Ammonium Nitrate and its Application Underground

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ABSTRACT

Ammonium nitrate and its application for use in underground mining. A brief resume of historical utilization of Ammonium nitrate up to present day.

Ammonium nitrate-fuel oil usage has progressed rapidly in recent years and requires care in order to assure proper results. A brief outline of methods for charging holes, methods of priming, types of air-placement equipment is described. Methods for determination of static electricity and recommendations for using air-placement equipment with suggested precautions in attempting to eliminate the hazards of static electricity are discussed.

INTRODUCTION

Ammonium nitrate has long been used as a component of explosives, being used from the start of the industry in the "extra" or ammonia dynamites. In World War I, the substance found a major use in the military explosive called "Amatol." It was not until the mid-1930's, however, that ammonium nitrate-fuel explosives were commercially introduced. Even then the material was sold only in a pre-packaged form and was intended for use in that manner.

The real blasting "revolution," as it might well be called, did not come until after World War II. In fact, it might be said that the war was in itself a major cause. Near the mid-point of the conflict a critical shortage of fixed nitrogen arose, caused by the tremendous amount of nitrogen compounds used in military explosives. The U. S. Government, of course, built many plants to make ammonia, nitric acid, and munitions-grade ammonium nitrate for explosive production, and these plants were turning out a great tonnage of these products including ammonium nitrate as the war ended.

In the years immediately after 1945, the great need for fertilizers to rehabilitate the farms of Europe and Asia prompted the U. S. Government to make munitions-grade ammonium nitrate available to the fertilizer industry (1). In fiscal year 1947 U. S. Army ordnance plants shipped 779,730 tons of ammonium nitrate fertilizer to Germany, Japan and Korea (2).

Many things have happened since then -- the Texas City disaster, which prompted both government and private investigations into the explosibility of ammonium nitrate; the wide-spread use of ammonium nitrate prills following the war, bringing lower costs to its production; the introduction of large rotary drills which eliminated the water formerly left in churn drill holes; and finally the introduction by Lee and Akre of the field mixed ammonium nitrate-fuel blasting agent. Even that event has been in history for eight or nine years, and much has happened since.

METHODS OF HOLE LOADING

The first method of hole loading was the pre-packaged, can, bag, or cartridge type. This method offers both advantages and disadvantages, the main advantage being ease of handling and good water resistance properties. Of course, the disadvantage is that the cartridge or can cannot completely fill a borehole, and thus an annulus filled with air or water is left which robs the blasting agent of its maximum effective strength. The bag may or may not fill the hole, depending upon its construction. Following the introduction of cartridged explosives free flowing bag powders were developed. For many years this type was poured directly into the blast hole and on many occasions blown in by air pressure.

Immediately upon the introduction of ammonium nitrate-fuel mixtures, operators who had dry, vertical drill holes began pouring the blasting agent into the hole filling all voids. It developed that this procedure frequently gave densities of loading approaching cartridged dynamite and made it possible to get the full blasting value from ammonium nitrate-fuel oil mixtures. Soon research was also being conducted in various underground mines in an effort to take advantage of the low cost of ammonium nitrate-fuel oil mixtures.

Naturally, since most underground holes were drilled horizontally, it was not feasible to fill them by pouring. The first step was to package the mixture in cartridges or bags and load in the conventional manner with a charging stick or tamping pole. It was found by experimentation that advantages in the price and blasting efficiency of ammonium nitrate-fuel oil mixtures were lost by using it in this manner. The natural next step, then, was to devise a method of filling the hole by forcing the mixture into the hole with air pressure.

Concrete placing machines had long been in use in the construction industry, and it was this type machine that was first adapted to placing prills and fuel oil into boreholes. The principle of operation with this "pressure-pot" method is very simple. The blasting agent is poured into the vessel, air is introduced for pressurizing, and the prills are pushed out through the placement hose into the borehole. Blowers of this type have rates of prill placement, with a 50 foot loading tube, on the order of 20-30 lb./min. at 20 psi of air pressure. At high pressures, the loading rates rise to better than 60 lb./min. When discussing loading rates, it must be remembered that the internal diameter and length of the placement hose are very critical factors. For example, if the placement hose with which the 60 lb./min. rate was realized is replaced with one that is 1/3 as long, the loading rate will rise to over 150 lb./min. This type of air placement equipment is in wide use today, and can be found with various vessel volumes ranging from a fraction of a cubic foot to many cubic feet.

In order to reduce the weight and cost that are inherent in the pressure vessels, at least those of larger capacity, the eductor or ejector principle has fairly recently been introduced by the explosives and mining industries. In this method, the ejector is usually situated beneath a hopper filled with the prill-oil mixture. Since there is no pressure in the hopper itself, the construction may be of very light material and be completely open at the top. With this placement apparatus the loading rate is considerably lower than with the pressure-pot type, even though the ejector's placement hose is typically much shorter. Many ejector-type placers use full air-line pressure (about 90 psi). With this pressure, and a 15 foot hose, they will place approximately 8-15 pounds of material per minute.

METHODS OF PRIMING

Ammonium nitrate-fuel oil mixtures are primed in essentially the same way that priming has always been done. A stick of dynamite, preferably of the largest diameter the hole will accept, is primed with a blasting cap of either the electric or non-electric variety, and pushed to the bottom of the borehole. It is essential that the dynamite chosen as a primer be of sufficient brisance to initiate the prills and oil efficiently. In other words, of sufficient priming power to avoid a marginal detonation which would produce toxic fumes and reduce blasting efficiency. A good rule of thumb is to use a primer that has a detonation velocity higher than that of the prill-oil mixture.

The loading can be a very efficient operation. Using the pressure vessel equipment, the primer is pushed to the back of the hole by the loading tube, and the blasting agent is loaded into the hole as the loading tube is withdrawn. With eductor equipment, the loading tube must be drawn back a number of feet from the primer (the exact distance must be determined under actual conditions), and the agent loaded into the hole. If the tube is not withdrawn in this manner extreme blowback will be experienced.

The question of safety in a loading operation is more important, certainly, than any consideration of cost saving or operations efficiency. That is why many companies have been reluctant to introduce air placement into their operations, particularly where they use electric initiation. Under certain conditions it is possible for a discharge of static electricity to travel through the leg wires of an electric blasting cap and spark discharge to the grounded cap shell in the vicinity of the explosive priming composition. If the energy of the spark is great enough a premature detonation may result. Recently a premature detonation occurred involving cap and fuse that was attributed to static electricity. Tests have shown that under some conditions a static charge can travel through the powder train in the fuse and spark discharge to the grounded shell resulting in detonation.

A major concern today is the question of static electricity generation and accumulation during the blowing operation. Four questions immediately arise: What is static and how is it generated? How do we measure it? How dangerous is it? And what can we do to prevent its accumulation?

STATIC ELECTRICITY

Static, from the greek word meaning "causing to stand," is defined by Webster as "designating, of, or producing stationary electrical charges, as from friction" (3). Static electricity then, is simply electricity at rest, as opposed to dynamic electricity, or electricity in motion. This dynamic electricity is what is found in normal circuits and is what runs our motors and causes lamps to glow.

The generation of static electricity is commonly believed to be possible only by friction -- in fact its original name, "frictional electricity," is still used to some extent. It has been determined, however, that static is generated also by the bringing together and separating of unlike substances (4). For example, everyone has sometime experienced the generation of static when picking up a sheet of paper from a glass-topped desk. That is an example of one type of generation. Other means of generation, which actually are variations on those mentioned above, are the movement of any vehicle equipped with non-conducting tires or over a non-conducting floor, or any forms of motion involving changes in the relative position of contacting surfaces of dissimilar substances, one or both of which may be a poor conductor or non-conductor, or electricity (4). In the case of air placement of ammonium nitrate, there apparently is a combination of factors to produce static -- the friction of the material in the eductor if such a device is used, the friction in the loading tube, and the friction in the borehole itself. Also, the act of separating the particles, with particular reference to the eductor method, will produce a static-generating condition. The generation of static cannot be prevented, and in itself is no hazard whatsoever. The hazard appears when the charge generated is allowed to accumulate upon men and equipment until a spark discharge occurs.

The detection and measurement of static may be done in a number of ways. The gold leaf electroscope is used in the laboratory to detect static -- in this apparatus, two delicate pieces of gold leaf separate when in the presence of a static charge. Neon tube testers also will indicate the presence of a very slight charge, but like the gold leaf electroscope, gives no indication of its magnitude.

The best means of measurement is with an electrostatic voltmeter. This device, designed for these measurements, is available in a number of voltage ranges, and is reasonably portable. An ordinary voltmeter is not suitable for measuring a static charge.

In measuring static with the electrostatic voltmeter, the high side terminal of the meter is connected to the blower, the hose, the capwires, or wherever else you desire a reading. The ground terminal of the meter is connected to a good ground. The blowing operation is commenced, and the meter reading is noted.

A simple device that Hercules recommends for field usage is a spark-gap with set distances between spherical electrodes. By use of an accompanying table, the voltage may be read directly. This gives an indication of the general static range present which, for the purpose of the mine operator, is sufficient. This device is readily portable, rugged and inexpensive.

The next logical question as stated earlier, is how dangerous is static electricity in the mine? Specifically, how much voltage are we likely to generate, and next, how much can we tolerate?

In regard to how dangerous static actually is, we might first determine how a static charge, once accumulated, might cause trouble. As stated before, the generation and accumulation of the charge are not the things that cause trouble -- it is the discharge of this accumulation. The best way to prevent the accumulation is to not allow any portion of the system to be insulated from the ground. In this way, any charge generated will immediately drain off harmlessly. It must be kept firmly in mind that any portion of the circuit that is not electrically connected to the other parts and to ground is a potential capacitor or storage point for static accumulation. Another, and possibly the most important point from the standpoint of alleviating the fears of many mine managers, is the fact that above about 70% relative humidity the air itself will prevent a static buildup in the system. Most mines, except those producing specific minerals incompatible with moisture, have relatively high humidity. Almost automatically, then, we may minimize the apprehension over static from a great percentage of our mines.

Regarding the danger if we did accumulate a large static charge; how might this cause trouble? This depends, of course, upon where the charge accumulates, and upon where it will be discharged. If for example it accumulates on the miner's body as he loads the hole, and he then touches the face accidentally, he will receive a shock of severity dependent upon the magnitude of the charge. However, this does not constitute an accident -- it is merely an unpleasant sensation. Consider now what the results would be had he touched only the shunted cap wires and his accumulated charge went to ground through the cap shell. The man, having acted as a storage point or capacitor for an electrostatic charge, will discharge to ground through the cap shell only if the shell is near a good ground. However, the shell itself being in approximately the center of a non-conducting cartridge of dynamite, this discharge is unlikely.

Three general ways for firing caps by static electricity are the following as illustrated in Diagram I:

Case A: Discharge from the leg wires to the shell through the cap. This could happen in various ways.

The cap shell is grounded through a resistance which can vary from zero to infinity. A condenser, such as a man or piece of equipment which is charged with static electricity, comes in contact with the shunted end of the cap and discharges through the cap to the shell. It may be necessary for the static to be at a potential of several thousand volts to get any discharge at all. Furthermore a considerably higher voltage is needed to cause the cap to fire and if the resistance to ground is high as for a cap in a cartridge of dynamite it will be virtually impossible to fire a cap in this way. Under the most unfavorable conditions, a static resistant cap will not fire with 25,000-35,000 volts or more from a condenser larger than a man.

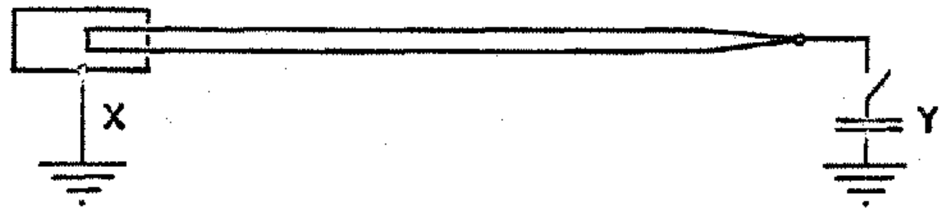
The actual path can be in various directions -- from a condenser to the cap shell to shunt to ground, or even through the insulation to wires to cap shell (however, over 30,000 volts is generally needed to break through the Hercules plastic insulation).

Case B: A second and less probable way of firing a cap by static electricity is under Case B.

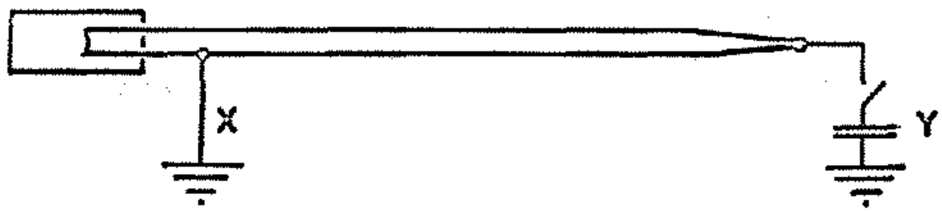
In this case it is assumed there is a bare spot near the cap shell and a discharge occurs to the wire and to the shunted end which is grounded through a resistance. Part of the discharge passes through the bridge and if it is large enough it can heat the bridge hot enough to fire the cap. However, the high voltage breakdown of the

THREE POSSIBLE WAYS IN WHICH ELECTRIC BLASTING CAPS MIGHT BE DETONATED BY ELECTROSTATIC DISCHARGES

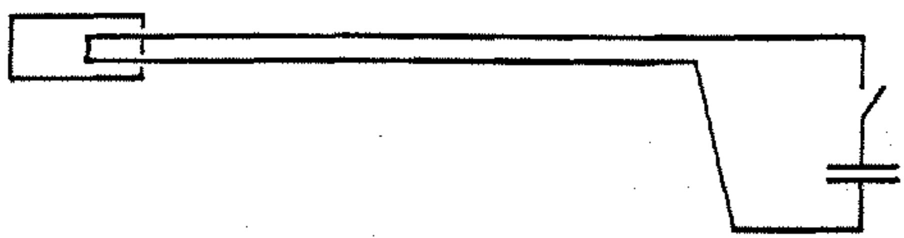
CASE A. DISCHARGE FROM SHUNTED LEG WIRES TO SHELL WALL



CASE B. DISCHARGE FROM ONE LEG WIRE CLOSE TO SHELL TO THE SHUNT



CASE C. DISCHARGE DIRECTLY THROUGH BRIDGE WIRE



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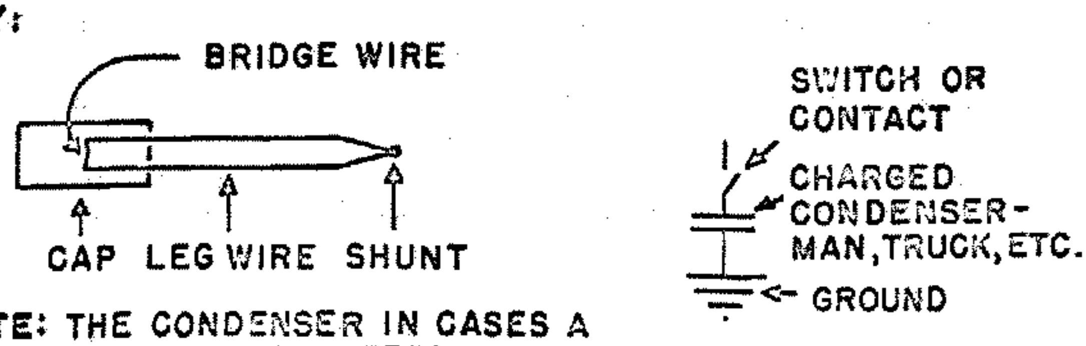

NOTE: THE CONDENSER IN CASES A AND B MAY BE INTERCHANGED FROM Y TO X.

Diagram I.

insulation (30,000+ volts) and the use of an insulated shunt make this a very improbable way to fire the cap accidentally.

Case C: A third way in which the cap can be fired is illustrated in Case C and only in case the shunt has been removed.

This method is similar to the firing of a cap by a condenser blasting machine except that in this case the condenser is thousands of times smaller and the voltage must be very high. Even in this case a man would have to be charged to over 25,000 volts, and he would have to take hold of one wire while the other was well grounded.

Tests with static-resistant caps show that over 25,000 volts may be discharged from a capacitor of greater rating than a man, through the shunt to shell path (Case A) or the shunt to wire path (Case B) without firing the cap. It might be mentioned here that in actual tests with properly grounded blowing equipment the maximum voltage produced on the operator, under the very worst conditions of low humidity was only a fraction of this minimum voltage.

Other possible situations exist, but the most likely subject to either accumulate static or discharge an accumulation from another object is the man himself. This is because he is the only moveable object in the system, and it is he that will likely transfer the charge. Possibilities also exist of a jumbo or loading platform becoming charged and the cap wires making contact there. Actually you will find, with serious thought, that the number of possible hazards are great; however, the ones that are probable are very few. This is only true, of course, if the recommended procedures and precautions are strictly observed.

The main point to remember is this: if the accumulation of static charge is prevented, then the danger is non-existent. The following list of considerations will serve as a guide in the use of air placement equipment:

A. Humidity

1. Greater than 70% relative humidity -- little hazard.
2. 50%-70% relative humidity -- somewhat borderline. Check should be made on possibilities of static build-up and suitable precautions taken.
3. Less than 50% relative humidity -- full precautions should be taken.

B. Precautions to Reduce Static Hazard

1. Ground blower.
2. For blowing ammonium nitrate, use a "semi-conductive" hose.
3. Ground operator through the "semi-conductive" hose which is grounded through the blower.
4. Under conditions where there is appreciable static build-up, use static-resistant caps.
5. Operate blower at lowest possible air pressure -- 50 to 60 psi or less for eductor type and 20 psi or less for pressure type in order to minimize generation of static electricity.
6. Be sure that the flexible hose from the compressed air supply is non-conductive. This will guard against stray mine currents being introduced into the borehole.
7. Keep the "semi-conductive" tube in the borehole while blowing, as there might be a tendency to remove the tube in order to fill the last few feet of hole without blowback of material.

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4. National Fire Protection Association, 1950, "Static Electricity" NFPA No. 77.