering as being connected. The Orica Blaster had indicated the particular unconnected detonator and it was located. This is an important feature, since it prevented the occurrence of a misfire. Also the Orica Blaster acted as a blasting galvanometer by checking the continuity of the system.

A pre-blast diagnostic was performed after the detonator for blast hole #92 was connected into the wired round. The I-KON Blaster 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 with the I-KON Blaster as planned. All holes fired and there was little vibration, noise, and dust from the blast as depicted in Figure 18. The blast was successful and the material from the blast was cast about 50 feet into the pit area.

This field trip to examine an actual blast showed that the Orica I-KON digital electronic detonator system performed as intended. The diagnostic evaluation using the I-KON programming logger and the preblast diagnostic testing performed with the I-KON Blaster satisfied the MSHA requirement for circuit testing.

5. Conclusions

The shunting issue was evaluated in the technical reviews of both the Daveytronic digital electronic blasting system and the Orica I-KON digital electronic detonator system. The internal means of shunting for the Daveytronic and Orica I-KON electronic detonator is provided by their different design and constructional features than the conventional electric detonator. Both of these systems have gone through extensive testing which included using sources of stray and extraneous electricity and they performed much safer than conventional electric detonators. Both of these systems have their own integral elements for shunting and circuit testing that meets the intended MSHA requirements. Therefore, from the detailed technical evaluation made by MSHA, these two systems do 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 these two systems, they 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.

Both the Daveytronic digital electronic blasting system and the Orica I-KON digital electronic detonator system have been technical reviewed and observed in actual operation at several mines sites. Both of these systems have their own proprietary electronic design elements for shunting and circuit testing that meets the intended MSHA requirements.

At this time, no other electronic detonator systems have been evaluated by MSHA Technical Support to determine if adequate means for shunting and circuit testing are incorporated into their designs. All other systems need to be physically shunted and conventionally circuit tested using a blaster's galvanometer (or equivalent device) as would any other electric detonator. Manufacturers desiring to have their electronic detonator systems evaluated may do so by making a request to MSHA's Technical Support, Approval and Certification Center.

A Program Information Bulletin on electronic detonators and requirements for shunting and circuit testing is also available and contains contact information. This bulletin may be viewed on the World Wide Web by accessing the MSHA home page (<http://www.msha.gov>) and then choosing "Statutory and Regulatory Information" and "Compliance Assistance Information."

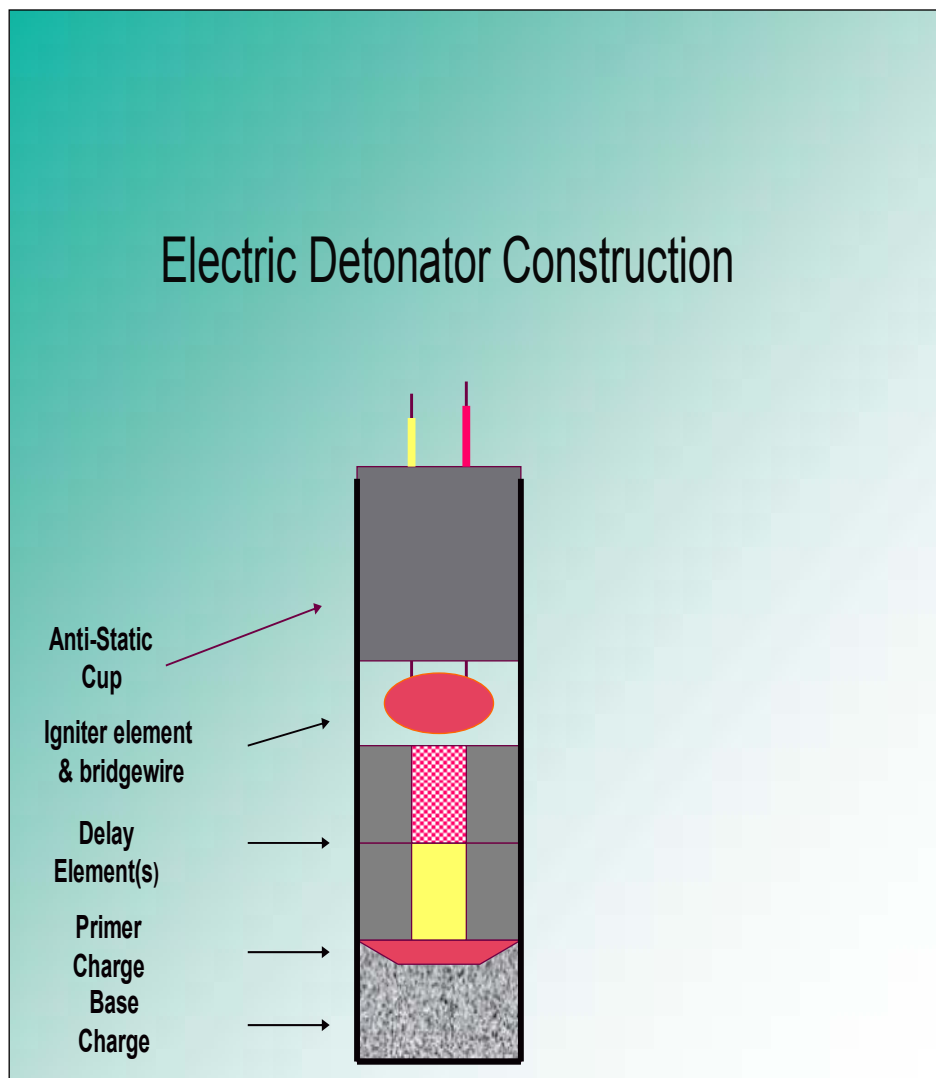


Figure 1 - Electric detonator components

Electronic Detonator

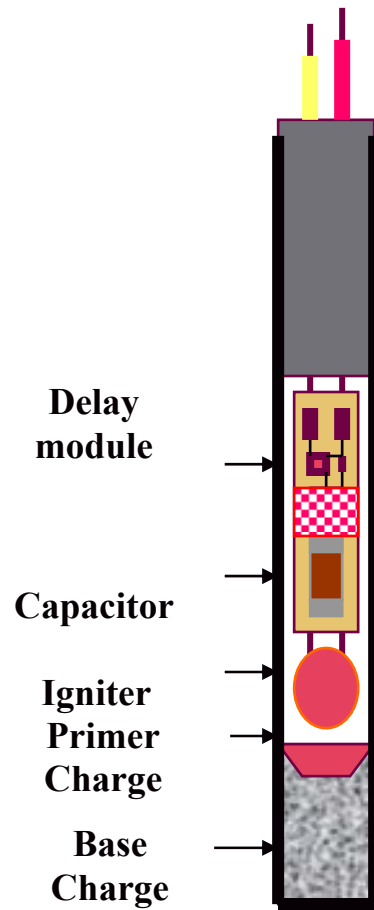


Figure 2 - Electronic detonator components

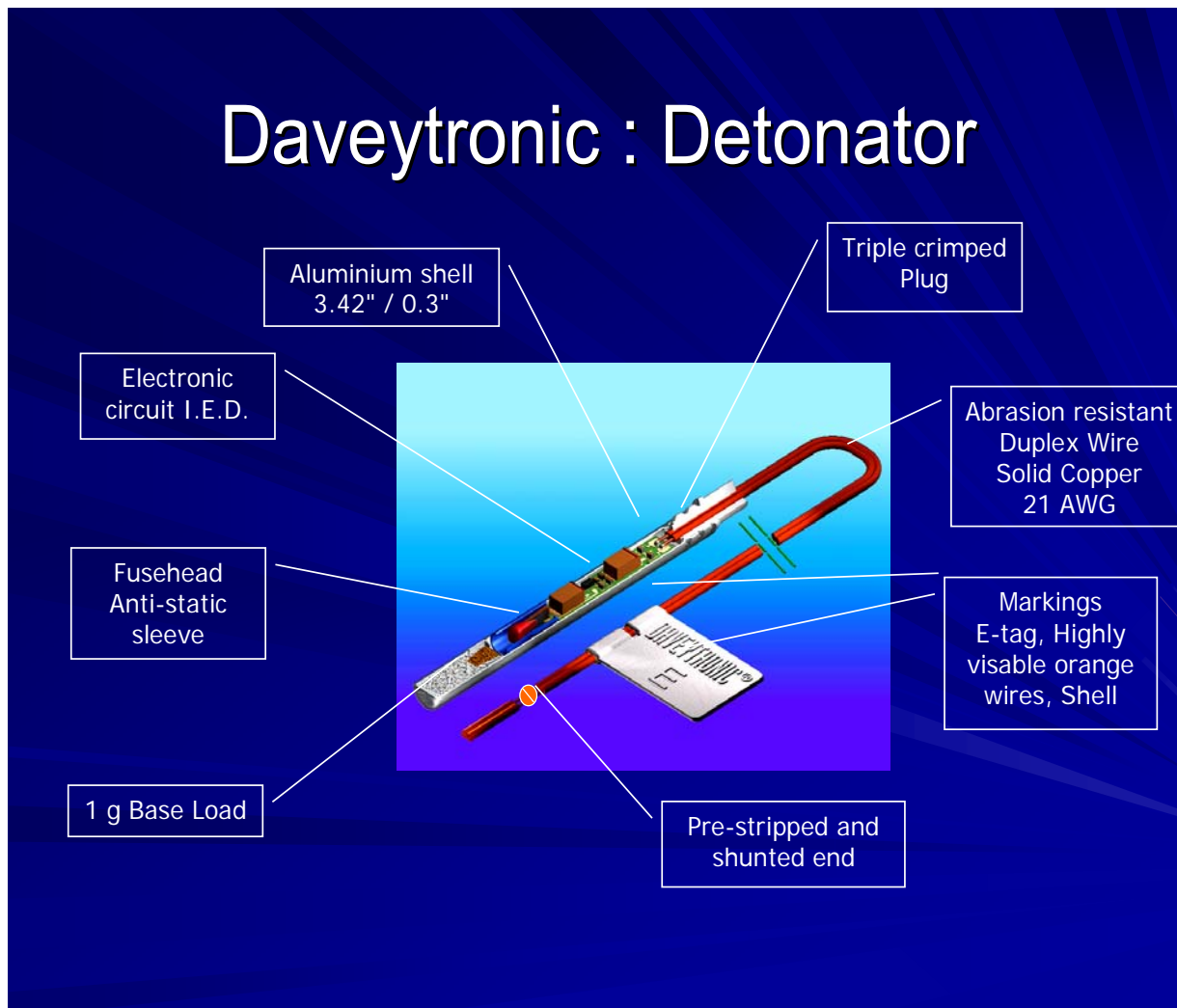


Figure 3 - Daveytronic Electronic Detonator

Daveytronic : Digital Blasting System



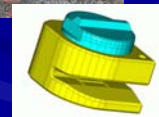
Daveytronic

1.4S UN0456

Programming Unit

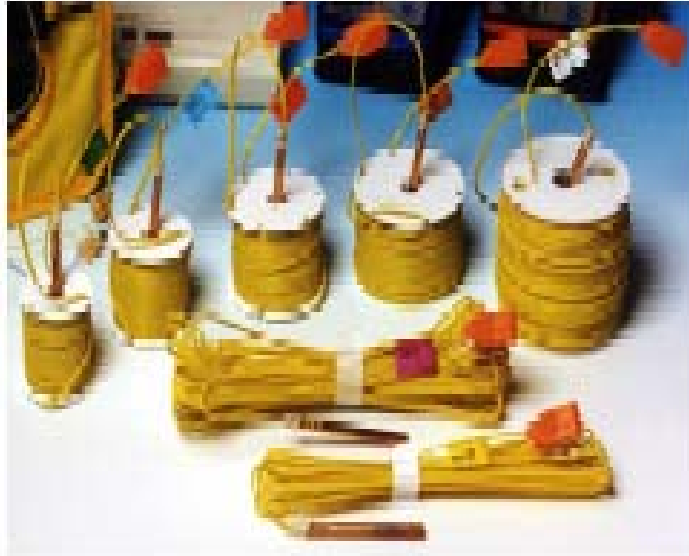


Blasting Machine



Wiring & connectors

Figure 4 – Daveytronic Digital Blasting System



**Figure 5 - Orica I-KON™ electronic detonator
& leg wire components**



Figure 6 -- Orica I-KON™ Digital Electronic Blasting System



Figure 7 -- Daveytronic® electronic detonator & leg wire system



Figure 8 - Daveytronic® electronic detonator & leg wire assembly



Figure 9 - Loading ANFO into a blast hole primed with a booster and Daveytronic® electronic



Figure 10 - Daveytronic® Digital Blast Controller



**Figure 11 – Area of blasted limestone using the Daveytronic®
electronic blasting system**



Figure 12 - Orca I-KON™ electronic detonator with unique ID tag



Figure 13 - Lowering a booster with an Orica I-KON™ electronic detonator into a blast hole



Figure 14 - Orica I-KON™ Logger used to program each electronic detonator



Figure 15 -- ANFO loaded into a borehole primed with a booster and Orica I-KON™ electronic detonator



Figure 16 - Stemming the loaded blast hole



Figure 17 - Orica snap-type connector for I-KON™ electronic detonator trunk line connection



Figure 18 - Firing of a blast using the Orica I-KON™ electronic detonator system