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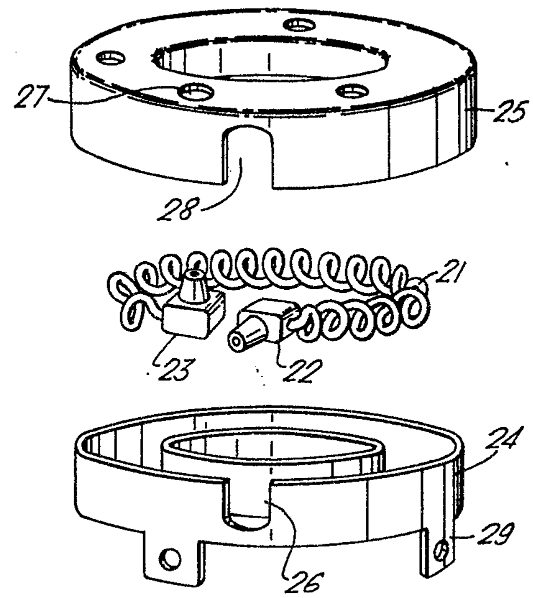
# (54) Pyrotechnic delay cord

(57) A pyrotechnic delay cord consists of a column of a pyrotechnic composition, which may be conventional, contained within a flexible tube of ductile metal, preferably lead or a lead alloy, or alternatively of aluminium, copper or silver copper, antimony or tellurium may be used as the alloying elements. The tube is in turn sheathed by a sleeve of a deformable, gas impervious plastics material, which may be a plastic or elastomeric, flexible or semi-rigid polyolefin, fluoroplastic, silicone or fluoro -elastomer and may be heat shrunk on. The cord is preferably surrounded by an elastomeric support matrix.

Cords according to the invention may be used over a wide range of environmental temperatures and pressures and may be made with metal tube diameters as low as 0.4 mm. The cords may be coiled into small volumes to enable them to be contained in an annular container 24, the plastics sheathing preventing crossover of the burning reaction. The cords may be used with a wide variety of conventional ignition means 22, and may be used for any sort of detonative, explosive or explosive/mechanical output 23. Two typical delay systems using the cord are described.

Fig. 2.




The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1.

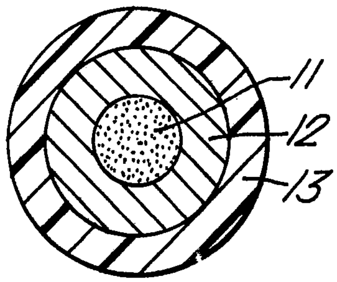



Fig. 2.

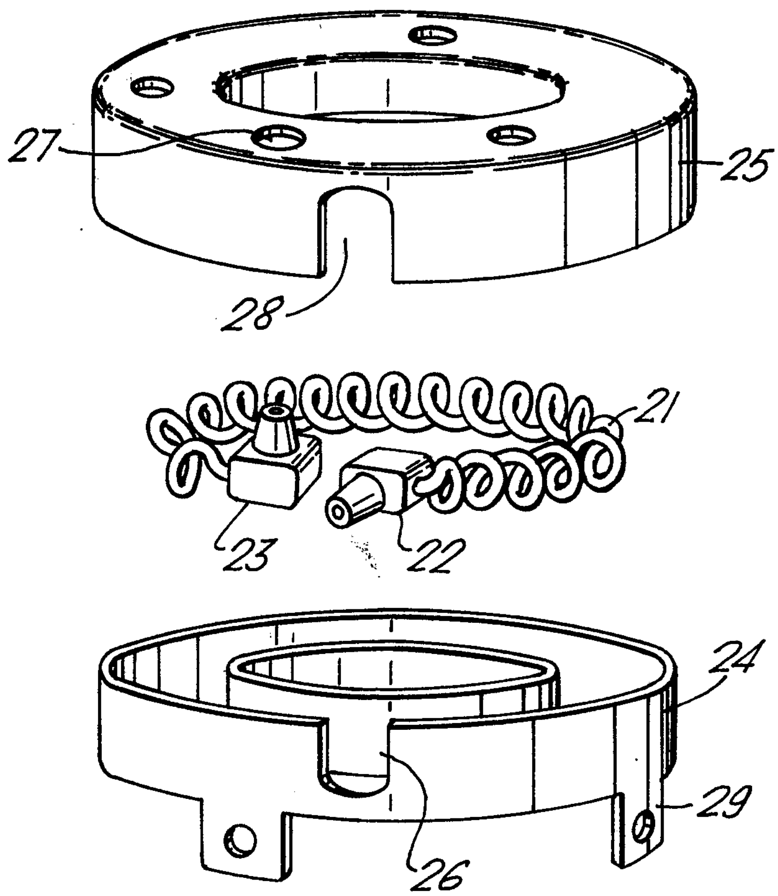
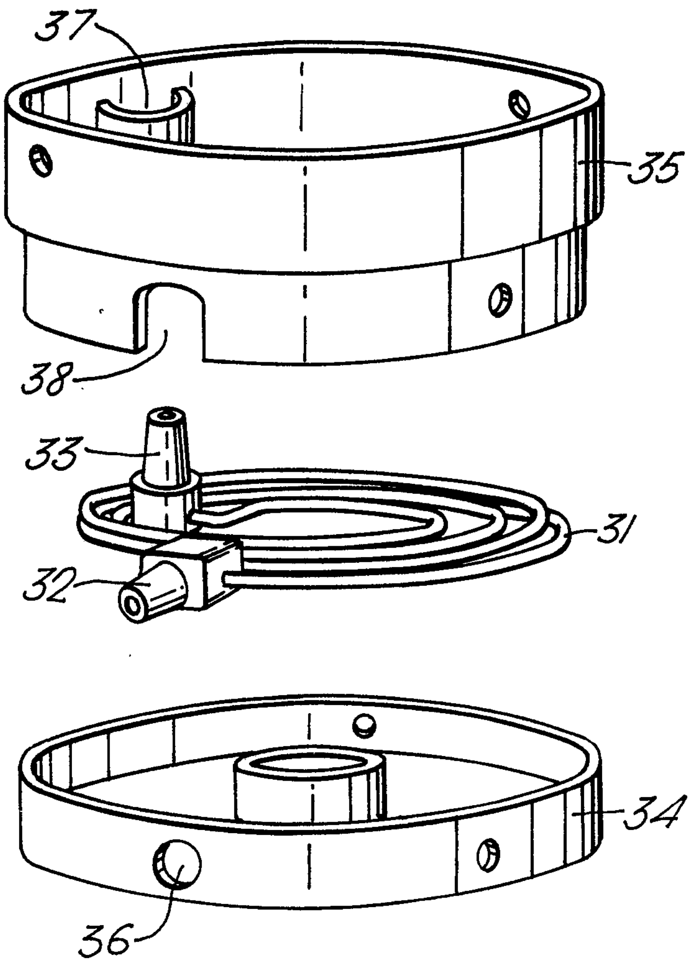


Fig. 3.



SPECIFICATION
**Pyrotechnic delay cord**

The present invention relates to pyrotechnic delay cords.

Pyrotechnic delay cords consist generally of a column of a pyrotechnic delay composition, enclosed within a tube. The density, length, diameter and nature of the pyrotechnic composition used are the main factors which determine the burning time. Such cords conventionally take either of two forms. One comprises a precision-engineered rigid metal tube into which a pyrotechnic delay composition is filled and consolidated by high pressing loads in a number of small increments, which may be either formed from the loose or pre-pelleted composition or the composition may be contained within a small lead sheath. A second form is manufactured by containing pyrotechnic delay composition of a relatively low density in a long ductile metal tube, made, for example, of lead or copper. The flexibility of the tube enables a greater length of composition and hence a longer delay time to be formed between two explosive events by folding or coiling of the tube.

Both these types suffer from disadvantages. Although the rigid type provides a physically strong and reliable unit, it requires expensive production tooling and components and more particularly does not make the most efficient use of the limited space within a given design envelope. The flexible cords have the disadvantage that the heat generated by the combustion of the relatively large quantities of pyrotechnic composition per unit length tends to melt the metallic sheath leading to a danger of cross-over of the combustion region, which limits the degree of folding or coiling which is possible. Attempts to prevent this cross-over of the burning reaction by the use of thicker sheathing have not been successful, as this leads to an increase in the amount of heat conducted away, which tends to stop the reaction. A disadvantage common to both types is that unreliable flame propagation occurs if the burning reaction zone is exposed or vented to low environmental pressures since the gas formed from the products of combustion rapidly escapes, with consequent loss of heat evolved from the combustion process, until a point is reached where the reaction ceaes to be self-sustaining. A further disadvantage of both types of pyrotechnic delay cord is that at the usual working limit of 60 seconds burning time, the physical size and weight of the delay unit designed for reliable performance is very restrictive for most applications.

According to the present invention there is provided an improved pyrotechnic time delay cord which is capable of providing reliable and compact time delay systems, the cord comprising a column of a pyrotechnic composition contained within a flexible metal tube, this metal tube being in turn sheathed within a sleeve of deformable, gas impervious plastics material. The whole cord is preferably surrounded by an elastomer which serves as a flexible matrix to provide support for the plastics sleeving when this is expanded by the gas pressure resulting from the combustion reaction. The plastics sleeving retains the gas pressure so that the combustion process is reliably maintained under exposure to low environmental pressures even if the metal tube should melt. Furthermore, the plastics sleeving ats as an effective barrier to prevent crossover of the burning reaction between adjacent cords. Systems of sequenced time delays using the cord of this invention are thus highly reliable over a wide range of environmental temperatures, e.g. −60° to +150°C and all environmental pressures including pressures above and below atmospheric. The environmental pressure will affect the mean burning time of the delay system, higher pressures resulting normally in an increased burning rate and hence reduced burning time. Pressures below atmospheric normally have the opposite effect. Such delay systems can also be made extremely compact by virtue of the fact that the delay cord is very flexible and can be readily bent and formed to fit the most complex physical geometry within a given explosvie system, linking together many explosive and mechanical events in a closely defined time sequence. Thus for example the cord may be helically wound or packed in layers and in this way relatively long delays, i.e. of many minutes' burning time can be engineered into very small volumes. Typically, for example, a delay unit formed by helically coiling approximately 800 mm of the delay cord of the invention with a core of pyrotechnic composition 1 mm in diameter contained in a metal tube of external diameter 1.8 mm and sheathed to a diameter of 2.5 mm, within a cylindrical housing 40 mm internal diameter by 8 mm height having a volume of approximately 10cm$^3$ may provide a delay time of 90 seconds. The rate of burning of a cord will depend, of course, on the reactivity of the composition, but the diameter of the cord has little effect on the rate of burning provided that it is above the minimum value at which the combustion reaction becomes self sustaining.

The pyrotechnic compositions used in the cord of this invention may be of a conventional type, comprising an homogeneous mixture of a stable inorganic based fuel, e.g. silicon, boron or titanium and a chemically stable oxidant, e.g. bismuth oxide, molybdenum trioxide, potassium nitrate or any explosive mixture of material capable of a self-sustaining exothermic chemical reaction, and may be either slow or fast burning. Many alternative compositions will be well known to those acquainted with the art. Using such materials, delay cords or burning times of parts of a second to several minutes may be manufactured.

The flexible metal tube which contains the core of the pyrotechnic composition may preferably consist of lead, usually alloyed with various quantities of other metals e.g. copper, antimony or tellurium etc to produce the required degree of strength and flexibility, or may alternatively consist of other ductile metals such as aluminium, copper or silver.

The plastics material used for the sheathing of the metal tube should be sufficiently deformable to allow it to expand slightly to contain any gas which is generated, but at the same time should be sufficiently strong not to burst under this pressure. Preferably, the plastics material is applied to the metal tube by heat-shrinking a length of conventional heat shrinkable sleeving of slightly larger diameter than that of the metal tube onto the outside of the tube. The plastics material may be plastic or elastomeric and may consist of a flexible or semi-rigid polyolefin, fluoro-plastic, silicone or fluoro-elastomer. The materials used should be related to the type of elastomer used as the support matrix to achieve maximum reliability. Examples of preferred materials are:

a. Flame retarded, flexible and semi-rigid polyolefins of tensile strength between 165 and 255 kN/m$^2$ and ultimate elongation of between 200 and 500%.

b. Non-burning fluoro-plastics of tensile strength between 390 and 495 kN/m$^2$ and ultimate elongation of between 200 and 400%.

c. Flame retarded fluoro-elastomers and silicone elastomers of tensile strength between 48 and 120 kN/m$^2$ and ultimate elongation of between 200 and 500%.

The elastomer forming the supporting matrix for the sheathed cord may preferably be a room temperature vulcanizing, filled or unfilled, silicone elastomer and may be foamed. Other well known materials, such as urethanes may also be used. Flexible elastomeric materials are to be preferred to rigid materials for the support matrix as a flexible elastomer allows expansion of the sheathed delay cord during the combustion reaction whereas a rigid matrix promotes internal pressurization of the cord. Examples of preferred materials are:

a. Self-extinguishing room temperature vulcanizing silicone rubbers of tensile strength of between 24 to 64 kN/m$^2$, with ultimate elongation of between 100 and 225%, and hardness (Shore A) of between 30 to 60.

b. A cellular silicone rubber system (10% closed cells structure) of tensile strength between 120 and 150 kN/m$^2$.

The delay cord of the invention may be manufactured by loading the pyrotechnic composition into a ductile metal tube of a suitable size, and then reducing the outside diameter of the tube by a conventional drawing and/or rolling process to a convenient size. Cords in which the outside diameter of the metal tube is approximately 2 mm with a wall thickness of approximately 0.5 mm have been found to be most convenient, and these dimensions may be scaled up or down depending upon the application and the performance required. Cords according to the invention with a metal tube diameter as low as 0.4 mm have been successfully tested. The use of lead sheath for this process of manufacture of delay elements is very safe even for the most sensitive explosive compositions as it eliminates the possibility of the pyrotechnic composition being subjected to friction between hard metallic surfaces during filling and drawing. Particles of explosive dust are not normally released into the atmosphere during this process.

Pyrotechnic delay systems using the delay cord of the invention are readily assembled by bonding metallic or plastic caps which house the various explosive functions onto the ends of the plastics sheathed delay cord. The plastics sheathing material should also be sealed onto these caps, epoxy resins being suitable for this purpose. Preferably the adhesive resin used should be highly flexible with a high peel strength to allow bending of the cord even at the ends, as cracking of the joint due to manipulation of the cord will allow the penetration of moisture and consequent deterioration in performance.

Delay cords according to the invention are suitable for a wide variety of applications, and any means of ignition of the cord may be employed, such as, for example, flash-receptive, electric, percussive or stab igniter devices. The cord may be used for any form of detonative, explosive or explosive/mechanical output.

The invention will now be described by way of example with reference to Figures 1, 2 and 3, in which:

Fig. 1 shows a cross section through a delay cord manufactured according to the invention.

Fig. 2 shows an exploded view of a pyrotechnic delay system containing a helical coil of the delay cord.

Fig. 3 shows an exploded view of a pyrotechnic delay system containing a spiral of delay cord.

With reference to Fig. 1, a delay cord comprises a core of pyrotechnic delay composition 11, contained within a cylindrical lead tube 12, which is surrounded by a sheath of heat-shrunk fluoroplastic material 13.

With reference to Fig. 2, a delay system comprises a helical coil of delay cord 21, to one end of which is attached a flash-receptive igniter 22, and to the other end a detonator cap 23, of a type that will be detonated by the heat of the delay cord combustion. The coil is bent into the form of a segment of a circle, to enable it to fit into an annular casing which comprises a body 24 and a corresponding cover 25 which may be fastened together, by, for example screws or adhesive. To assemble the device, the cord 21, igniter 22 and detonator 23 assembly is positioned in the body 24 so that the igniter 22 projects through a cut-out 26 in the side of the body. A castable liquid silicone elastomer foam material is then poured around the delay cord, in sufficient quantity to embed it and support it rigidly within the body on curing. The cover 25 is then positioned on the body 24 so that the detonator cap 23 projects through a hole 27 in the cover, and the cut-out 28 in the cover fits over the igniter 22. The cover is then fastened down and the silicone allowed to set. The assembled delay system may then be mounted within an explosive device using for example fixing lugs 29.

With reference to Fig. 3, a delay system comprises a length of delay cord 31 coiled into a flat spiral. To one end of the coil is attached a flash-receptive igniter 32 and to the other a suitable detonator 33. The spiral of delay cord is positioned within a casing which comprises a base 34 and a body 35 which may be fastended together by for example adhesive or screws. To assemble the device, the spiral of delay cord is positioned within the base 34 so that the igniter 32 projects through a hole 36 in the side of the base, and the body 35 is then positioned on the base so that the detonator fits inside a bracket 37 in the side of the body, and a cut-out 38 in the body fits over the igniter 32. The body and base are then fastened together. A castable liquid silicone elastomer is then poured over into the assembled casing, to embed and support the delay cord and is allowed to set. The delay system may then be mounted within an explosive device using well known means. In a modified version, the delay cord may be in the form of a double spiral reversing direction at its centre.

CLAIMS

1. A pyrotechnic time delay cord comprising a column of pyrotechnic composition contained within a flexible metal tube, said metal tube being in turn sheathed within a sleeve of deformable, gas impervious plastics material.

2. A delay cord according to any of the preceding claims in which the flexible metal tube consists wholly or partly of lead.

3. A delay cord according to claim 2 in which the flexible metal tube contains copper, antimony or tellurium as alloying elements.

4. A delay cord according to any of claims 1 to 3 in which the flexible metal tube consists of aluminium, copper or silver.

5. A delay cord according to any of the preceding claims in which the metal tube has an internal diameter of 0.4—1.0 mm.

6. A delay cord according to any of the preceding claims in which the plastics material consists of a polyolefin or fluoroplastic.

7. A delay cord according to claim 6 in which the plastics material is a flame retarded, flexible or semi-rigid polyolefin, of tensile strength between 165 and 255 kN/m$^2$ and ultimate elongation of between 200 and 500%.

8. A delay cord according to any of claims 1—6 in which the plastics material is a non-burning fluoroplastic of tensile strength between 390 and 495 kN/m$^2$ and ultimate elongation between 200 and 400%.

9. A delay cord according to any one of claims 1—5 wherein the plastics material is a silicone elastomer or fluoro elastomer.

10. A delay cord according to claim 9 in which the plastics material has a tensile strength between 48 and 120 kN/m$^2$ and ultimate elongation of between 200 and 500%.

11. A delay cord according to any of the preceding claims in which the plastics material is applied to the metal tube by heat-shrinking a length of heat-shrinkable sleeving onto the outside of the tube.

12. A delay cord according to any of the preceding claims in which the delay cord is surrounded by an elastomeric support matrix.

13. A delay cord according to claim 12 in which the support matrix is a room temperature vulcanising, filled or unfilled, silicone elastomer.

14. A delay cord according to claim 12 in which the support matrix is a urethane.

15. A delay cord according to any of claims 12 to 14 in which the support matrix is foamed.

16. A delay cord according to any of claims 12 to 15 in which the support matrix is flexible.

17. A delay cord according to claim 20 in which the support matrix is a self extinguishing room temperature vulcanizing silicone rubber of tensile strength between 24 and 64 kN/m$^2$, with ultimate elongation of between 100 and 225%, and hardness (Shore A) of between 30 to 60.

18. A delay cord according to claim 20 in which the support matrix is a cellular silicone rubber system (10% closed cells structure) of tensile strength between 120 and 150 kN/m$^2$.

19. A delay cord according to any of the preceding claims which is manufactured by a process including the step of loading the pyrotechnic composition into a ductile metal tube and then reducing the diameter of the tube by a drawing and/or rolling process.

20. A delay cord substantially as hereinbefore described with reference to the accompanying drawings.

21. A pyrotechnic delay cord according to any of the preceding claims in the form of a flat spiral.

22. A pyrotechnic delay cord according to any of the preceding claims in the form of a helical coil.

23. A pyrotechnic delay system comprising a delay cord according to any of the preceding claims sealed to end caps housing explosive or pyrotechnic compositions.

24. A pyrotechnic delay system according to claim 23 wherein the delay cord is sealed to the end caps by an epoxy resin.

25. A pyrotechnic delay system substantially as hereinbefore described with reference to the accompanying drawings.

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