United States Patent [19]

Zebree

[11] **3,776,135**

[45] **Dec. 4, 1973**

[54] **NON-ELECTRIC BLASTING CAP ASSEMBLY**

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[73] Assignee: **Hercules Incorporated**, Wilmington, Del.

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[52] **U.S. Cl.** **102/29**
[51] **Int. Cl.** **F42b 3/10**
[58] **Field of Search** 102/27–29, 70

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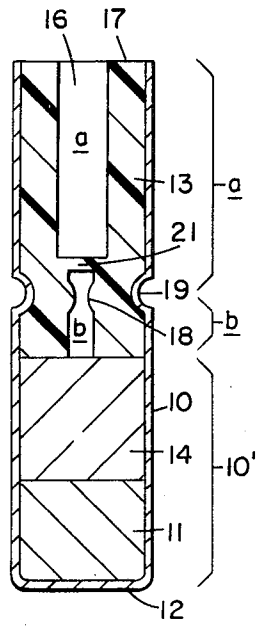
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Primary Examiner—Verlin R. Pendegrass
Attorney—S. Grant Stewart et al.

[57] **ABSTRACT**

Non-electric blasting caps, preferably of the delay type, containing a shell closure plug of new configuration, including a perforation extending through the shell and a constriction in the perforation intermediate the ends thereof to divide the perforation into upper and lower sections. The constriction is cross-sectionally dimensioned to retard egress of heat and pressure from the lower perforation section passed thereinto from combustion of one or more of the charges in the ignition area, when the combustion is initiated by action of a detonator cord positioned in the perforation. The volume of the lower perforation section is correlated with the cross-sectional dimension of the constriction to permit egress of sufficient heat and pressure from the combustion for maintaining integrity of the shell while retaining sufficient heat and pressure for the combustion to propagate the resulting burning front for subsequent detonation of the base charge. A further feature of the invention is means, such as a web, or diaphragm, at least partially closing the perforation intermediate the constriction and the ingress end of the perforation for the detonator cord, as a blocking member for spacing the cord in the perforation, albeit the constriction, per se, can serve, without further means, as that stopping means.

20 Claims, 17 Drawing Figures



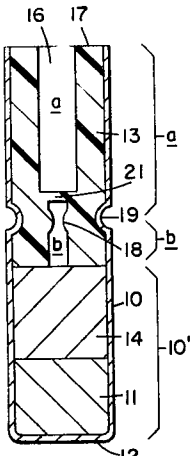


FIG. 1

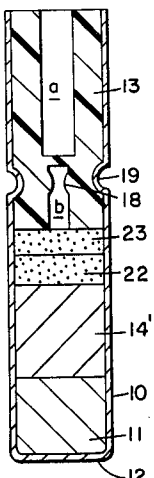


FIG. 2

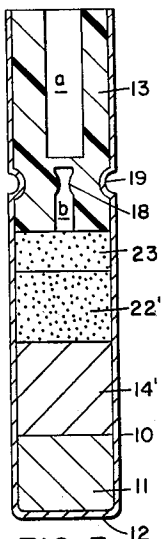


FIG. 3

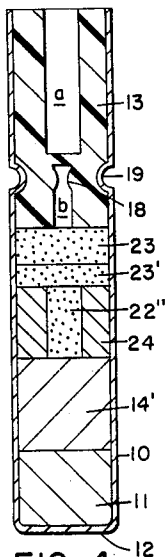


FIG. 4

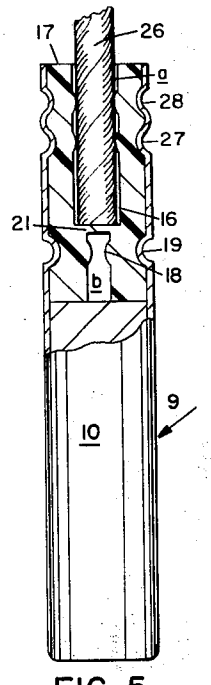


FIG. 5

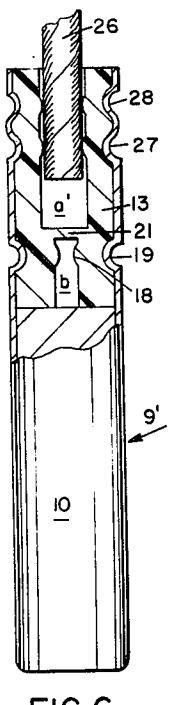


FIG. 6

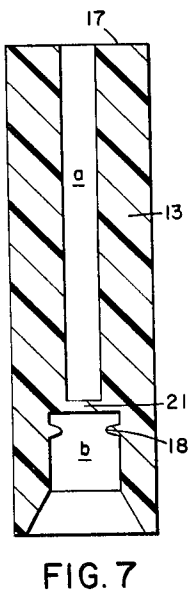


FIG. 7

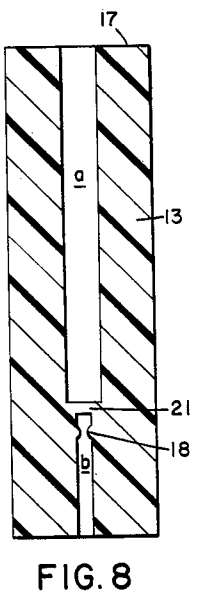


FIG. 8

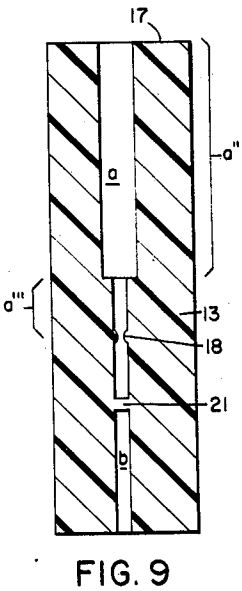


FIG. 9

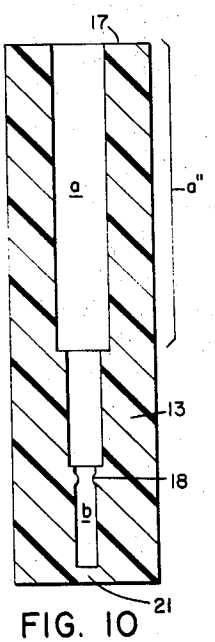


FIG. 10

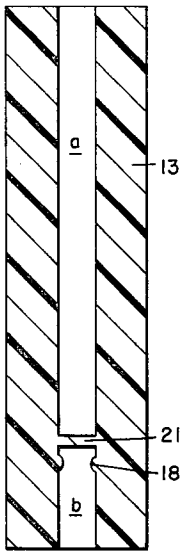


FIG. 11

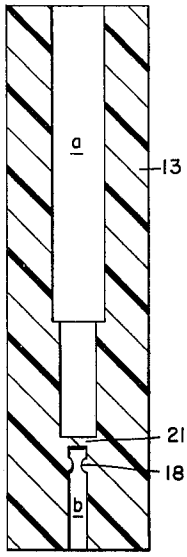


FIG. 12

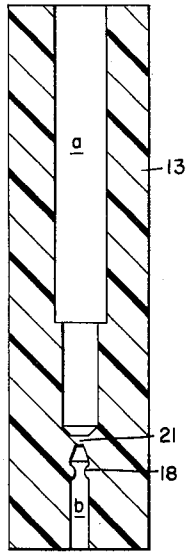


FIG. 13

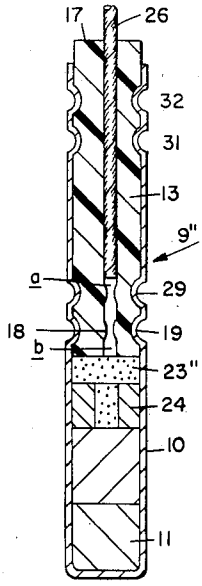


FIG. 15

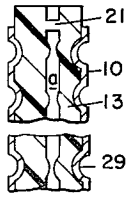


FIG. 16

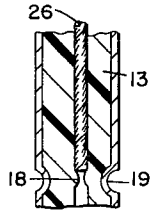
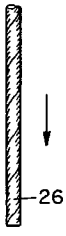
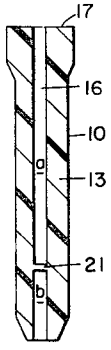
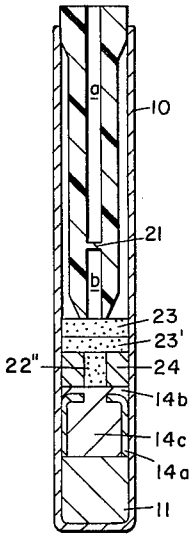


FIG. 17

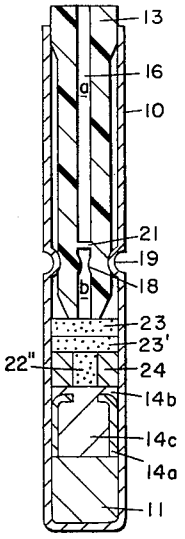




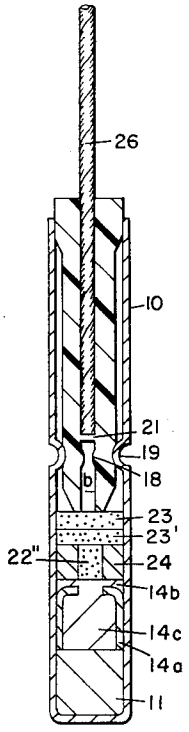
A



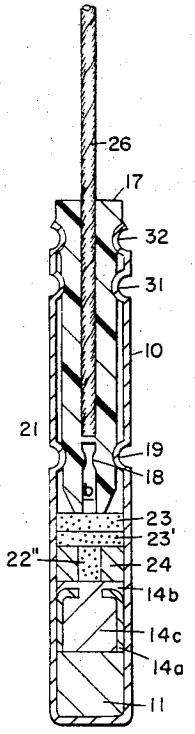
B



C



D



E

FIG. 14

NON-ELECTRIC BLASTING CAP ASSEMBLY

Other embodiments include a web member above, or below, the constriction serving only to protect the interior of the shell against moisture ingress during storage when the constriction serves as the sole blocking member of the cord.

The invention thus provides for a detonator cord initiator system free from rupture of the cap shell with concomitant venting of pressure and heat not needed for the detonation.

This invention relates to non-electric blasting caps. In one aspect this invention relates to non-electric blasting caps containing closure plug structure providing for greater reliability of performance, broader range of choice of ignition components, longer shelf-life, and for greater ease of assembly, than heretofore. Other aspects will be apparent in light of the accompanying disclosure and the appended claims.

Blasting caps generally comprise a closed shell loaded with base charge, primer, and ignition components in that order, together with electric or non-electric initiator means therefor. Electric type caps generally utilize a bridge wire, or an electric arc means, disposed in igniting relationship with the ignition component and connecting with lead wires extending to an external power source; and non-electric type caps generally utilize a detonator fuse extending from a suitable actuator means into the cap shell in operative contact with the ignition component for the initiation. Alternatively, in either type, a slot burning material is disposed as a delay fuse, intermediate the ignition and the primer to burn in response to ignition of the ignition composition and hence delay communication of the ignition with the primer until expiration of the delay period. These blasting caps are referred to generally as of the "delay" type when containing a delay element and of the "instantaneous" type in the absence of that component.

Non-electric cap assemblies often fail due to premature rupture of the cap shell by force from detonation of the cord. The rupture causes loss from the ignition area of the heat and pressure necessary for sustaining the combustion for the subsequent detonation. Further, these assemblies must be assembled at the plant, and stored with the cord in emplaced position, due to the otherwise adverse effect of moisture ingress into the combustion area through the passageway support means for the detonator cord. Accordingly, cap failure, or at least serious impairment of the cap operation, and hence, unreliable performance of these assemblies has been encountered in numerous instances.

This invention is concerned with detonator cord initiatable blasting cap assemblies having closure plug structure providing for improved reliability of performance and shelf-life.

In accordance with the invention, a non-electric blasting cap assembly is provided which comprises

a closed shell including a plug closure member therefor,

a base explosive charge, and an ignition-primer charge system, with or without delay charge, disposed in said shell for operative relationship with a detonator cord for detonation of said base charge when said cord is disposed in said plug as described hereinafter,

said plug closure containing a perforation extending therethrough in communication with the outside of said shell and with the interior thereof,

a constriction in the cross-section of said perforation intermediate the ends thereof and dividing said perforation into an adjacent lower section extending to the shell interior and an adjacent upper section extending to the outside of said shell and adapted to coaxially accept along at least a portion of its length, said detonator cord extending thereinto from outside said shell,

means in said perforation at least partially closing same and disposed ahead of said cord, when extending into said performation as described, so as to interceptively block extension of said cord beyond said upper perforation section, and said constriction being adaptable to constitute said means,

said constriction cross-sectionally dimensioned to retard egress of heat and pressure from said lower perforation section passed thereinto from ombustion of one or more of said charges when said combustion is initiated by detonating action of said cord extending into said perforation as described, and

said lower perforation section having a volume correlated with the cross-sectional dimension of said constriction so as to permit egress of sufficient heat and pressure from said combustion for maintaining integrity of said shell while retaining sufficient of said heat and pressure for said combustion to propagate the resulting burning front for subsequent detonation of said base charge.

Although the constriction in the perforation is advantageously adapted to also function as means for blocking further extension of the detonator cord, a diaphragm, or web, member, extending across the upper perforation section in water-tight closing relationship therewith is now preferred. The web member is generally emplaced substantially adjacent the constriction, and is generally integral with the plug material. Use of the web member is particularly preferred inasmuch as it precludes ingress of moisture into the shell interior and hence provides for prolonged shelf-life of the assembly without need for emplacement of the detonator cord therein.

The web structure is of sufficient dimension for stability against breaking during storage and handling of the assembly, but is sufficiently thin to rupture in response to force generated by detonation of the cord when the latter extends into the perforation as described, to thereby permit direct communication of shock waves with the shell interior for the ignition.

Although in some embodiments the detonator cord is advantageously extended in the perforation into substantially abutting relationship with the above described blocking means, it is, in other embodiments, extended in the perforation to a point spaced from the blocking means to thereby afford a void area adjacent the constriction in each of the upper and lower perforate sections. This practice is particularly advantageous in those embodiments utilizing charges having a relatively high gas generation rate, and thus offers more space for egress of excess pressure and heat from the combustion area to maintain integrity of the shell. The additional space in the upper perforation section serves to absorb excess energy from detonation of the cord to afford selection of core loadings over a broader range, without risk of rupture of the shell in the ignition area.

When adapting the constriction to function also as the interceptive blocking member, the upper perforation section is substantially unobstructed and is in direct open communication with the outside of the cap. Hence, prior to emplacement of the detonator cord, the shell interior is vulnerable to ingress of moisture from outside the shell. In that embodiment, it is necessary that the device, prior to emplacement of the detonator cord, be stored in a low humidity atmosphere in order to assure against undue rapid deterioration of the charges resulting from moisture ingress. However, alternatively a diaphragm type member is emplaced in water-tight closing relationship with the upper perforation section in a length thereof adapted to receive the detonator cord, to protect the cap interior from moisture ingress, thus enabling long shelf-life properties. This diaphragm member is readily ruptured by penetrating action of the detonator cord during its emplacement in the upper perforation section, and hence provides no further function after the detonator cord is emplaced.

The constriction element and associated void space intermediate the constriction element and the cap interior, and their correlation above described are critical to the practice of the invention. Thus, during operation of the blasting cap the burning of the combustible charges generates heat and pressure which must, to a minimum degree, be retained within the combustion area to propagate the burning front to the detonation function. Due to the limited volume in the burning area, the heat and pressure often develops in amounts to cause the shell to rupture, thus venting to the atmosphere the heat and pressure needed to propagate the burning front. The result is, of course, failure of the shot. In accordance with the invention, the lower perforate section provides additional volume for receiving sufficient heat and pressure from the burning area to prevent its accumulation in the shell interior in amount causing rupture of the shell. However, it is necessary that the quantity of heat and pressure passed into the lower perforation section be limited so that the amount of heat and pressure retained in the burning area is sufficient for the required propagation of the burning front.

The invention provides for that balance of heat and pressure. The volume of the lower perforate section in the closure plug is correlated with the cross-sectional dimension of the constriction to prevent undue loss of heat and pressure from the burning area. Accordingly, the cross-sectional area of the constriction means, on the one hand, must be limited to preclude venting more than the permissible amount of heat and pressure from the lower perforate section, and on the other hand it must be sufficiently great to permit flow of hot gases and energy from detonation of the detonator cord into the cap interior. Further, the volume of the lower perforate section must be limited so that in conjunction with the cross-sectional dimension of the constriction, the amount of heat and pressure withdrawn from the cap interior is correspondingly limited to provide the requisite amount of heat and pressure in the ignition area for sustaining combustion.

Dependent on the core loading of the detonator cord, and the composition of the particular combustion charges in the shell interior, the cross-sectional area of the constriction, expressed in terms of diameter of a constriction having a circular cross-section is generally within a range of from 0.02 to 0.18 inch and the volume of the lower perforate section is in the range of from 0.00002 to 0.196 cubic centimeters; the respective lengths of the lower perforation section being in the range of from 0.04 to 0.50 inch. Each dimension to be correlated, varies inversely with the other to provide the requisite correlation above described. I have found however that a minimum volume of the lower perforate section in the order of about 0.004 cc. at a minimum diameter of the constriction in the order of about 0.06 inch, are generally applicable to practice of the invention.

The closure plug of the assembly can be made from any one of a number of suitable materials such as rubber, plastic, particularly polyethylene or polypropylene, cork, lead and the like. Generally the detonator cord to be extended into the perforation has a core loading in the order of from 2 to at least 7 grains per foot (PETN or equivalent) and often from 15 to 25 grains per foot or higher.

The web or diaphragm member adapted to function as a blocking element, above described, and generally integral with the plug material, generally has a thickness in the order of from about 0.001 to 0.02 inch although thickness values outside that range can be utilized dependent upon the core loading of the detonator.

The invention is further illustrated with reference to the drawings which are elevational views, mostly in cross-section, of various embodiments.

Thus,

FIGS. **1–4** are cross-sectional views of the various blasting cap assemblies of the invention without the detonator cord emplaced therein, and particularly illustrate various types of blasting cap charge components and combinations thereof generally utilized;

FIGS. **5** and **6** illustrate the blasting cap assemblies of FIGS. **1–4** containing a detonator cord emplaced in the upper perforation section of the closure plug;

FIGS. **7–13** illustrate different configurations of closure plug structure, including integral web structure in the perforation, utilized in practice of the invention;

FIGS. **14A–E** illustrate a now preferred blasting cap of the assembly, including a detonator cord initiator (FIG. **14E**), and a now preferred method for manufacture of same (FIGS. **14A–D**);

FIG. **15** illustrates an embodiment of blasting cap assembly of the invention devoid of web or diaphragm structure, in which the upper perforation section is in open communication with the exterior of the cap shell;

FIG. **16** illustrates an assembly embodiment of FIG. **15** in which a diaphragm closure member is disposed across the upper perforation section solely for maintaining the interior of the cap free from moisture, and penetratable by the detonator cord during its emplacement; and

FIG. **17** illustrates an embodiment in which the constriction member is adapted to also interceptively block extension of the detonator cord beyond the upper perforation section.

Referring to FIG. **1** elongated shell **10** contains base explosive charge **11** in integrally closed end **12**, and closure, or ignition, plug member **13** in the opposite end. Primer-ignition charge **14** is superposed on base charge **11**. Closure plug **13** is in water-tight closing relationship along substantially its entire external surface with the inner wall of shell **10** and is superposed on ig-

nition-primer charge 14. Plug 13 is supported in shell 10 by any suitable means, generally by interference fit, preferably in combination with suitable crimp means, including crimp 19 further described herein.

Closure plug 13 contains perforation, or bore 16 extending therethrough so as to communicate the outside of shell 10 with the interior thereof through top end 17. Perforation 16 is constricted in cross-section intermediate the ends thereof by constriction 18 to thereby divide perforation 16 into an adjacent upper section *a* leading to the outside of shell 10 and an adjacent lower section *b* extending to the shell interior; and when referring herein to the shell interior it is meant the interior shell portion containing the base explosive charge and associated ignition-primer charge(s), and delay charge when utilized, specifically illustrated with reference to intermediate shell portion 10' of FIG. 1.

Upper perforation section *a* is adapted to coaxially accept, at least along aportion of its length, extending from upper end 17, a detonator cord extending therein from outside shell 10. Diaphragm, or web member 21, integral with plug 13, transversely closes upper perforation section *a* in water-tight relationship therewith, and is disposed substantially adjacent constriction 18. Web member 21 not only functions to bar ingress of moisture into the shell interior prior to emplacement of a detonating cord in section *a*, but also as a stop, or blocking means, to preclude extension of the detonator cord beyond section *a*. The cross-sectional dimension of constriction 18 is correlated with the volume of lower perforate section *b* to provide a desired balance of heat and pressure egress from the interior of shell 10 for sustained combustion of the ignition charge, as described herein above.

Lower perforation section *b*, dependent on its permissible volume, has any suitable cross-sectional dimension. Section *b* provides an open, or void length portion of perforation 16 intermediate constriction 18 and the shell interior to receive any undue excess of heat and pressure that is generated in the shell upon initiation of the ignition-primer, and delay charge when present, to thereby preclude premature rupture of the shell under those conditions, as above described. In the embodiment shown, section *b* is of less cross-sectional dimension than that of section *a*, and the minimum cross-sectional dimension of perforation section *a* is that for accepting the detonator cord, generally in substantially force-fit relationship.

When the detonator cord, emplaced in perforate section *a*, is initiated, the forces of explosion of the resulting detonation on the plug inner wall forming the perforation 16, are of such magnitude that in many instances the explosion will cause the plug and shell to rupture along the length of the cord. This difficulty is reduced, in degree, by limiting the core loading of the detonator cord. However, constriction 18 is advantageously formed by a peripherally disposed crimp 19 extending through plug 13 into perforation section 16; and crimp 19 not only functions to form constriction 18, but it also serves to stengthen shell 10 about web 21 to further assure integrity of the shell after initiation of the detonator cord. Crimp 19 further serves to support plug 13 in position during detonation of the detonator cord. Optionally, as further support for plug 13 in shell 10 adjacent, or encompassing, crimp 19, plug 13 can be glued along its external surface to the inner wall of shell 10, and/or staked to shell 10.

The cap assemblies of FIGS. 2–4 are the same as that of FIG. 1 except that they illustrate various combinations of delay, primer, and ignition, components utilized in the cap assemblies of the invention, which is turn often determine the length of shell 10 nd the relative dimensions of the lower perforate section and constriction 18. All embodiments of FIGS. 2–4 utilize a conventional base charge 11 and a diaphragm 21 in section *a*, substantially adjacent constriction 18.

Thus, as shown in FIG. 2, base charge 11 is in the integrally closed end 12 of shell 10 and primer charge 14', delay charge 22, and ignition charge 23 contiguous with the other and in that order extend from closed shell end 12 to plug 13 which is superposed on charge 23. As further illustrated with reference to FIGS. 3 and 4, various charge systems can be utilized. Thus, in FIG. 3 loose delay charge 22' is pressed into position, and ignition charge 23 is superposed thereon as shown in FIG. 2. In FIG. 4 delay charge 22'' is of the well known core type loaded in a lead tube 24. In the embodiment of FIG. 4 a wafer charge 23' is disposed intermediate delay 22'' and ignition charge 23, to burn in response to ignition of charge 23, but at a higher temperature in order to effect ignition of the core delay charge 22'' which is longer burning, but less sensitive than corresponding charge 22 of FIG. 3. Dependent upon selection of delay and ignition systems of FIGS. 3 and 4, delay times are reliably effective over a broad range, often from about 100 milliseconds to as high as 16 seconds.

A non-electric blasting cap of the invention, assembled for detonation of the main charge, is illustrated with reference to FIG. 5 which is in turn directed to closure plug embodiments illustrated with reference to FIGS. 1–4. Thus, assembly 9 of FIG. 5 includes a detonator cord 26 extending from outside shell 10 through upper shell end 17 coaxially into perforation *a* into substantially abutting relationship with web 21, and is secured in that position by crimp 19 in turn forming constriction 18. Supplementary auxiliary peripheral crimps 27 and 28 extending from the periphery of the shell 10 through plug 13 into engaging relationship with cord 26 in section *a*, are advantageously utilized. The supplementary crimps 27 nd 28 are helpful from the standpoint of not only providing for resistance of the assembly to accidental pull-out of the cord during emplacement and use, but also as support against premature disintegration of the shell portion surrounding the cord, upon detonation of the latter.

FIG. 6 shows the assembly 9' which is the same as assembly 9 of FIG. 5 except that the terminating end of cord 26 in perforation section *a* is spaced from web 21 to provide an intermediate, and additional, void space *a'* in perforation *a* which serves to absorb any excess energy generated by detonation of the detonator cord which, if not arrested, would cause premature bursting of the shell with undue loss of detonation energy for the shot.

The core loading of the detonator cord is dependent upon the particular charge combination of ignition, primer, and delay when the latter is present, and upon the particular shell casing material. Generally, however, the core loading is in the order of from about 2 to 7 grains (PETN or equivalent) per foot.

In FIGS. 7–13 various configurations of plug closure strucutre 13 including alternative perforation sections *a* and *b*, constriction 18, and generally, web 21, struc-

ture in the cap assemblies of the invention are further illustrated; it being required in all instances that the perforation section *a* be adapted to receive the detonator cord to the degree of desired extension therein, and that the volume of the perforation section *b*, be correlated with the constriction cross-sectional area to provide the desired balance of heat and pressure egress from the ignition area. Thus, perforation section *a* of FIGS. **7–13** is always of dimension sufficiently for accepting along at least a part of its length a detonator cord extending from outside shell **10.** In the embodiments of FIGS. **7, 8** and **11** the web **21,** in perforation section *a*, serves as a "stop" to block extension of the detonator cord beyond a predetermined point in section *a*. HOwever, when desired, as illustrated with reference to FIG. **6,** the detonator cord can be extended any desired distance along the length of the perforation section *a;* and, by any suitable means such as by peripheral crimp, it can be supported in any desired spaced apart relationship with the web **21.** Although constriction **18** in the closure plug assemblies of FIGS. **7–13** is generally formed as illustrated herein with reference to crimp **19** of FIGS. **1–8,** it can be formed in any suitable manner prior to emplacement of the closure plug in shell **10.** In the embodiments of FIGS. **9** and **10** the web member **21** is disposed in perforation section *b* and hence below constriction **18,** to maintain the shell interior free from moisture during storage prior to emplacement of the detonator cord. It is rupturable in response to impact of force of detonation of the detonator cord.

Thus as shown in FIG. **9,** perforation section *a* is dimensioned along an initial portion of its length *a''* extending from upper end **17** for accepting the detonator cord. However, the cross-sectional dimension of the remainder of perforation section *a* is reduced to less than that of the detonator cord. Hence, at the point of reduced cross-section further extension of the detonator cord is blocked. FIGS. **10, 12** and **13** further illustrate the relative dimensions of the perforation sections *a* and *b* and associated stepped perforation structure embodiments.

FIG. **10** illustrates still another plug configuration which is substantially the same as that of FIG. **12** except that the web structure **21** is placed in the end most portion of perforation *b*. In this manner web **21** is of necessity of limited thickness so as to rupture in response to force of detonation of the detonator cord, when emplaced in section *a*, to thus permit detonation energy to enter the shell interior and mingling of the hot gases from the detonation among the ignition particles.

With reference to FIG. **15** is shown an assembly **9''** of the invention including a detonator cord **26** emplaced in the perforate section *a*, and containing a system of base explosive, primer, delay and ignition charges the same as that of FIG. **4,** except that the ignition charge **23''** is a high temperature burning charge in lieu of the ignition-wafer system of FIG. **4,** and there is no web structure **21** in perforation **16.** In this embodiment, the constriction **18** and the lower perforation section *b* function exactly as described hereinabove with reference to their correlation requirements. Intermediate constriction **18** and opposite end **17** of perforation **16,** is a peripheral crimp **29** about the shell **10** extending through the plug **13** into perforation **16** to reduce the cross-sectional dimension of perforation section *a* sufficiently for it to function to block further extension of cord **26** into section *a*, and, often to also supplement constriction **18** in the latter's function in combination with perforate section *b*. Hence, in this embodiment there is a void space in perforation **16** in each section adjacent constriction **18.** Additional crimp means for support of plug **13** and detonator cord **26,** such as peripheral crimps **31** and **32** intermediate crimp **29** and shell end **17** and applied after emplacement of cord **26** in perforation section *a*, are advantageously utilized. In other embodiments not specifically shown, the crimp **29** can be dispensed with and in lieu thereof constriction **18** also serves as the blocking member to preclude further extension of cord **26.**

FIG. **16** is a partial section of FIG. **15,** additionally shows web member **21** transversely closing a portion of section *a* adapted to accept a detonator cord from outside shell **10,** to assure protection of the shell interior from moisture ingress prior to emplacement of the detonator cord. Web **21'** is sufficiently thin to be ruptured by penetration of cord **26** upon emplacement of the latter.

FIG. **17** is a partial view of FIG. **15** and is the same as FIG. **15** except that it is devoid of crimp **29,** and the detonator cord **26** is emplaced in substantially abutting relationship with constriction **18.**

The invention is further illustrated with reference to FIGS. **14** A–E which show a now preferred embodiment of cap assembly without the detonator cord (FIG. **14** C), and with the detonator cord (FIG. **14** E) and an embodiment of manufacture of these assemblies. Thus referring to FIG. **14**A elongated plug member **13** contains centrally disposed perforation **16** extending therethrough and web member **21** integral with plug member **13,** and in water-tight closing relationship with perforation section *a*. Plug **13** at its upper end **17** is of diameter sufficient to enable it to extend into shell **10** in force fit contact of upper end **17** with the shell inner walls thus forming an annulus between the shell inner wall and the remainder of the length of plug **13.**

FIG. **14B** illustrates shell **10** containing base charge **11** and a now preferred diazodinitrophenol primer charge consisting of capsule **14***a*, a diazodinitrophenol wafer **14***b* pressed above and superposed on capsule **14***a* and a second diazodinitrophenol charge **14***c* of density lower than that of primer wafer **14***b*. Capsule **14***a* extends substantially coaxially within shell **10** in closing or near closing relationship therewith; it is open at each end and is superposed on base charge **13.** Primer wafer **14***b* is of sufficiently high density to be ignitable in response to contact with flame from ignition of delay fuse **24** superposed thereon, and diazodinitrophenol charge **14***c* is of sufficiently low density to be detonatable in response to heat developed by ignition of wafer charge **14***b* to in turn cause detonation of base charge **11.**

Delay charge **22''** as illustrated with reference to FIG. **4** is of the core type encased in a lead tube **24** exemplary of which is barium peroxide-selenium. Superposed on delay charge **22''** is an ignition-wafer type system **23–23'** of FIG. **4.** Thus ignition charge **23** burns at a sufficiently high combustion temperature to in turn cause ignition of wafer charge **23'**, the latter in turn initiating burning of delay fuse **22''**. Plug **13** is emplaced in shell **10** through the open end thereof so as to be superposed directly on ignition charge **23** and in water-tight closing relationship about its periphery with shell **10** adjacent the open end **17** thereof.

As shown in FIG. 14C constriction **18** has been formed in perforation **16** by crimp **19** peripherally disposed about shell **10** and extending through plug **13** into perforation **16** to divide perforation **16** into upper perforation section *a* and lower section *b*, and web **21** is positioned in perforation section *a* so as to be in close proximity to constriction **18.**

As illustrated in FIG. 14D detonator cord **26** shown in FIG. 14C ready for insert into the assembly, is extended from outside shell **10** into perforation section *a* and into abutting relationship with the web **21.** As described hereinabove, detonator cord **26** can be extended to any predetermined point intermediate web **21** and the opposite end **17** of perforation section **16,** and supported in that resulting spaced apart position from web **21** by a supplemental crimp in perforation section *a*, serving to stop further extension of the detonator cord. As illustrated with reference to FIG. 14E, the assembly of 14D is advantageously completed by auxiliary crimps **31** and **32** peripherally disposed around the shell **10** near the end **17** thereof into engaging relationship with the detonator cord. In this manner crimps **31** and **32** also serve to secure the position of detonator cord **26** against accidental "pull-out" from the plug. One or more additional crimps and/or stake marks can be utilized to augment crimps **31** and **32,** as desired.

Any suitable ignition charge can be utilized in the blasting cap assemblies of this invention such as lead-selenium, lead tellurium, lead oxide-boron, and lead oxide-metallic borides, are now preferred. Further exemplary of these ignition compositions are lead-selenium (72–28), lead tellurium (62–38), red lead/-manganese boride (65–35), lead-selenium (72–28)/-lead oxide-boron (97–3), 75/25 red lead/boron, red lead-manganese boride, and various known additives such as for example 1–2 percent Snow Floss. Exemplary delay fuse compositions include barium peroxide/selenium (60/40), barium peroxide/selenium/-tinned lead (60/20/20), barium peroxide/tellurium/-selenium (40/40/20), barium peroxide/tellurium (70/30), and the like.

Exemplary primer charges are diazodinitrophenol, diazodinitrophenol/potassium chlorate (75/25), lead azide, lead stiphnate, and mercury formate.

Any suitable base explosive charge can be used such as pentaerythritol tetranitrate, cyclonite (RDX), trinitrophenyl-methylnitramine, and the like.

Often, as illustrated with reference to FIG. 1 a combined ignition-primer charge is used, generally in a cap of the instantaneous type. Such charge undergoes ignition and detonation in response to initiating action of the detonator cord, the detonation in turn causing detonation of the base charge.

The invention is illustrated with reference to the following examples.

EXAMPLE 1

A series of three delay time tests was made utilizing a detonator cord initiated blasting cap assembly generally illustrated with reference to FIG. 5 and having a cylindrical aluminum shell containing a base charge, primer, ignition, and delay system of FIG. 4. The closure plug configuration was that of FIG. 7. The closure plug was a molded copolymer of styrene and butadiene, and had a diametric cross-section of 0.252 inch, and a length of 0.900 inch. The web member was integral with the closure plug and had a thickness of 0.012 inch. The detonator cord was emplaced in abutting relationship with the web **21,** and had a core loading of 3–6 grains PETN per foot. The perforation (section *a* and *b*) not including the bottom flared end, was of circular cross-section, and the web member, substantially normal to the perforation axis was about 0.05 inch above the constriction **18,** the latter dividing the perforation to form upper perforation section *a* having a length of 0.6 inch and lower perforate section *b* having a length of 0.25 inch. The flared out portion of section *b* was frusto conical and 0.03 inch in length and 0.210 inch wide at the base. The ignition charge was a loose ignition mixture, immediately subjacent the closure plug of 0.6 gram Pb/Se, 72/28, together with a supplementary wafer charge of 0.2 gram Pb/Se/BaO_2/Al/Snow Floss, 69.12/26.88/1.00/1.00/2.00; the primer charge was 0.30 gram diazodinitrophenol; the delay was a core of about 1.0 gram of BaO_2/Te/Se, 40/40/20, swaged to a density of about 4.4 grams/cc in a lead tube, and the base charge was 0.40 gram PETN pressed to 4,000 p.s.i.g.

In two of the three tests, shots were obtained having delay times of 10.2 and 10.4 seconds, with a failure of the third test. The unsuccessful shot was the result of failure of the delay fuse to ignite, due to repture of the aluminum shell in response to impact of force of detonation of the initiator cord, thus blowing the plug from the assembly with concomitant loss, by venting, of the heat and pressure required for ignition of the delay charge. This example demonstrates criticality of need for correlation of the closure plug dimensions with the core loading of the initiator cord utilized. As demonstrated hereinafter, had the terminating end of the detonator cord been emplaced in spaced apart relationship with the web member **21** to provide a resulting intermediate void space, the latter would have absorbed sufficient of the force of impact from detonation of the cord to preclude rupture of the shell, and the shot would have been successful.

EXAMPLE 2

A series of 30 delay time tests were carried out utilizing blasting cap assemblies the same as thoseof Example 1, except that they contained the extended most end of the detonator cord spaced from the web member, a distance of 0.25 inch, thereby providing adjacent void spaces in perforation sections *a* and *b*.

In a first series of 5 delay times tests, all shots were successful and were within the range of from 9.3 to 10.0, at an average of 9.6 seconds. In a second series of 10 shots, the delay times varied from 9.0 to 10.2 seconds at an average of 9.9, with no failures. In a final series of 15 shots there were two failures, the remaining shots being within the range of from 8.9 to 10.8 seconds at an average of 9.9 seconds. Of these 30 shots, there Were no failures due to rupture of the shell, demonstrating the pertinency ofthe additional void space in section *a*, which absorbed the excess impact energy from detonation of the cord initiator to preclude shell rupture.

The two failures that were encountered were the result of improper correlation of the volume of the lower perforation section *b*, with the constriction dimension. The failures resulted because the volume of thelower perforation section *b* was of such size as to cause venting of heat and pressure from the ignition area, to the

extent that insufficient heat and pressure were available in the shell interior for ingiting the delay fuse, thereby failing to sustain the combustion for moving the burning front to the detonation. In these two instances of failure, had the ignition mixture been of a higher temperature burning composition sufficient additional heat and pressure would have remained in the ignition area to compensate for that drawn into the perforation section *b*, and the combustion would have been sustained. This example further demonstrates the need for selection of suitable charge composition for use in the particular assembly design contemplated.

EXAMPLE 3

A series of 19 shots utilizing the blasting cap assemblies of Example 2 was made, except that a "hotter" ignition system, illustrated with reference to FIG. **3**, was utilized, viz., 0.25 gram of a prepressed (2,000 p.s.i.) red lead/boron/Snow Floss, 89/9/2, and the cored delay charge was varied. Ten of these tests were made with delay times of from 410 to 400 milliseconds at an average of 420, utilizing 0.17 gram of BaO_2/Se/PbSn, 60/20/20 as the cored delay fuse. There were no failures.

An additional series of the above tests were repeated except that the cored delay charge as 0.31 grams BaO_2/Se/PbSn, 60/20/20. A total of **9** shots was made at delay times of from 826 to 882, at an average of 854, milliseconds. There were no failures.

The tests of this example illustrate the need for correlation of the ignition mixture composition with plug structure, in any given instance, for achieving successful shots.

EXAMPLE 4

A series of delay time shots was made utilizing a cap assembly of Example 3 except that the length of the closure plug perforate section *b* was 0.25 inch and the diametric cross-section of the perforate section *b* was constant and was the same as that of section *a*, viz., 0.118 inch, as illustrated with reference to FIG. **11.** The cored delay charge was 0.31 gram BaO_2/Se/PbSn, 60/20/20. Ten shots were made having a delay time of from 828 to 875 milliseconds, at an average of 853. There were no failures.

EXAMPLE 5

Two series of additional tests of Example 4 were made utilizing the same cap assembly except that the closure plug structure was that of FIG. **8,** the web member **21** thickness was 0.015 inch, the diametric cross-section of the perforation section *b* was 0.060 inch and the diametric cross-section of the perforation section *a* was 0.115 inch.

In the first series, a total of 15 tests, the delay times were from 780 to 874, an average of 816 milliseconds; and in the second series, a total of 21 tests, the delay times were from 760 to 810, an average of 870 milliseconds. There were no failures in either series.

EXAMPLE 6

Several delay time tests were made utilizing the blasting cap assembly of Example 5 except for the plug configuration which was that of FIG. **10,** and for the use of two different delay charges. In all tests, the length of the perforation *a* was 0.635 inch and its diametric cross-section was 0.085 inch along its initial length of 0.385 inch and 0.060 inch along the remainder of its length (0.250 inch). The diametric cross-section of the perforate section *b* was 0.060 inch.

A series of 20 delay time tests was made in which the ignition and delay system was that of Example 5, and the delay times were in the range from 780 to 818 milliseconds, an average of 803. There were no failures.

Another series of the same tests was made except that the cored delay was 1.0 gram BaO_2/Te/Se, 40/40/20, and a wafer-ignition system of FIG. **4** was utilized in which the wafer charge was 0.20 gram Pb/Se/BaO_2/Al/Snow Floss, 69.12/26.88/1.00/1.00/2.0, and the loose ignition superposed thereon was 0.25 gram Pb_3O_4/B/Snow Floss, 89/9/2. The delay times were in the range of from 9.0 to 10.4 seconds, an average of 10.0 seconds. There were no failures.

Examples 4, 5 and 6 demonstrate proper correlation of different closure plug configurations with ignition and delay components in cap assemblies of the invention.

EXAMPLE 7

A series of tests was made utilizing blasting cap structure of FIG. **12** containing a shoulder on the plug inner wall in the upper perforate section *a* as a block, or stop, means for precluding further extension of the detonator cord toward the cap shell interior. In each assembly, the shell was cylindrical and aluminum, the plug was a molded ethylene-propylene copolymer and the entire perforation was of circular cross-section; and the web member, integral with the plug, was in the perforation above the constriction **18** a distance of about 0.05 inch, and it had a thickness of about 0.015 inch. The length of the perforation *a* portion to the shoulder was 0.385 inch and its diametric cross-section was 0.115 inch. The length of the remaining perforation portion *a* was 0.025 inch and its diametric cross-section was 0.085 inch. The length and diametric cross-section of the perforate section *b* were respectively 0.25 and 0.06 inch. The detonator cord extended into perforation section *a* into abutting relationship with the shoulder on the inner wall, thus leaving a void space of 0.25 inch in length in perforate section *a* immediately adjacent the web member. The base charge and primer charge in each assembly were those of Example 6.

In a series of four tests, the delay and ignition system in each assembly was that of FIG. **4** in which the ignition charge was 0.25 gram of red lead/B/Snow Floss, 87.9/9.8/2.4, superposed on 0.20 gram Pb/Se/BaO_2/Al/Snow Floss, 69.12/26.88/1.00/1.00/2.0, as a wafer charge. The cored delay charge was 1.0 gram of BaO_2/Te/Se, 40/40/20. There were three failures, with one shot showing a delay time of 10 seconds.

In a series of five tests, the same as the first series except for the presence of a larger wafer charge, i.e., 0.6 in lieu of 0.2, gram there were three failures with two successful shots at a delay time of 11.0 and 11.1 seconds.

The failures in these series of shots were due to lack of correct correlation of wafer composition with the particular plug structure utilized.

EXAMPLE 8

Three series of the tests of Example 7, utilizing the same assembly except for 0.20 gram of a "hotter" burning wafer charge were carried out. In one series of 10 shots, utilzing a wafer charge of PbSn/Se/BaO_2.

/Al/SF, 36/14/24/24/2, delay times of from 3.2 to 4.9 seconds were observed, at an average of 3.9. There were no failures.

In a second series, a total of five shots, utilzing the same wafer ingredients but in proportions of respectively 48/20/15/15/2, the delay time was from 4.1 to 4.8, an average of 4.5. There were no failures.

In a third series a total of five tests, utilizing the same wafer ingredients but in the respective proportions, 27/11/30/30/2, the delay time was from 2.1 to 3.0 at an average of 2.5, seconds. There were no failures.

Examples 7 and 8 demonstrate the need for correlation of blasting cap charges with a particular closure cap and detonator fuse assembly utilized. In these instances, the delay compositions, less sensitive than the shorter burning time compositions, required a higher temperature burning ignition system and hence were correlated with the "hotter" burning wafer charge.

EXAMPLE 9

A series of 10 delay time tests was carried out utilizing a blasting cap assembly of Example 8 containing a closure plug of FIG. 13 which is the same as that of FIG. 12 except that an end wall portion of each perforation section adjacent the constriction was beveled, as illustrated. The ignition delay system was that of FIG. 4, utilizing 0.25 grams Pb_3O_4/B/Snow Floss, 87.8/9.8/2.4 (2,000 p.s.i.) and 0.20 gram of PbSn/Se/-BaO_2/Al/Snow Floss, 36/14/24/24/6, wafer charge pressed to 2,000 p.s.i. Nine of 10 shots were successful, having a delay time of from 8.9 to 9.6 seconds, an average of 9.3. The one failure was due to failure of the web to break in response to the impact of the force of the detonation of the cord. The hot gases of detonation of the cord could not penetrate the ignition wafer charge and the shot failed.

A series of 10 of the same tests was carried out utilizing the same device except that the web thickness was reduced to 0.010 inch, and 0.20 gram of the wafer charge containing the same ingredients but in the proportions 36/14/24/24/2. The delay times were from 9.1 to 10.8 seconds, at an average of 9.5. There were no failures.

This example illustrates the criticality of correlation of web thickness with the blasting assembly charge materials to be associated therewith.

EXAMPLE 10

Three delay blasting cap assemblies of Example 1 except that the perforation in the closure plug was devoid of the web member **21** and constriction means **18**, were tested for delay time, and the diametric cross-section of the perforation was 0.12 inch. All three caps failed to detonate due to rapid escape of heat and pressure from the burning area in the shell through the unobstructed perforation.

These tests, as compared with those of Example 1, demonstrate the criticality of the perforation section *b* and the correlation of its volume with the constriction cross-sectional dimension.

EXAMPLE 11

Five non-electric blasting cap assemblies of FIG. 3 were immersed in water for 24 hours. The detonator cord, was thereafter emplaced by crimp, as illustrated in FIG. 5, and initiated. All shots were successful.

The above tests were repeated except that the web member was omitted. All shots failed due to ingress of water into the cap assembly.

Although a wide range of materials can be utilized in fabrication of the closure plugs, those materials having a durometer hardness of about 20 to 120 are preferred. Butadiene/styrene copolymer, and low density polyethylene, are now preferred closure plug materials.

EXAMPLE 12

Seven series of delay time tests of an assembly of Example 7 containing 0.25 gram of the wafer charge were carried out except that in lieu of aluminum, each cap shell was fabricated from bronze (copper/zinc, 90/10) and had a wall thickness of about 0.009 inch.

In one series, there were 20 test shots, and in each of the others there were 10, an average delay time varying over the seven series was from 2.3 to 3.1 seconds. All shots were successful.

As set forth herein, the ignition system can be a single ignition charge or a combination of ignition and wafer charges. Thus with a decrease in burning rate of the delay fuse composition, there is an accompanying decrease in its sensitivity, and hence a correspondingly "hotter" ignition system is required. I have discovered, in the operation of a delay cap assembly of the invention, that when the burning rate of the delay fuse composition is about 3 seconds per inch or faster, any suitable ignition system can be advantageously utilized; but that at slower delay fuse composition burning rates an ignition system having a heat of reaction of at least about 110 calories per gram, often in the now preferred range of about 400–600 calories per gram, is required for optimum fuse ignition reliability.

Although various single ignition charges having a heat of reaction of about 110 calories per gram, or higher, are available for the above described ignition of delay fuse compositions having a burning rate slower than about 3 seconds per inch, a combination of ignition and wafer charges, such as charges **23** and **23'** of the drawings, is generally preferred, and particularly when the heat of reaction of the ignition system is to be in the 400–600 calorie per gram range.

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

1. In a non-electric blasting cap assembly,

a closed shell including a plug closure member therefor,

a base explosive charge, and an ignition-primer charge system, with or without delay range, disposed in said shell for operative relationship with a detonator cord for detonation of said base charge when said cord is disposed in said plug as described hereinafter,

said plug closure containing a perforation extending therethrough in communication with the outside of said shell and with the interior thereof,

a constriction in the cross-section of said perforation intermediate the ends thereof and dividing said perforation into an adjacent lower section extending to the shell interior and an adjacent upper section extending to the outside of said shell and adapted to coaxially accept along at least a portion of its length, said detonator cord extending thereinto from outside said shell,

means in said perforation at least partially closing same and disposed ahead of said cord, when ex-

tending into said perforation as described, so as to interceptively block extension of said cord beyond said upper perforation section, and said constriction adaptable to constitute said means,

said constriction cross-sectionally dimensioned to retard egress of heat and pressure from said lower perforation section passed thereinto from combustion of one or more of said charges when said combustion is initiated by detonating action of said cord extending into said perforation as described,

and said lower perforation section having a volume correlated with the cross-sectional dimension of said constriction so as to permit egress of sufficient heat and pressure from said combustion for maintaining integrity of said shell while retaining sufficient of said heat and pressure for said combustion to propagate the resulting burning front for subsequent detonation of said base charge.

2. In a non-electric blasting cap assembly of claim **1,** said closed shell being tubular, and said plug substantially coaxially disposed as an end closure therefor.

3. In a blasting cap assembly of claim **2,** said means for interceptively blocking extension of the cord disposed intermediate said constriction and the opposite end of said upper perforation section.

4. In a blasting cap assembly of claim **3,** a diaphragm closing said perforation as said means for blocking extension of the cord, and rupturable by force from detonation of said cord when extended into said perforation as described.

5. In a blasting cap assembly of claim **4,** a crimp about the periphery of said shell extending through said plug closure into said perforation, as said constriction, in a plane subjacent said diaphragm.

6. In a blasting assembly of claim **2,** said constriction adapted to also constitute said means for blocking extension of said cord.

7. In a blasting cap assembly of claim **6,** a crimp about the periphery of said shell and extending through said plug into said perforation as said constriction.

8. In a blasting cap assembly of claim **3,** a crimp disposed about the periphery of said shell extending through said plug and into said perforation intermediate said constriction and the opposite end of said upper section to partially close said perforation as said means for blocking extension of the cord.

9. In an assembly of claim **5,** said diaphragm integral with said plug member, and closure means for said shell, integral therewith, at the end of said shell opposite said closure plug.

10. In an assembly of claim **9,** a base charge, a primer charge, a delay charge and an ignition charge disposed contiguously in that order from the integrally closed end of said shell, and said plug member superposed on said ignition charge.

11. In a blasting cap assembly of claim **2,** a diaphragm in transverse water-tight closing relationship with said lower perforate section, and rupturable in response to force of detonation of said cord when extending into said perforation as described.

12. In a blasting cap assembly of claim **2,** a diaphragm in water-tight closing relationship with said upper perforate section in a plane in the portion thereof accepting said cord, in open communication with the outside of said shell, and yieldable to penetrating action of said cord when said cord is extended within said perforation as described.

13. In a blasting cap assembly of claim **5,** a detonator cord extending into said upper perforate section into substantially abutting contact with said diaphragm.

14. A blasting cap assembly of claim **13** wherein the core loading of said cord is from 2 to 7 grains per foot (PETN or equivalent).

15. In a blasting cap assembly of claim **5,** a detonator cord extending into said upper perforate section into spaced apart relationship with said diaphragm.

16. A blasting cap assembly of claim **15** wherein the core loading of said cord is from 2 to 25 grams per foot (PETN or equivalent).

17. A blasting cap assembly of claim **1** containing a delay charge having a burning rate faster than about 3 seconds per inch.

18. A blasting cap assembly of claim **1** containing a delay charge having a burning rate slower than about 3 seconds per inch; and, as an ignition system, an ignition charge, with or without a wafer charge, having a heat of reaction of at least 110 calories per gram.

19. A blasting cap assembly of claim **18** containing said ignition and wafer charges in combination.

20. A blasting cap assembly of claim **19,** wherein the heat of reaction of said combination of ignition and wafer charges is within the range of about 400–600 calories per gram.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,776,135 Dated December 4, 1973

Inventor(s) David T. Zebree

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, first 2 paragraphs (lines 3 through 11) should be part of the abstract, not the specification

Column 1, line 32, "slot" should read --slow--

Column 2, line 13, "performation" should read --perforation--

Column 2, line 19, "ombustion" should read --combustion--

Column 5, line 19, "aportion' should read -- a portion--

Column 6, line 4, "is" should read --in--

Column 6, line 5, "nd" should read --and--

Column 6, line 44, "nd" should read --and--

Column 10, line 26, "repture" should read --rupture--

Column 10, line 38, "of impact" should read --of the impact--

Column 10, line 49, "times" should read --time--

Column 10, line 44, "thoseof" should read --those of--

Column 11, line 26, "as" should read --was--

Column 14, line 51 (Claim 1), "range" should read --charge--

Signed and sealed this 16th day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

[redacted]

PO-1050
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Column 10, line 38, "of impact" should read --of the impact--

Column 10, line 49, "times" should read --time--

Column 10, line 44, "thoseof" should read --those of--

Column 11, line 26, "as" should read --was--

Column 14, line 51 (Claim 1), "range" should read --charge--

Signed and sealed this 16th day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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