Nov. 23, 1965 F. A. LOVING ETAL 3,218,972

CONTOURED SPOOL FOR SUPPORTING SHEET EXPLOSIVE

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FIG. 1

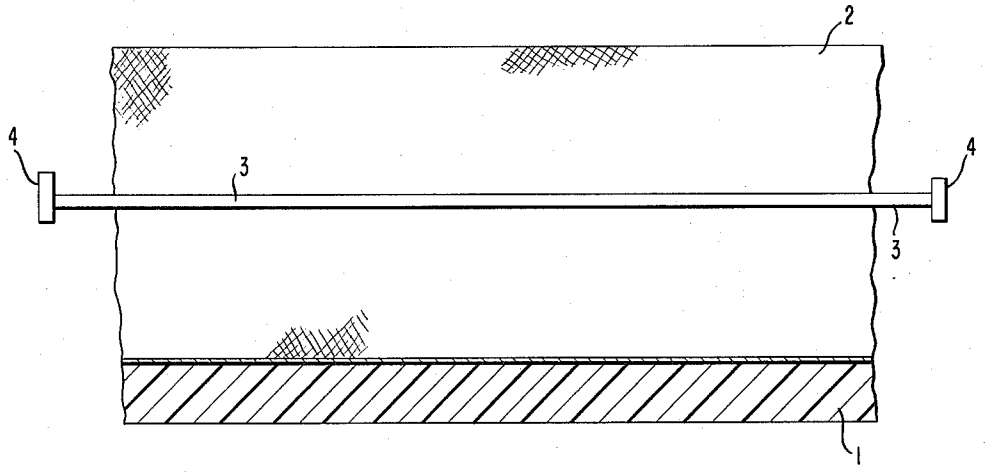


FIG. 2

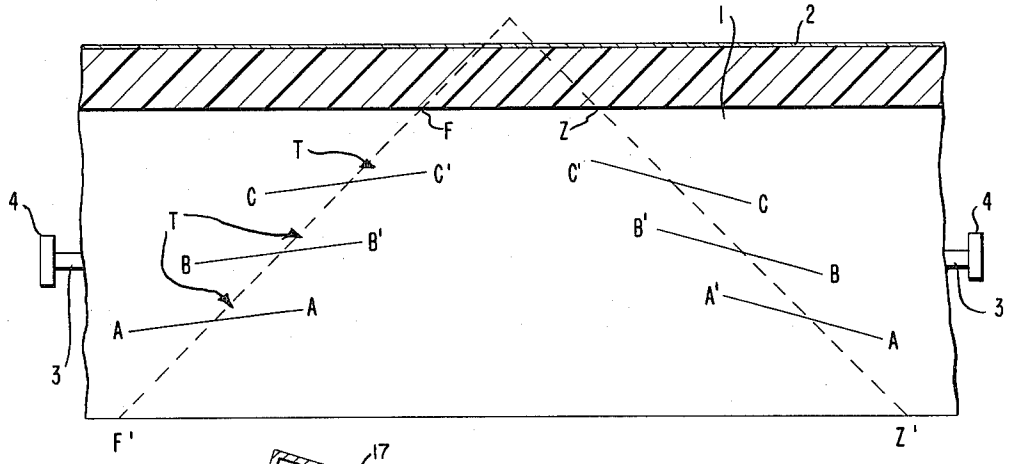
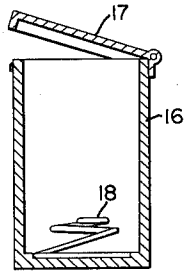


FIG. 11



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FIG. 3

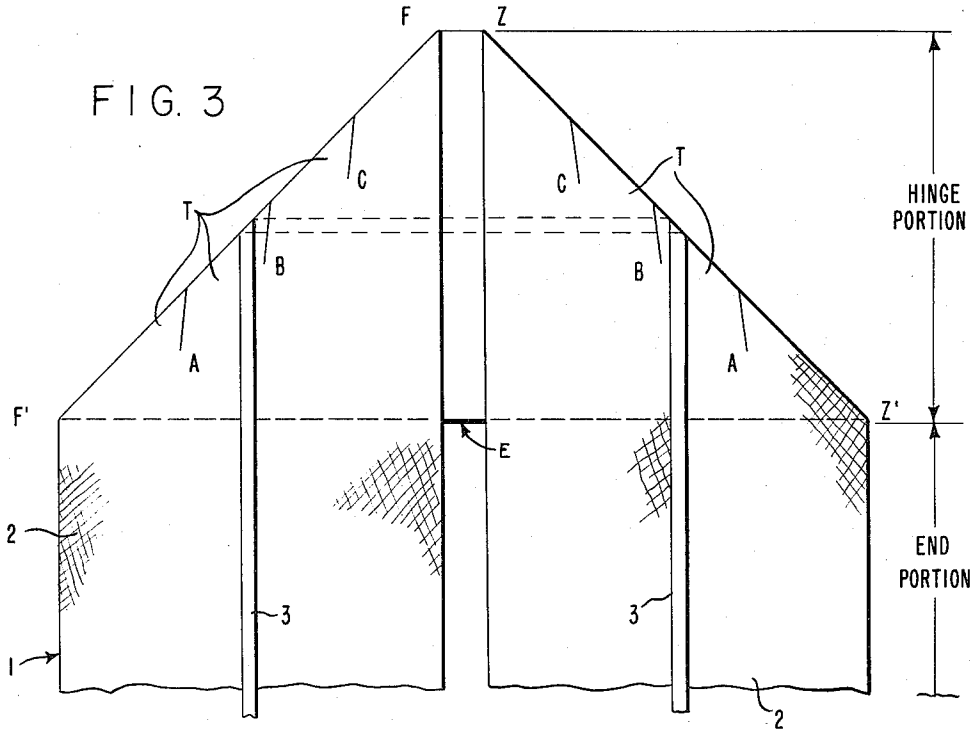


FIG. 4

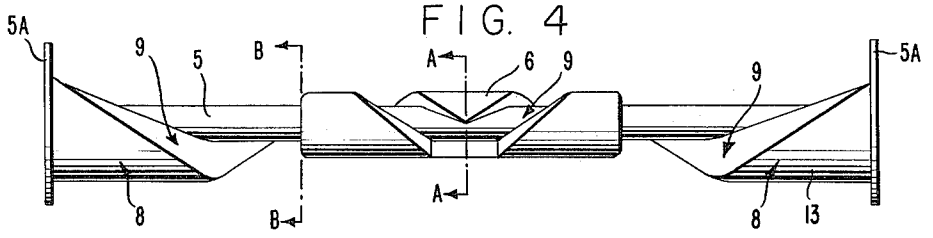
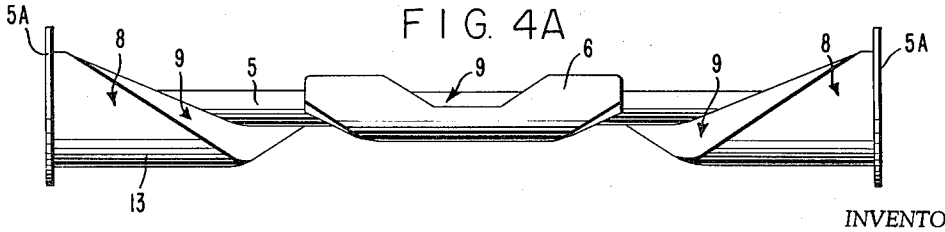


FIG. 4A



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FIG. 4B

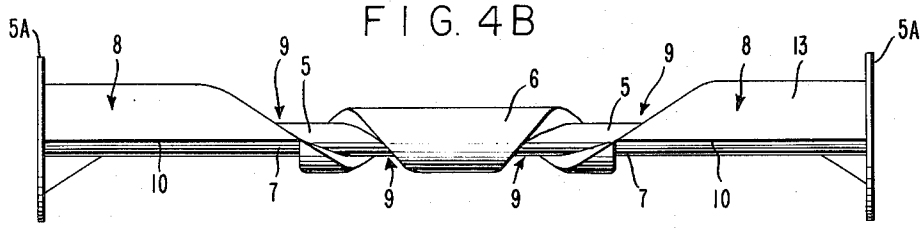


FIG. 5

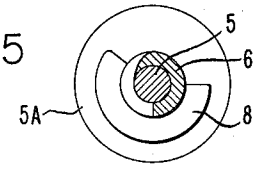


FIG. 6

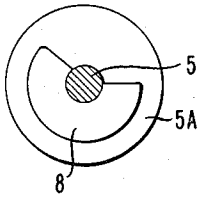


FIG. 7

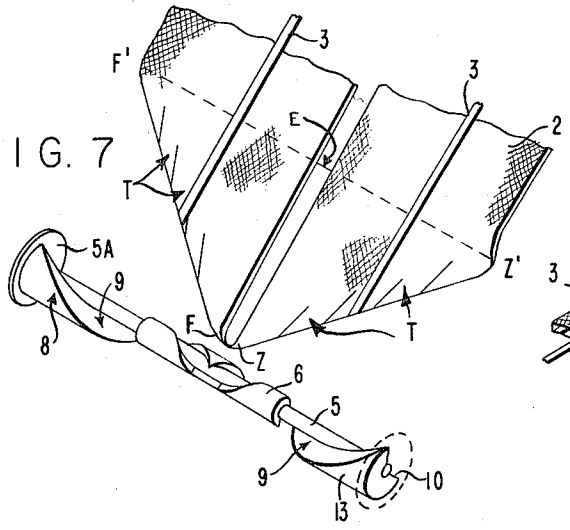


FIG. 8

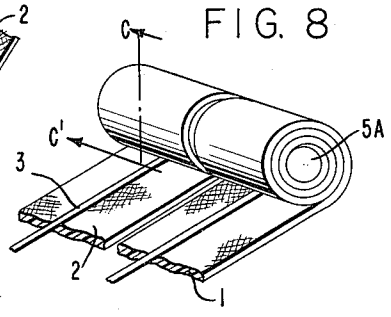


FIG. 9

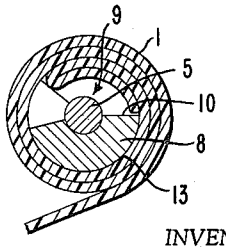
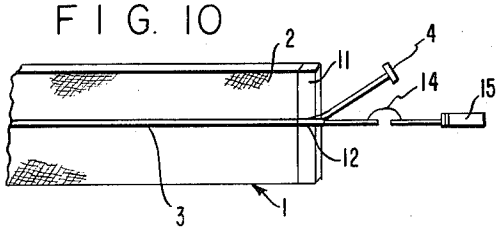


FIG. 10



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United States Patent Office 3,218,972 Patented Nov. 23, 1965

3,218,972
CONTOURED SPOOL FOR SUPPORTING SHEET EXPLOSIVE

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Filed Apr. 16, 1964, Ser. No. 360,233
7 Claims. (Cl. 102—22)

This invention relates to a contoured spool for supporting a flexible tape or strip of explosive material and, more particularly, to a compact package comprising a contoured spool for winding, supporting, storing and dispersing a tape of self-supporting explosive composition. The spool is so constructed that the exposive tape element can be wound around the spool and supported thereon and readily unfurled to expose the entire elongated surface of the exposive tape element free from cracks or tears and in such condition that the propagating characteristics of said tape are not detrimentally affected.

Recently, self-supporting exposive compositions which can be formed into flexible sheets or tapes have been developed. These compositions generally comprise from about 15 to about 92.5% of a cap-sensitive crystalline explosive in admixture with an elastomeric binding agent. Compositions of this type and their preparation are described in detail in U.S. Patents 2,999,743, 2,992,087, and 3,093,521. Such compositions have won wide commercial and military acceptance owing to their ability to propagate a detonation impulse reliably even in thin sheets and at low explosive loadings. Accordingly, thin sheets, strips or tapes of the self-supporting compositions are prime candidates for use as the explosive charge in such applications as seismic exploration, both on land and in off-shore locations; in underwater detection or communication systems; as airborne line charges such as defoliation, anti-personnel and similar warhead and/or demolition charges; and in metal working. However, up to the present time, the use of relatively long strips or tapes, e.g. on the order of 10 feet or more, of such composition has been curtailed, since no entirely satisfactory means have been devised for storing and handling these compositions and for positioning them at the time of use which would not, at least to some degree, impair the propagation characteristics of the strips, i.e., by tearing or discontinuity of the explosive composition.

Briefly, the present invention comprises an improved spool for winding, supporting, storing and dispensing an elongated flexible, self-supporting tape of a cap-sensitive exposive composition in admixture with an elastomeric binding agent such that it is free from tearing, cracking or fraying due to crushing or similar deformative forces that are applied to the tape on the spool. The explosive composition of predetermined thickness is in the form of an elongated tape or strip, and is wrapped about the novel spool. Before the tape is wound about the spool it is first folded intermediate to its ends so that the tape takes a configuration comprising two extended laterally-aligned, substantially parallel end portions, which preferably are essentially equal in length, and a hinge portion. As shown in FIGURE 3, this hinge portion has two converging peripheral edges that have a thickness of about twice that of said tape. The hinge portion also has on one side thereof an edge of tape E extending transversely to said extended end portions. The contoured spool member around which the above described folded tape is wrapped comprises an axis of rotation and has a contoured, generally cylindrical surface for supporting the tape element, as shown in FIGURES 4 and 7. A portion of the contoured, cylindrical surface 13 is provided with an inwardly recessed portion. The specific configuration of the inwardly recessed portion corresponds to the hinge portion of the tape, and said recess is so constructed and arranged that when the tape element is wound about the spool the hinge portion of the tape is innermost on the roll and positioned in the recessed portion of the spool and thereby held substantially out of contact with detrimental deformation forces produced by succeeding wraps of the tape element on said cylindrical portion. The recessed portion comprises two converging grooved portions 9 for containing the converging peripheral edges of the tape F–F', Z–Z', said grooved portions have a radial depth at least about twice the thickness of the tape element. The recessed portion further comprises a radially extending abutment 10 constructed and arranged to engage the transversely extending edge of the hinge portion of the tape E. Therefore, in accordance with this invention, there is now provided a package in which a relatively long strip or tape of an explosive composition is stored in a compact roll or furl in a configuration which can be unfurled readily to expose the entire surface of the tape with no detriment to the propagation properties of the explosive composition during storage, handling, or unfurling of the tape in which a tape of an explosive composition is folded at a hinge formed in the composition and rolled, i.e., furled, around a contoured, channeled spool, with the recessed portion of the contoured spool containing the hinge and supporting the composition along its entire length. A protective casing may be provided for the roll, and means for positioning and actuating the explosive tape may be affixed to the strip.

The novel features of the invention will best be understood from the following description, when considered with the accompanying drawings, which show the sequence of preparing the package of this invention. In the drawings:

FIGURE 1 is a (perspective) top view of the top of explosive composition provided with a backing of flexible material and with a strain-relieving band,

FIGURE 2 is a perspective view of the hinge provided at the section of the tape to be folded,

FIGURE 3 is a top view of the hinge portion and end portion of the tape in a condition suitable for wrapping around the spool,

FIGURES 4, 4A and 4B are views of the contoured spool at different degrees of rotation,

FIGURES 5 and 6 are sectional views taken along lines A–A' and B–B' of FIGURE 4, respectively,

FIGURE 7 is a perspective view of the folded tape about to be positioned on the contoured spool,

FIGURE 8 is a view of the rolled assembly,

FIGURE 9 is a cross-sectional view taken along lines C–C' of FIGURE 8,

FIGURE 10 is a view of means for initiating the tape, and

FIGURE 11 is a cross sectional view of a canister and means for releasing the contoured spool and tape.

Having more particular reference to the drawings, in which like reference characters designate like or similar elements, in FIGURE 1, the explosive material to be packaged comprises a self-supporting tape of explosive composition 1, a backing material 2 and a strain relieving band 3. The self-supporting explosive composition comprises from about 15% to about 92.5% and preferably 50 to about 85% of cap-sensitive crystalline high explosive such as PETN, RDX, or HMX in admixture with an elastomeric binding agent, e.g., comprising a plasticized nitrocellulose or a mixture of natural or synthetic rubber and a thermoplastic terpene hydrocarbon resin. The self-supporting composition must be capable of propagating a detonation impulse at relatively low explosive loadings and in sheets as thin as about 25 mils. The thick-

ness of the tape will generally not exceed about 1 inch to facilitate rolling of the strip. Further, the composition must be initiatable by customary initiation means, e.g., by blasting caps or by a line wave generator such as described in U.S. 2,943,571. Its sensitivity to mechanical shocks and to stray electric discharges desirably is low to enable machining, handling, and transportation of the explosive composition. The water resistance and wet strength of the composition should be high. The physical characteristics of the composition must be such that it can be readily formed into strips, sheets, or takes which will retain their dimensional stability during handling, transportation and storage. Changes in dimensional stability would result in undesirable variations in weight of explosive per unit area in the configuration. The tapes formed of the composition should be tough, i.e., strong and firm, in texture but flexible to facilitate bending. Exemplary of explosive compositions having the requisite characteristics are described in U.S. Patents 2,999,743, 2,992,087, and 3,093,521, the teachings of which are included in this application by reference.

Flexible backing material 2 is attached to one surface of tape 1 and coextensive with the area of this surface. This material, which is used to insure the dimensional stability of the tape, should be relatively thin in relationship to the tape, e.g., 1/30 to 1/10 the thickness of the tape and should be characterized by a tensile strength at least 1.5 times that of the explosive composition. In general, this material will be a thin strip or film of a material inert to the explosive composition and will have a tensile strength of at least about 35 kg./sq. mm. Exemplary materials for use as this backing material include flexible polymeric films such as of a polyolefin, polyvinyl chloride, polyvinylidene chloride, polyesters such as polyethylene terephthalate, polytetrafluoroethylene, rubber hydrochloride and the like; flexible metal foils; woven fabrics of cotton, nylon, linen, jute, hemp, polyesters, e.g., polyethylene terephthalate, acrylics and the like; or high wet-strength paper or porous fibers impregnated and unified by an elastomeric composition admixed with a resinous composition. The backing material is affixed to the explosive by a flexible adhesive of any of the conventional types, particularly by a water-resistant, pressure-sensitive adhesive.

In addition to the provision of backing material 2, strain-relieving band 3 preferably is positioned along the longitudinal axis of the tape 1. This strain-relieving band 3, which is employed to minimize strain on the tape 1 as it is unfurled, preferably is of a flexible material having a tensile strength at least about 2 to 3 times that of the tape of explosive composition. Exemplary of a particularly preferred material for strain relieving band 3 is glass-filament tape which has a tensile strength of 500 pounds per inch of width and approximately 3% stretch when it breaks. Representative of other suitable bands are those containing filaments such as of nylon, rayon, or polyethylene terephthalate.

Although the strain-relieving band is shown as a separate element in FIGURE 1, it is to be understood that the band may be a stripe woven into the backing material or, should the backing material have a tensile strength of at least two to three times that of tht explosive composition, the band may be omitted.

At each end of band 3, when utilized, or explosive tape 1 are connectors 4 that provide means for securing the tape to positioning or lowering lines. These connectors or clasps, which may be of metal wire or chain, nylon, high strength twine, or the like, are preferably of tubular or ring-like configuration but may be of ellipsoidal, triangular, elongated, rectangular or other suitable configuration adapted to mate (releasably) with appendages such as hooks or clasps on lines used to position or lower the charge into place when it is to be used.

Subsequent to the provision of the backing material 2 and band 3, explosive tape 1 is prepared for folding as shown in FIGURE 2 in order to provide a hinge therefor. The provision of a hinge in the section of the tape to be folded, generally the midsection, is necessary for satisfactorily wrapping the tape about the spool. This hinge is formed by providing two echelons of slits along fold lines, indicated in the drawing as F–F′ and Z–Z′ in the explosive composition. Each echelon of slits, which in the embodiment shown, comprise slits A–A′, B–B′, and C–C′, intersects one of the two fold lines F–F′ or Z–Z′. In practice, points F and Z may coincide. The area defined on the tape by lines F–F′, Z–Z′ and F–Z, as alternatively shown in FIGURE 2 may be modified by extending the lines F–F′ and Z–Z′ until they intersect to form an isosceles triangle, preferably at right isosceles triangle. Each of the fold lines F–F′ and Z–Z′, preferably forms an angle of about 45° or its positive supplement with the longitudinal axis of the strip. The angle formed by the intersection of each slit in the echelon with the fold line must be greater than about 0° and less than about 60°. An angle of 0° would induce strain and lead to tearing at the fold line, and an angle of 60° would result in increasing twist being imparted to the tape along the fold line. The slits in each echelon are essentially equal in length. Each slit extends across the fold line when the tape is folded and into the explosive composition on either side of the fold line a distance at least equal to twice the thickness of the tape. Each slit cuts completely through the explosive composition; however, it need not cut through the backing material. The number of slits formed in echelon along each fold line will depend upon the width of the strip and the angle which each slit forms with the fold line. In general, it has been found preferable that an angle of about 15° to about 40° be inscribed between each of the slits and the fold line. With this degree of angle, an optimum number of torsion bars T will be formed across the width of the tape to provide flexibility in the area of the fold and to provide a redundancy by a plurality of paths for the detonation impulse. The length of each slit preferably will be ¼ of to slightly less than the width of the tape at the section where the hinge is to be provided. The width of the slits will be negligible with respect to their length and thickness. The section of the hinge between each two slits defines torsion bars T which are subjected to twisting as the strip is being folded. The provision of the echelon of slits is discussed in copending application S.N. 211,636, now Patent No. 3,169,478, filed July 23, 1962 in the name of H. L. Schaaf, the teachings of which are intended to be included in this application by reference.

The tape is folded along the fold lines, bringing the portion of the tape extending on each side of the hinge across the composition in the area of the tape defined by F–F′, Z–Z′, and F′–Z′. As the tape is folded, the explosive composition parts cleanly and easily at the slits with no tearing or fraying. Torsion bars T remain unitary with the explosive composition in the hinge and are not torn or frayed when the tape is folded. These torsion bars provide a continuous path for a detonation impulse when detonation in the strip is initiated at one end enabling the impulse to be propagated without interruption along the entire length of the tape. Should, however, the strip be folded without the provision of the echelon of slits, and, accordingly, torsion bars, tearing, discontinuity and hiatus of the explosive composition would occur in the area of the fold line such that a detonation impulse could not be reliably propagated from one side of the fold to the other. As stated above, the hinge preferably will be formed at or near the longitudinal mid-section of the tape such that two laterally aligned, essentially parallel end portions, preferably of essentially equal length, extend from the hinge portion of the tape. The folded tape illustrating the hinge portion and end portion is shown in FIGURE 3.

The folded tape is subsequently rolled, i.e., furled, about the novel contoured spool; the recessed portion of the

spool contains or cradles the hinge portion of the tape and the cylindrical surface **13** of the spool supports the composition in the strip along the entire length of the spool. Three views of a single embodiment of this spool are shown in FIGURES 4, 4A, and 4B. This spool, which is contoured and provided with an inner recess as hereinbefore described, is complementary to the volume of the open space provided in the center of the furled, i.e., rolled, tape. The spool may generally be described as a cylinder, particularly a right circular cylinder, whose lateral surface is inscribed with that surface generated by an isosceles triangle having its altitude deformed to form a spiral, the apex of the triangle being at essentially the center of the spiral. The edges of the deformed triangle thus define, on either side of a plane bisecting the altitude of the cylinder upon which the surface is inscribed, a conical helical surface, i.e., the surface is that of a spiral helix or a helix of constantly increasing radius of curvature and pitch. This surface provides a helical channel **9** of gradually increasing diameter and width which is adapted to receive and support the peripheral converging edge sections of the folded, hinged portion of the tape, i.e., the portions along lines F–F′ and Z–Z′. An approximate pattern or model of the contoured spool may be built up around a generally cylindrical shaft **5** which extends the length of the spool, and which is provided with rims or radially extending flanges **5A**. Support piece **6**, whose configuration is generally that of a truncated prism having a base which is generally of a chevron configuration cut out of a wedge-shaped piece of material, is wrapped about the mid-section of the shaft. Tape support surfaces develop on either side of the hinge support piece, i.e., from the base angles **7** of the truncated prism. These generally cylindrical surfaces are supporting surfaces and are provided by wrapping about the shaft a piece **8** whose configuration is generally that of a right pyramid, i.e., a pyramid which has one lateral face perpendicular to its base. The base of the pyramid may be a rectangle, an arc of a circle, a triangle, a rhombus, or a trapezoid. The vertex of this pyramidal piece **8** is positioned to overlie the base angles **7** of the truncated prismatic support piece **6**. The altitude of the pyramidal piece **8** is essentially equal to the distance between the apex of base angle **7** of the truncated prism and the flange **5A** of the cylindrical shaft **5**, plus the radius of the shaft. The length, i.e., longitudinal dimension, of the base of the pyramidal piece **8** is essentially equal to the circumference of the shaft so that the piece can be wrapped around the shaft with negligible overlapping. It is to be understood that pyramidal pieces **8** are provided on both sides of the support piece **6** such that mirror-image channeled surfaces are provided on either side of a plane passed perpendicular to and bisecting the altitude of the shaft. The edges of support piece **6** and pyramidal piece **8**, when wrapped on shaft **5**, thus form a pair of helical grooves **9** intersecting at the midpoint of the shaft. These grooves thus form a clearance space in which the torsion bars T rest. The base edges of the right pyramidal piece **8** form an abutment **10** to contact the transversely extending portion of the hinge. Sharp edges on the surface are smoothed so that no rough surfaces are present to snag the explosive composition. For the mass production of the spools, a pattern may be made as discussed supra and from this model or pattern a number of spools may be prepared by means such as machining, e.g., by methods similar to that used by a locksmith in preparing duplicate keys, by sculpturing, by molding, by casting, or by similar means.

In the embodiment shown, the length of the spool is about twice the width of the tape and its circumference at the section adjacent the flanges is essentially equal to the width of the tape so that the hinge will be completely taken up upon one revolution of the spool. The spool should be of a relatively rigid, firm composition which maintains its dimensional stability even during exposure to heat and moisture. The composition of the spool should be chemically inert to the explosive composition and backing material, i.e., it should contain no reactive functional groups which could combine with the self-supporting explosive composition or backing material to effect deterioration of the physical or explosive properties of the tape. Since the spools are, in some instances, to be used to position or deploy the charge underwater, the spool should have relatively low water absorption characteristics and high wet strength. It also should be stable to altitude changes and temperature/humidity cycling. In some instances, it is desirable that the spool be of a composition which is electrically an insulator in order to offer some protection against accidental actuation of the explosive by stray electric current. Representative of suitable material for use as the spool include materials such as molded nylon, acetal resins, thermoplastic carbonate such as produced by the reaction of bisphenol A and phosgene, Bakelite, polyvinyl formal resins, polytetrafluoroethylene, polyvinyl fluoride, polyvinyl chloride, polyesters formed by the reaction of polybasic alcohols with polyfunctional aliphatic or aromatic carboxylic acids, polystyrene, polyurethane, polycaprolactam, epoxy resins, metal-filled epoxy resins, and the like. Also suitable are machinable or moldable metals such as aluminum, magnesium, steel, copper, tin, and the like; compacted or cemented metal powders; ceramics; natural products such as glass, stone, ivory, bone, hair, jade, amber and the like; cement or concrete; soap; hard rubbers of either the natural or synthetic type; laminated paper or cardboard of high wet strength; and similar materials.

Preferably, a length of release paper having a configuration of that of the hinged tape may be rolled with the tape to insure that the layers in the furled strip do not stick together and to facilitate unfurling of the tape. Typically, the release paper is about one-half the total length of the explosive tape and twice the width. This paper then unitizes the lengths of strip during wrap-up and subsequent handling.

In rolling the tape, the apex of the hinge portion of the tape is positioned to rest on the support piece **6** of the spool as shown, for example, in FIGURE 7, the apex of the hinge being contiguous to the apex of this piece. The converging peripheral side edge portions of the hinge, e.g., along lines F–F′ and Z–Z′, are positioned and lie in two converging groove portions identified as helical channel **9** and the transversely extending edge of the tape F′–Z′ rests on radially extending abutment **10** as schematically shown in FIGURE 7. Subsequently, the spool is rotated such that the lengths of the strip extending from the hinge are "taken up" on the spool, the release paper, when utilized, being interleaved with the explosive tape. The previously rolled section of the tape and the built-up or cylindrical surface portion **13** of the spool provides a support for the tape which is later rolled on the spool such that the tape of explosive composition in the roll is supported along the entire length of the spool and is not subject to tearing or fraying owing to crushing or similar deformative forces applied to the spool during storage or handling of the spool. The rolled tape on the spool has the appearance of a carpet roll as shown in FIGURE 8. If the contoured spool were not provided, the section of the roll of tape overlying the piece **6** would be subjected to greater pressure than that at the edges of the spool so that a crushing or bending force applied inadvertently to the spool would tear or crack the explosive composition in this area, impairing the propagation characteristics of the explosive strip.

Provision for actuation of the tape charge is made by clipping a pick-up ignition assembly to one end of the tape. This ignition assembly is shown in FIGURE 10 which shows the assembly affixed to the end of the tape. The ignition assembly provides a U-shaped clip **11** of metal or high strength plastic having an aperture which holds an initiator **12**, which comprises a shell containing a charge of a detonating explosive, such that the detonating

charge of the initiator is in propagating relationship to the explosive composition of the tape. Detonating fuse **14** closes the mouth of the initiator shell and extends to pick-up initiator **15** which also contains a charge of a detonating explosive in a cylindrical shell. In preferred embodiments of this invention, fuse **14** is of the same composition as the tape and is protected by a sheath of nylon, polyurethane, polyethylene, polyethylene terephthalate, braided textile or the like. This fuse **14** alternatively may be conventional detonating fuse, e.g., "Primacord," or mild detonating fuse.

The rolled tape is subsequently encased in a tube, e.g., of cardboard, for shipping. The charge can be deployed directly from the shipping tube. However, in preferred embodiments, the rolled tape is transferred to another container or canister **16**, for example, a cylindrical container integrally closed at one end and closed at the other end by readily removable closure means **17** and provided, at the closed end, with means, e.g., propellant charge or a compression spring **18**, for ejecting the rolled tape therefrom. Connectors **4** are attached to lowering or positioning lines (not shown) which are provided with hooks, bars, clips or the like and through which relatively small differential opposed forces can be applied to each end of the tape, e.g., through the tubular connectors **4**. The tape, in response to these forces and to external force, e.g., gravity and mechanical force, becomes spatially separated from the canister, and unfurls, allowing the contoured spool to fall away. After the tape is so released and unfurled, the initiator **15** of the pick-up ignition assembly is actuated by conventional instantaneous or delay means, e.g., a pressure or fluid actuated igniting means. Fuse **14** transmits the detonation to initiator **12** whose actuation initiates a detonation impulse in the self-supporting explosive composition. The detonation impulse is propagated uninterrupted and at a uniform rate throughout the entire length and area of the tape, the detonation impulse being transmitted by the torsion bars indicated at T in the drawing in the hinged section of the tape.

Thus, the provision of the novel package of this invention, the flexible tape of self-supporting explosive composition can be quickly laid out or deployed by a minimum of personnel. The tape can be unfurled underwater, laid on the ground, hung in trees, along road sides, in mine fields, planted on beaches, deployed from airplanes, missiles, warheads, etc. For some applications, such as anti-personnel work, the tape charge may be made more effective by incorporating metal components in the tape, for example, a thin layer of foil or fracturable metal rings or balls may be incorporated in the tape. Although the spool of this invention is particularly adapted for use with the self-supporting explosive composition described, it also is well suited for use in rolling other self-supporting (elastomeric) compositions, e.g., laminated fabrics, which when bent or rolled, have a tendency to crack and break if not supported. Other modifications and alterations to the structure disclosed will be apparent to one skilled in the art; it is obvious that these may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. An explosive package comprising a contoured spool comprising a cylinder whose lateral surface is inscribed with that surface generated by an isosceles triangle having its altitude deformed to form a spiral, the apex of the triangle being at essentially the center of said spiral, and the edges of the deformed triangle defining, on each side of a plane perpendicular to and bisecting the altitude of said cylinder, a conical helical surface and a helical channel of gradually increasing width and pitch, a flexible self-supporting tape of an explosive composition comprising from about 15 to about 92.5% by weight of cap-sensitive explosive in admixture with an elastomeric binding agent rolled about said contoured spool, said tape being folded about a hinge, said hinge formed by the provision of two sets of slits essentially equal in length extending through said explosive composition, said slits of each set being arranged in echelon between the sides of the tape at an angle of 0° to 60° with one of two fold lines on which said tape is to be folded, the said fold lines defining on said tape an area having the general configuration of an isosceles triangle, and torsion bars being defined along said fold lines by the section of tape lying between said slits, the width of the torsion bar being essentially equal to the thickness of the tape, said hinge being positioned in the conical helical channel.

2. The explosive package of claim **1** wherein the said tape is mounted on a flexible backing, said backing being thin in relationship to said tape and having a tensile strength at least 1.5 times that of said tape; a strain relieving band is coextensive along the length of said tape; and positioning clasps are affixed to the ends of said tape.

3. The explosive packages of claim **1** wherein one end of said tape is provided with means for initiating a detonation impulse in said tape.

4. The package of claim **1** wherein said rolled strip is encased in a canister and means for releasing said rolled tape from said canister are provided.

5. The package of claim **1** wherein metal components are incorporated in the explosive tape.

6. A contoured spool comprising a cylinder whose lateral surface is inscribed with that surface generated by an isosceles triangle having its altitude deformed to form a spiral, the apex of the triangle being at essentially the center of said spiral, and the edges of the deformed triangle defining, on each side of a plane perpendicular to and bisecting the altitude of said cylinder, a conical helical surface and a helical channel of gradually increasing width and pitch.

7. An article according to claim **4** in which the spool is provided with radially extending flange members for providing lateral support.

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