FIG. 3

FIG. 4
DETONATING AND DEFLAGRATING FUSE

George L. Griffith, Coopersburg, Pa., assignor, by mesne assignments, to Commercial Solvents Corporation, a corporation of Maryland


7 Claims. (Cl. 102—27)

ABSTRACT OF THE DISCLOSURE

A flexible, continuous length of explosive fuse is provided, composed of a wrapper of flexible material enclosing a cracked and discontinuous column of solid explosive. The column is made up of a plurality of irregularly shaped matching particles arranged in matching positions such that the composite corresponds to a continuous column of explosive before cracking.

The process for preparing this fuse is described and claimed in Patent No. 3,327,582.

This application is a division of U.S. Patent application Serial No. 503,756, now U.S. Patent No. 3,327,582, which is a continuation-in-part of U.S. Patent application Serial No. 177,583, filed March 5, 1962, now U.S. Patent No. 3,216,307.

This invention relates to a process for preparing detonating and deflagrating fuses, and to products obtained by this process, and more particularly to a process for preparing detonating and deflagrating fuse in continuous lengths in cracked cast form, and to the cracked cast detonating and deflagrating fuse obtainable by this process.

There are two main types of chemical explosives, detonating or high explosives, characterized by very high rates of reaction and high pressure, and deflagrating or low explosives, which burn more slowly, and develop much lower pressure. Detonating explosives are usually subdivided into primary and secondary explosives. The primary explosives nearly always detonate by simple ignition, such as by means of a spark, flame, or impact, whereas secondary explosives require the use of a detonator, and frequently a booster. A detonator contains a primary explosive as an essential element, but it may be even more complex, and include a number of modifying ingredients as well.

The oldest type of detonator is the mercury fulminate cap, first used as a detonator by Nobel. Many variations of this came into use during the latter part of the 19th century, but they are used very little at the present time. Electric blasting caps were introduced early in the present century, and these have now reached a high state of development, and contain elements each of which plays its part in the complicated process of developing the necessary high pressure detonation wave needed to detonate the secondary explosive. However, it is not very well suited for the simultaneous detonation of multiple charges.

For this purpose, the detonating fuse was developed. This is composed of a long narrow tube filled with high explosive. When an explosion is initiated at one end, by means of a detonator, the explosive shock or detonating wave travels along the fuse with a high velocity, and causes the detonation of other high explosives which lie in its path. In this way, it can procure the almost simultaneous explosion of a number of charges.

The first form of detonating fuse was a lead-bound trinitrotoluene core fuse, called Cordeau fuse, or Cordeau detonant. A long thick-walled lead tube is filled with molten trinitrotoluene, which is solidified, and the tube and its contents are then drawn out in a series of successive drawing operations, until reduced in diameter to the size of a straw, in which condition it is highly flexible, and at the same time of a very considerable length, as compared to the original tube. Later, aluminum or block tin tubes were prepared, filled with picric acid. However, this type of fuse has now almost entirely been replaced by a tube of woven fabric filled with nitrocellulose or with Pentolite (pentacyanhydrate tetrattirate), called Primacord.

In addition, it can be made in continuous lengths, much more simply and less expensively than Cordeau fuse. The cloth binding is normally waterproofed with wax or other water-resistant fillers, and is usually reinforced with a wire or cord binding. This cord has a detonation velocity of about 6500 meters per second, as compared with about 5000 meters per second for Cordeau fuse. However, neither of these are the maximum velocities of detonation of these explosives. The velocities could be greater, and would be, if the explosives were more densely packed.

Both Cordeau fuse and Primacord contain finely-divided crystalline explosives, but in these the explosive is in a somewhat different condition. Cordeau fuse is filled with cast trinitrotoluene, and as the lead tube is drawn out, the cast trinitrotoluene becomes pulverized, so that the finished tube is tightly packed with finely-divided crystalline trinitrotoluene. Primacord is made by filling the cloth or plastic bound tube with finely-divided pentacyanhydrate tetrattirate, which is packed in the tube as tightly as possible. In the case of Primacord, the problem of packing the explosive in the tube is quite difficult to resolve, and because of the difficulty of packing, it is not possible to realize the full velocity of detonation that might otherwise be obtainable with pentacyanhydrate tetrattirate or nitrocellulose. Furthermore, the packing operation itself can be dangerous.

In accordance with the invention, a process is provided for manufacturing detonating fuse and deflagrating fuse filled with a column of solid detonating or deflagrating explosive, cracked in situ, so as to cause discontinuity throughout the column of explosive. The cracking increases sensitivity, due to deflection of the detonating or deflagrating wave from the cracked crystals in the column. The process is adapted for the production of fuse, so as to make detonating fuse and deflagrating fuse in any desired length, and without restriction as to diameter, being adaptable for the production of detonating fuse and deflagrating fuse in any desired diameter, ranging upwards from 5/32 inch to approximately one inch or higher, as required. The process further ensures close packing of the explosive in the wrapper, substantially without voids between the particles, and thus of a high density even in the cracked condition to ensure maximum velocity of travel of the detonating wave or deflagration through the fuse.

In accordance with the process of the invention, detonating fuse and deflagrating fuse are formed by filling a tube or shell of the desired length and diameter with molten or semi-solid detonating fuse high explosives, or deflagrating fuse low explosive, and allowing this to harden or solidify to a solid column within the tube, filling it substantially completely. In this way, endless tubes previously formed in a continuous tube extruder, for instance, can be employed. In the preferred process, referred to herein as a fill-and-wrap self enclosing process, the filling of the tube is made to form the tube or enclosing wrapper as well, by extruding the detonating or deflagrating explosives with which it is to be filled in a column of the desired diameter and length, and forming the fuse wrapper about and enclosing the ex-
The extruded column of explosive is brought into contact with the enclosing sheet of wrapping material so as to have become sufficiently hard after leaving the extruder, and through frictional engagement thereby draws with it the sheet of wrapping material. Upon continued outward movement of the wrapper with the extruded column, the wrapping material is caused to form an envelope about the column, thereby enclosing it in a wrapper of the wrapping material. Preferably, the wrapping material is folded lengthwise over a forming mandrel, such as an extrusion tube or nozzle, using a wrapping sheet of such width as to completely enclose the extruded column in a small overlap to strengthen the longitudinal seam where the two edges of the wrapper join. If necessary, due to the fluidity of the explosive, pressure is applied to the surface of the package sufficient to retain the explosive therewithin, and prevent distortion of the column of explosive and therefore the fuse wrapper under the pressure of extrusion. Preferably, however, the explosive is in the fluid or semi-solidified condition at the time it contacts the wrapping material, or shortly thereafter. The lapped edges of the wrapper are next closed, and perfectly sealed, and the fuse wrapper or tube is complete, with a solid column of explosive enclosed therewithin.

After completion of the fuse wrapper, the explosive column is subjected to compressive stress in situ, so as to crack the column and render it discontinuous within the wrapper. At the same time, because the column is held within the wrapper, the cracked particles of explosive are prevented from significant displacement relative to each other, and thus retain the form of a cast column, as originally formed. The cracking is sufficiently thorough to reduce the particles to a small size, of which at least 50% are less than 1/8 inch in diameter, and preferably, approximates a crushing operation, as a result of which at least 50% pass through a 35 mesh screen; and at least 25% through a 120 mesh screen. All of the particles of course have a diameter appreciably less than the diameter of the fuse. The cracking renders the fuse more flexible, and ensures the development of maximum sensitivity. As a result of this cracking operation, the fuse will transmit a detonating wave from one end to the other.

After cracking or crushing, the fuse is complete. Any desired length of fuse can be obtained by measuring and cutting off an appropriate length of the tube. The process of the invention is applicable to detonating fuse high explosive and deflagrating fuse low explosive compositions of all types. It is of particular application to extrudable explosives or cast explosives, which can be extruded or filled in semi-solid or liquid form, and which can harden to form a solid in situ in the wrapper. If the column is to be filled into a tube formed over it, it is brought to a solid state in the form of a column prior to contact with the wrapping material, and can then in the hardened condition act as the motive force for drawing with it the sheet of wrapping material in the ensuing enclosing operation.

The usual detonating and deflagrating explosives can be modified to improve extrudability by the addition of plasticizing or softening additives, and additives also can be added to harden an otherwise too soft explosive composition that is not readily cracked or broken up, in reduction of the cast or hardened material to smaller particle size.

When a molten filling is used, or when an extruded column of explosive itself serves as the motive force for drawing the wrapper and sheet of wrapping material forward, and forming the envelope surrounding the column, consolidation of the explosive composition within the wrapper to a uniform density of explosive is ensured. Thus, it is possible to avoid the accidental formation within the fuse wrapper of partially filled areas, or of voids or open areas, in which the explosive composition is at a lower density, or is completely missing, with disastrous effects upon propagation of the detonating wave or deflagrating detonation beyond that point. This also ensures that the explosive composition will more or less completely fill the wrapper and, being tightly held therein, will be kept in a columnar form by the wrapper after cracking. This ensures close juxtaposition of the explosive particles and the wrapper product, which makes it possible for the detonating wave or deflagration to travel along the fuse at a high velocity. As a result, the detonating velocity of Pentolite in the detonating fuse prepared in accordance with the invention has exceeded a velocity of 6200 to 6300 meters per second.

In order that an extruded column of semi-solid or thixotropic explosive can draw the wrapping material forward, it is necessary that the seam formed in folding the wrapping sheet about the column be held together closely before sealing. The pressure necessary to hold the seam together before sealing can be applied to the package by any of several means. The open seam between the edge or fold of the wrapper can be glued or heat-sealed promptly after forming. The wrapped package also can be retained between vanes or a series of circular rolling surfaces. One simple and preferable method which improves flexibility of the fuse is to encircle the package with one or two sets of a spiral wind of filamentary material, such as string, cord, or wire. If two sets are used, one is wound clockwise, and the other counterclockwise, about the package.

The retaining filaments can be applied by conventional means which are well known to those skilled in the packaging art, and form no part of the instant invention.

The filaments can, if desired, be bonded to the package by application of the same means used to bond the seam. The retaining filaments are preferably of a material such as fiber glass, which does not result in generation of an appreciable quantity of fumes when the fuse is fired. Other materials which can be used include polyamides, such as nylon, viscose rayon, acetate rayon, polyvinyl chloride, Orlon and Dacron.

In a fill-and-wrap self-enclosing process, the wrapping material may have a tendency to wrap itself spirally about the loading mandrel under packaging conditions. This spiralling tendency can be counterbalanced by an opposite force sufficient to restrain it. A counterbalancing force can be applied by means of a belt or other means, which slips over the wrapped fuse and tends to wind the fuse in a direction opposite to that of the spiralling tendency of the wrap. The application of a filament wound about the tube in the direction opposite to the spiralling also is effective. While one filament winds to counterbalance the tendency of a wrapping material to wrap itself about the loading mandrel is usually adequate, a double wind in both directions gives a far greater and more satisfactory strength to the package.

The open seam of the wrapper can be bonded by any desired means appropriate to the wrapper material used. A bonding agent or composition can be applied on the overlapped edges can be sealed by application of heat or pressure, or by application of a solvent for the resin and pressure, removing the solvent by heating. After the seam or seams have been bonded, there is no longer any need to apply external pressure to retain the explosive.
within the package, and any filamentary material wound about it temporarily for this purpose can be removed. Any type of wrapping material can be employed, including, for example, paper, cloth, non-woven cloth, plastic material, such as polyethylene, polypropylene, polyvinyl chloride, and copolymers of vinyl chloride and vinyl acetate, rubber hydrochloride, cellulose acetate, and glassine or wax paper. Extrudable plastic materials are particularly useful in the formation of extruded tubes in continuous lengths for filling with molten detonating explosive, but sheet, plastic can be extruded, filamentary material wound about it temporarily for this purpose can be removed.

Cracking of the cast or hardened explosive is effected after filling and solidifying are completed. For this purpose, the fuse can be passed between crushing rollers, which subject the tube and its contents to compressive stress sufficient to crack the column into small particles, of the order of ½ inch in diameter, and preferably, to a finely-divided condition. The pressure is not critical, but it will be no greater than required to crack, because of the possibility of detonation at excessive pressures. Thus, the cracking pressure limit is established by detonation pressure, and is usually below about 60 p.s.i. Cracking results in a small increase in volume, due to the spaces introduced between the particles by the cracks, even when the particles are not appreciably displaced with each other. However, most cast explosive materials shrink slightly on solidifying, due to the decrease in volume upon cooling, and these two factors usually result in a cracked fuse which is substantially unchanged in volume from the original fuse, due to the compensating effect of the two opposing tendencies.

If the fuse is distorted in shape, due to the cracking operation, it can be passed between forming rolls or through a forming die, so as to restore it to the desired shape, such as a round configuration.

In the preparation of detonating fuse, the process is applicable for detonating fuse explosives of any type. Preferred explosives are those which can be molten and then cast, such as, Pentolite (a mixture of equal parts by weight of pentacycloheptane trinitrate and trinitrotritro- lunene), trinitrotoluene, the amatolos (combinations of ammonium nitrate and trinitrotritro-lunene), the sodatols (combinations of sodium nitrate and trinitrotritro-lunene), Composition B (a mixture of up to 60% RDX, up to 40% TNT, and 1 to 4% wax), Cyclonite (RDX, cyclotrimethylenetetranitramine), tetryl, Cyclotol (Composition B without the wax), and mixtures of these.

The process is also applicable to deflagrating explosives of any type, such as black powder, smokesless powder, trimethylene trinitrate, gun powder, and mixtures of these.

Cast explosives are best filled in the following manner. They are first brought in the molten condition, and then filled into a previously prepared tube. If they are to be used in a fill-and-wrap process, they are passed through the extruder under pressure, and under conditions such that they harden into a solid or semi-solid not necessarily finally hardened cast condition, at the time they are brought in contact with the wrapping material. In the solid or semi-solid condition they can be used as the motive force for driving the wrapper forward and forming the package, and pressure can be applied to the fluid being fed to the wrapper, so as to push the solidified explosive column forward for this purpose. Solidification to this extent requires careful control of temperature at the point of contact between the explosive and the wrapper, but this is readily achieved by conventional equipment, such as by an extruder nozzle provided with a temperature control jacket.

The invention also is applicable to explosive materials that can be brought into a semi-solid condition for the purpose of extrusion, and then become hard upon curing or aging, or heating, or cooling, according to the explosive composition. Such explosives are readily extruded in the semi-solid condition, and in this condition pressure can be applied thereto so as to provide the motive force for drawing the wrapper forward and completing the package, and they can be allowed to harden either before or after the fuse package has been formed, but before cracking or crushing.

Explosives of this type to which the invention is applicable include combinations of nitrostarch and nitrocellulose with gelatinizing or plasticizing agents, such as nitroglycol, dinitrotoluene, and trimethylolhexanetrinitrate, combinations of tetraniortrodiglycerine with nitrocellulose, and combinations of nitramin and trimethylolhexanetrinitrate.

Various additives can be incorporated in the detonating or deflagrating explosive composition, either to improve or to reduce hardness. Trimethylolhexanetrinitrate and dinitrotoluene are good hardness-reducing additives, which will improve lubricity during extrusion, and in fact, any liquid explosive will serve this purpose. Only small amounts are usually required, of the order of from 0.5 to about 20% by weight of the explosive composition.

It is generally preferable that the detonating or deflagrating explosive have a softening point above the temperatures to which the fuse may be subjected during storage and use. Usual use conditions will require that the explosive have a softening point at least 120°F., and preferably above 150°F. There is no upper limit on softening point, except as may be dictated by the extrusion conditions and equipment that may be available for preparing the fuse, in bringing the explosive composition into the necessary molten or semi-solid condition required for forming and filling the wrapper.

It is also possible to apply the process to the formation of detonating or deflagrating fuse using detonating or deflagrating explosive powders as the filler material. These are, however, more difficult to process, and accordingly the use of explosives which can be made molten or semi-solid for filling or filling-and-wrapping are preferred.

When the explosive composition itself serves as the motive force for forming the package, and the package is formed with an open seam ab initio, air which may be trapped in or with the explosive composition can leak rapidly from the wrapper through the open seam. The extruded column will move forward, drawing the wrapping material with it, only when explosive material is being pushed forward. Where there is an air pocket in the interior of the mass of explosive, there is no explosive mass to apply the necessary motive force, and hence there is no further movement of the extruded explosive until the air pocket has been eliminated.

The finished detonating fuse or deflagrating fuse can be disposed of in any manner known to the art. Very long and continuous lengths of fuse can be stored by winding the fuse on a spool or roll. The fuse may be packaged to any desired length by cutting it off either automatically or manually at the desired length. The exposed ends can be protected or closed off by spraying, dipping, applying caps, or other well known packaging methods. In many cases, it is unnecessary to protect the ends, since the finished fuse can be shipped in cases which are themselves closed, and thereby prevent atmospheric moisture from entering the fuse. It is also possible to improve the strength of the outer covering by means of gluing, spraying, coating or continuous dipping. All such procedures are well known to those skilled in the explosives and packaging arts.
3,367,266

7. Simultaneously the wrapping material 2 is formed into a hollow tube 5, which is held within the folder 3 well into the cooling jacket 8; and thus can retain the detonating or deflagrating explosive composition therein without distortion. As the explosive is solidified within the cooling jacket 8, it becomes unnecessary to provide external support for retaining the tube seam together, and the cast column and tube are carried on rolls 14 to the point of application of glue or other bonding agents from nozzles 40 and 41, and after which the sealed and coated tube is heated to complete the bond. The finished cast column of explosive within the tube is then cracked or crushed in situ between the rolls 60, 61, 62 and 63, and the finished fuse 13 emerges from the system in a flexible continuous length, which can be wound up on the storage roll 50 as shown, and packaged as such.

The apparatus shown in FIGURE 4 is adapted for use of a prefomed folded open side tubing, filling this with molten detonating or deflagrating explosive. The explosive in a powdery form 70 is fed into the hopper 71, which is heated to a temperature at which the explosive powder melts into a viscous fluid, which is then fed by the screw loader 72 through the extrusion nozzle 73, which is also heated to maintain the explosive in fluid condition, and emerges into the feeding nozzle 74, which shapes it into columnar form. A supply of folded sheets of plastic material, such as polyethylene or polyvinyl chloride, in the wound form of supply roll 75, is fed over the guide roll 82, beyond which the folded sheet is opened, so that one half passes over one side of the feed nozzle 74, and the other half passes over the other side of the feed nozzle, which extends into the tubing beyond this point. The sheet sides are brought back together over the outside of the nozzle by means of the folder 3, which is of a type similar to that of FIGURES 1 to 3, forming a tube with a lapped seam, and the seam is heat-sealed by application of heat and pressure through the heated heat-sealing rollers 85, which ride along the top of the feed nozzle 74, thus forming a closed tube at this point.

The feed nozzle 74 extends well into the tube, beyond the rollers 85, and feeds molten explosive into the tube at a rate sufficient to completely fill the tube with explosive. The pressure of feed is such that any air which may be present is forced out of the column and escapes from the tube over the top of the nozzle and out through the open seam before the rolls 85.

The filled tube then passes into a cooling jacket 8, through which a cooling fluid such as water is circulated via pipes 9 at a temperature sufficient to solidify the molten explosive in the course of its passage through the jacket. Usually, a temperature of from 10 to 20° C. below the softening temperature of the explosive is adequate to ensure complete solidification of the explosive into a cast solid form by the time the tube emerges from the cooling jacket.

The tube then passes into the bite of two pairs of cracking or crushing rollers 60, 61, 62, 63 as in the apparatus of FIGURES 1 to 3. A carrying belt 45 passes over the rollers and serves to cushion the force supplied from the rollers to the column of explosive within the tube. The remainder of the system is exactly as in FIGURES 1 to 3.

In operation, the molten explosive is fed at the required rate to completely fill the tube, fed to its over the outside of the feed nozzle 74. The feeding pressure is sufficient to ensure that the force-fed molten explosive will provide the sole motive force for carrying the tube forward through the system, thus making possible consolidation of the explosive within the tube, and the elimination of any air pockets.

In the case of a mixture of pentaaerythritol tetranitrate and trinitrotoluene, such as Pentolite, the operating temperature in the hopper is approximately 90° C. and this temperature is maintained through the first portion of the extrusion nozzle 73. Thereafter, the apparatus is open.

the mandrel about which the wrapper is folded in forming the fuse. FIGURE 2 is a cross-sectional view on an enlarged scale to the apparatus to the FIGURE 1, taken along the line 2—2.

FIGURE 3 is a view on an enlarged scale, and partly in section, of the wrapping and cracking portion of the apparatus of FIGURE 1, viewed from the back.

FIGURE 4 is a view of another embodiment of apparatus, adapted to load molten castable detonating or deflagrating explosive into a preformed open-seam folded tubing.

The apparatus shown in FIGURES 1 to 3 comprises an extruder 1 equipped with an extrusion nozzle 4 from which the detonating or deflagrating explosive composition emerges in a semi-solid condition in the form of an extruded column 6. Explosive compositions which can be extruded in this way are, for example, a combination of dinitrotoluene and nitrostarch, or a mixture of nitrocellulose, nitroglycerin and nitrocellulose. Positioned at a point a short distance from the extruder is a folder 3, in the form of a flared hemicylinder, at the near side end 10 where it first engages the wrapping material having a diameter approximately twice that of the extruder, and at the outside end 11 having a diameter very closely approximating that of the extrusion nozzle, i.e., ¾ inch. Wrapping material 2, for example, strong brown manila paper, from the storage roll 7 is brought into contact with the forward near side end of the folder, and there folded about the extrusion nozzle 4, and is formed into the tube at the tip of the extrusion nozzle.

Surrounding the folded tube 5 beyond the first half portion of the folder 3 is a cooling jacket 8, through which water or cooling fluid is circulated via pipe 9, to cool the extruded column of explosive to a solidifying temperature, bringing it into the cast solid condition. The jacket is sufficiently long to assure completion of solidification before the column emerges from the extruder at the travel speed of the fuse through the system.

Beyond the cooling jacket 8 are positioned a pair of applicator nozzles 40 and 41, which feed a wax coating and bonding composition to the tube from the reservoir 42. These are in close juxtaposition to the wrapped tube of explosive, now a detonating or deflagrating fuse 13, emerging from the jacket 8, one nozzle 40 being directed at the seam thereof. The coating seals the seam and waterproofs the tube.

A pair of carrying belts 45 are provided, to support the fuse and apply heat thereto from the heater 46 to dry the bonding composition applied by the nozzle. Just after it contacts the belts 45, the fuse passes into the adjustable bite of a pair of cracking or crushing rollers 60 and 61, and then into the adjustable bite of a second pair of crushing rollers 62, 63, which grip the fuse at the top and bottom, in sequence, to ensure thorough cracking, and even crushing, if desired, depending on the width of the gap between the rollers, of the solid cast explosive column within the tube. The second set of rollers 62, 63 can alternatively be arranged to grip the fuse at the sides, if desired.

Finally, a storage roll 50 receives and winds up the fuse 13 emerging from the system.

In operation, detonating or deflagrating explosive composition in a semi-solid condition is passed through the extruder 1. The wrapping material 2 in sheet form is drawn from the storage roll to and through the folder 3, where it is folded over the exterior of the extruder 4, and then brought forward along the outside of the extruder nozzle 4 over the end thereof, at which point it comes into contact with the semi-solid extruded column 6 of detonating or deflagrating explosive composition emerging from the extruder nozzle. The explosive composition draws the wrapping material with it, as it emerges from the extruder, and thus continuously draws off a supply of wrapping material 2 from the storage roll.
to atmospheric temperature, and some cooling is effected. By the time the explosive has reached the heat-sealing rollers 85, it is in a semi-solid condition, virtually ready to solidity, and the temperature is within the range from 85 to 77° C. The cooling jacket is maintained at 60° C., and this quickly brings the temperature of the explosive to below 75° C, whereupon it solidifies in cast form, and can then be cracked or crushed in the bite of the rollers 60, 61, 62, 63.

The following examples in the opinion of the inventor represent preferred embodiments of the invention.

Example 1

Using the apparatus shown in FIGURE 4, a ¼ inch detonating fuse was prepared using Pentolite (a 50-50 mixture of pentaerythritol tetranitrate and trinitrotoluene). The detonating explosive was fed at 90° C., and solidified in the jacket, which was held at 60° C. It was then crushed.

A 36 inch length of the fuse that was obtained was detonated with a No. 6 Du Pont blasting cap, butted against one end. 17 inches out of 36 inches were detonated. Another length of the same fuse was opened, and the crushed Pentolite subjected to screen analysis, with the following results:

<table>
<thead>
<tr>
<th>Percent Pentolite</th>
<th>34.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>On 35</td>
<td>34.0</td>
</tr>
<tr>
<td>On 60</td>
<td>34.0</td>
</tr>
<tr>
<td>On 90</td>
<td>34.0</td>
</tr>
<tr>
<td>On 120</td>
<td>6.1</td>
</tr>
<tr>
<td>On 230</td>
<td>10.9</td>
</tr>
<tr>
<td>Through 230</td>
<td>26.5</td>
</tr>
</tbody>
</table>

A length of the fuse was removed before reaching the crushing rolls, and detonation was attempted on the cast fuse. The fuse detonated only 6 inches out of 36 inches. The effectiveness of the crushing in improving sensitivity is evident from this test.

Example 2

A ¼ inch detonating fuse was prepared using the apparatus of FIGURE 4, with Composition B as the detonating explosive. The detonating explosive composition contained 60% RDX, cyclotrimethylene trinitramine, 39% trinitrotoluene, and 1% wax. The hoper of explosive was held at 85° C, and the explosive was cooled to solid cast condition in the jacket held at 60° C.

A 36 inch length of the detonating fuse that was obtained was detonated with a No. 6 Du Pont blasting cap butted against one end. 18 inches out of 36 inches detonated.

Another length of the detonating fuse was removed before passing through the crushing rollers, and then tested for detonating ability. The fuse detonated only 7 inches out of a 16 inch length, thus evidencing the importance of crushing, in imparting the necessary sensitivity to the fuse.

A length of the crushed fuse was opened, and subjected to screen analysis, with the following results:

<table>
<thead>
<tr>
<th>Percent Composition B</th>
<th>28.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>On 35</td>
<td>28.6</td>
</tr>
<tr>
<td>On 60</td>
<td>28.6</td>
</tr>
<tr>
<td>On 90</td>
<td>28.6</td>
</tr>
<tr>
<td>On 120</td>
<td>4.2</td>
</tr>
<tr>
<td>On 230</td>
<td>14.7</td>
</tr>
<tr>
<td>Through 230</td>
<td>35.5</td>
</tr>
</tbody>
</table>

The detonating fuses of Examples 1 and 2 were compared to Primacord for rate of detonation and cavitation in a lead plate. The lead plate cavitation was determined by placing a length of detonating fuse or 50 grain Primacord core load with the reinforcement removed; only the black asphalt countering remaining on a lead plate. The length of cord was held in contact with the plate by a strip of masking tape running its entire length. Initiation was by No. 6 Du Pont blasting cap.

<table>
<thead>
<tr>
<th>Material</th>
<th>Rate of Detonation</th>
<th>1/4” Thick Lead Plate Cavitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Depth, mm.</td>
</tr>
<tr>
<td>Example 1</td>
<td>5,911</td>
<td>19.1</td>
</tr>
<tr>
<td>Example 2</td>
<td>5,623</td>
<td>22.0</td>
</tr>
<tr>
<td>Primacord</td>
<td>6,565</td>
<td>17.2</td>
</tr>
</tbody>
</table>

It is apparent that the Examples 1 and 2 fuses had a higher brisance than Primacord, and that Example 1 had a faster rate of detonation than did Primacord.

Example 3

Using the apparatus of FIGURES 1 to 3, a ¼ inch detonating fuse was prepared from Pentolite. The fuse that was obtained detonated 30 inches out of 30 inches, when initiated by a Du Pont No. 6 blasting cap butted against the end of the fuse. On the other hand, an uncrushed cast fuse detonated only partially under the same conditions.

Example 4

Using the apparatus of FIGURE 4, a ¼ inch deflagrating fuse is prepared from smokeless powder, gelatinized by trimethylolethanetriaminite. The fuse deflagrates well, and quickly, throughout its entire length.

Having regard to the foregoing disclosure, the following is claimed as the inventive and patentable embodiments thereof:

1. A flexible continuous length of explosive fuse comprising a wrapper of flexible material continuous for substantially the entire length of the fuse, enclosing a cracked and discontinuous column of like length of solid explosive, said column being composed of irregularly shaped matching particles in close juxtaposition to each other and in matching positions so that the composite of particles corresponds to a continuous column of explosive, at least 50% of the particles being less than ¾ inch in diameter, the fuse being sufficiently flexible to be wound about a core, and having sufficient sensitivity to conduct a detonating wave or deflagration therethrough.

2. An explosive fuse in accordance with claim 1, in which the wrapper comprises a continuous sheet folded longitudinally and sealed.

3. An explosive fuse in accordance with claim 1, in which the wrapper is provided with a coating of protective material.

4. An explosive fuse in accordance with claim 1, substantially uniform in density and diameter and free from air pockets.

5. An explosive fuse in accordance with claim 1, filled with a detonating explosive.

6. An explosive fuse in accordance with claim 1, filled with a deflagrating explosive.

7. An explosive fuse in accordance with claim 1, in which at least 50% of the particles of explosive pass through a 35 mesh screen and at least 25% pass through a 120 mesh screen.

References Cited

UNITED STATES PATENTS

1,923,761 8/1933 Snelling et al.         102—27 X
2,982,210 5/1961 Andrew et al.         102—27 X
3,155,038 11/1964 Smith               102—27 X

BENJAMIN A. BORCHELT, Primary Examiner.
V. R. PENDEGRASS, Assistant Examiner.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,367,266

February 6, 1968

George L. Griffith

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, lines 48 to 50, strike out "length, and without restriction as to diameter, being adaptable for the production of detonating fuse and deflagrating fuse in any desired"; column 8, line 64, for "its" read -- it --.

Signed and sealed this 15th day of April 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents