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PATENT SPECIFICATION

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(54) BLASTING CAPS INITIATABLE BY THERMAL DETONATION ENERGY OF AN EXPLOSIVE GAS MIXTURE, AND BLASTING SYSTEM

(71) We, HERCULES INCORPORATED, a Corporation organised under the laws of the State of Delaware, United States of America, of 910 Market Street, City of Wilmington, State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates of nonelectric blasting caps initiated by explosive energy from detonation of an explosive gas mixture. In one aspect, this invention relates to such blasting caps formed from a metal shell and including shell closure means containing an open space and associated conduits for emplacement and detonation of the explosive gas in the cap, and crimp sealed with the metal shell without interference by the crimp(s) with flow of the explosive gas through the conduits.

Nonelectric blasting caps initiatable by explosive energy from the detonation of an explosive gas mixture are disclosed and claimed in our U.K. patent 1,449,560. These blasting caps contain an open space adjacent the initiator charge, and a first conduit extending from outside the blasting cap into the open space in open communication with the initiator charge so as to convey the explosive gas as a confined stream into the open space for responsive ignition of the initiator charge; and a second conduit extending from the open space to the outside of the shell so that a stream of the explosive gas mixture can be continuously passed from the first conduit through the open space and through the second conduit to purge the system for the detonation and responsive ignition of the initiator charge.

In the embodiment illustrated in the above patent, the cap shell is elongated and closed,

including at one end a plug type closure member spaced from the initiator charge to form the requisite open space. Both conduits are of plastics and thin walled for flexibility purposes. The first conduit extends into the shell through the end closure member and the second conduit extends from the open space either through the plug end closure or through the side of the cap shell.

Due to the conduit capacity required for the flow of the explosive gas into and from the open space in the cap assembly, and hence the size of the conduits, the available wall thickness of the plug closure portion encompassing the conduits extending therethrough is limited to the extent that often the plug wall cannot sustain the conventional crimp type shell to plug to conduit closure and the result in those instances is undue ingress of the crimp into the conduit passageways with constriction impairing requisite gas flow therethrough.

This invention is concerned with nonelectric blasting cap assemblies of the type described in which both conduits are flexible, generally plastics, and hence thin walled; and extend within the closure member; and the closure member contains, and is correlated with, the requisite open space to provide for crimp support of the closure member in the shell without impairment of flow of explosive gas through the conduits.

In accordance with the invention we provide a nonelectric blasting cap assembly which comprises: a shell including an elongated closure member therefor deformable by crimping; an initiator charge within the shell ignitable in response to action of the thermal detonation energy of an explosive gas mixture; and an explosive charge within the shell detonatable in response to ignition of said initiator charge; said closure member containing a substantially axial bore including an

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enlarged cavity within the closure member in open communication through the bore at one end of the closure member, with said initiator charge; first and second conduits at the other end of the closure member and in watertight relationship with the material thereof, communicating between said cavity and the exterior of the shell so as to convey an explosive gas mixture as a confined stream into a detonating position in said cavity for responsive ignition of the initiator charge and to permit said cavity to be purged of gases other than said explosive gas mixture prior to detonation of said confined stream; the wall of the shell and the closure member being crimped together in watertight relationship about the bore but not about the cavity to fasten the closure member in the shell with the bore open.

In one embodiment, the closure member is superposed on the initiator charge, thus lending support to the initiator charge in operative position in the shell. In another embodiment, particularly in which the initiator charge is self-supporting, the closure plug is spaced apart from the initiator charge thus providing a purge space supplementary to that contained within the closure member.

In preferred practice, the blasting cap shell is metallic and elongated and the end closure member and the first and second conduits within same are each formed from a plastics material such as polyethylene, polypropylene and the like. The invention is illustrated with reference to the drawings of which Figure 1 is a cross-sectional view of a cap assembly of the invention in which the closure member is spaced from the initiator charge; Figure 2 is the same as Figure 1 except that the closure member is superposed on the initiator charge; Figure 3 is a sectional view of the embodiments of Figures 1 and 2 taken along the line 3—3; Fig. 4 illustrates a blasting system including a plurality of blasting caps of the invention; Figs. 5 and 5A show a now preferred means for sealing the conduits in water tight relationship with the end closure member; and Fig. 6 is a sectional view of an additional embodiment differing from those of Figs. 1 and 2 with reference to perforation structure. In the drawings, like parts are designated by like numbers, and corresponding parts are designated by the same, but primed, numbers.

Referring to Fig. 1, elongated metal shell 10 of blasting cap assembly 9 contains base explosive charge 11 in closed end 12, primer assembly 13 superposed on base charge 11, delay assembly 14 superposed on primer assembly 13, and initiator charge 16 superposed on delay assembly 14.

Primer assembly 13 is a diazo-

dinitrophenol charge including the lower density charge 13a contained in capsule 13b with the higher density charge 13c superposed on capsule 13b. Delay assembly 14 is preferably a metal tube 14a with a delay charge disposed as core 14b. Ignition charge 16 is any suitable charge ignitable by thermal detonation energy from detonation of an explosive gas mixture described hereinafter. Often a supplemental, or wafer ignition charge is disposed intermediate charge 16 and delay 14b to provide a hotter ignition in those instances in which such is required, often with longer burning delay charges. Base charge 11 is detonatable in response to detonation of primer charge 13a which in turn is detonatable in response to burning of charge 13c; and charge 13c is ignitable in response to burning of delay charge 14b which in turn is ignitable in response to burning of initiator charge 16.

Flexible plastics conduits 24 and 26 are sealed with closure member 17 at each conduit/closure member interface 28 in water tight relationship therewith in any suitable manner such as by an adhesive of the epoxy resin type, fusion, or the like. A now preferred conduit-closure member seal, as illustrated with reference to Figs. 5 and 5A, is provided by the emplacement of metal powder particles in a top portion of the plastics plug member for induction heating that plug portion and transferring the heat generated by the induction heating to the adjacent plastics conduit surfaces for fusion of the two surfaces at the conduit-closure plug interface followed by cooling with formation of the resulting water tight fusion seal. The conduits 24 and 26, and closure 17 are advantageously formed from the same plastics material, often polyethylene. In that embodiment, a top end portion of closure 17 containing dispersed iron, or other suitable, metal particles 17b, extends above top end 18 of shell 10 so that the induction of magnetic energy to the closure conduits interface for the seal will not be impaired by a shielding effect of the metal shell, see Fig. 5. By induction heating the unshielded end closure portion 17a, the metal particles 17b are then magnetized and hence reoriented, see Fig. 5A, and the heat resulting from that reorientation is transferred to the interface of the conduits 24, 26 and closure 17 for fusion of the interface surfaces to provide the requisite water tight seal between closure 17 and the conduits 24 and 26.

It is of course required that the plastics closure 17 be disposed in water tight relationship with shell 10. Heretofore, to emplace the conventional crimp closure around the shell and into the closure plug, it was necessary that the crimp encompass the

flexible plastic conduits 24 and 26, and that practice has often been satisfactory in view of the limited wall thickness of the closure wall leading to undue ingress of the crimp into the conduits with excessive constriction of gas flow therethrough.

The invention, in the incorporation of the open space 19 into the closure member in lieu of disposing the open space intermediate the closure member and the initiator charge, and disposing the perforation 22 as part of open space 19, provides sufficient wall thickness of the closure plug, i.e., encompassing the perforation 22, for sustaining a water tight crimp between shell 10 and closure 17 without undue ingress of the crimp into the perforation, thus precluding unsatisfactory flow of the explosive gas through the conduits 24 and 26 and open space 19. Hence, closure member 17 is crimp-closed in water-tight relationship with shell 10 by crimps 29 on the exterior of shell 10 encompassing perforation 22 and extending into closure member 17 into supporting water tight relationship therewith, i.e., along a locus of points intermediate the cavity portion 21 and the bottom end 23 of perforation 22.

The blasting assembly of Fig. 2 is the same as that of Fig. 1 except that closure member 17 is superposed directly onto initiator charge 16 thus imparting peripheral support to the initiator 16 for maintaining it in operative position.

Generally, the coaxial length of the cavity 21 is less than its maximum linear cross section, the coaxial length of perforation 22 is greater than its maximum linear cross section, and the maximum linear cross section of perforation 22 is less than the maximum linear cross section of cavity 21; each said cross section being measured on a line normal to the longitudinal axis of the closure plug. In preferred practice, the cavity 21 and perforation 22 are of circular cross section, and perforation 22 is cylindrical. However, cavity 21 and perforation 22 can be of any suitable length, width or shape so long as the crimp 29 can be applied as required. Thus in the embodiments of Figs. 1 and 2, it is required that the maximum linear cross section of perforation 22 be less than that of the central portion 20 of closure plug 17 (see Fig. 3) immediately encompassing conduits 24 and 26 within plug 17 adjacent top end 18 thereof, in order that there is provided sufficient wall thickness of end closure member 17 for the crimp(s) 29. However, as illustrated with reference to Fig. 6, a suitable reinforcing sleeve 22b can be coaxially disposed within perforation 22 in peripheral contact with the inner wall

thereof, to reinforceably support perforation 22 against a predetermined undue constriction by a crimp 29', thus permitting any suitable, and larger, cross sectional dimension of perforation 22 concomitantly with wall thickness of closure 17 for the crimp regulated only by the reinforcement provided by the sleeve member 22b.

Although a single blasting cap assembly of the invention can be fired as an initiator of a main explosive charge, a plurality of blasting cap assemblies of the invention are more often utilized in a blasting system as illustrated with reference to Fig. 4, and as disclosed in our patent above referred to. Thus, referring to Fig. 4, each of the separate bore holes 31, in earth formation 30, is loaded with any suitable cap-insensitive main explosive charge 32 such as an aqueous gel-type explosive, a dynamite, prills/fuel oil or the like. A pair of suitable boosters 33 is embedded in each of the main explosive masses. Each booster is cap-sensitive and is in detonating relationship thereto, and is initiated by action of a blasting cap system of the invention such as that of Figs. 1, 2 or 6.

Thus, in each bore hole 31, two booster units 33, e.g., each comprising about 500 grams of PETN, tetryl or the like, are embedded, and spaced apart, in explosive mass 32 to provide for detonation of the main explosive charge along its entire length. Each booster unit 33 contains a blasting cap 9, 9' or 9'' of Figs. 1, 2 or 6. The explosive gas mixture from a source not shown is supplied via line 34 and passed in series through the entire plurality of blasting caps in the separate booster charges in the three bore holes via conduits 24 and 26 of each blasting cap. The flow of explosive gas mixture from line 34 in series through the entire plurality of blasting caps in the bore holes is continued until each open space 19 (cavity 21 plus perforation 22 or 22') or 19 plus 22a, is substantially free from initially present gas, after which the flow of the explosive gas mixture is terminated or continued as desired, followed by detonation of the gas upstream from the first of the bore holes 31 and travel of the detonation wave front in series through each of the blasting caps in ignition relationship with the initiator charge therein. Dependent on whether the main charge is reliably cap-sensitive, a booster charge(s) may not be required, in which event one or more of the blasting caps are embedded directly in the main charge.

The system of Fig. 4, containing delay caps, regulates the burning time of each delay fuse and hence the delay between

shots in each bore hole including when desired, a progressively longer delay time along the entire series of boosters in the bore holes.

In assembling a blasting cap of the invention, as illustrated with reference to Figs. 1 and 2, the base, primer, delay (if required) and initiator charges are in that order pressed into emplacement in a cap shell 10 through an open end 18 thereof. Closure member 17 containing passageways for receiving conduits 24 and 26 in position and containing conduits 24 and 26 emplaced therein is then inserted friction tight into closing relationship with shell 10 in the open end thereof, either spaced from the initiator charge or seated on the initiator charge, as required.

Conduits 24 and 26 when inserted into the passageways are secured therein in water tight relationship with the closure member at the closure-conduit interface as described above. One or more crimps 29 are then applied to the exterior of shell 10 for ingress into closure 17 or 17' intermediate cavity 21 and bottom end 23 of perforation 22 or 22' to effect the requisite water tight seal.

By way of further illustration, blasting cap assemblies of the embodiment of Fig. 1 formed from a cylindrical metal shell, wherein the end closure plug and the conduits are formed from a solid polyethylene, and the cavity 21 and the perforation 22 are each of circular cross section, often have dimensions within the following ranges.

	Inches
Conduits 24 and 26	
inside diameter	0.040—0.080
outside diameter	0.060—0.120
Shell 10	
length	1.5—4.5
wall thickness	0.005—0.020
inside diameter	0.20—0.30
Plastic Closure Plug 17	
length	0.5—1.5
cavity 21	
minimum diameter	
top	0.180
bottom	0.060
minimum axial length	0.060
perforation 22	
diameter (uncrimped)	0.06—0.20
length	0.50—1.0
Open space 22a (Fig. 1)	
diameter	0.040—0.080
length	0.03—0.25
Charges	Grams
ignition 16	0.20—0.80
delay 14b	0.20—2.0
primer 13	0.20—0.30
(13c:13a, about 1:4)	
base charge 11	0.20—1.00

Although the plug closure member is preferably formed from a suitable solid plastics material such as polyethylene, polypropylene, Nylon, polyvinyl chloride, and the like, it can be formed from other materials such as cork, lead, rubber or the like. Similarly, conduits 24 and 26 which can be formed from any suitable flexible material are more often formed from polyethylene or polypropylene often having a wall thickness from about 0.02 to 0.04 inches.

Further exemplary of charges utilized in the cap assemblies of the invention are ignition charges 16 such as lead/selenium often with suitable additives such as lead oxide/boron, lead oxide/manganese boride, and the like; primer charges such as diazodinitrophenol charges 13a and 13b, and lead azide; and base charges 11 such as PETN, tetryl and the like.

In our abovementioned Patent Specification No. 1,449,560 we claim a nonelectric blasting cap which comprises: a shell; an initiator charge in said shell ignitable in response to action of the thermal detonation energy of an explosive gas mixture, said shell containing an open space adjacent said initiator charge; a first conduit means extending from outside said shell into said open space in direct open communication with said initiator charge so as to convey an explosive gas mixture as a confined stream into a detonating position in said open space for responsive ignition of said initiator charge; conduit means permitting said open space to be purged of gases other than said explosive gas mixture prior to detonation of said confined stream for said responsive ignition comprising a second conduit means extending from said open space to the outside of said shell, whereby a stream of said explosive gas can be continuously passed from said first conduit means through said open space and through said second conduit means to purge said open space and thereafter explosive gas in said first conduit means can be detonated for propagation of resulting thermal detonation energy to said open space for ignition of said initiator charge.

WHAT WE CLAIM IS:—

1. A nonelectric blasting cap assembly which comprises: a shell including an elongated closure member therefor deformable by crimping; an initiator charge within the shell ignitable in response to action of the thermal detonation energy of an explosive gas mixture; and an explosive charge within the shell detonatable in response to ignition of said initiator charge; said closure member containing a substantially axial bore including an

shots in each bore hole including when desired, a progressively longer delay time along the entire series of boosters in the bore holes.

5 In assembling a blasting cap of the invention, as illustrated with reference to Figs. 1 and 2, the base, primer, delay (if required) and initiator charges are in that order pressed into emplacement in a cap shell 10 through an open end 18 thereof. Closure member 17 containing passageways for receiving conduits 24 and 26 in position and containing conduits 24 and 26 10 emplaced therein is then inserted friction tight into closing relationship with shell 10 in the open end thereof, either spaced from the initiator charge or seated on the initiator charge, as required.

Conduits 24 and 26 when inserted into the passageways are secured therein in water tight relationship with the closure member at the closure-conduit interface as described above. One or more crimps 29 are then applied to the exterior of shell 10 for ingress into closure 17 or 17' intermediate cavity 21 and bottom end 23 of perforation 22 or 22' to effect the requisite water tight seal.

By way of further illustration, blasting cap assemblies of the embodiment of Fig. 1 30 formed from a cylindrical metal shell, wherein the end closure plug and the conduits are formed from a solid polyethylene, and the cavity 21 and the perforation 22 are each of circular cross section, often have dimensions within the following ranges.

	Inches
Conduits 24 and 26	
40 inside diameter	0.040—0.080
outside diameter	0.060—0.120
Shell 10	
length	1.5—4.5
45 wall thickness	0.005—0.020
inside diameter	0.20—0.30
Plastic Closure Plug 17	
length	0.5—1.5
50 cavity 21	
minimum diameter	
top	0.180
bottom	0.060
minimum axial length	0.060
perforation 22	
diameter (uncrimped)	0.06—0.20
55 length	0.50—1.0
Open space 22a (Fig. 1)	
diameter	0.040—0.080
length	0.03—0.25
Charges	Grams
60 ignition 16	0.20—0.80
delay 14b	0.20—2.0
primer 13	0.20—0.30
(13c:13a, about 1:4)	
base charge 11	0.20—1.00

Although the plug closure member is preferably formed from a suitable solid plastics material such as polyethylene, polypropylene, Nylon, polyvinyl chloride, and the like, it can be formed from other materials such as cork, lead, rubber or the like. Similarly, conduits 24 and 26 which can be formed from any suitable flexible material are more often formed from polyethylene or polypropylene often having a wall thickness from about 0.02 to 0.04 inches.

Further exemplary of charges utilized in the cap assemblies of the invention are ignition charges 16 such as lead/selenium often with suitable additives such as lead oxide/boron, lead oxide/manganese boride, and the like; primer charges such as diazodinitrophenol charges 13a and 13b, and lead azide; and base charges 11 such as PETN, tetryl and the like.

In our abovementioned Patent Specification No. 1,449,560 we claim a nonelectric blasting cap which comprises: a shell; an initiator charge in said shell ignitable in response to action of the thermal detonation energy of an explosive gas mixture, said shell containing an open space adjacent said initiator charge; a first conduit means extending from outside said shell into said open space in direct open communication with said initiator charge so as to convey an explosive gas mixture as a confined stream into a detonating position in said open space for responsive ignition of said initiator charge; conduit means permitting said open space to be purged of gases other than said explosive gas mixture prior to detonation of said confined stream for said responsive ignition comprising a second conduit means extending from said open space to the outside of said shell, whereby a stream of said explosive gas can be continuously passed from said first conduit means through said open space and through said second conduit means to purge said open space and thereafter explosive gas in said first conduit means can be detonated for propagation of resulting thermal detonation energy to said open space for ignition of said initiator charge.

WHAT WE CLAIM IS:—

1. A nonelectric blasting cap assembly which comprises: a shell including an elongated closure member therefor deformable by crimping; an initiator charge within the shell ignitable in response to action of the thermal detonation energy of an explosive gas mixture; and an explosive charge within the shell detonatable in response to ignition of said initiator charge; said closure member containing a substantially axial bore including an



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5 enlarged cavity within the closure member
in open communication through the bore at
one end of the closure member, with said
initiator charge; first and second conduits
5 at the other end of the closure member and
in watertight relationship with the material
thereof, communicating between said
cavity and the exterior of the shell so as to
10 convey an explosive gas mixture as a
confined stream into a detonating position
in said cavity for responsive ignition of the
initiator charge and to permit said cavity to
be purged of gases other than said explosive
15 gas mixture prior to detonation of said
confined stream; the wall of the shell and
the closure member being crimped together
in watertight relationship about the bore
but not about the cavity to fasten the
closure member in the shell with the bore
20 open.

2. An assembly according to Claim 1,
wherein said shell is metallic and elongated,
and said end closure member and said first
25 and second conduits are each formed from
plastics material.

3. An assembly according to Claim 1 or 2,
wherein said closure member is spaced
from said initiator charge to provide an
open space supplemental to the bore and
30 cavity in said closure member.

4. An assembly according to Claim 1 or 2,
wherein said closure member is superposed
on said initiator charge to provide
peripheral support for said initiator charge
35 in its operative position in said shell.

5. An assembly according to any
preceding Claim wherein the coaxial length
of said cavity is less than the maximum
linear cross-section thereof, the coaxial
40 length of said bore is greater than the
maximum linear cross-section thereof, said
maximum linear cross section of said bore
is less than said maximum linear cross
section of said cavity, each said linear cross
45 section being measured on a line normal to
the longitudinal axis of said end closure.

6. An assembly according to any
preceding Claim, wherein said shell, said
end closure, said cavity and said bore are
50 each of circular cross section.

7. An assembly according to any
preceding Claim further comprising a
reinforcing sleeve member disposed
coaxially within said bore in contact along
55 its outer surface with the end closure wall
surface forming said bore to support said

bore against a predetermined undue
construction by the crimping.

8. An assembly according to any
preceding Claim further comprising a 60
primer charge in said shell intermediate
said explosive charge and said initiator
charge and detonatable in operative
responsive to ignition of said initiator
charge; said explosive charge being 65
detonatable in response to detonation of
said primer charge.

9. An assembly according to Claim 8,
comprising a delay charge intermediate
said primer charge and said ignition charge, 70
and ignitable in response to burning of said
ignition charge, said primer charge being
detonatable in operative response to
burning of said delay charge.

10. A blasting cap assembly substantially 75
as described and shown in the
accompanying drawings.

11. A cap assembly according to any
preceding Claim wherein the closure
member is a plastics closure plug and said 80
conduits are sealed in watertight
relationship with said plug by means of the
emplacement of metal powder particles in a
top portion of said plug for induction
heating that plug portion and transferring 85
the heat generated by the inductive heating
to the adjacent conduit surfaces for fusion
of the two surfaces at the conduit-plug
interface followed by cooling with
formation of the resulting watertight fusion 90
seal.

12. A blasting system including a plurality
of blasting cap assemblies as claimed in any
preceding Claim, wherein said first conduit 95
of the first of said plurality is connected
with a source of an explosive gas mixture,
and said second conduit of the first of said
plurality is connected with said first conduit
of the second of said plurality and so forth 100
in series to provide for purging action of
said open space in each said blasting cap by
flow of the explosive gas mixture in series
flow therethrough and subsequently for
detonation of said explosive gas mixture to 105
propagate a detonation front in series
through each of said caps in said plurality.

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