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DIGIDET™ delay detonators: a new approach to electronic delay blasting

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DIGIDET™ DELAY DETONATORS: A NEW APPROACH TO ELECTRONIC DELAY BLASTING

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SYNOPSIS

The DIGIDET™ electronic delay detonator is a device whose economy, simplicity of design, ease of application, application features, ruggedness and general utility are considered unique in the explosives industry. It is expected that the device will receive wide application and acceptance when it is introduced to the commercial blasting market place later this year.

The initial version DIGIDET™ device is virtually indistinguishable from a standard PRIMADET® delay detonator. This design means that the device can be initiated non-electrically using standard shock tube or low energy detonating cord, the same as currently available PRIMADET® detonators. This permits the use of the device by existing blasting crews with virtually no additional training. Also, the device can be combined with standard pyrotechnic delay detonators and detonating cord. This provides what is arguably the optimum electronic system, combining the well known timing flexibility of current non electric systems with fast hookup and precision in-hole burn times.

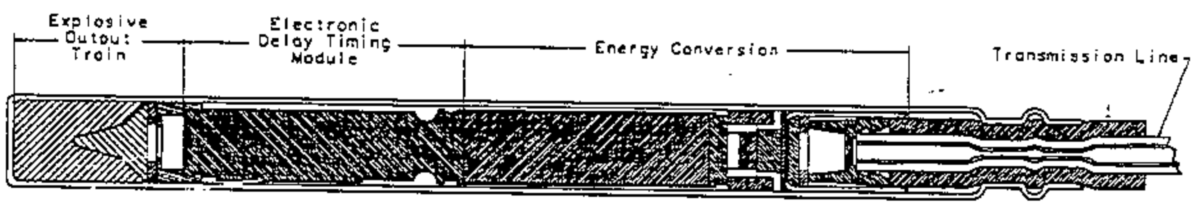

Figure 1. Section view of a typical shock tube DIGIDET™ unit.

BACKGROUND

The introduction of safety fuse to the United States in 1836 provided the first look at how increased precision can affect blast efficiency. This innovation not only provided a safety advantage over earlier forms of blast initiation, it provided miners their first look at fragmentation improvements and significant control over explosive energy.

Following safety fuse, blast initiation precision has incrementally improved as other innovations and technologies emerged. Electric blasting caps, delay detonators, detonating cord connectors and shock tube systems have all contributed to improvements in precision over the past century.

In addition to innovations, the overall quality of pyrotechnic delay manufacturing has generally improved by all manufacturers. Today, blasters have the ability to meet most current challenges encountered with existing delay blast initiation products.

However, even today some explosive engineering projects require greater precision and accuracy than can be achieved through current technology. Public encroachment on blast sites, regulatory constraints on vibration and air blast, and the economic pressure to squeeze every last ounce of energy out of the explosives are facts of life. Electronic timing technology would appear to offer tangible advantages to mine operators, quarry operators and construction contractors.

INTRODUCTION

Developmental work is ongoing by perhaps a dozen manufacturers and research organizations for production of electronic delay detonators. These devices, although differing somewhat from each other are more or less similar in their design. They are characterized externally by the use of wires for signal transmission, and some type of electronic testing and blasting protocol (i.e.; shot box system). Internally, they are characterized by a timing circuit comprised of an oscillator and a counter; logic circuitry controlling detonator firing time, and a main energy storage capacitor that supplies operating power to the circuit and also igniter firing energy. Some of these systems have been discussed in this forum in past sessions.

Typically, the characteristic surface and down hole connection wires consist of multiple conductor ribbon cables with suitable connectors. Virtually all of the proposed systems are field programmable, meaning that the actual function time is programmed into the logic circuitry of the detonator by the user. Sometimes this occurs before the detonator is loaded. In other systems this is done after all of the holes are loaded and hookup is complete. When the units are programmed before loading they are commonly done one at a time at the face. When they are done after loading they are programmed using a device similar to a laptop computer. These schemes can lead to certain difficulties.

Programming the delays can be a time consuming process, since function times are usually input one at a time. Sometimes it is possible to load "canned" shot designs from a disk. However, this may limit flexibility, since the actual drill pattern can differ from the pattern planned in the office. Control boxes and programmers, like all electronic devices are sometimes subject to failure due to dust, moisture contamination, and rough handling. Trained personnel are often required to do the programming. Even when suitably trained individuals are used mistakes can still be made.

Electrical connections are sometimes prone to failure as well. Usually, all connections must be made on the surface since few common electrical connection devices can survive the rugged in-hole environment.

Lastly, trouble shooting can be a problem. In many cases, it is difficult to relate the information given on the control box panel to the actual location of the troublesome component. The probability of some type of electrical fault can increase with the complexity of the shot, and can also be increased by the adverse conditions such as water and mud commonly encountered in commercial blasting.

In order to solve some of these potential problems, The Ensign-Bickford Company (EBCo) has taken a different approach from most other manufacturers. EBCo has a tradition of experience in the design and application of *non-electric* blast initiation systems, and has long recognized the advantages these systems. Non-electric systems are characterized by high resistance to radio frequency initiation, static electric charges, stray current and other electrical hazards. Other advantages of non-electric blast initiation systems are their simplicity, reliability and hookup efficiency. These features translate into overall economy to the operation of blasting crews. Non-electric hookups are very durable, and can easily withstand virtually any blasting environment encountered in mining and construction.

Recognizing these advantages, EBCo research personnel have developed an electronic delay detonator system called DIGIDET™ that maintains all the advantages of current non-electric systems while also offering the advantages of electronic timing. These advantages include millisecond timing accuracy and precision even at long burn times, with no sacrifice in flexibility, reliability or simplicity of application.

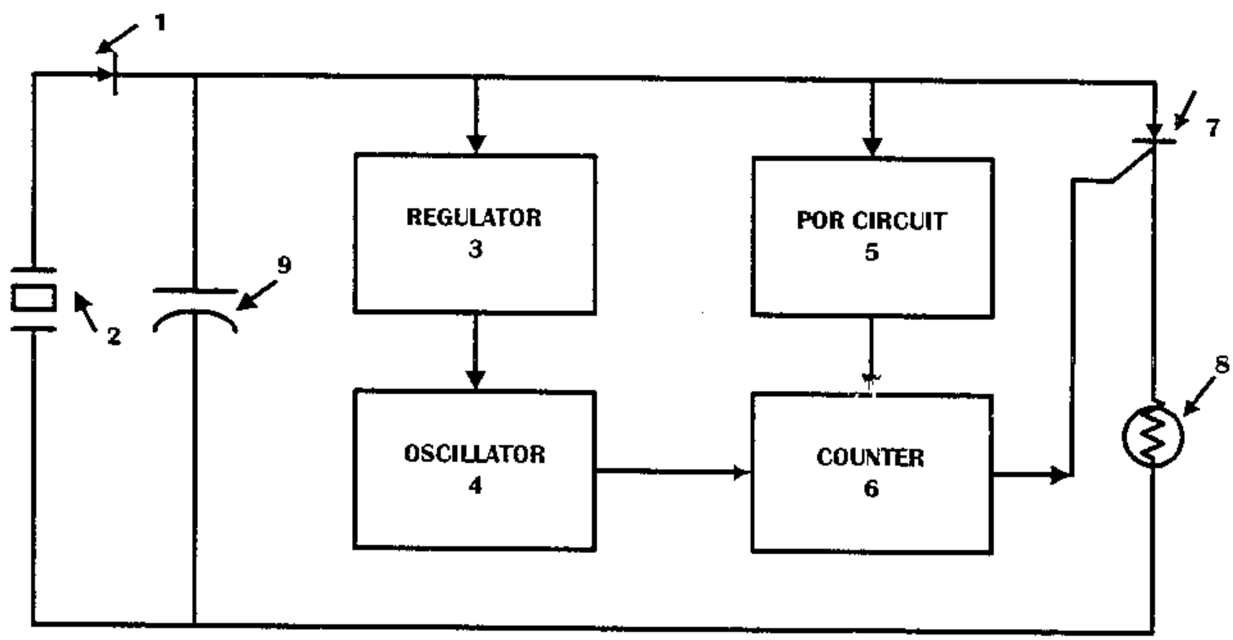

Figure 2. <u>Circuit Schematic</u>: The basic circuit operations are shown, including the steering diode (1), piezo ceramic generator (2), voltage regulator (3), oscillator (4), power-on reset circuit (5), counter (6), firing switch (7) and igniter (8), the main storage capacitor (9).

OPERATION

A brief technical description of the makeup and operation of the DIGIDET™ electronic delay detonator is helpful in order to understand the utility of the system. The DIGIDET™ electronic delay detonator was designed to be initiated non-electrically. This is accomplished by use of an energy generation and energy storage mechanism as described in United States Patent 5,173,569. (Other patents related to this device are pending.) This mechanism consists of three principal elements: a small explosive charge (booster detonator) coupled to a highly efficient multiple layer piezo ceramic element and storage capacitor.

Upon receipt of a (thermal) signal from some energetic transmission line such as shock tube, the small explosive charge in the booster detonator fires. This activates the piezo ceramic device, which in turn causes current to flow through the steering diode to charge the storage capacitor. A voltage regulator provides a substantially constant voltage source to the oscillator to control the frequency of the oscillator. A "power on reset" circuit preloads the counter upon initial application of the input voltage. Once the voltage on the storage capacitor has increased beyond a threshold setting, the counter begins decrementing upon each input pulse from the oscillator. As the counter digitally decrements past zero, the output to the firing switch is activated and all remaining energy in the storage capacitor is dumped to the igniter. The end result is an electronic delay detonator that can be initiated by non electric means. . Figure 1 shows a block diagram of the electronic delay circuit which illustrates the description in this paragraph. Figures 2 through 6 detail the actual construction of DIGIDET™ electronic delay detonators to help understand how the device works.

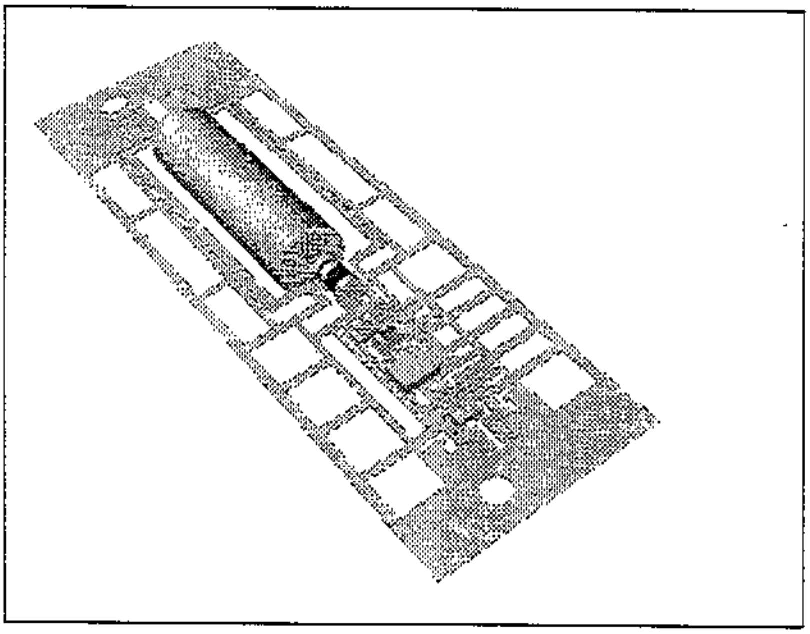

Figure 3. <u>*Circuit Elements Placed on Frame.*</u>

The construction of a DIGIDET™ electronic delay detonator starts with the assembly of the discrete components, including the main storage capacitor, ASIC chip, and other circuit elements on a frame. The frame serves to locate components and connect them electrically.

FEATURES

DIGIDET™ detonators are resistant to initiation from spurious electric sources in the same manner that a PRIMADET* unit is resistant. This protection is not based on a complex internal coding scheme and/or internal protection devices which are subject to possible failure. This protection is a result of basic physics. Spurious electrical energy is blocked from entry into the device through the shock tube in the same manner as with PRIMADET* detonators. Namely, the non-conductive nature of shock tube coupled with the anti static properties imparted by an isolation cup molded from semi conductive plastic. This is exactly the same system that has been proven resistant to static and RFI initiation in millions of production holes shot every year for the last twenty years.

The inside electronics are rendered resistant to radio frequency and other electric field energy sources by the metallic cap shell. The shell surrounds the electronic elements, effectively creating a Faraday cage that requires the field strength to be zero (except for insignificant leakage) at all points within the shell. This effect has been confirmed through extensive testing, including testing to MIL-STD 461-D which has demonstrated the unit's non-susceptibility to initiation from extremely high electric field density environments.

DIGIDET™ detonators, like all electronic detonators, is a stored energy device. This means that once energized, the detonator contains within its firing capacitor sufficient energy to initiate the detonator. This is somewhat different from all detonators that have been used in the past thereby introducing operational considerations that have not existed in previous products. Ensign Bickford has conducted extensive failure mode analysis into DIGIDET™ detonators. The result is sufficient protection built in to the unit using proprietary internal safeguards to insure that the device operates as designed. DIGIDET™ detonators are considered unique in this respect

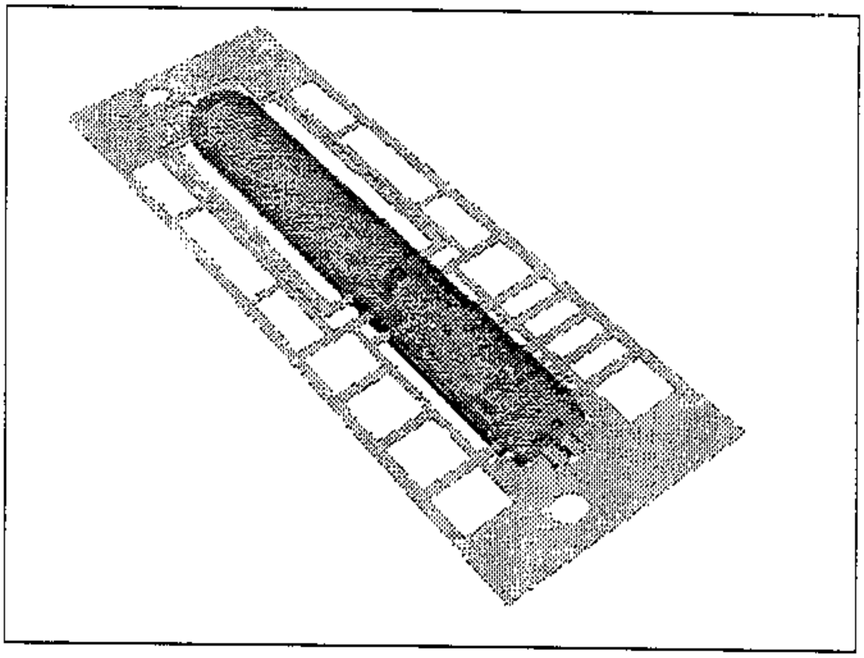

Figure 4 Encapsulated Delay on Frame.

After mounting the circuit components, the entire circuit including the main storage capacitor is encapsulated. This isolates the circuit from the environment. Certain frame elements remain extended through the encapsulating compound. These later serve as input and output terminations and programming leads.

SPECIFICATIONS (PRELIMINARY)

(Note: specifications are presented for reference only. All specifications are subject to change following the completion of the acceptance testing program.)

Physical Dimensions:	standard 3.5" or 4.0" by 0.296" outside diameter aluminum cap shell with variable length shock tube lead.
Range of Function Times	0 through 10,000 milliseconds, factory programmed in standard and non-standard delay periods.
Detonator Strength:	standard number eight or number twelve strength depending on application.
Timing Accuracy:	+/- 1 millisecond across the timing range.
Storage Temperatures:	-65F to 150F.
Operating Temp.	-65F to 150F.
Shelf Life:	> five years.
Vibration Resistance:	passes MIL-STD 810C Method 514.2; MIL-STD 331 Test 119.
RFI Resistance	MIL-STD 461-D RS103 (200 V/m from 14kHz to 18 GHz.).
ESD Through Shock Tube:	tested to 30,000 volts from 2000pF.

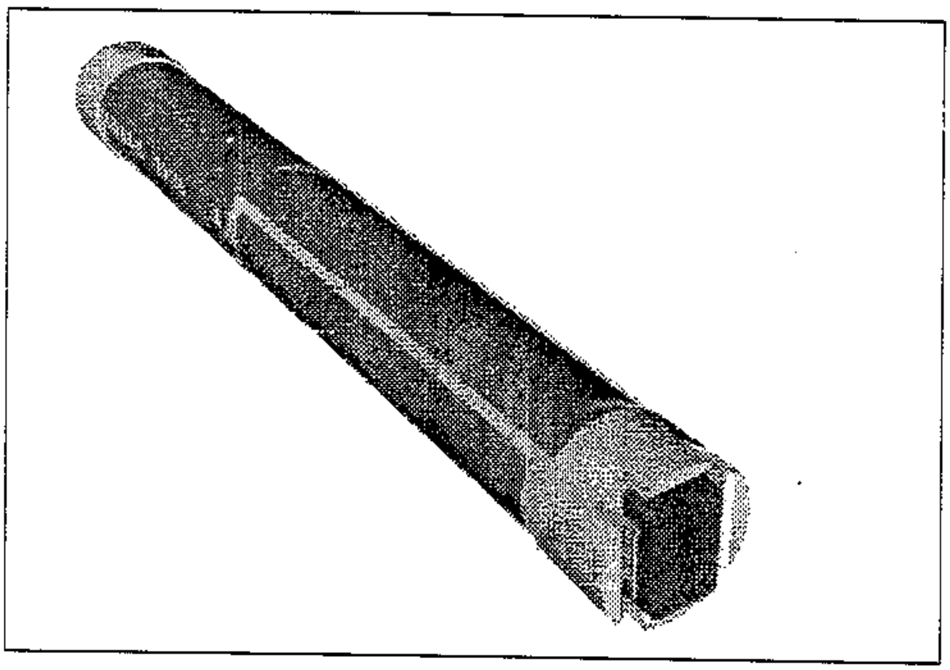

Figure 5. Delay Element.

After programming, the extended programming leads are cut off the delay and folded flush. The piezo ceramic generator is mounted and the igniter is attached. The delay is now ready for insertion into the detonator.

COST

The first question most mining personnel ask when discussing electronic delay detonators is cost Most blasters recognize the possibilities that precision electronic timing can offer for improving blasting results using today's methods. However, since many mines operate within tight economic limitations, there seems to be a practical upper limit to the cost of blasting improvements. For some operations, it might appear that the upper limit is quite close to the cost of existing detonators.

DIGIDET™ detonators will certainly be offered to the market at a price premium over conventional detonators. Initially, that price will be attractive to a relatively low percentage of blasting customers. However, EBCo will not only roll out a new product at the end of 1995, but will also assist its customers in the application of this new technology. The company has dedicated some of its top field engineers to the development of programs designed to lower the cost of blasting for its customers by use of DIGIDET™ detonators. This will be the case whether at the initial roll out pricing, or further into the product introduction, when projected sales volumes will lower unit costs

APPLICATION

DIGIDET™ detonators have no testing and blasting protocol, other than the hookup and inspection procedures currently in use for standard non electric blast initiation. There are no face boxes, programming boxes, data input, or electrical connections of any type. There is no special training or special personnel required to use the system. There are no parts that are susceptible to deterioration from dust, mud, moisture, cold temperature or any other harmful elements of the rugged blasting environment. Hookup is accomplished in exactly the same way as PRIMADET® units using existing shot crews. Components are inventoried in exactly the same manner as for current detonators.

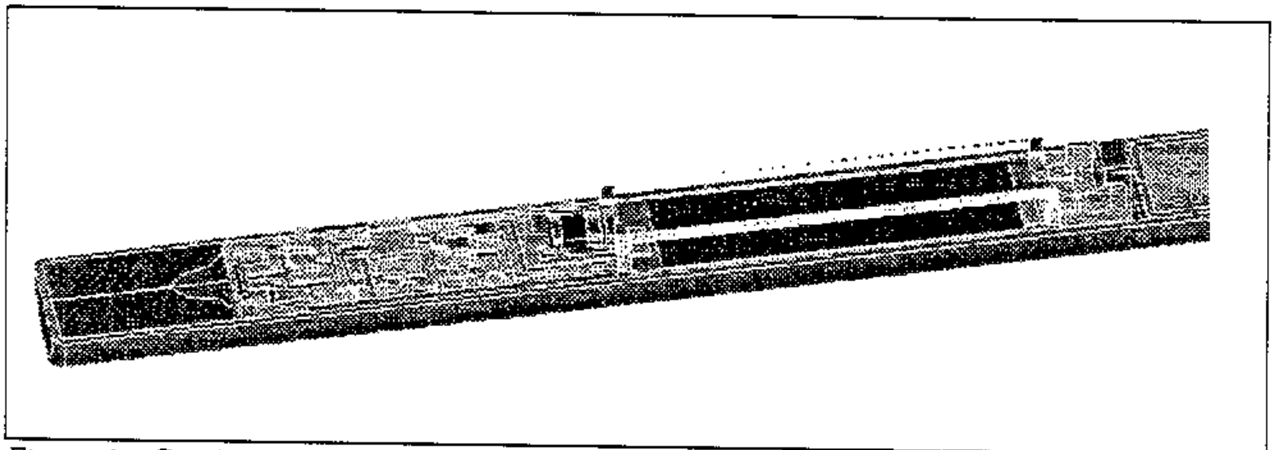

Figure 6 <u>*Cut Away DIGIDET™ Detonator*</u>

This view depicts the assembled DIGIDET™ unit, with the main capacitor removed for clarity. Circuit components are shown in raised relief.

DIGIDET™ electronic delay detonators can be used in combination with existing shock tube or detonating cord products as required. This allows for the ultimate in flexibility, for instance using pyrotechnic sequential delays on the surface with long burn, accurate electronic delays down the hole. (Large open pit blast designs often require significant in-hole times in order to provide adequate time for rock movement).

Such a scheme insures that the sequential surface timing scheme is not disrupted by in-hole cap scatter, even in applications where nominal in-hole timing separation is small. In this case, a wide variety of in-hole times can be achieved without the need for time-consuming field programming. The result is flexibility in timing with no possibility of timing reversals regardless of how close the timing separation.

Precision blasting applications that require decking of explosive charges within a borehole will certainly benefit from the simplicity of shock tube and the precision of electronics. (This is especially true for potential mid-column air decking applications). Decks may be loaded with factory programmed in-hole delay units. Delays would not necessarily be limited to minimum 25ms intervals as with pyrotechnic technology. Half periods, quarter periods and even eighth periods could be used without the possibility of timing reversal due to in-hole cap scatter.

There are certainly many other applications that could benefit from the added precision of electronic timing. In particular, any mining application requiring long burn times coupled with millisecond timing precision in its delay blasting design would be improved by the use of this technology. DIGIDET™ electronic delay detonators offer a level of technology in this respect previously unobtainable, and will probably spur the development of blasting techniques similarly unobtainable in the past..

CONCLUSION

The introduction of DIGIDET™ to market in late 1995 is viewed by The Ensign Bickford Company as a first step, not a final step in the progression of advancements in the field of blast initiation. Although it will be several years before the utility of the current generation of electronic delay detonators is field proven and accepted, plans are already being made at EBCo for subsequent generations of electronic systems.

This paper could only begin to disclose the general design approach and product features of DIGIDET™ detonators. Additional details will become available to our customers as the final stages of the product design program conclude within the next several months. DIGIDET™ units are reality and have been tested in the form described in this paper since the latter part of 1994. When DIGIDET™ detonators become available at the end of 1995, customers can be sure that the device will meet the standards for reliability, simplicity and economy that the blasting industry requires.

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