May 22, 1962 D. L. COURSEN 3,035,518

DETONATION-WAVE SHAPER

Filed May 25, 1959 4 Sheets-Sheet 1

Fig. 1

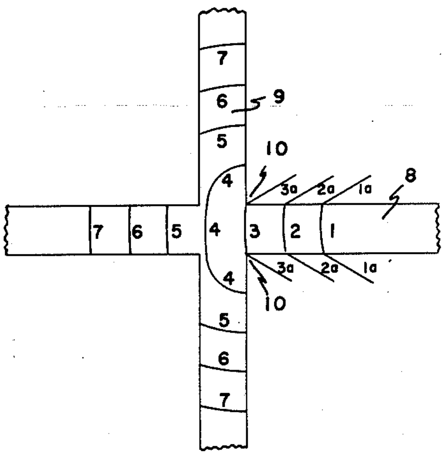


Fig. 2A

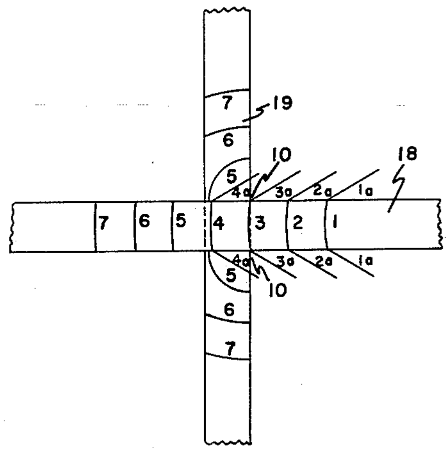


Fig. 2B

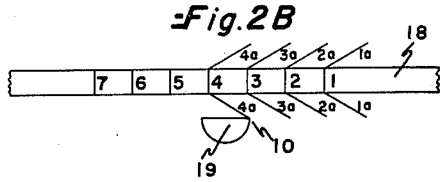


Fig. 3

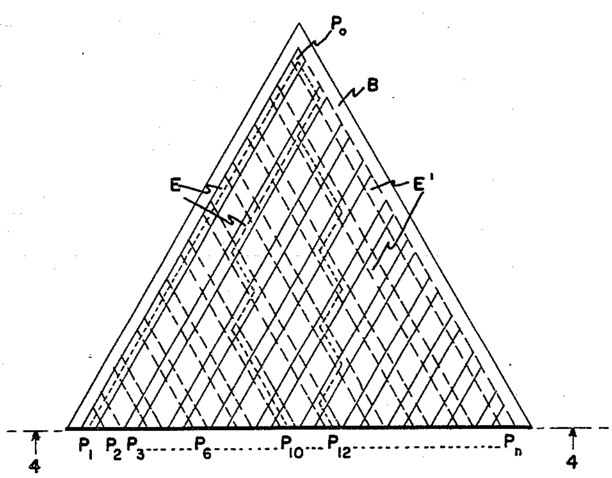
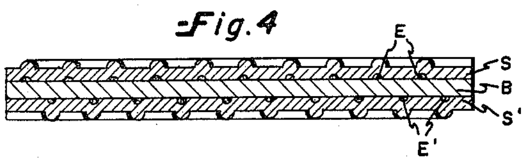


Fig. 4



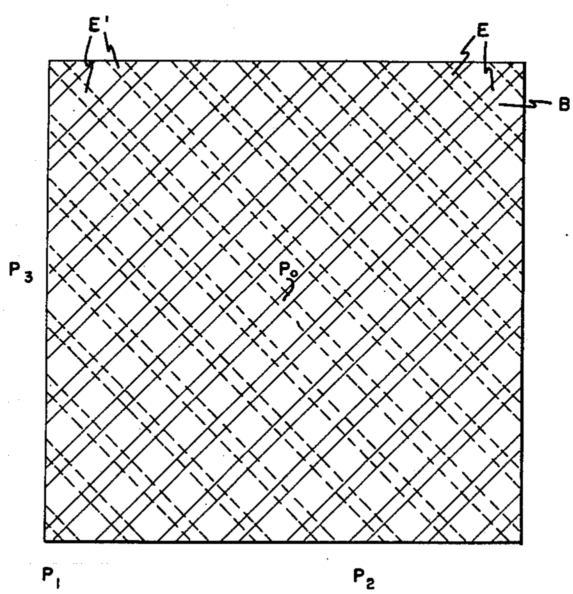
INVENTOR.

DAVID L. COURSEN

BY

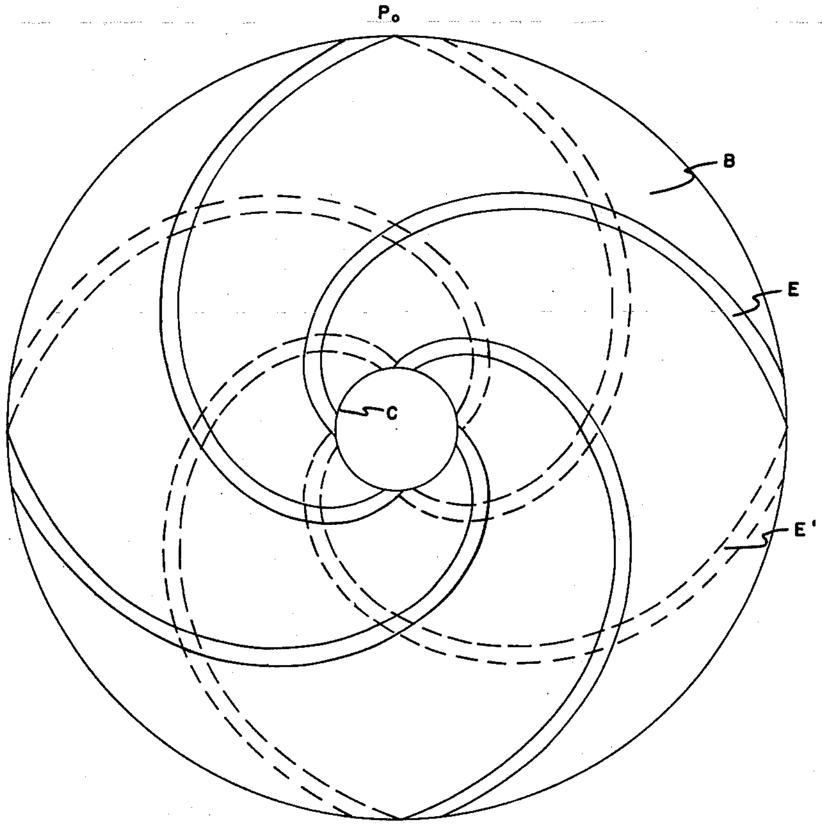
Julius H. Steinberg

Fig. 5



INVENTOR.
DAVID L. COURSEN
BY
Julius H. Steinberg

Fig. 6



INVENTOR.
DAVID L. COURSEN
BY Julius H. Steinberg

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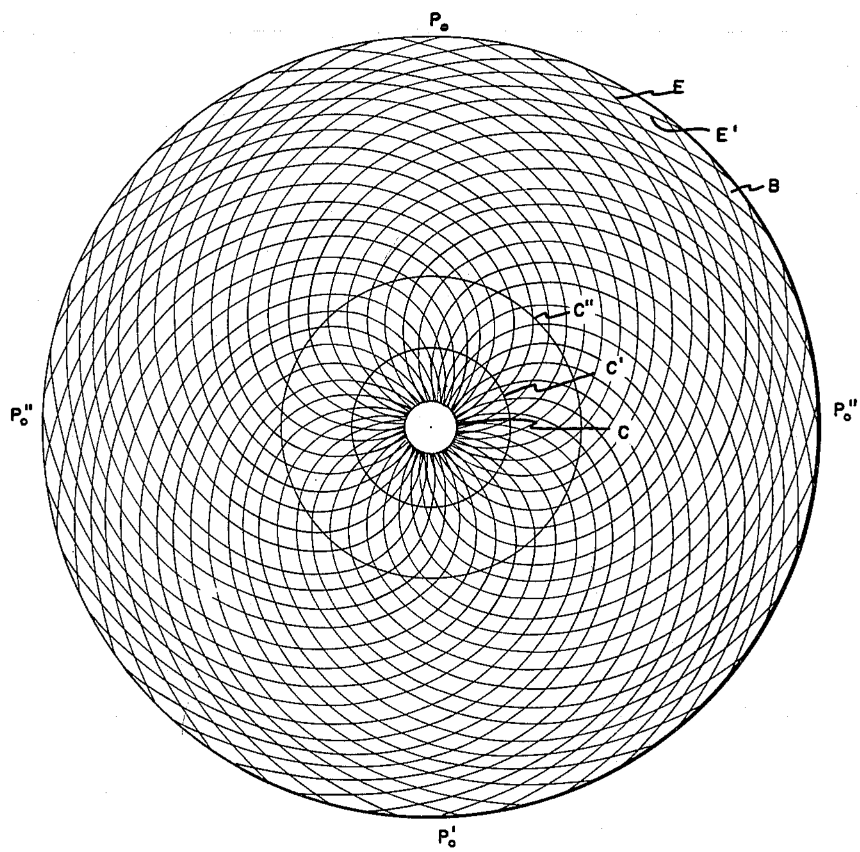
DETONATION-WAVE SHAPER

Filed May 25, 1959 4 Sheets-Sheet 4

Fig. 7



INVENTOR.
DAVID L. COURSEN
BY Jules H. Steinberg

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DETONATION-WAVE SHAPER

David L. Coursen, Newark, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed May 25, 1959, Ser. No. 815,336
8 Claims. (Cl. 102—22)

The present invention relates to a novel high-explosive device wherein the natural detonation front is distorted. More particularly, the present invention relates to a high-explosive device wherein a detonation front generated at one locus is made to arrive simultaneously at a plurality of loci along a desired boundary. This application is a continuation-in-part of my co-pending application Serial No. 739,529, now abandoned, filed June 3, 1958.

When a mass of a high explosive is initiated at one locus, the resultant detonation wave proceeds outwardly from the locus at uniform velocity in all directions. For example, when a thin, flat circular charge of a high explosive is initiated at the center, the detonation front proceeds through the charge in the form of an expanding circle and arrives simultaneously at all points along the perimeter of the charge. When the thin, flat charge has straight line boundaries, the detonation front initially constitutes an expanding circle until the portion of the boundary nearest the point of initiation is reached, thereafter the front travels through the remainder of the charge as an expanding arc of a circle, the radius of curvature of the arc at any given point in the charge being determined by the distance from the initiation point. It is obvious that in the latter case, the detonation front, because of its curvature, does not arrive simultaneously at all points along the periphery of the charge but arrives at various times, depending upon the distance between each finish locus and the starting, or initiation, locus. Obvious also is the fact that the detonation front cannot arrive simultaneously at a number of loci along a curved line which does not coincide with the natural curvature of the detonation front.

In many industrial applications of explosives aside from blasting, improved results are obtainable when the explosive charge is initiated simultaneously at a plurality of loci along its surface. For example, when a linear, or wedge-like, shaped charge, such as that described in U.S. Patent 2,605,704 (Jacques Dumas, August 5, 1952) for slotting pipe and the like, is initiated at a plurality of loci in a straight line along its surface, rather than at one locus, increased uniformity of penetration is obtained. Also, in the method of joining metal elements explosively as described in U.S. Patent 2,367,206 (C. O. Davis, to du Pont, January 16, 1945), localized initiation of the explosive charge surrounding the metal sleeve in the assembly sometimes results in damage to the juncture, whereas such damage does not occur when the sleeve-like charge is initiated at a plurality of loci defining a circle around one end of the charge.

The use of a series of individual initiators, such as blasting caps, to effect the simultaneous initiation at a number of loci along a straight or curved line is not always feasible, because the eccentricities of the individual initiators, although slight enough to be generally ignored, preclude the accomplishing of the desired truly simultaneous initiation. Moreover, the mechanical assembly of a large number of the initiators adjacent to the surface of the high explosive to be initiated is extremely difficult, if not impossible, due to space requirements. The brisance, or shattering action, of the individual initiator also may prohibit the use of such a large number of the initiators in close proximity because of their destructive effects. The provision of a line wave

generator, i.e. a device wherein a detonation front generated at one locus is distorted so that it arrives simultaneously at a number of loci along a straight or curved line, is of great value in the art.

One type of such a line wave generator has been provided and comprises a flexible sheath containing a number of inert spacing members which form a network of interstices in which is disposed a high explosive. When the detonation propagates along all the various equilength paths defined by the spacers, the front arrives simultaneously at all the finish loci delineating the desired line. This device, which is described in U.S. Patent 2,774,306 (N. A. MacLeod, December 18, 1956), however, not only suffers from the complexity of design, the number of components in the device resulting in complications of fabrication, but also at times gives unsatisfactory results. The detonation front naturally can by-pass one or more of the right-angle turns of the equilength explosive paths and can "cut corners," following a shorter route. Since the explosive constituting the line wave generator detonates at constant velocity, the time required to travel a longer route exceeds that required for travel along a shorter route. Thus, the detonation front, instead of arriving at all the finish loci simultaneously, arrives at different times, those segments of the front which "cut corners" arriving before those making the right-angle turns.

Accordingly, an object of the present invention is the provision of an explosive device wherein the detonation front generated at a single locus is made to arrive simultaneously at a plurality of loci along a curved line or one or more straight lines. Another object of the present invention is the provision of an explosive device suitable for use as a simple and efficient line wave generator. A further object of the present invention is the provision of an explosive device which is facilely and inexpensively manufactured. A still further object of the present invention is the provision of an explosive device whereby the initiation of an adjacent explosive charge at a plurality of loci along its surface can be induced simultaneously in an efficient manner. Other objects will become apparent as the invention is further described.

The foregoing objects may be achieved when I provide a line wave generator comprising a barrier plate, a first set of explosive trains on one side of the barrier plate, and a second set of explosive trains non-parallel to the first set on the opposite side of the barrier plate, each of the explosive trains being of a cap-sensitive high explosive of sufficient cross-sectional area to support detonation and spaced from any train in the same set by a distance equal to at least twice the thickness of the barrier plate, the barrier plate having a thickness such that propagation of the detonation from a train in one set to a train directly opposite in the other set is delayed for an interval of time substantially equal to the time required for the detonation to traverse the width of a train, the two sets of trains together constituting detonation paths from a single initiation locus to a plurality of finish loci delineating a predetermined line, the shortest paths from the initiation locus to any of the finish loci being equal in length.

Throughout this description, the terms "locus" and "loci" have been used to designate that portion of an explosive train at which detonation is initiated or to which detonation is propagated. Inasmuch as the explosive train must be three-dimensional, the use of the terms "locus" and "loci" is believed more appropriate than would be the terms "point" and "points." However, for a mathematical treatment of the devices of the present invention, the consideration of the loci as points is appropriate.

In order to describe more fully the nature of the present invention, reference is made to the accompanying figures.

FIGURE 1 is an illustration of the phenomenon of "corner cutting" in intersecting explosive trains.

FIGURES 2A and 2B are illustrations in top and end views, respectively, of the relationship of the explosive trains in the present invention, whereby the undesirable effect of "corner cutting" is overcome.

FIGURE 3 represents a top view greatly enlarged of one embodiment of the present invention which embodiment is constructed in accordance with the principles illustrated in FIGURES 2A and 2B.

FIGURE 4 is a cross-sectional end view taken on line 4—4 of FIGURE 3.

FIGURE 5 represents a top view greatly enlarged of another embodiment of the present invention, which embodiment again is constructed in accordance with the principles illustrated in FIGURES 2A and 2B.

FIGURE 6 shows in top view and enlarged form still another embodiment of the present invention; this embodiment also is constructed in accordance with the principles illustrated in FIGURES 2A and 2B. FIGURE 6 is greatly simplified, only a few of the explosive trains being shown fer the sake of clarity.

FIGURE 7 shows in top view the embodiment of FIGURE 6, FIGURE 7 being so drawn as to illustrate a particular characteristic of this embodiment of the present invention.

Referring now to the figures in more detail, FIGURE 1 shows intersecting explosive trains **8** and **9**, and the position of a detonation front is shown at successive equal time intervals by lines **1**, **2**, **3**, **4**, **5**, **6**, and **7** drawn across trains **8** and **9**. Lines *1a*, *2a*, and *3a* indicate the diverging shock fronts corresponding to the detonation fronts at 1, 2, and 3, respectively. A similar shock front exists corresponding to each detonation front but these shock fronts are omitted for the sake of clarity. The detonation front at **3** in train **8** initiates loci **10** which serve as focal loci for the propagation of detonation in train **9**. Because train **9** is not initiated at the midpoint of the intersection of trains **8** and **9**, but is initiated instead at loci **10**, i.e., the detonation "cuts corners" instead of making a right angle turn at the midpoint of the intersection, the detonation fronts at time intervals **4**, **5**, **6**, and **7** in train **9** are farther from the midpoint of the intersection than is the detonation front in train **8** at the same time intervals.

FIGURES 2A and 2B show explosive train **18** crossing over but not intersecting explosive train **19**. The space between trains **18** and **19** may be occupied by a barrier plate (not shown) which will be described later. Again, the position of a detonation front is shown at successive equal time intervals by lines **1**, **2**, **3**, **4**, **5**, **6**, and **7** drawn across trains **18** and **19**. Lines *1a*, *2a*, *3a*, and *4a* indicate the diverging shock fronts generated by detonation fronts at **1**, **2**, **3**, and **4**, respectively. Because trains **18** and **19** are separated, neither the detonation front at **3** nor the shock front at *3a* can initiate train **19**. However, when the detonation front in train **18** reaches position **4**, corresponding shock wave *4a* initiates train **19** at loci **10**. Thus, the detonation fronts at time intervals **5**, **6**, and **7** in train **19** are the same distance as is the detonation front in train **18** at the same time intervals from the midpoint of the overlapping portions of trains **18** and **19**. The separation of trains **18** and **19** thereby overcomes the undesirable effect of "corner cutting." The end result of introducing a space between explosive trains **18** and **19** is the same as though the detonation progressing through train **18** made a right-angle turn into train **19** at the midpoint of the overlapping portions of trains **18** and **19**.

FIGURE 3 illustrates a form of the present line wave generator designed so that the detonation front generated at locus P_0 arrives simultaneously at finish loci P_1 to P_n to give a straight-line front. This embodiment comprises

a set of parallel explosive trains E maintained within the grooves of a supporting plate (not shown) on the top of barrier plate B and a second set of parallel explosive trains E′ maintained within the grooves of a supporting plate on the bottom of barrier plate B. Trains E are diagonally disposed with respect to trains E′ to form a triangular grid wherein trains E traverse, i.e., cross over but do not intersect, trains E′.

Upon initiation at locus P_0, the detonation can follow a number of possible paths, some of which are indicated on FIGURE 3 by dotted lines. For example, the detonation can propagate without deviation along any one explosive train in either set of trains. This action is illustrated by the straight dotted line between initiation locus P_0 and finish locus P_1. Alternatively, the detonation can cross back and forth between the E and E′ explosive trains at the places at which the trains traverse. This action is illustrated by the zig-zag dotted lines on the drawing, one zig-zag line indicating a detonation which branched off the P_0–P_1 path to arrive at finish locus P_{10}, and the other dotted line indicating a detonation which branched off the P_0–P_{10} path to arrive at finish locus P_{12}.

If explosive trains E and E′ intersected each other, detonations along paths P_0–P_{10} and P_0–P_{12} could "cut corners" as illustrated in FIGURE 1, thus causing the resultant detonation front to "bulge," e.g., the detonation front would reach loci P_{10} and P_{12} prior to reaching loci P_1 and P_n. This bulging of the front is the situation which occurs in the afore-mentioned patented line wave generator. However, when, as in accordance with the present invention, a barrier plate is interposed between the two sets of explosive trains, the delay occasioned by passage of the detonation through the barrier prior to initiation of detonation in the opposite train can be made to compensate for the time saved by "cutting corners." Obviously, then, by equalizing the time required for the detonation to travel all the initiation locus-to-finish locus paths regardless of their length or tortuosity, the detonation which propagates at constant velocity can be made to arrive simultaneously at all the finish loci. In the embodiment shown in FIGURE 3, the detonation front delineates a straight line at any given distance beyond the traverse loci nearest the initiation locus P_0.

FIGURE 4 shows explosive trains E maintained within the grooves of support plate S on the top of barrier B, and similarly, explosive trains E′ maintained within the grooves of support plate S′ on the bottom of barrier B.

FIGURE 5 illustrates a line wave generator so designed that the detonation front generated at a central initiation locus P_0 arrives simultaneously at a plurality of finish loci, some of which are indicated by P_1 to P_3, delineating a square. The explosive trains and barrier are again indicated by E and E′ and B. This generator actually comprises 4 of the triangular grids of FIGURE 3, abutted to give a square rectilinear grid. Thus, the action of this grid and its construction principles essentially are identical to those of the FIGURE 3 embodiment.

In FIGURE 6, E, E′, B, and P_0 again identify the explosive trains, barrier, and initiation locus, respectively. In this embodiment of the invention shown in simplified form, the explosive trains in both sets are spirals, the parallel sets being superimposed so that the spirals of set E are oppositely directed to those of set E′. In this configuration, the detonation travels as in the FIGURE 3 embodiment, but the detonation initiated at P_0 converges and finally arrives simultaneously at a series of finish loci defining circle C, the original curvature of the front as generated being inverted.

FIGURE 7 illustrates the effect of multipoint initiation of the embodiment of FIGURE 6, E, E′, B, P_0, and C being as in FIGURE 6. For convenience of illustration, the trains, shown as separated by a transparent barrier, are indicated by lines. When point source initiation is used, the converging detonation front will achieve circular form at the series of finish loci delineating circle C; the front prior to arrival at these loci delineates an arc of the circle. If, however, the detonation is initiated at two loci, P_0 and P_0', on the grid periphery, the front will delineate a complete circle at a series of loci nearer the periphery of the charge, to give a circle of larger circumference, C′. Initiation at locil P_0, P_0', and P_0'' will give a circle of even larger circumference, C″. As is evident, for a given line wave generator constructed in accordance with this embodiment of the invention, the circumference of the circle defined by the finish locus may be regulated to some extent by the number of initiation loci used.

The following examples are presented to illustrate specific embodiments of the present invention. However, they will be understood to be illustrative only and not as limiting the invention in any manner.

Example 1

A square 6 x 6 inch brass plate was engraved with a series of diagonal, parallel, equidistant grooves. Upon this die was placed a 6 x 6 inch square 0.005 inch-thick lead foil and then the matching punch was pressed down on the foil and die. Onto the resultant grooved foil was poured a water slurry of finely divied PETN containing 1% gum arabic as a flow promoter. The raised portion of the foil was wiped clear of the slurry, and the water was allowed to evaporate from the grooves, leaving PETN trains of 0.8-square millimeter cross-sectional area in the grooves. Another PETN-containing lead foil was prepared in similar manner. The two foils were fastened together in face-to-face arrangement by a 6 x 6 inch sheet of pressure-sensitive adhesive tape, the adhesive mix being present on both sides of the sheet. The thickness of the sheet, i.e. the barrier, was 8 mils. Upon central initiation of the resultant rectilinear grid (FIGURE 3) by an electric blasting cap, the detonation wave thus generated was distorted to arrive simultaneously at a plurality of finish loci on the periphery of the grid.

Example 2

The procedure of Example 1 was repeated with the exception that 8-mil-thick tape barrier was replaced by a barrier comprising 4 layers of the tape and one layer of 9-mil-thick polyethylene sheeting, the polyethylene being sandwiched between double layers of the tape. The resultant barrier had a thickness of 41 mils. Satisfactory results were obtained upon testing this square grid, which upon diagonal cutting of course would give 4 of the triangular grids of FIGURE 3.

Example 3

A series of square grids having various barriers were prepared according to the procedure of Example 1 and were tested successfully. The barrier construction is given in the following table.

Grid No.	Layers of 8-mil Adhesive Tape	Layers of 17.5-mil Cardboard	Layers of 9-mil Polyethylene	Total Thickness of Barrier (mils)	Barrier Construction
1	2	0	1	25	Polyethylene sandwiched between tape layers.
2	2	1	0	33.5	Cardboard sandwiched between tape layers.
3	3	2	0	59	Layer of tape, layer of cardboard, layer of tape, layer of cardboard, and layer of tape.

Example 4

Two circular sheets of lead foil were impressed by means of matched dies with a set of spiral grooves. The grooves were filled with finely divided PETN by the procedure of Example 1, the cross-sectional area of the resultant explosive trains being 0.5 square millimeter. The explosive-containing surface of each foil was covered with a circular sheet of the 8-mil-thick double-coated adhesive tape, and a layer of 49-mil-thick cardboard was fastened between the parallel foils which were in face-to-face relationship so that the spirals of one foil were oppositely directly to those of the other foil. When the resultant circular grid (FIGURE 7) was initiated at one locus on its periphery, the detonation front eventually assumed circular shape near the center of the grid. A similar grid initiated at two opposite loci on the periphery gave a circular detonation front of larger circumference.

Although the grid-type line wave generators of the present invention may be prepared readily by the afore-described procedure using support plates, i.e. the lead foils, the units may also be prepared without support plates by use of the following procedure.

Example 5

Onto a triangular sheet of cardboard the surfaces of which are covered with adhesive are extruded a number of diagonal, parallel strips of an RDX-containing extrudable composition. After setting up of the composition, a number of explosive strips are extruded on the opposite surface of the cardboard barrier such that their direction is opposite to that of the previously extruded strips, i.e. the strips of one surface are non-parallel to those of the other surface.

The action of assemblies constructed as described in Examples 1, 2, 3, and 4 was determined by high speed X-ray photography. As the trains detonate, the lead foil directly over the trains is disintegrated and thus no longer forms a barrier for X-rays. Thus, the photographs obtained had light-colored sections representing the undamaged lead foil and darkened sections indicating the portions disintegrated by the detonation. In all cases, the photographs clearly showed the detonation front proceeding in a line corresponding to the design of the assembly.

As has been illustrated, the desired distortion of the detonation front may be achieved readily in a number of ways without excessive complications of fabrication. The only critical features required to achieve the distortion are: (1) that the explosive trains constituting a set must be nonconnected to each other and must be nonparallel to the trains of the other set, (2) that the planes of two sets must be parallel, (3) that the high-explosive trains must be of sufficient cross-sectional area to support the detonation, and (4) that the barrier plate separating the two parallel sets must be of such thickness as to delay for a short interval of time the propagation of the detonation from a train in one of the sets to the opposite train in the other set. The first two features of course are inherent to the structure of a grid, but in the present explosive grid, in contrast to conventional grids, any given train in one set does not actually intersect but traverses, i.e. crosses without contact, a train in the other set. Upon the basis of the afore-listed four considerations, many variations of the line wave generators, in addition to the exemplified variations, may be prepared to produce linear detonation fronts of various geometric forms.

The exact explosive composition used is not critical so long as the explosive material detonates in the grid at high velocity, e.g. at least 3000 meters per second, and is cap sensitive. Such cap-sensitive high explosive materials include PETN, RDX, HMX (cyclotetramethylenetetranitramine), tetryl, lead azide, and nitroglycerin among others. Although the exact cap-sensitive high-velocity material used is a matter of choice based upon such considerations as economics, availability, and the like, PETN because of its general availability and ease of handling is preferred. The specific explosive used also will depend somewhat upon the method of fabrication used in preparing the explosive grid. In the extrusion process exemplified, naturally an extrudable composition, such as that of Example 5 or one of the conventional nitroglycerin-based compositions or the like, would be used. Greater adaptability with respect to explosive composition is possible of course in other fabrication methods, e.g. the support plate method.

As indicated, the exact method used to prepare the grids does not form a part of the present invention but rather is in the purview of the mechanical arts. Use of the support plates does to some extent simplify operations. However, the plates themselves do not constitute an essential feature of the explosive grid. Naturally, the confinement offered by such support plates as lead foils does influence the detonation inasmuch as confinement increases the detonation velocity. For this reason, the use of these plates may be desirable at times, for example when increase in the detonation velocity of a given explosive may be desired or necessary. Although lead foil plates were used in the examples to permit X-ray photography of the grid detonations, the material of the support plates is not critical, any material being suitable which is of a nature such that it can be formed into a support medium for noncohesive, e.g. free-flowing, explosive compositions. For example, grooves could also be formed in a thermoplastic synthetic material such as polyethylene by a hot-pressing operation.

The minimum cross-sectional area of the explosive train necessary for support of the detonation is dependent upon the specific explosive comprising the trains, since the minimum detonation-supporting area is a direct function of the explosive. I have determined that for a very sensitive explosive, this minimum area is 0.09 square millimeter. However, as stated previously, the specific value of the cross-sectional area will vary with the specific explosive used, the exact minimum cross-sectional area not being a fixed value.

The trains of explosive within a set are spaced apart a distance equal to at least twice the thickness of the barrier plate to insure that the detonation can propagate more rapidly through the barrier than from one train to an adjacent train in the same set. The maximum distance between the explosive trains in a set is not critical, but is, of course, governed by the number of loci desired along the finish line.

A large number of materials are suitable for use as the barrier plate, including paper, e.g. cardboard, a plastic film such as polyethylene, polyvinyl chloride, et cetera, cloth, felt, cork, and the like. Adhesives used to fasten the assembly together also act as a portion of the barrier plate, and, as exemplified, such integral combinations of an adhesive and other materials as the pressure-sensitive adhesive tape function satisfactorily.

The thickness of the barrier plate required to delay for a short interval the propagation of the detonation from one explosive train to its opposite train is a function of the variable conditions: barrier material, specific explosive used, and cross-sectional area of the explosive train. I have found that the least thickness of barrier plate, regardless of the above listed conditions, required to delay such propagation is 4 mils. Thus, the minimum lower limit on barrier thickness may be set at 4 mils, the exact minimal thickness not being a specific value but being governed and determined by the afore-mentioned variables. Obviously, the barrier plate must be of such dimensions merely to delay the detonation propagation and not to prevent entirely such propagation.

Furthermore, the over-all dimensions of the grid, i.e. its length and width or its circumference, are not critical. On a practical basis, these dimensions will be limited by economics, that is, the use of a grid which is beyond the size necessary to effect the desired distortion is unfeasible, because unnecessary increases in size increase to no purpose the amount of explosive material and the like required for its construction.

As indicated by references to the relationship of the triangular grid of FIGURE 3 and the square grid of FIGURE 5, the final configuration of the detonation front may be varied by using a section of a grid, for example a triangular portion of the square grid to obtain a straight line rather than a square detonation front or half of the spiral grid to obtain a semicircular detonation front. A number of the explosive grids may be disposed over a surface to provide simultaneous initiation at many points on the surface. For example, a spherical explosive charge may be symmetrically surface-initiated by disposing a number of grids providing semicircular detonation fronts about the sphere in such manner that the grids form longitudinal fins about the sphere. These longitudinal fins meet at the poles of the sphere, thus providing an axis common to all of the grids. Initiation of the grids at either end or simultaneous initiation at both ends of the axis thus formed will provide simultaneous initiation at many points on the surface of the sphere.

The invention has been described in detail in the foregoing. However, it will be apparent to those skilled in the art that many variations, for example in the specific explosive used and in the configuration and dimensions of the grid, are possible without departure from the scope of the invention. I intend, therefore, to be limited only by the following claims.

I claim:

1. A line-wave generator which provides a detonation front along a predetermined line comprising a plate, a first set of explosive trains in lateral array on one side of and contiguous to said plate, and a second set of explosive trains in lateral array on the opposite side of and contiguous to said plate, the first set of trains lying in a plane parallel to the plane of said second set of trains while the individual trains of said first set are non-parallel to and cross without contact the comparable individual trains of said second set, the trains in each of said sets being of a cap-sensitive high explosive of sufficient cross-sectional area to support detonation and spaced apart from any train in the same set by a distance equal to at least twice the thickness of said plate, all of said trains having substantially uniform and equal cross-sectional area, said plate having an essentially uniform thickness such that propagation of the detonation from the train in one of said sets to a train directly opposite in the other set is delayed for an interval of time substantially equal to the time required for the detonation to traverse the width of a train, said first and second sets of trains together constituting means for conveying the detonation from an initiation locus to each of a plurality of finish loci delineating said predetermined line, the shortest path from said initiation locus to any of said finish loci being equal in length to that of the shortest path to any other of said finish loci.

2. A line-wave generator which provides a detonation front along a predetermined line comprising a plate, a first set of explosive trains in lateral array on one side of and contiguous to said plate, and a second set of explosive trains in lateral array on the opposite side of and contiguous to said plate, the first set of trains lying in a plane parallel to the plane of said second set of trains while the individual trains of said first set are non-parallel to and cross without contact the comparable individual trains of said second set, the trains in each of said sets being of a cap-sensitive high explosive of at least 0.09 square millimeter in cross-sectional area in order to support a detonation and spaced from any train in the same set by a distance equal to at least twice the thickness of said plate, all of said trains having a substantially uniform and equal cross-sectional area, said plate having an essentially uniform thickness of at least about 4 mils such that propagation of the detonation from a train in one of said sets to a train directly opposite in the other set is delayed for an interval of time substantially equal to the time required for the detonation to traverse the width of a train, said first and second sets of trains together constituting means for conveying a detonation from an initial locus to each of a plurality of finish loci delineating said predetermined line, the shortest path from said initiation locus to any of

said finish loci being equal in length to that of the shortest path to any other of said finish loci.

3. A line-wave generator according to claim 2 wherein the individual explosive trains within each separate set of trains are all parallel to each other.

4. A line wave generator according to claim 2, wherein the explosive trains of each of said sets are spirals.

5. A line wave generator according to claim 2, wherein said cap-sensitive high explosive is PETN.

6. A line wave generator according to claim 2, wherein said barrier plate is selected from the group consisting of paper and plastic film.

7. A line wave generator according to claim 2, wherein the explosive trains of each of said sets are maintained within a supporting plate.

8. A line wave generator according to claim 7, wherein said supporting plate is of lead.

References Cited in the file of this patent

UNITED STATES PATENTS

2,311,721	Wilson	Feb. 23, 1943
2,455,354	Bisch	Dec. 7, 1948
2,708,408	Sweetman	May 17, 1955
2,764,938	Harcus	Oct. 2, 1956
2,766,690	Lebourg	Oct. 16, 1956
2,774,306	MacLeod	Dec. 18, 1956
2,782,715	Udry	Feb. 26, 1957
2,873,676	Caldwell	Feb. 17, 1959