High Strength Primadets®, the Modern Approach to Direct Initiation of ANFO in Salt Mining

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ABSTRACT

The properties of all available modern blasting initiation techniques are reviewed. The concept of direct initiation of ANFO by blasting caps is discussed.

High Strength Primadets are nonelectric initiators of sufficient strength to directly initiate properly formulated ANFO mixtures in small diameter drill holes used in salt mining. The nonelectric features of the system eliminate concern for premature initiation from static or stray currents. The loading techniques are simple and a minimum of training is required. There is no limitation on the number of necessary sequences in which the High Strength Primadet need be connected for initiation. These units have had wide acceptance in the salt industry because of their safety features, ease of use and non-contaminating properties.

HIGH STRENGTH PRIMADETS®

The Modern Approach to Direct Initiation of ANFO in Salt Mining.

INTRODUCTION

This paper reviews various blasthole initiation systems. In mining and quarrying, the power provided by commercial explosives and blasting agents is one of the most useful and convenient forms of energy available to man. A nonelectric system for direct initiation of ANFO in small diameter holes now is available which has already found wide acceptance in the Salt Mining Industry. The past fifteen years have witnessed major technological changes in the explosives industry. These changes have had widespread effects on blasting as practiced by mining and quarrying industries. Ammonium nitrate, sensitized with a carbonaceous fuel, first used in commercial blasting in 1955 as an effective low-cost blasting agent, revolutionized the explosives industry. This revolution has, in addition to the technological advances, had two important side effects on costs and safety.

The cost of commerical explosives energy to break a given quantity of rock has been reduced as a result of the introduction of blasting agents based on ammonium nitrate. This aspect of blasting practice has been adequately documented over the last decade. The safety aspect of commercial blasting has far out paced both the technological and economic advances. In short, the sensitivity, the handling methods, the accuracy, the control, not only of energy but of excess-energy which shows up as airblast and seismic shock, have been so improved that practical production blasting of today is hardly recognizable through 1950 eyes. Nevertheless, it must not be overlooked that regardless of how much safer blasting is today, as compared to fifteen or twenty years ago, explosives and blasting agents are designed to release incredible amounts of energy and as such remain a serious safety hazard when not properly managed. This revolution is still going on and it is an open question when the many new products and technical concepts will be fully evaluated.

The safe and efficient use of this energy depends, to a large degree, on how explosives are initiated. Recent developments and trends in products for explosives initiation are matters of interest to the salt mining industry. A blast initiation system may be defined as that element which provides: 1) signal transmission and sufficient energy impulse to trigger the main charge, and 2) a sequential delay between adjacent charges when required.

Two initiation systems will be reviewed here, cap and fuse, and electric blasting caps. In addition a third and relatively new system, High Strength Primadet® Nonelectric Delays, will be discussed.

In cap and fuse initiation, the fuse provides the signal transmission and the cap provides the energy impulse. For

electric blasting caps, the leg wires transmit the signal and the cap provides the energy impulse. With nonelectric delays the miniaturized detonating cord leads only transmit the signal and the cap again provides the energy impulse.

It is important to briefly review three general blasting fundamentals so that subsequent points will fall quickly and logically into place:

1. All methods of initiation must release enough energy to reliably initiate some larger explosive mass. A simple example would be a blasting cap to a charge of cap-sensitive dynamite. In all instances, the initiating strength of the first must be capable of detonating the second.

2. For obvious safety reasons, the first release of energy in any blast must be timed to take place after all personnel, mobile equipment, etc., are removed from the scene of the blast. Further, for ultimate safety, the system must be insulated from external influences that would either prematurely trigger the reaction or impede it in any way. Time, then, is a basic factor.

3. In many blasting applications, ultimate performance can only be achieved if time becomes a factor in yet another way. That is, there is provision for sequential-delay-firing for multiple-shot blasts.

With these three principles in mind one can compare cap and fuse, electric blasting caps, and High Strength Primadet Nonelectric Delay Units, to see how they satisfy the three criteria for the initiation system.

CAP AND FUSE (NONELECTRIC)

The cap and fuse method of initiation remains the oldest, and still the most widely used system in the world today. The initiating energy is satisfied by a blasting cap which is sensitive to fire as provided by the fuse. Expressed in a different way, the fuse is simply a means of transmitting a signal from one point to another by time-controlled burning. The length of the fuse provides the time required for safety. Varying the length of individual fuses in multiple-shot blasts is one of two ways of providing sequential delay.

The system has inherent limitations with regard to delays in timing. Unless the blast design can tolerate delay intervals of one second or more, cap and fuse can be ruled out of use. Cap and fuse has a high degree of safety from premature explosion as a result of outside influences and handling.

The use of ANFO mixtures introduced several factors to cap and fuse detonation. First, oil becomes a possible contaminant, second, static electricity is a threat if holes are charged with pneumatic loaders, and third, blasting agent charges are used that are not sensitive to the energy output of a No. 6 cap. New fuse structures which have an impervious plastic jacket, however, adequately dispose of the problems that could conceivably stem from oil or static electricity.

The use of a primer, generally dynamite, provides the necessary punch to reliably detonate the main charge of ANFO or blasting agents. There is, however, a decided trend in some countries, including Canada, South Africa, Australia, and the United States, to double, triple, or even further increase the strength of the blasting cap so as to avoid the use of a separate primer. Unfortunately, in salt mining, contamination of the product often cannot be tolerated. When fuses are used, undesirable fragments of the fuse carcass invariably end up in the product, and this contamination is often enough to rule out this system for salt mining.

ELECTRIC BLASTING CAPS

Like the cap and fuse system, the energy impulse is provided by a cap and the leg wires carry the signal transmission. Unlike cap and fuse, the fire or heat is conveyed to the cap in the form of electrical energy which is converted to heat within the confines of the cap. The time required for safe removal of personnel is normally controllable in as much as electrical circuits convey the triggering signal from a point of safety. Time increments for delay blasting are built into the cap with accuracy and the capacity for setting timing intervals is completely beyond the scope of cap and fuse. If precise, short interval delays are required because of the blast design, electrical blasting caps can be used rather than the cap and fuse system. One of the major disadvantages of electrical initiation is that the caps are activated by relatively small quantities of electric current. Extraneous electricity, whether generated by nature or man, is common and insidious. To isolate electrical circuits from undesired extraneous electricity defies definitive resolution at this time.

Over the years, the crispness or accuracy and range of delay timing have been significantly improved and extended. Work is continually in progress to improve the system. It is questionable, however, if technology will ever disclose a practical way to build an electrical system which will accept only desired electrical energy.

The introduction of ammonium nitrate—particularly in small diameter underground blasting, and the subsequent use of pneumatic loading equipment, has brought with it hazards in the form of static electricity. While there has been an effort to design electric blasting caps so that they would be reasonably immune to this type of energy, most work has been directed towards resolving the problem by the use of specially designed and maintained equipment in conjunction with specific handling procedures during loading such as reduced loading rates. These rates

are generally well below levels that a man on the end of the loading hose can control with resultant sacrifice of borehole density. If industry recommendations are maintained and followed, electric blasting with ammonium nitrate can be carried on with relative safety.

A comparison of the two most common initiation schemes in use today is simple in their main points. One is nonelectric, having limitations in sophistication of delay time. The other system, electric blasting caps, provides the ultimate in delay timing but has inherent disadvantages, advantages, and limitations. In other words, there has been a void in initiation systems which if filled would satisfy many blasting requirements which are now accomplished with products which fall short of the ultimate in safety or performance.

NONELECTRIC DELAY SYSTEM

The desirability of, and need for, a precise, nonelectric delay system to fill this void has been recognized for many years. The problem was how to transmit the signal. The feasibility of using the inherent advantages of detonating cord, coupled with those inherent in the cap portion of an electric cap, seemed the logical approach. That is, a low-energy detonating cord would be used to transmit a relatively innocuous signal and this signal would be married to a cap with the delay timing built into the cap itself. Early research and development efforts assumed that such a nonelectric delay would have to be compatible with nitroglycerin base explosives. On this assumption, a product was developed and proved several years ago and is currently on the market. Unfortunately, the criteria established for this product necessitated the use of a costly, sophisticated, low-energy detonating cord with equally costly connectors. Since this first commercial nonelectric delay was introduced, the widespread use of relatively insensitive blasting agents as well as primers has led to relaxing the original criteria. Fortunately a less costly type of low coreload detonating cord was found to be feasible. Furthermore, no special attachments were required for reliable performance. Such a product was originally developed in Canada and has been in use for eleven years.

Parallel work was undertaken in the USA, using a different approach which was judged more flexible and, therefore, better suited to the many different field requirements that exist there.

Early in this program, it became apparent that Ensign Bickford had developed a system that was particularly suited to the salt industry. With the cooperation of Morton Salt Co., Diamond Crystal, and Carey, field testing confirmed the development of a system that gave the precise timing of electric delays. This new system also eliminated the inherent electrical problems of electric delays and the nuisance of wire fragments and other residue in the salt product. The salt industry rapidly adopted the system.

In 1970 a further refinement of this system was tested at the Cargill Cayuga Rock Salt Co. mine. The results of the evaluation of High Strength Primadet Delays confirmed a workable system and a conversion program began. These High Strength Primadet Delays have since found wide acceptance in the salt mining industry. In some cases, they have replaced the earlier No. 6 cap strength model and in other cases have replaced electric blasting caps or fuse and caps. Now, after hundreds of thousands of these units have been consumed, we can say they constitute a viable system meeting all criteria of safety, efficiency, and precise timing.

High Strength Primadet Delays are nonelectric delay blasting caps incorporating a high strength cap. This cap is of sufficient strength to provide direct initiation of properly formulated ANFO mixtures when pneumatically loaded or in some cases, gravity poured into holes up to 2-1/2" in diameter under normal conditions of density, confinement and dryness. High Strength Primadets provide the precise timing of delay electric blasting caps in both millisecond and long period ranges, but are immune to static electricity that may be generated during pneumatic loading operations, as well as other types of extraneous electricity normally encountered in mining operations.

This new unit consists of five major components:

1. Primaline®—a miniaturized (approximately 4 grains/foot) PETN detonating cord. The PETN explosive core is encased in a textile braid and a relatively thick, abrasion resistant outer plastic jacket. The average tensile strength is 60 pounds.
2. A high strength blasting cap that contains a delay element.
3. An iron ferrule which is placed on the cap shell and locked in the crimp that holds the delay element. This ferrule is of sufficient mass to allow magnetic scavengers to recover Primadet delay elements or entire caps not consumed in the blast.
4. A color coded tag to provide identification of the delay period number.
5. A plastic cap holder to position the cap centrally within the borehole and to provide an extra measure of safety to prevent whipping of the cap during pneumatic loading. The cap holder fits over the top charge of the cap to provide mechanical protection during pneumatic loading.

In principle, the High Strength Primadet System utilizes a detonation impulse or signal via the Primaline to ignite the delay element which, in turn, actuates the special cap. The explosives base charge of the special high

strength cap provides sufficient output to initiate the ANFO.

Primaline, which conveys the initiation impulse to the delay element in the cap, is initiated by a Primacord trunkline system. Because both the Primaline and the trunkline function at a high velocity of detonation (approximately 20,000 feet/second), all delay elements in a given hookup, for all practical purposes, ignite simultaneously.

HIGH STRENGTH PRIMADET CHARACTERISTICS

Safety features of this initiator is that it:

1. Eliminates concern for all electrical hazards of premature initiation by stray or extraneous electrical currents normally encountered in mining operations, including induced currents from nearby lightning strikes.
2. Is immune to premature initiation from static electricity that has been generated during pneumatic loading operations.
3. Eliminates the need for a high explosive primer cartridge.
4. Is highly resistant to accidental detonation from rough handling during loading operation.
5. High Strength Primadets may be used without risk in close proximity to radio transmitters, radar or similar installations. This is an important safety feature where no knowledge or control exists over transmitting equipment.

Improved performance of ANFO

Since the High Strength Primadet is immune to static generated during pneumatic loading operations, maximum air pressure can be used with the various types of ANFO pneumatic loaders. The possible increase in loading pressure not only increases the loading rate but will also contribute to optimum borehole loading densities, with a subsequent improvement in the performance of the ANFO.

Positive performance is enhanced by:

1. Precise, accurate timing in millisecond intervals.
2. Lack of misfires in conductive orebodies because of current leakage.
3. Simple hookup; therefore, less chance of human error.
4. Capability of withstanding exposure to adverse temperatures and conditions.

Avoidance of contamination

High Strength Primadet units are almost totally consumed in blasting operations. In most instances the innocuous residue will float off in routine mineral dressing operations. In addition, the Primadet has magnetic properties, compatible with tramp iron scavenging devices in ore dressing plants.

Simplicity in handling

Loading techniques in which the High Strength Primadet Delay System are used are simple, and a minimum of training is required. Two techniques may be used.

1. *Single Stage Loading.* The High Strength Primadet, with cap holder attached, is inserted to the bottom of the hole in the indirect position (cap pointing toward collar of hole) by means of the loading hose. The loading hose is then withdrawn slightly to give about 8 inches of stand-off (cap stays in bottom as held by cap holder), and the loader is turned on. The loading hose is then withdrawn at an even rate until the required charge is placed.
2. *Double Stage Loading.* The loading hose is inserted to the bottom of the hole, and about two feet of the charge is loaded. The hose is withdrawn then the High Strength Primadet with cap holder attached is inserted in the direct position (cap pointing to bottom of hole) and snugged up to the charge already in the hole. The hose is withdrawn about 8 inches and loading is resumed for the balance of the hole. This technique requires a slight increase in loading time, but will ensure that the ANFO is detonating at a high order by the time it detonates to the bottom of the hole. This technique should also be used if the holes are not blown clean prior to loading.

If for any reason, ANFO cannot be used, e.g., water, cracked ground, etc., cartridges of explosives that are insensitive to initiation from Primaline may be substituted for the ANFO. These explosives are readily available. Conventional nitroglycerin or nitrostarch-based explosives *must not* be used under any circumstances since Primaline will, in most instances, initiate these types of explosives, resulting in an instantaneous shot without the required delay action.

While the High Strength Primadet is being placed and during actual loading, slight tension should be maintained on the Primaline to ensure that it does not kink or loop in the hole.

Hookup of high strength primadet initiation system

The usual practices for hooking up Primacord should be employed. The Primadet-to-trunkline connection should be made by tying the Primaline to the trunkline with a double wrap half-hitch knot. Lead lengths of 20' and over are supplied with a J-Connector to simplify connections. Trunkline cross ties should be provided to permit at least two paths of initiation. Care should be taken to keep the hookup neat. Connections to the trunkline should be made with a minimum of slack and all loose ends should be trimmed to prevent Primaline-to-trunkline crossovers, which could result in "cut-offs". Primaline, although sensitive to initiation by PD Cord®, E-Cord®, or Reinforced Primacord®, will not reliably initiate itself. Therefore, no attempt must be made to knot or join Primaline to Primaline. Connecting the Primaline leads to

the trunkline is simple and rapid. A quick visual check will ensure that all units are included in the blast. Firing of the round is accomplished by attaching a cap and fuse or electric blasting cap to a pigtail attached to the Primacord trunkline and initiating when ready to blast.

FINAL REMARKS

High Strength Primadets are being used on a routine basis in bench blasting of all but one of the active domes in Louisiana. The bench holes, from 1-7/8" to 2-1/2" in diameter and up to 60' in depth are first plugged at the kerf by dropping a cartridge of explosive into them. A 14' to 16' High Strength Primadet is then inserted with cap holder attached into the hole. ANFO is then simply poured into the hole, flowing past the Primadet and filling from the bottom up to the desired collar.

At three mines, a combination of MS Primadets are used within the row with Long Period Primadets used as surface delays to give a delay between rows. This combination of MS delays and LP delays is reducing pillar damage with the larger bench shots.

High Strength Primadets have often replaced electric delay blasting caps without any or very little increase in cost to the operation when all factors such as electrician's time, lead wire, etc., are taken into account, and have often contributed to increased productivity from improved fragmentation.