Aug. 22, 1961 J. T. PAUL, JR 2,996,987

BLASTING CAP ASSEMBLY

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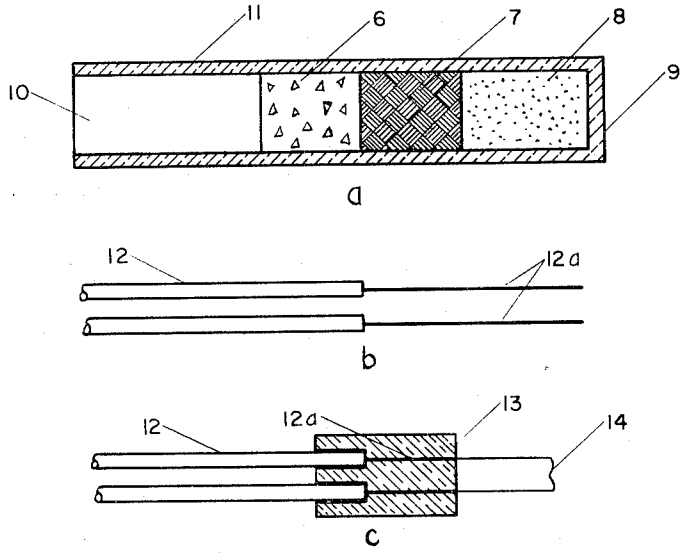


FIG. 1

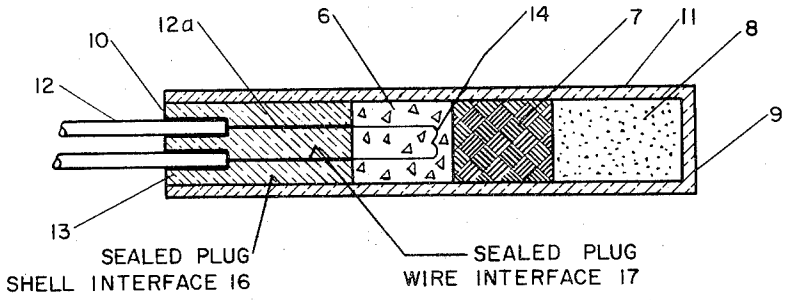


FIG. 2

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BLASTING CAP ASSEMBLY

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This invention relates to blasting caps and to their manufacture. In one aspect this invention relates to a method for the manufacture of blasting caps utilizing at least one plastic of the group of polyethylene, polypropylene and an alloy thereof. In another aspect this invention relates to electric blasting caps formed from a plastic material above defined. In another aspect this invention relates to a heat treatment method for sealing an ignition plug in a blasting cap shell, both plug and shell being formed from at least one of polyethylene, polypropylene and an alloy thereof. In still another aspect this invention relates to a method for effecting an improved, and watertight, seal between conductor wires and ignition plug of an electric blasting cap, formed from a plastic of the group of polyethylene, polypropylene and an alloy thereof, by sandblasting the said wires prior to effecting the said seal.

Electric blasting caps, or initiators, are employed for the detonation of high explosives often by actuation of a pressed charge at the base of the cap shell. A pair of conductor lead wires, or "leg" wires, as often referred to, is disposed in a plug or closing element in the cap shell and extends through the plug into the shell in communication with a heat-sensitive material which is an ignitable or a detonatable composition. The leg wires are connected in operative communication with such a heat-sensitive material by a high resistance wire, or bridge wire, which becomes heated on the passage of an electric current via the leg wires to provide the necessary heat for transfer to the composition to ignite it or detonate it, as the case may be. Electric blasting caps generally consist of an elongated metal cap shell containing the base charge on which is superposed a smaller charge of initiating or priming explosive and an ignition composition as the immediate heat-sensitive material surrounding, or in operative contact with, the bridge wire.

In herent with operations relating to the use of electric blasting caps is the problem of maintaining the said cap under waterproof conditions when water head is encountered, which can be up to 500 p.s.i. or higher, i.e., so that there is no leakage of water into the cap in contact with the explosive component. Thus, various methods and means have been provided in the past for effecting the requisite watertight seals and have been directed to sealing the plug with the shell and the leg wires with the plug. Thus, one common practice has been that of disposing a layer of a waterproof compound in the shell above a cast sulfur plug and around the leg wires entering the cast sulfur plug and then pressing or casting a top seal of sulfur in the remaining open end of the metal shell. Such a waterproofing layer has usually consisted of an asphaltic material poured in place and then cooled to normal temperatures to form the solid seal.

Such methods both with reference to the shell plug seal and the leg wire-plug seal have been accepted in the art and although in many instances they provide an adequate seal, much has been left to be desired with reference to safety in manufacturing, handling and use and particularly in respect of failures encountered when the cap is placed under a high head of water. Fluctuations in temperature and pressure under water head conditions have particularly had their adverse effects upon these conventional type seals.

Various plastic-type blasting cap assemblies have been proposed in the art which contemplates effecting the necessary plastic seals by solvent or adhesive action, and which are disadvantageous in many respects. Thus, the ignition plug, cap shell, or both, must be dipped into or coated with some suitable solvent. In making the seal it is necessary that the fit between the plug and shell be such that the solvent gelled surfaces are forced to flow together to form the bond, but not so tight that the gelled surface is scraped away. Then, in order to assure a physically strong and water-resistant bond, the solvent must be allowed to escape from the gelled surfaces, either by migration through the shell wall, or into the bridge plug, or by evaporation out through the glue line. This evaporation of solvent is at best slow, and very difficult to control accurately, and leads to poor seals.

This invention is concerned with new plastic blasting caps, and particularly with a new electric blasting cap exhibiting improved watertight seal between leg wires and plug and between plug and cap shell, which exhibits improved resistance to discharge by stray currents, and which advantageously lends itself to continuous mechanized production.

An object of this invention is to provide new plastic blasting cap assemblies. Another object is to provide for the production of new plastic blasting cap assemblies. Another object is to provide a method for effecting a watertight seal between an ignition plug and a cap shell, both made from one of a polyethylene, a polypropylene and an alloy thereof, in a blasting cap assembly. Another object is to provide for a watertight seal between leg wires and a plug, made from one of polyethylene, polypropylene and an alloy thereof, in an electric blasting cap assembly. Another object is to provide blasting caps, highly resistant to stray currents and exhibiting higher resistance to water than heretofore. Other aspects and objects will be apparent from the accompanying disclosure and the appended claims.

In accordance with the invention, an improvement is provided in the manufacture of a blasting cap which comprises forming the ignition plug from a solid polymer consisting essentially of one of the group of a polyethylene characterized by a softening point of at least 100° C., a polypropylene characterized by a softening point of at least 160° C., and an alloy of said polyethylene and said polypropylene, inserting said plug into a blasting cap shell, also formed from the above described polymer, and applying heat to the resulting plug-shell interface to heat-seal said plug and said shell in watertight relationship. Also in accordance with the invention, an improvement in a blasting cap assembly is provided which comprises a plastic shell, and a plastic ignition plug in said shell fused in watertight relationship therewith; said plastic consisting essentially of a solid polymer of the group of a polyethylene and a polypropylene, each characterized by a softening point as above described, and an alloy of said polyethylene and said polypropylene. Further in accordance with the invention, an improvement in a blasting method wherein an electric blasting cap is disposed in detonating relationship with an explosive charge, is provided, for firing the blasting cap under improved conditions of cap strength, moisture resistance, and stray current resistance which comprises disposing a blasting cap, in said detonating relation, having both the shell and ignition plug formed from a solid polymer consisting essentially of one of the group of a polyethylene and a polypropylene, each characterized by a softening point as above described, and an alloy of said polyethylene and said polypropylene, and having the said ignition plug disposed within the shell in fused sealed relationship therewith, and disposed in watertight relationship with the conductor wire sections extending therethrough.

In accordance with one process embodiment of the invention, the ignition plug assembly is formed by injection molding the plastic plug material hereinabove described around bared sections of the separate conductor leads, in watertight relationship therewith. A bridge wire, or resistance element, is connected across the terminal ends of the conductor wires and the plug is then inserted into the loaded cap shell also formed from the said plastic material, with the ignition wire in contact with the heat sensitive material. Heat is then applied to the interface of the plug and shell at a temperature sufficiently high to cause fusion of the polymer at the interface subsequent to which the fused polymer is cooled to below the said fusion temperature. In this manner, an electric blasting cap exhibiting especially high resistance to moisture and stray currents is provided. Sandblasting, or otherwise roughing, the wire surfaces prior to injection molding provides even a stronger watertight seal.

In accordance with one embodiment of blasting cap assembly of the invention, the assembly comprises the shell and the ignition plug, each formed from the hereinabove described plastic; the ignition plug being fused with the shell at the plug-shell interface in watertight relationship therewith; a detonatable explosive material in the shell supported in one end; an ignitable material capable of detonating said explosive, when ignited, and supported in the said shell in close proximity to the explosive material in detonating relation therewith, and ignitable by heat evolved when an electric current is passed through a resistance wire described hereinafter; a pair of electric conductor wires extending into the shell through the ignition plug and terminating in close proximity to the ignitable material; the plug being fused in sealed relationship with a section of each of said conductors, extending through the plug, so as to be in sealed watertight relationship therewith; and a resistance wire connecting the said conductors, within the shell, in operative contact with the ignitable material so as to ignite same when heated by said passage of electric current.

The blasting cap assemblies of this invention exhibit high resistance to water, particularly by virtue of the improved fused seal between the shell and ignition plug and the seal between leg wire and plug. These seals are markedly improved over those of the plastic assemblies of the prior art, which employ solvent action to effect the seal.

Any suitable polyethylene, generally one having a softening point above about 100° C., can be utilized in the practice of this invention by which I mean to include both linear-type and branched-type polymers, the former prepared under pressure approximating atmospheric, the latter being prepared at under several thousand pounds pressure.

Branched polyethylenes, suitable in the practice of this invention, can be prepared in accordance with any of the high pressure processes of the prior art. They are generally characterized by a softening point above about 100° C. and an RSV from about 0.9 to 1.7, although higher values can be employed depending on the moldability of the polymer.

Linear-type polyethylenes, particularly suitable in the practice of this invention, are those produced by polymerizing ethylene under relatively mild conditions of temperature such as described in the Belgian Patents 533,362, 534,792 and 534,888 which are directed to the polymerization of ethylene, using as the catalyst for the polymerization a mixture of a compound of a metal of groups IV–B, V–B or VI–B of the periodic table in combination with an organometallic compound of an alkali metal, alkaline earth metal, zinc, earth metal (preferably aluminum), or rare earth metal.

The transition metal compound may be any inorganic salt or organic salt or complex of titanium, zirconium, hafnium, vanadium, columbium, tantalum, chromium,

molybdenum, tungsten, thorium or uranium. Exemplary of such compounds are titanium and zirconium tetrachlorides, tetrabutyl titanate, zirconium acetylacetonate, vanadium oxyacetylacetonate, chromium acetylacetonate, etc. The organometallic compound that is used in combination with the transition metal compound may be any organo compound of an alkali metal, alkali earth metal, zinc, earth metal, or rare earth metal as, for example, alkali metal alkyls or aryls such as butyllithium, amylsodium, phenylsodium, etc., dimethylmagnesium, diethylmagnesium, diethylzinc, butylmagnesium chloride, phenylmagnesium bromide, alkyl- or aryl-aluminum compounds as, for example, triethylaluminum, tripropylaluminum, triisobutylaluminum, trioctylaluminum, dimethylaluminum chloride, diethylaluminum chloride, ethylaluminum dichloride, the equimolar mixture of the latter two known as aluminum sesquichloride, diisobutylaluminum chloride or fluoride, diethylaluminum hydride, ethylaluminum dihydride, diisobutylaluminum hydride, triphenylaluminum, diphenylaluminum chloride, etc., and complexes of such organometallic compounds as, for example, sodium aluminum tetraethyl, lithium aluminum tetraoctyl, etc. The polymerization in accordance with the above referred to Belgian patents is usually carried out by mixing the two catalyst components in a diluent such as a hydrocarbon solvent and then passing ethylene into the catalyst mixture at atmospheric or slightly elevated pressure and at room temperature or moderately elevated temperatures.

The molecular weights of the polyethylene referred to in the patents above referred to are measured by reduced specific viscosity values (RSV) by which is meant the specific viscosity, corrected to zero shear gradient, divided by the concentration of the solution in grams per 100 milliliters, measured at 135° C. on a solution in decalin containing 0.1 g. of the polymer in 100 ml. of solution. Those polyethylenes are characterized by a molecular weight such that the polymer has a reduced specific viscosity of at least about 1.2 and preferably the range of about 2.0 to 3.5 to as high as 4.0 or higher, the maximum RSV or molecular weight of the polymer being limited only by its moldability.

Softening point values of the linear-type polymer, in the practice of this invention, are preferably above about 125° C.

Softening point values set forth herein with reference to polyethylene and polypropylene are those temperatures at which total loss of crystallinity, accompanied by disappearance of the birefringence due to crystallinity, occurs.

The invention is further illustrated with reference to the attached drawings, of which FIG. 1 illustrates various elements of a blasting cap of the invention. FIG. 2 illustrates a preferred form of such a blasting cap.

With reference to FIG. 1 elongated shell **11** is formed from a plastic consisting essentially of a polyethylene, or a polypropylene or an alloy of those polymers preferably by injection molding, having closed end **9** and open end **10**. The wall thickness of shell **11** is preferably in the order of about $\frac{1}{32}$ inch although any suitable thickness can be utilized, as described hereinafter.

Shell **11** is then loaded with a base charge **8** such as, for example, a high explosive as PETN or RDX pressed to raise the density, and a superposed loose priming charge **7** as diazodinitrophenol or pressed lead azide. An agnition mixture **6**, as for example, a lead-selenium powder, is then placed on top of mixture **7**.

Insulated leg wires **12** are partially bared and the bared portions **12***a* are sandblasted, the bared and sandblasted portions together with some of the insulated portion being disposed in plug **13** formed from the defined plastic. Any suitable length of sandblasted wire portion can be employed, although the wire is most advantageously sandblasted along its entire length through the plug. Generally at least one half of the said wire length is sandblasted.

Any suitable sandblasting procedure can be employed in sandblasting wires **12***a*. However, in accordance with a now preferred method for disposing a wire **12** in the plastic plug **13**, each wire is sandblasted and supported in a suitable mold with the sandblasted portions in close proximity to the other so that the plastic can be injection molded around the sandblasted portion to form the plug-wire assembly to be inserted in the cap shell.

Leg wires **12** are any suitable conductor material such as used in the art. Thus, they may be copper wire, or iron wire, either plain or tinned. They may be insulated in a desirable manner such as, for example, by using enamel, cotton servings, or plastic materials.

Bridge wire **14** is any suitable resistance wire connecting leg wires **12** and which is heated by passage of electric current through leg wires **12** and disposed in operative contact with ignition mixture **6** in shell **11** to heat and ignite the mixture.

Bridge wire **14** can be formed from any suitable high resistance wire material. Thus, they may be composed of noble or base metal, or alloys thereof. For example, platinum, Nichrome, copper-nickel, or other alloys may be employed. The bridge wire is welded, soldered or otherwise secured adjacent the ends of the pins.

The elements of FIGS. 1*a*–1*c* are assembled to provide a blasting cap of this invention. Thus, with reference to FIG. 2, plug **13** with leg wires **12** and bridge wire **14** is inserted into open end **10** of shell **11** in snug fit, and positioned preferably about flush with the end **10**, and heat sealed at the plug-shell interface **16**.

Seal between bridge plug **13** and shell **11** is effected by heating alone, or pressure applied with heating. In one embodiment a heated iron with a semicircular cross-section can be employed while maintained at a temperature say from 250–300° C. by pressing the same against the cap at the point where the seal is desired. The cap is then slowly rotated until the plug material flows together with the shell material giving a solid continuous wall of polymer from the shell to the plug. Circular tabs on the plug or circular protrusions on the plug and shell at one section can be employed in conjunction with application of heat, to effect the seal when desired.

Although any form of heating can be employed, it is to be noted that open contact of a flame with the plastic is not desirable due to the proximity of heat-sensitive explosive with consequent danger. Other forms of heating are induction heating, radiant heating, and hot gas heating.

A now preferred form of applying heat to effect the said seal to form a strong watertight seal utilizes a light beam played on the section to be so joined. Thus, the plastic bridge plug, generally dark colored (preferably black), is force-fitted into a translucent plastic cap shell, the plastic material in each instance being as above defined. This assembly is placed in a jig which rotates the cap in its longitudinal axis. The light from a filament of a projection lamp is then concentrated such as by a lens or mirror on the section of the bridge plug and cap shell to be sealed. As the cap rotates in this beam, the dark plug absorbs the light energy and converts it to heat. Both the plug and the cap shell at the interface between the two reach a fusion point and fuse together to form a strong watertight seal on cooling.

Use of a light beam as described has the advantage that, although the subsurfaces of the materials being sealed, melt, the surface is kept solid. Heat sealing of plug and shell by this method prevents any distortion of the heated material such as may ordinarily occur by use of sealing platens. Thus, with this type of seal, a watertight closure is effected and the seal area can be made as wide as necessary by proper choice of the dimensions of the projection lamp filament, which completely eliminates the chances of obtaining a poor seal.

Equipment required in utilization of a light beam as described is quite simple and need only consist of a projection lamp, preferably a 500–1000 watt lamp, dependent on the time to be utilized, a concentrating lens and a motor to provide power for the rotary motion. Rotation up to 5000 r.p.m. and higher can be advantageously employed. This embodiment is advantageously applied to a continuous type manufacturing system by employing a turntable to transport the caps automatically around the light source.

The invention is illustrated with reference to the following examples:

Example 1

Fifty cap shells were molded on a Moslo one-ounce injection molding machine from a polyethylene, produced by the process described in the above referred to Belgain patent, which had an RSV in the order of 2.3 and a softening point of about 130° C. Each cap was loaded with 0.250 g. PETN base charge, (pressed to 5000 lbs./in.^{2}) and 0.175 g. diazodinitrophenol primer charge, (loose). The pressing was carried out with the shells in a die with a 0.003 inch clearance between the shell and die. This prevented excessive expansion of the plastic during pressing. The bridge plugs, containing two sandblasted leg wires each with a fine bridge wire soldered to the leg wires on the primer side of the plug, was inserted into each cap shell until the plug top was approximately flush with the cap shell wall. A heated iron (300° C.) of a semicircular cross section was pressed gently against the cap shell about midway between the top and bottom of the bridge plug. The shell assembly was rotated at about 30 r.p.m. for 20 to 30 seconds, at the end of which time the shell and plug were completely fused together at all points touched by the iron. The shell-plug interfaces solidified quickly upon cooling.

These caps were stored 21 hours under water pressure at 200 lb./in.^{2} at 60° F. They were then held in Dry Ice acetone (—78° F.) for 1 hour and then dropped immediately into 60° F. water at 200 lb./in.^{2} for 1 hour. They were then placed in an oven under 150° F. water for 1 hour and then dropped immediately into ice water (32° F.) at 200 p.s.i. for 1 hour. The caps were then shot and gave holes in a ⅛ inch by 1 inch by 1 inch lead plate measuring 1 mm. to 4 mm. in diameter, the majority of hole diameters being 3 mm.

Example 2

Fourteen polyethylene caps were made by the procedure of Example 1 using 0.250 g. PETN base charge (pressed to 3500 p.s.i.) and 0.200 g. diazodinitrophenol priming charge (loose). Seven bridge plugs with leg wires were molded from polyethylene using nonsandblasted No. 22 B and S tinned copper wire. Seven plugs were similarly made but using No. 22 B and S tinned copper wire which had been sandblasted with No. 30 grit carborundum at points passed through the bridge plug. The plugs were heat sealed into the loaded cap shells, using a heated iron (300° F.) of semicircular cross section, as in Example 1. The finished caps were then tested overnight in 60° F. water at 200 p.s.i. Six of the seven caps with nonsandblasted wire failed. The seven with sandblasted wire were then placed in Dry Ice acetone (—78° F.) for 1 hour and then into 60° F. water at 200 p.s.i. for 1 hour. They were then placed in 150° F. water for 1 hour and then into ice water (32° F.) at 200 p.s.i. for 1 hour. All seven of these caps shot satisfactorily. The polyethylene from which the cap shells and plugs of this example were made was produced by the process described in the above referred to Belgian patents, and had an RSV of about 2.3 and a softening point of about 130° C.

Example 3

Ten bridge plugs of polyethylene were injection molded around nonsandblasted No. 22 B and S tinned copper wire. Ten more were molded around the same wire which had been sandblasted with 30 grit carborundum until the tinning was completely gone. Ten more were

molded around the same wire that was not sandblasted but had a small flat pressed in them. The wires were then pulled, one at a time, out of the bridge plug and the pullout force measured. The nonsandblasted wires pulled out at an average load of about 4 lb. The wires with the flat in them pulled out an average load of about 8 lb. The sandblasted wire, however, would not pull from the plug, but broke instead at an average load of about 21 lb. The polyethylene from which the plugs were molded was produced by the process described in the above referred to Belgian patents and had an RSV of about 2.3 and a softening point of about 130° C.

Example 4

Twenty-two electric blasting cap assemblies, made from branched polyethylene having a softening point of about 110° C. and an RSV of about 1.2, were tested for water resistance. The plug, shell, and leg wire were assembled in accordance with the procedure of Example 1 except for the presence of a 50/50 mixture of calcium oxide-phenolphthalein in lieu of a base charge and primer. All plugs contained No. 22 sandblasted copper wire. Each shell was $1\frac{1}{64}$ inches long and contained 200 milligrams of dry 50/50 (weight) calcium oxide-phenolphthalein. The light beam sealing method was employed for sealing the shell to the plug, a beam of light for a 500 watt projection bulb being projected onto the shell and the shell-plug interface while rotating the shell-plug unit at 5000 r.p.m. The seal time was 8 hours. The plugs were black and the shells were of clear color, regular low modulus-type polyethylene.

All 22 assemblies were held in water at 250 p.s.i. at 60° F. for 24 hours. No water leaks were noted. The assemblies were then held for one hour in a Dry Ice-acetone bath (−78° C.) after which no leaks were observed. The caps were then held in water at 60° F. at 250 p.s.i. for 16 hours after which time one leak was noted through a crack in a shell wall. The plugs were then immersed in water at 150° F. for one hour, there being no further leaks observed. Finally the shells were immersed in water at 32° F. for 24 hours at 250 p.s.i. after which it was observed that one shell had developed a leak through the shell wall. Assemblies were transferred from one test condition to

Example 5

Twenty cap shells were molded on a Moslo one ounce injection molding machine from a solid polypropylene having a softening point of about 168° C., and a density of about 0.901 gram per cc. The mold temperature was 170–190° F., the plastic temperature was 460° F. and the cycle was 35 seconds. Each cap shell was loaded with 0.24 gram PETN/graphite, 98/2, as base charge pressed at 3500 p.s.i., and 0.23 gram of loose diazodinitrophenol as primer. Bridge plugs of size for insertion in the shell were formed from polypropylene of the above composition but also containing 2½ percent carbon black, by extrusion around sand blasted portions of two number 22 tinned copper wire pins, in a Plasticor machine, at a plastic temperature of 510° F. and at a pressure of 65 p.s.i., for 10 seconds, with the mold at ambient temperatures. The plugs were bridged with a 79/15/6 platinum/rhodium/ruthenium wire (365 ohms per yard). The plug assembly, bridged end first, was inserted into the open shell end until the plug top was approximately flush with the top of the cap shell under which conditions the bridge wire was in contact with the loose primer. The resulting shell-plug interface was heated to fusion temperature by rotating the assembly at 5000 r.p.m. while applying heat to the interface from a 500 watt projection bulb for 13 seconds, and then cooled, to below the fusion temperature. The lead wires extending from within the plug were insulated with solid linear polyethylene.

Ten of the above cap assemblies were shot in a series of lead plate tests, the lead plate being ⅛ inch by 1 inch by 1 inch, the depth indentation from the shots varying from 0.108 to 0.160 inch. The remaining 10 assemblies, prior to the same shot tests, were subjected in a series of successive tests to a cycle of temperature, pressure and water conditions as follows: (1) 60° F. and 250 p.s.i., for 24 hours, in water (2) −78° C., for one hour, in a Dry Ice-acetone bath (3) 60° F. and 250 p.s.i., for 16 hours, in water (4) 150° F., for one hour, in water and (5) 32° F. and 250 p.s.i., for 24 hours, in water. There was no evidence of water leakage into any shell throughout the entire cycle. The assemblies were then subjected to lead plate shot tests, the same as above described, with hole formation in four instances and the depth of indention in the remaining instance varying from 0.105 to 0.160 inch, demonstrating that the seals were water tight and free from impairment by the temperature and pressure conditions encountered, and that the operability of the cap was not in any way adversely affected by those extreme conditions.

Example 6

Thirteen cap assemblies the same as those of Example 5 were made up except that 0.28 gram of diazodinitrophenol primer was employed and five contained a black polyethylene plug, having a softening point in the order of about 130° C. in lieu of the polypropylene plug. The said five assemblies were shot without exposure to test conditions of temperature, pressure and water, such as of Example 5, with hole formation in four instances and the indentation in the fifth instance being 0.140 inch. The remaining eight were subjected to the cycle of temperature, pressure and water conditions of Example 5 after which they were shot, with hole formation in six instances and the depth of indentation in the remaining two instances being 0.120 and 0.143 inch.

Example 7

Ten cap assemblies, the same as those of Example 5, were made up except that they contained no electrical assembly and 0.2 gram of dry 50/50 calcium oxide/phenolphthalein was placed in the cap in lieu of the primer and base charges. These caps were subjected to the cycle of temperature, pressure and water conditions of Example 5 and showed no evidence of water leakage into the cap.

The polypropylene, from which the blasting caps of this invention are made, is characterized by a degree of crystallinity such that the softening point, measured as described hereinafter, is not less than about 160° C. It can be prepared by any suitable method, as for example, by that of one or both of the Belgian Patents 546,856 and 538,782 referred to hereinafter. Polypropylene characterized by a softening point below 160° C. contains such a high amorphous content that it is, structurally, too weak to be suitable for the practice of the invention. I have, therefore, chosen to define the crystalline polypropylene employed in accordance with the invention as that characterized by a softening point of at least about 160° C., the softening point measurement being that hereinabove described, i.e., at which total loss of crystallinity, accompaned by disappearance of the birefringence due to crystallinity, occurs. The crystalline polypropylene employed in the practice of the invention is further characterized by an RSV value within the range of from about 2 to about 10, the density generally being within the range of about 0.89 to 0.905 gram per cc. The said RSV is the same as defined herein with reference to polyethylene and is preferably within the range of about 3 to 7, the RSV of the polypropylene of Examples 5, 6 and 7 being in the order of about 5.9.

One method for the preparation of polypropylene suitable for the manufacture of electric blasting caps of the invention is described in Belgian Patent 546,856 dated April 7, 1956, in accordance with which propylene, preferably in liquid phase, is polymerized in the presence of

a two component catalyst system comprising (1) the hydrocarbon-insoluble reaction product, produced by the reaction of a compound of a metal selected from the group consisting of metals of groups IV–B, V–B, VI–B, and VIII of the periodic table and manganese with an organometallic compound of a metal selected from the group consisting of alkali metals, alkaline earth metals, zinc, earth metals and the rare earth metals, and (2) an organometallic compound of a metal selected from the group consisting of alkali metals, alkaline earth metals, zinc, earth metals and the rare earth metals.

The polymerization can be carried out at a temperature in the range of —50–150° C. at a pressure of from partial vacuum to about 1000 pounds. Solid polypropylene of sufficiently high crystallinity for the practice of the invention is advantageously recovered from total product as n-heptane-insoluble product of n-heptane solvent extraction.

Another method suitable for the preparation of polypropylene suitable for the manufacture of blasting caps of this invention is described in Belgian Patent 538,782, dated June 6, 1955. That process polymerizes propylene, at a temperature of about 20 to 150° C. and a pressure of about atmospheric to 30 atmospheres, in the presence of a catalyst prepared by reacting a compound of a metal of the subgroups of the fourth to sixth groups of the periodic system, including thorium and uranium, with metals, alloys, metallic hydrides or organometallic compounds of the first to third groups of the periodic system. Solid polypropylene suitable for the practice of the invention is recovered from total product in a manner similar to that of the Belgian Patent 546,856.

Although injection molding is preferred, any suitable procedure can be employed in the formation of the plug and shell members of this invention, such as transfer molding or compression molding.

It is a feature of this invention that the plastic polymer material from which our cap assemblies are made is of rigidity such that the requisite thin walls, e.g., 1/32 inch, are rigid so as to substantially prevent any flexing movement of the shell which, if such occurred, could in some instances cause a shifting movement of the powder in the cap against the bridge wire with a concomitant severing of the connection of bridge wire with the pins and failure of the cap. As to the polyethylenes, I generally prefer the cap assemblies made from linear-type polyethylene because it exhibits somewhat greater rigidity than that of the branched polymer and therefore offers greater resistance to flexing and to collapse due to external pressure.

Blasting cap assemblies fabricated from polypropylene in accordance with this invention exhibit strength, surface hardness, and rigidity greater than that of corresponding structure fabricated from polyethylene, which of course insures greater resistance to crushing or otherwise rough usage. Further, moldability of polypropylene is excellent and offers an advantage, in that respect, in the manufacture of the assembly.

Although assemblies fabricated from polyethylene and polypropylene retain their properties over a range of temperatures generally encountered in blasting operations in the United States, those assemblies fabricated from polypropylene are less suited for operations at temperatures in the order of —60° F., inasmuch as at those temperature levels they generally exhibit unsatisfactory brittleness properties and consequently lowered resistance to fracture.

I have found, however, that polyethylene-polypropylene alloys can be used advantageously particularly in respect of the proportionately increased strength, hardness, and rigidity that is imparted to the assembly by the polypropylene component. Further, solid polypropylene, alloyed with solid polyethylene, in any proportion provides for heat distortion temperatures above those of polyethylene as well as for improved moldability.

When desired, the leg wire portion in the ignition plug can, in lieu of being sandblasted, contain a flat, or be crimped, to facilitate the watertight wire-plug seal. The crimp or the flat, as the case may be, is such that it will not cut through the plastic plug when a load is applied to the wire.

Although any suitable thickness of shell 11 can be employed, a thickness within the range of from about 1/64 inch to 1/8 inch is often employed, 1/32 inch being now preferred. The thickness of bottom end 9 of FIGS. 1*a* and 2 is preferably in the order of about 10–20 mils, preferably about 15, whereby to enhance explosive output of the cap.

Although it is generally advantageous to employ the same plastic composition for both plug and shell, different ones of the defined plastic compositions can be employed so long as they are compatible in the practice of this invention.

The wire-plug seal is generally formed by application of heat to the wire-plug interface to dispose the plug in fused sealed relationship with the wire, injection molding being generally preferred. However, any suitable method by which the plastic can be fused at the plug wire interface to surround the wire and then cooled to below its fusion temperature is satisfactory, such as by disposing the conductor wires through the plug and acting the wires to provide the necessary heat, and cooling to solidify the fused plastic.

Alternatively, the watertight wire plug seal can be made by forming passageways through the plastic plug and disposing each wire within a passageway so as to maintain the plug in surrounding stressed contact with each wire. In the practice of that embodiment, the inside diameter of each passageway is slightly less than the outside diameter of the wire extending therethrough so that when the wire is forced through the passageway, the stressed contact relation results.

The fused wire-plug seal is preferred inasmuch as it does not depend upon a stressed condition, and there is, therefore, no possibility of failure of the seal that might result due to loss of stress over long storage periods.

It is an added feature of the invention that lead wires coated with polyethylene, polypropylene, and alloys thereof, described hereinabove, can be disposed within the plastic ignition plug and heat sealed with the plug to provide a fused plug to insulation plastic seal about the insulated wire. Such an embodiment is an assembly formed by injection molding the plug element around the plastic insulated wire section to provide the fused plastic-plastic seal. The insulated lead wire portions extend outside the cap any desired length of the wire for connection with the power source. The polyethylene and/or polypropylene insulated wires provide a degree of flexibility which is markedly higher than that of other insulated wires ordinarily employed, particularly at the low temperatures ordinarily employed, e.g., when utilizing lead wires insulated with ethyl cellulose. Such flexibility also further adds to the ease in handling the assembly during shipping and storage in view of the rather voluminous lead wire bundles often associated with the assembly.

This application is a continuation-in-part of my copending application, Serial No. 631,580, filed December 31, 1956, and now abandoned.

As will be evident to those skilled in the art, various modifications can be made or followed, in light of the foregoing disclosure and discussion, without departing from the spirit or scope of the disclosure or from the scope of the claims.

What I claim and desire to protect by Letters Patent is:

1. A blasting cap assembly which comprises a plastic shell closed at one end and formed from a solid polymer selected from the group consisting of a linear polyethylene characterized by a softening point of at least 125° C. and a reduced specific viscosity within the range of 2.0 to 4.0, a crystalline polypropylene characterized

by a softening point of at least 160° C. and a reduced specific viscosity within the range of 2 to 10, and an alloy consisting of said polyethylene and said polypropylene; a plastic plug formed solely from the above defined solid polymer and disposed within said shell in complete closing relationship therewith, and heat sealed with said shell in fused watertight relationship therewith at the plug-shell interface; a pair of electrical conductor wires extending separately, into said shell from points external thereto through the end thereof opposite said closed end and through said plug, and terminating in said shell intermediate said plug and the above said closed shell end; means for electrically insulating said conductor wires; said plug being sealed in watertight relationship with a section of each of said conductor wires extending therethrough; a resistance wire within said shell intermediate said plug and the said closed shell end and connecting the said conductor wires; and a heat sensitive explosive initiatable by heat developed by passage of electric current through said resistance wire, and disposed within said shell intermediate said plug and the said closed end in operative relationship with said resistance wire so as to be so initiated by passage of electric current via said conductors through said resistance wire.

2. In an assembly of claim 1, a waterproof coating sealed around a length of each said conductor wire extending from outside said shell into said plug, and fused to said plug in heat sealed watertight relationship therewith, and said coating consisting of said solid polymer.

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