

Dec. 21, 1965

M. L. KEMPTON ETAL

3,224,371

WARHEAD FOR MISSILES

Filed June 7, 1956

5 Sheets-Sheet 1

FIG. 2.

SINGLE LAYER ROD PARTIALLY EXPANDED

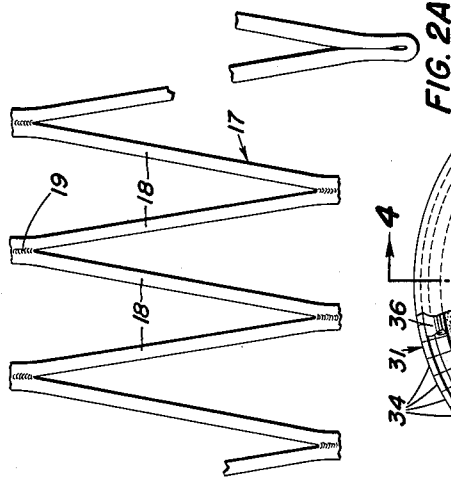


FIG. 2A.

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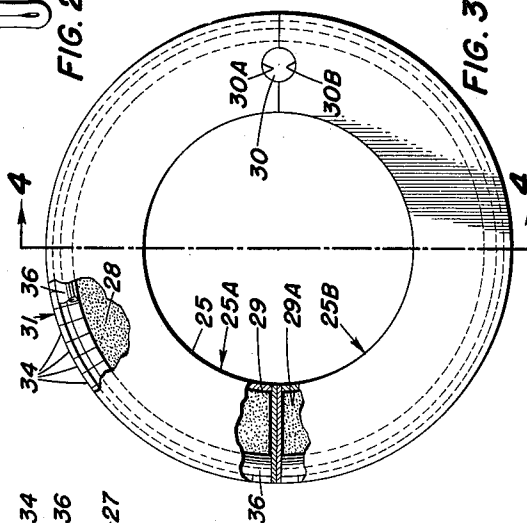


FIG. 3.

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FIG. 1.

SINGLE LAYER, SINGLE DETONATION POINT, SOLID WARHEAD

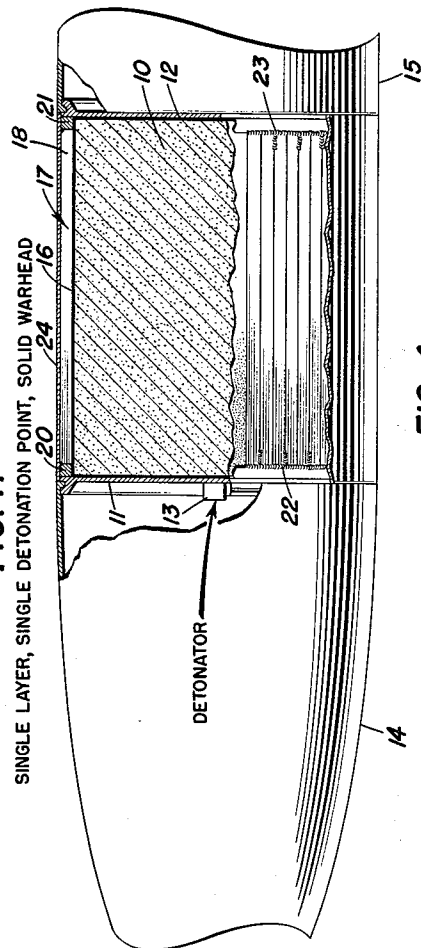
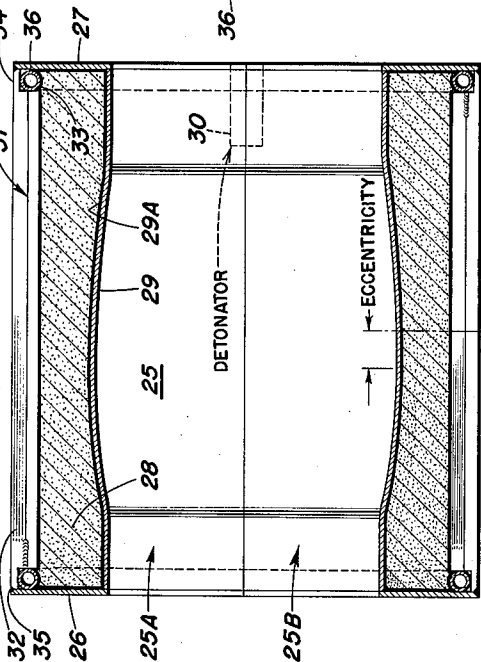


FIG. 4.

DOUBLE LAYER, SINGLE DETONATION POINT, SHAPED HOLLOW WARHEAD WITH LEAN-TO RODS (SEE FIG. 5.)



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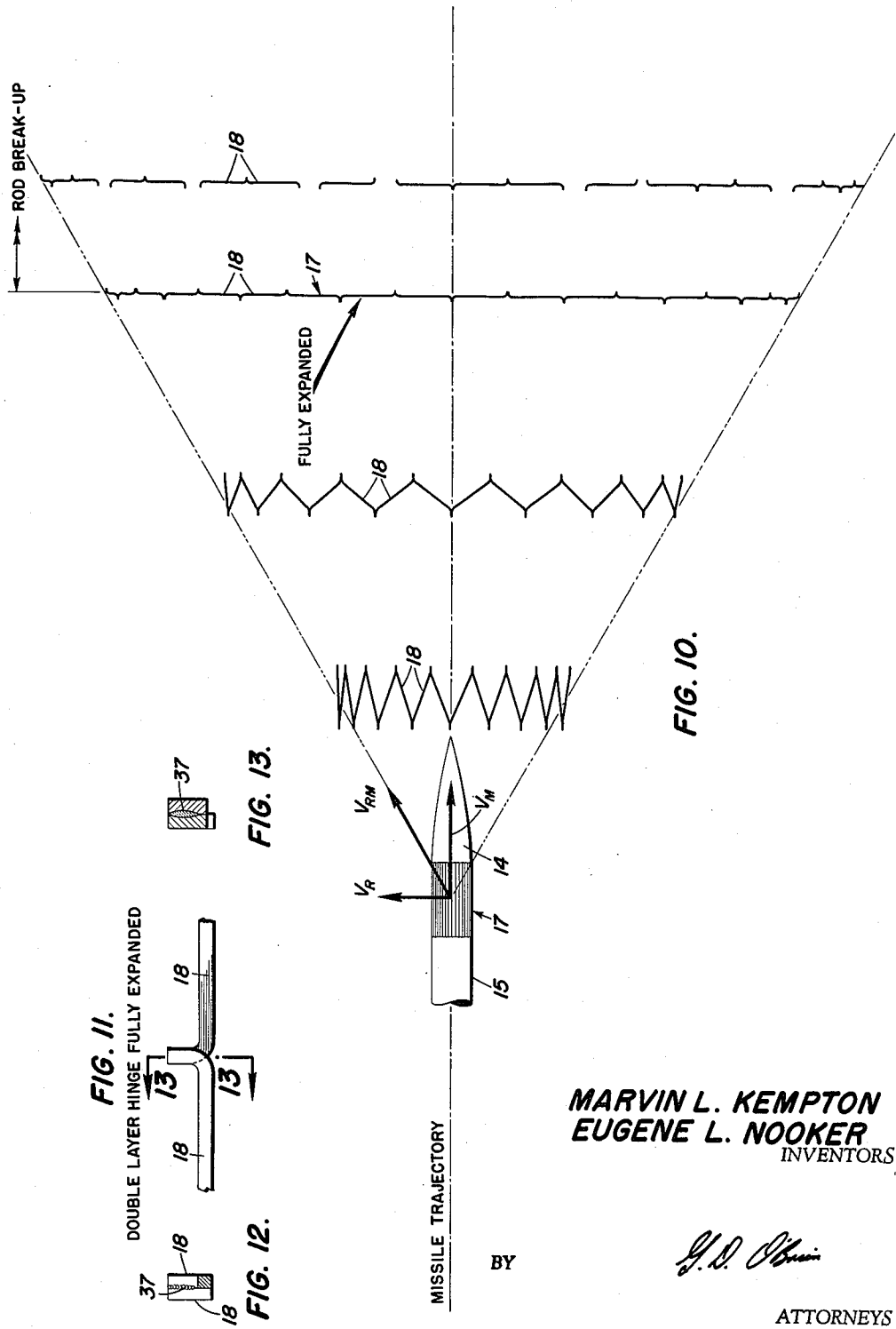
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5 Sheets-Sheet 3



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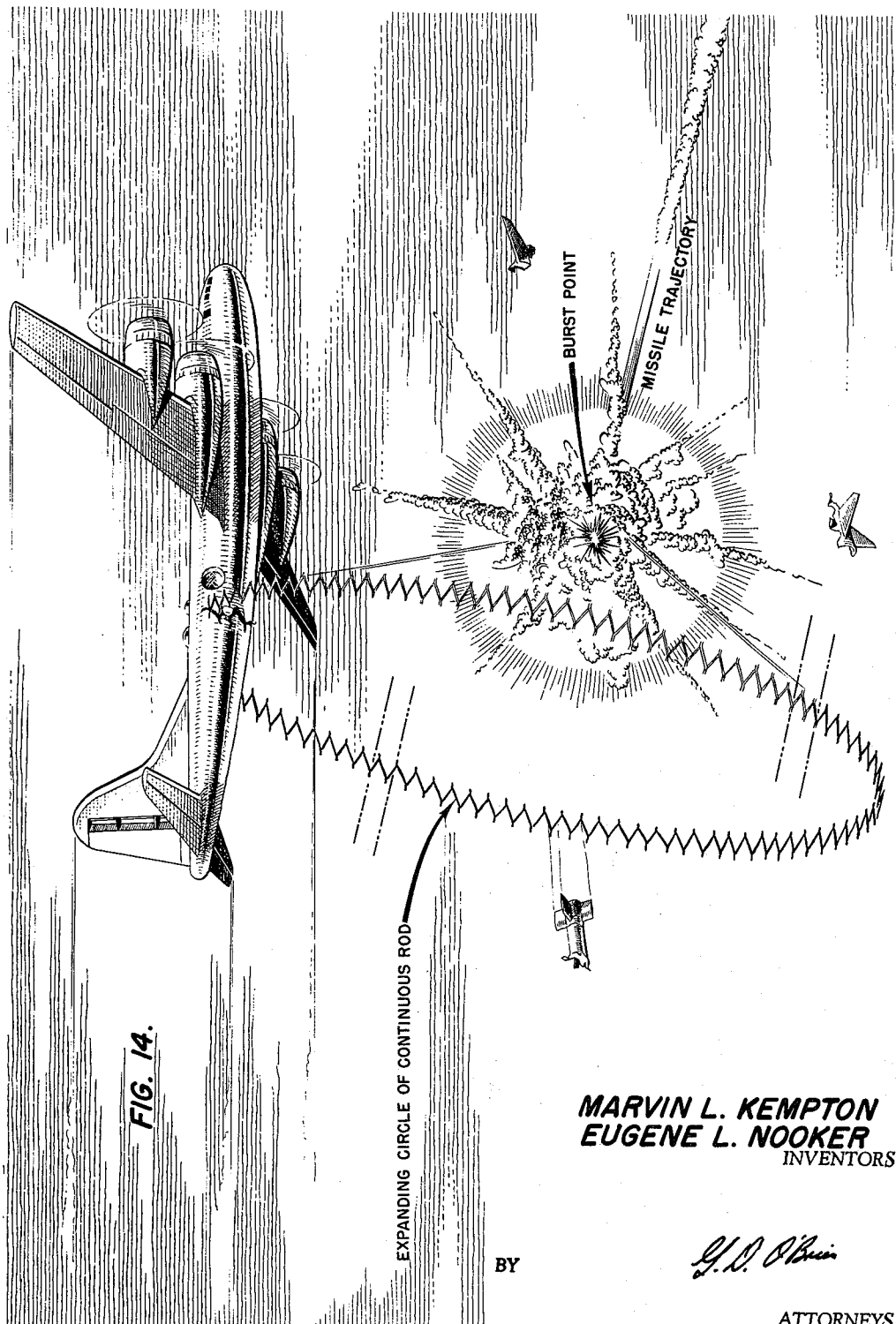
M. L. KEMPTON ETAL

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5 Sheets-Sheet 4



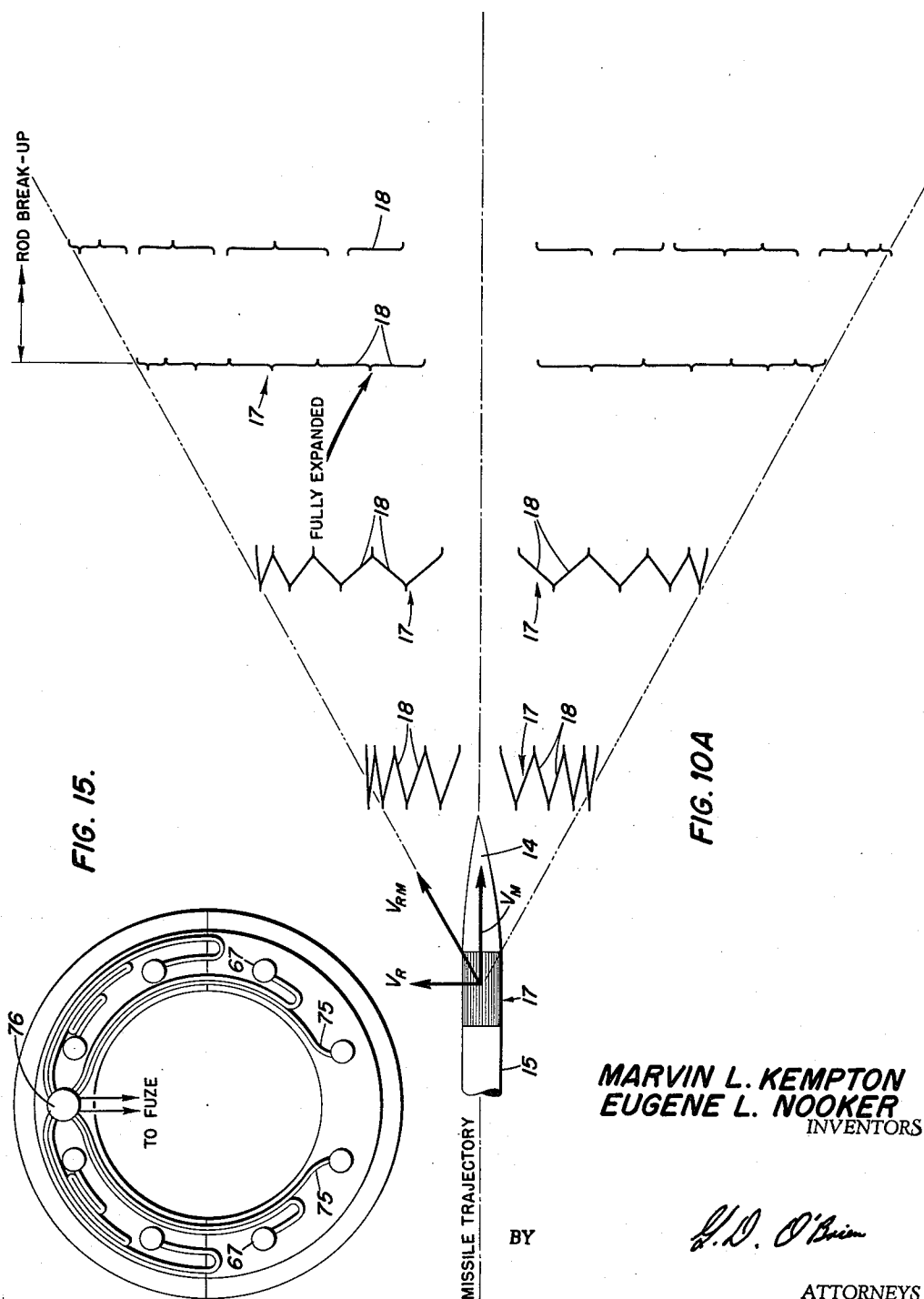
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M. L. KEMPTON ET AL
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Filed June 7, 1956

5 Sheets-Sheet 5



1

3,224,371

WARHEAD FOR MISSILES

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2 Claims. (Cl. 102-67)

The present invention relates generally to explosive projectiles and more particularly to an improved warhead for use with aerial missiles.

Extensive studies have been made and experimental data accumulated on the effect of anti-aircraft artillery shell fragments on aircraft components. The objectives of these studies were to determine the effects of fragment size, shape, velocity and composition on the ability of such fragments to damage targets, and to establish general relationships between design parameters. These studies resulted in the adoption of smaller fragments of far higher velocity than had previously been used, and indicated the need for the production of fragments of uniform size.

Following the establishment of the general principles for achieving optimum design of fragmentation warheads, the investigations were extended to include methods of target damage other than the impairment of components by fragments, including studies of internal and external blast damage with particular reference to the effects of altitude on the distances at which damage can be produced by a given charge weight.

These studies and experiments revealed that small fragments have insignificant damage effects unless they are in dense patterns or at short distances from the target where blast becomes a major factor. In view of this situation extensive studies of larger fragments were made, particularly of rectangular rods of sufficient cross-section and length to sever structural elements of a target that lies in their path. These additional studies have led to the conclusion that a continuous circle of connected rods is far more effective than any dispersed pattern of discrete rods. It has been demonstrated experimentally that warheads can be made that eject connected rods at the necessary high velocities with few or no breaks in the continuity of an expanding ring until it has extended beyond its maximum circumference.

The principal object of the present invention, therefore, is to provide a warhead consisting of a plurality of connected rods, expandable at high velocity by the detonation of a high explosive charge into a continuous ring (or semi-ring) for projection into a target, for increasing the probability of destruction thereof, which said object is attained by the necessary cooperation of the mechanical, explosive and detonation systems employed. It is also an object of the invention to provide a warhead which is sufficiently compact to fit within the allotted space in the airframe of an aerial missile.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a sectional view, partially in elevation, of a warhead constructed in accordance with one embodiment of the present invention, as said warhead would appear installed in an aerial missile;

FIG. 2 is an elevation showing a fragment of the continuous rod assembly of the warhead of FIG. 1, with said rod assembly partially extended;

FIG. 2A is a detail elevation of a fragment of a continuous rod assembly formed according to a modified embodiment of the invention;

2

FIG. 3 is an end view of a modified embodiment of the invention;

FIG. 4 is an axial section on the line 4-4 of FIG. 3; FIG. 5 is an elevation of the rod assembly according to one modified form of the invention, said assembly being shown with a portion thereof partially extended;

FIG. 6 is an axial section illustrating still another modified form of the invention;

FIG. 7 is an enlarged detail section of the warhead of FIG. 6, particularly showing the explosive charge shaping arrangement for effecting the separation of the rod assembly from the end caps employed, upon detonation of the warhead;

FIG. 8 is a sectional view on the line 8-8 of FIG. 9, said view being partly in elevation;

FIG. 9 is a section on the line 9-9 of FIG. 8;

FIG. 10 is a schematic representation showing shapes or patterns of a warhead rod assembly for use with a unitary warhead, after detonation of the warhead, as it spreads to fully expanded and, thereafter, rod break-up positions;

FIG. 10A is a view similar to FIG. 10, but showing patterns obtained with a two-piece warhead rod assembly;

FIG. 11 is a detail elevation showing one of the rod hinge connections in fully expanded position;

FIG. 12 is an end view of the hinge connection of FIG. 11, particularly showing the weld;

FIG. 13 is a section on the line 13-13 of FIG. 11;

FIG. 14 is a perspective view showing the effect of a fully expanded warhead on the fuselage of an airplane, following the explosion of a missile mounting the warhead of the present invention, in the vicinity of said airplane; and

FIG. 15 is a schematic view showing primacord and electrical connections for a multiple detonator warhead of the type shown in FIG. 8.

In order to obtain a better understanding of the present invention, a brief discussion of the background which led to its development is thought to be in order.

Of the several means of "killing" (destroying) an aircraft, a direct attack on its airframe offers three special advantages, i.e. (1) the airframe is the largest component of the aircraft; (2) unlike most other components it cannot readily be protected; (3) the results of most rounds are immediately apparent; that is, complete and almost instantaneous destruction is usually effected.

Against small aircraft, fragments of substantial size or rods 1 to 2 feet long, if approaching from certain directions, are capable of producing destruction. Against the structure of larger and more modern aircraft, however, it has been established that unless cuts several feet long are made, the kill probability can be extremely low. That is, it is necessary to cut from $\frac{3}{4}$ to the full length of the structural face; generally stated, if the design load factor is 4, then $\frac{3}{4}$ of the structure must be severed.

It has been found difficult to produce long cuts in heavy structure, such as exists in a modern heavy airplane, with discrete rods no longer than two feet, because random motion of individual rods results in only a small percentage of effectiveness of the total rod length at the point of target intersection. To make long cuts, either the rods must be oriented on the target in such a manner that several rods contribute to an essentially single cut, or long rods must be used. Although the desirability of long rods is clearly recognized, their practical value as a weapon has been discounted, because maximum discrete rod length is necessarily limited to warhead length. The present invention overcomes this limitation by providing a warhead including a plurality of individual rod elements connected to produce a single, endless folded rod which, upon deto-

nation of the warhead, unfolds into an expanding circle. Ideally, this circle remains unbroken until total rod length is reached and after target intersection is attained. If break-up into random lengths should occur before target intersection takes place, however, the target kill probability will remain high if lengths of substantial size intersect it.

The warhead constituting the present invention, as shown in FIGS. 1 and 2 (in its basic form), includes a bursting charge 10 which is confined between end plates 11 and 12. The charge 10 may conveniently be black powder, and a detonator 13 for said charge is mounted axially of the end plate 11. The warhead is shown mounted in an aerial missile, portions of which are illustrated at 14 and 15. The diameter of the charge 10 is slightly less than that of the end plates 11 and 12 for defining a shallow annular chamber, the purpose for which will become apparent hereinafter. Completely enveloping the charge 10 is a coating 16, of thermoplastic material, for protecting the charge from shocks incident to handling.

Mounted in the chamber and overlying the coating 16 is a rod assembly which is shown generally at 17, and which defines a projectile. The rod assembly is formed of a plurality of rod elements 18, each of rectangular cross-section, laid side by side and connected at alternate ends so as to form a cylinder. As best seen in FIG. 2, the ends of the rods are secured by substantial welds 19, and the assembly is retained in cylindrical form by end hoops 20 and 21 which are secured to opposite ends of the rod elements by running welds 22 and 23. As shown in FIG. 2A, the rod assembly may be constituted by a single rod with end portions folded, in lieu of individual rod elements with their end portions welded. An outer covering or skin 24 surrounds the assembly and preserves the unbroken outer contour of the missile.

In operation, upon initiation of the detonator 13, by the functioning of an influence fuze mechanism or the like (not shown), the charge 10 is exploded, whereupon the forces created by said explosion will cause breaking of the running welds 22 and 23 and releasing of the rod assembly 17 from between the end hoops 20 and 21. The forces of the exploding charge will cause the rod elements to unfold, in the manner shown in FIG. 2, into a continuous ring which functions as a projectile. The manner of unfolding will best be understood after a study of FIG. 10 of the drawings. Experimental firings of warheads made according to FIGS. 1 and 2 of the drawings have occasionally resulted in separation of some of the rod elements forming the circle of rods. However, such separation has rarely caused all of the rod elements to separate from each other, and two or more connected rods constitute a lethal missile when striking a target. Experiments with various types of connections for the ends of the rod elements resulted in the determination that, for the embodiment of the invention shown in FIGS. 1 and 2, the welds 19 were the most successful.

Rod elements of the type shown at 17 are relatively large in cross-section (say $\frac{1}{2}$ "") and therefore result in a projectile having, in its fully projected position, a relatively small diameter with consequent reduced lethality. Such projectiles, moreover, lost rod element continuity when subjected to velocities in excess of approximately 2000 ft./sec. and were therefore not suitable for use with supersonic guided missiles. This loss of continuity was brought about by forces which, upon bursting of the charge 10, moved radially from the warhead axis (and thus at slightly divergent angles) and tended to destroy the hinges at the welds 19.

Experimental work revealed that a projectile having adequate rod continuity and greater destructive power could be made if a larger number of rod elements were used. Necessarily such rod elements had to be of smaller cross-section if the warhead were to be placed in the allotted space in the missile. Very high power explosives were needed with the smaller rods, however, in order to

impart to the rod elements the velocities necessary to produce a lethal warhead. Accordingly, a projectile was developed consisting of a rod assembly wherein each pair of connected ends of rod elements was positioned in a radial plane instead of in a tangential plane, so that, for a given pair of rod elements, explosive forces acted on the connected end portions of said elements along the same radii rather than at slightly different radial angles, with the result that the rod elements received their propulsive forces simultaneously, and the hinges connecting the elements were not subjected to forces which would tend to effect separation of said elements. Such a rod assembly consists of two layers of rod elements rather than one layer and is shown in FIGS. 3 and 4 of the drawings.

The embodiment of the invention of FIGS. 3 and 4 is shown applied to a warhead for use in a ramjet aerial missile. The warhead of this embodiment is shown generally at 25 and consists of companion hollow semi-cylindrical sections 25A and 25B each having end plates 26 and 27, a high power explosive charge 28, a liner 29, a rod assembly defining a projectile, and a thermoplastic coating 29a for the charge. A single detonator 30 is positioned at one end of the warhead, in companion recesses 30a and 30b formed in meeting faces of the sections 25A and 25B. Thus, a single detonator suffices to explode the charge 28 in each of said sections. For a reason to be pointed out hereinafter, the explosive charge 28 is reduced in thickness between its mid-point and its end most remote from the detonator 30.

The numeral 31 indicates generally the rod assemblies of this embodiment of the invention. Each rod assembly 31 consists of inner and outer layers of rod elements 32 having alternate ends of individual rod elements so attached by welding that said assembly will, when projected by explosion of the charge 28, assume the shape of an unbroken half-ring.

As best seen in FIG. 5, the rod elements 32 of each rod assembly 31 are mounted at an angle of approximately 2° from an element of the cylinder constituted by the warhead, which angular mounting will be referred to hereinafter as "lean-to," for convenience. The lean-to is in the direction of the single detonator and is for the purpose of equalizing the ejection angles of successive rods following detonation of the warhead by a high explosive charge, so that they will move uniformly and without inter-rod interference in the same direction when the detonator is exploded.

Referring again to FIGS. 3 and 4, it will be seen that opposite end portions of the rod elements 32 are cut to refine annular recesses 33 and, as to the outer layer of rod elements, end tabs 34, said end tabs being welded, at 35, to the end plates 26 and 27. Positioned in each of the recesses 33 of each warhead section is a semi-circular spalling tube 36, the operation of which will be explained hereinafter. Assembly of a warhead constructed in accordance with this embodiment of the invention is effected by the welds 35. More specifically, after the spalling tubes 36 have been placed in their respective recesses 33, the end tabs 34 are secured to the end plates 26 and 27 by the welds 35, for retaining the rod assembly, end plates, said tubes, liner 29 and explosive charge as a unitary structure.

In order to form the two layers of rod elements as shown in FIGS. 3 and 4, the alternate end portions of adjacent rods are positioned and secured in overlapping relation by welds 37, as shown in FIGS. 12 and 13. The actual welding process forms the subject matter of a separate patent application and therefore constitutes no part of the present invention. To permit installation in an appropriate space on a ramjet missile, the companion sections of the warheads are separated and fitted together in such space, with their outer surfaces lying flush with the outer surface of the missile. As best seen in FIG. 3, the single detonator 30 is mounted in companion arcuate recesses in corresponding ends of the warhead sections.

In operation, when the detonator 30 is exploded, by an influence or impact exploding device (not shown), the charge 28 in the sections 25A and 25B will be exploded for breaking the opposite ends of the rod elements 17 from their respective end plates 26, 27 and propelling the said elements outwardly as a pair of semi-circular projectiles. The appearance of the projectiles during propulsion thereof toward a target would be somewhat as shown in FIG. 10A.

Considered in greater detail, the projection of the rod elements in a manner to form semi-circular projectiles is accomplished by the simultaneous or nearly simultaneous occurrence of several effects, viz., the breaking away of the ends of the rod elements 17 from the end plates; the application of explosive contouring to equalize the forces applied to the rod elements throughout their length to minimize tumbling and bending of said elements; and the application of explosive forces to each pair of rod elements at a slightly different radial angle from its next adjacent pair of elements.

To cause the explosive forces to project radially at the ends of each of the explosive charges 28, semi-annular grooves 38 are formed in said charges. The grooves 38 receive portions of the spalling tubes 36. Thus, when the charges 28 are detonated, explosive forces will move radially outwardly and will cooperate with stress waves moving transversely and lengthwise of the rod elements 17 for effecting the breaking of the tabs 34, substantially at the points indicated by the line X in FIG. 7. Breaking of the tabs at the points Y (FIG. 7) will also be effected, in all probability. Separation of the ends of the rod elements from the tabs 34 will take place when the internal reflected tension stresses thereon are greater than the dynamic ultimate strength of the material of which said tabs are formed. As best seen in FIG. 4, the charges 28 in the sections 25a and 25b are shaped by varying their thicknesses from near their midpoints to their corresponding opposite ends. The areas of maximum shaping are located short distances from a center line passing through said sections normal to the warhead axis and in the portions of said sections which are remote from the portions carrying the detonator. The exact locations of the areas of maximum shaping depend upon the variation of explosive power of the explosive charge with the length of the rods, and the extent of the mechanical and explosive effects at the rod ends. The purpose of the shaping of the charges is to impart uniform explosive forces to the rods of the rod assemblies along their lengths, so that bending and tumbling of the rods will be held to a minimum.

It is desired to point out that the liners 29 are needed only in connection with the casting of the explosive charges and to provide a psychological safety factor when handling; they are not requisite for warhead operation.

Referring now to the embodiment of the invention disclosed in FIG. 6 of the drawings, the numeral 40 designates a warhead which is generally similar to the warhead disclosed in FIG. 1, the principal differences residing in the use of a shaped charge and a multiple-layer rod assembly projectile. The rod assembly is shown at 42 and is identical to the rod assembly 31. Spalling tubes 43 are shown in recesses at the ends of the rod assembly and serve the same purpose as the tubes 36. Unlike the tubes 36, which are semi-circular, the spalling tubes 43 are circular, since this embodiment of the invention is not of sectionalized construction. If desired, end hoops similar to those shown at 20 in FIG. 1 may be substituted for the tubes 43.

Closing the ends of the warhead of FIG. 6 are end plates 44 and 45, the plate 45 having a central opening 46 therein. The end plates are secured to the end tabs of the rod assembly by running welds 47, to provide a unitary structure. Contained within the hollow body defined by the rod assembly and the end plates is a high explosive

charge 48 which is shaped by the provision of a substantially pear-shaped recess 49. The recess 49 defines a relatively thick end portion 49a adjacent the end plate 45, a relatively thin central portion 49b, and a relatively thick end portion 49c which merges into an end portion 50 covering the inner surface of the end plate 44. Annular grooves, similar to the groove 38 in FIG. 7 and for the same purpose, are formed in the outer wall of the charge 48, near its ends, to receive the spalling tubes 43. A single detonator 51 is mounted on the end plate 44, for ignition by a suitable fuze (not shown). A coating 52 of thermoplastic material surrounds the charge 48, for the same purpose as that of the coatings 16 and 29a.

Ignition of the detonator effects the explosion of the high explosive charge 48, for projecting the rod elements as a continuous ring-like projectile, in the manner shown diagrammatically in FIG. 10. The shaping of the explosive charge 48, by providing the relatively thick end portions 49a and 49c and the relatively thin central portion 49b, directs the maximum explosive power toward the opposite ends of the rod assembly simultaneously, with the result that rod bending and tumbling will be reduced to a minimum. The grooves cooperate with the spalling tubes for forming localized shaped charges, as shown in FIG. 7, for breaking the end tabs of the rod assembly and freeing said assembly from the end plates 44 and 45.

The modified form of the warhead, illustrated in FIGS. 8 and 9, is similar to the embodiment shown in FIGS. 3 and 4, to the extent that a two-section, shaped charge construction is employed. In the structure of FIGS. 8 and 9, however, a multiple detonator arrangement is used, the spalling tubes are dispensed with, and no "lean-to" is needed for the rod elements. In FIGS. 8 and 9 the semi-cylindrical sections are shown at 60 and 61. Each of said sections includes a semi-cylindrical shaped charge of high explosive 62, semi-circular end walls 63 and 64 and a rod assembly 65 which defines a projectile. Liners 66 and coatings 66a similar to the liners 29 and coatings 29a, are also provided for each section, as is a plurality of detonators 67, said detonators being arranged in a spaced series on the end wall 63 (four detonators being shown for each section).

As in the embodiment shown in FIGS. 3 and 4, the charges 62 in the sections 60 and 61 are shaped by forming them with relatively thin portions offset from their mid-points away from the detonators, the distance from a center line passing through the warhead axis normal thereto to a line passing through the points of maximum thinness being called the eccentricity dimension, for convenience.

The rod assemblies 65 each consist of a double layer of connected rod elements somewhat similar to the rod elements 32 of the assemblies 31, the principal differences residing in the omission of the end tabs and the substitution of semi-circular end hoops for the spalling tubes 36. The end hoops, of rectangular cross-section, are shown at 68 and 69 and are secured to the ends of the rod elements by running welds 70.

As best seen in FIG. 9, the end wall 64 is extended radially to define a flange which has bearing thereagainst the end hoop 69. The end hoop 68, however, extends about the charge 62 in spaced relation to the end wall 63. A band 71 surrounds the charge between said wall 63 and the end hoop 68, to protect the end portion of said charge and to space the projectile 65 from the detonators. The spacing of the projectile from the detonators permits the explosive wave, initiated by the firing of said detonators, to build up to a maximum force as it moves from the point of detonation along said charge.

As in the embodiments of the invention shown in FIGS. 3, 4 and 6, the shaping of the charges 62 has the effect of projecting the maximum explosive forces thereof at the ends of the projectiles 65, to break the welds between the end hoops and the rod elements and also to prevent bending and tumbling of said rod elements. Detonation of

7

the charges 62 is effected by the simultaneous initiation of the detonators 67 by a suitable fuze device (not shown), such detonation resulting in the projection of the rod elements of the sections 60 and 61 as semi-circular projectiles, generally in the pattern shown in FIG. 10A. In FIG. 15 there is shown schematically an arrangement for initiating the detonators, by a plurality of equal-length primacord elements 75 one such element being connected to each detonator and the ends of all of the primacord elements remote from the detonators being connected to an electrically detonatable squib 76 which is, in turn, connected in the missile fuze firing circuit (not shown).

It is desired to emphasize that, with respect to all embodiments of the invention, a successful continuous rod warhead requires that a number of criteria be satisfied, i.e., all of the following features must be present; effective, cooperating mechanical, explosive and detonation systems. The mechanical system must comprise satisfactorily designed rod hinge and rod-end structures, all manufactured to close tolerances. The explosive system must be so designed that the explosive impulses applied to the rod elements throughout their lengths will be controlled. The detonation system must provide for controlling the detonation wave, i.e., axially with a multi-point system, and with "lean-to," as previously described, with a single detonator.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. A warhead for a missile, including an explosive charge, a plurality of detonators in one end of the explosive charge, a plurality of rod elements interconnected at their alternate opposite ends, means for initially retaining them in parallel relation, and means for controlling the detonation wave produced upon simultaneous initiation of the detonators and consequent explosion of the charge, for breaking said first-mentioned means and releasing the rod elements, said explosive charge projecting the interconnected rod elements as an arcuate projectile, said first-

8

mentioned means including tabs formed at the ends of the rod elements, end plates at opposite ends of the rod elements, a weld securing an end plate to the tabs at each end of the warhead, said tabs defining grooves between the elements and the end plates, and spalling tubes in the grooves.

2. A missile warhead including an arcuate explosive detonating charge, an arcuate projectile embracing the outer surface of the charge, said projectile having interconnected rod elements and end hoops connected with the rod elements at their opposite ends, a plurality of detonators mounted in one end of the charge, said detonators being circumferentially spaced in the charge and said projectile extending from the end of the charge most remote from the detonators to a point in spaced relation to the end of the charge nearest the detonators, whereby the projectile will be longitudinally spaced from said detonators, an end wall embracing the end of the charge remote from the detonators and connected with one of the end hoops, an end wall at the opposite end of the charge and supporting the detonators, a band surrounding the charge between the other of the end hoops and the end of the charge mounting the detonators, and means for effecting simultaneous initiation of the detonators.

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