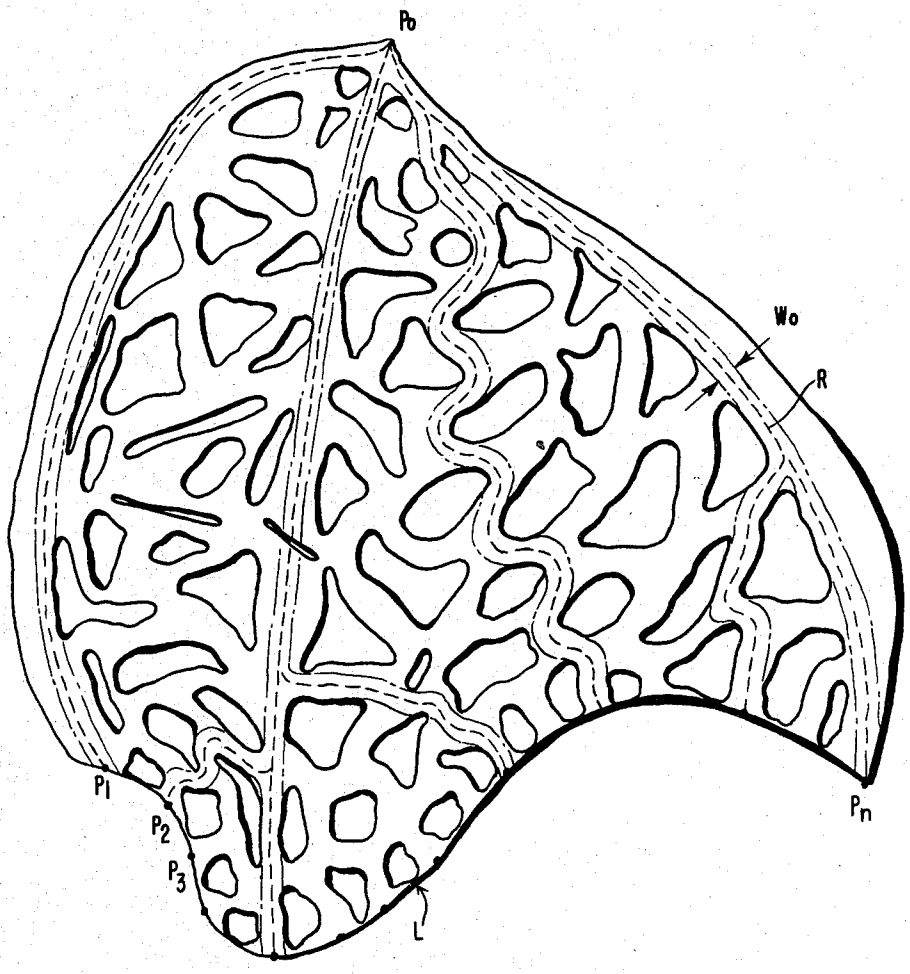
July 5, 1960 D. L. COURSEN 2,943,571

EXPLOSIVE DEVICE

Filed March 18, 1958 5 Sheets-Sheet 1

FIG. 1



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July 5, 1960 D. L. COURSEN 2,943,571

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Filed March 18, 1958 5 Sheets-Sheet 2

FIG. 2C

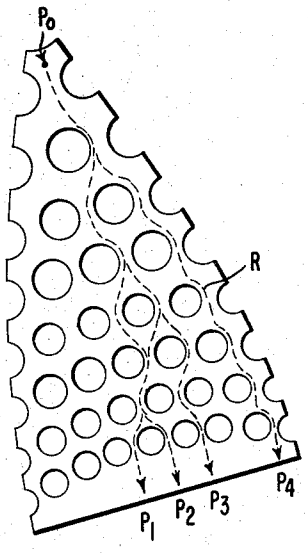
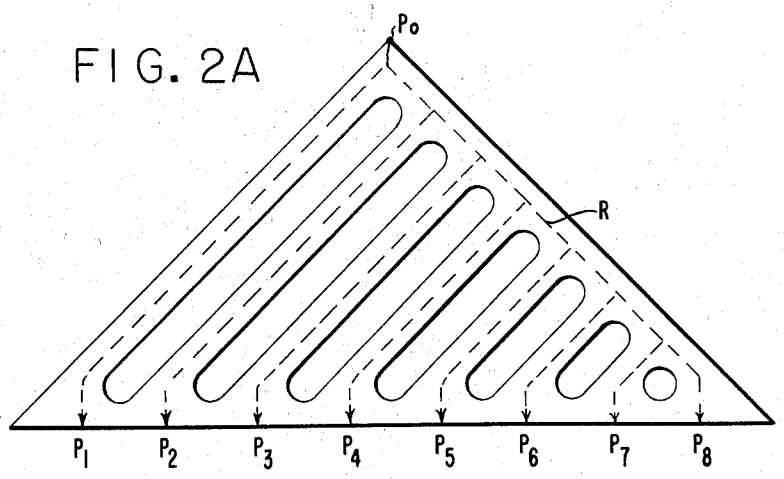


FIG. 2A



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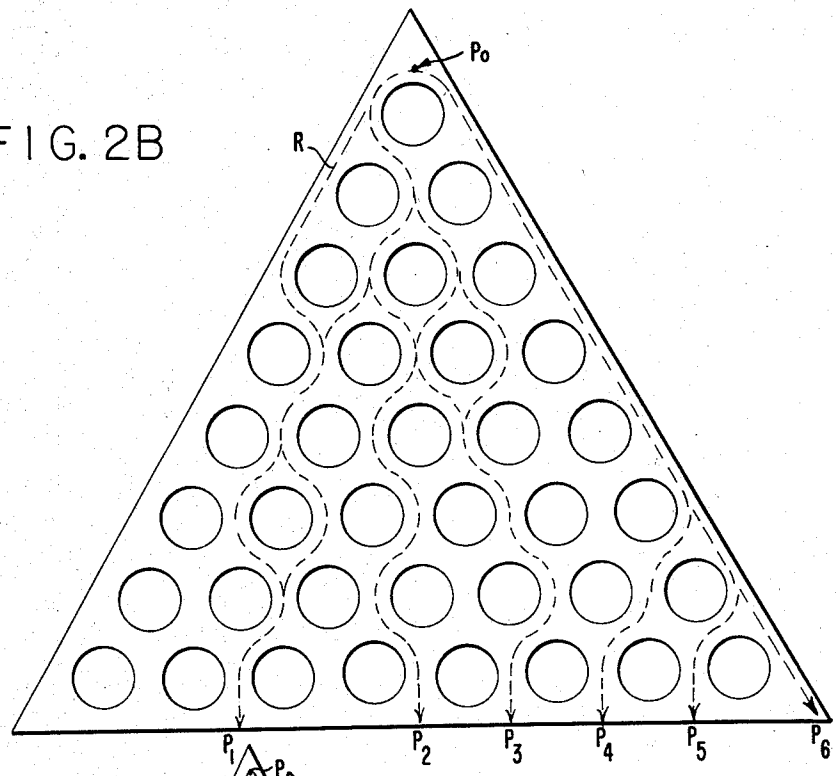
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EXPLOSIVE DEVICE

Filed March 18, 1958 5 Sheets-Sheet 3

FIG. 2B



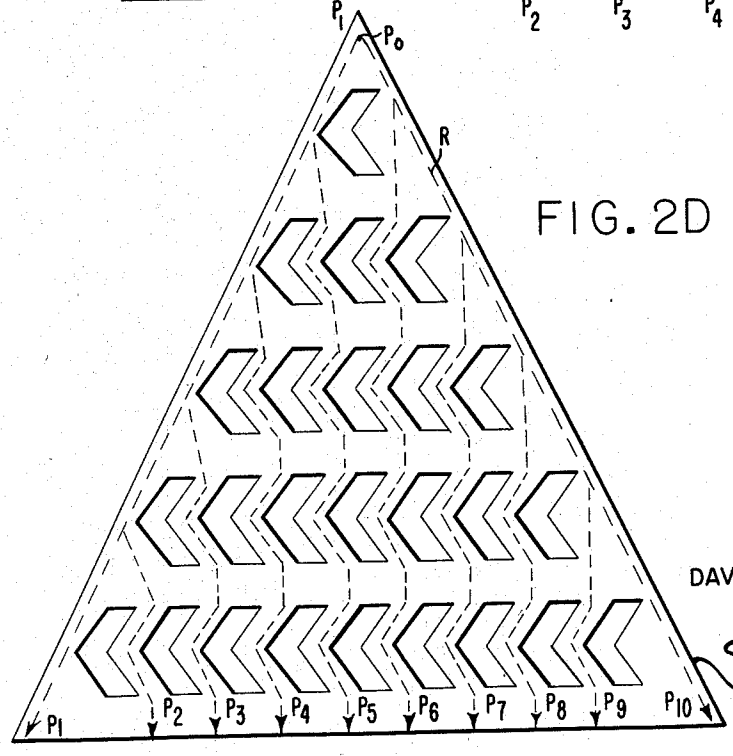


FIG. 2D

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July 5, 1960 D. L. COURSEN 2,943,571

EXPLOSIVE DEVICE

Filed March 18, 1958 5 Sheets-Sheet 4

FIG.2G

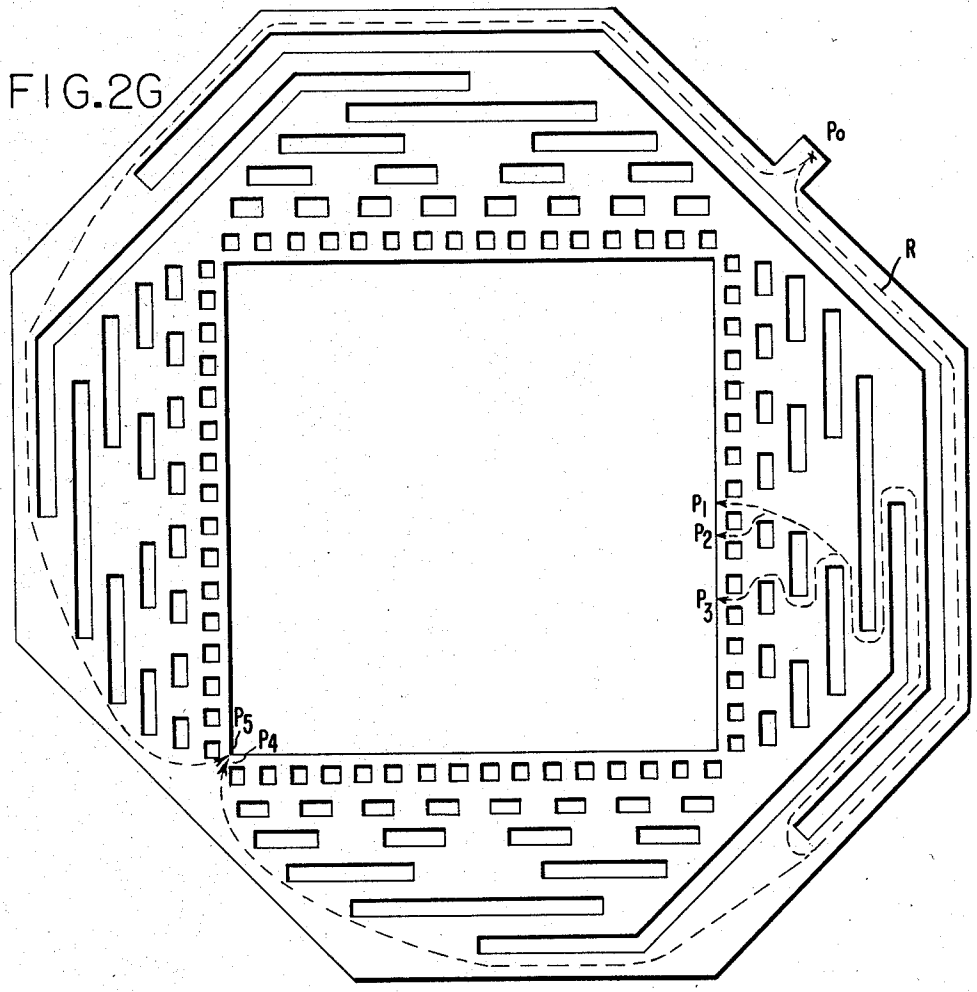
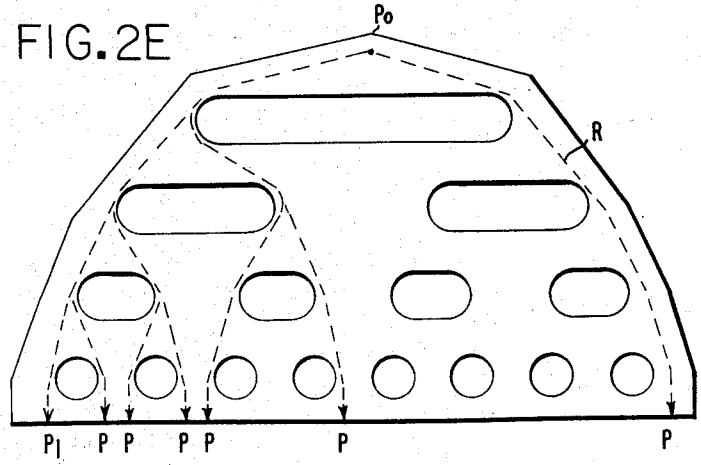


FIG.2E



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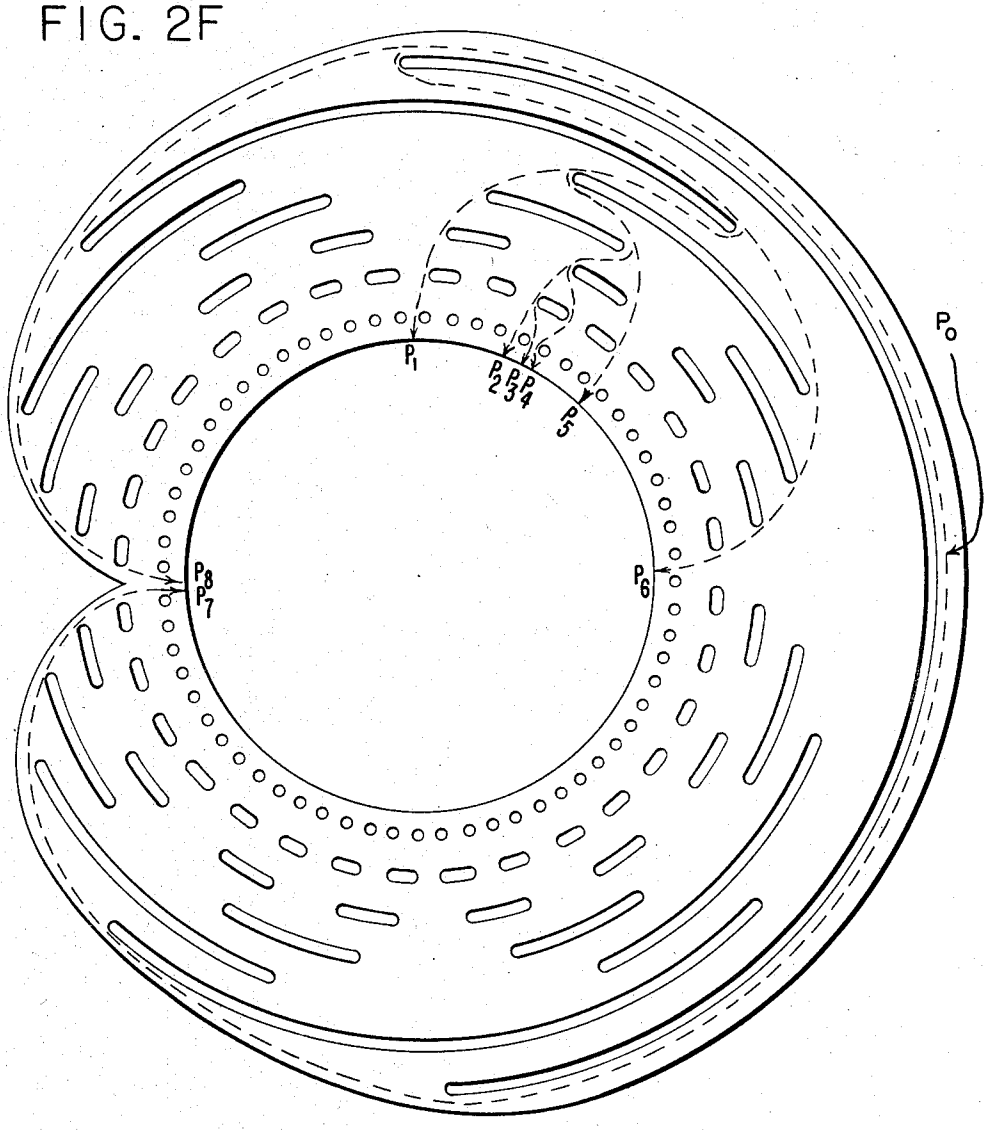
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July 5, 1960 D. L. COURSEN 2,943,571

EXPLOSIVE DEVICE

Filed March 18, 1958 5 Sheets-Sheet 5

FIG. 2F



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United States Patent Office 2,943,571 Patented July 5, 1960

2,943,571

EXPLOSIVE DEVICE

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Filed Mar. 18, 1958, Ser. No. 722,329

6 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 point is made to arrive simultaneously at a plurality of points along a desired line.

When a mass of a high explosive is initiated at one point, the resultant detonation wave proceeds outwardly from the point 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 point and the starting, or initiation, point. Obvious also is the fact that the detonation front cannot arrive simultaneously at a number of points 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 points 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, Aug. 5, 1952), for slotting pipe and the like, is initiated at a plurality of points in a straight line along its surface, rather than at one point, 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, Jan. 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 points 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 points 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

prohibits 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 is generated at one point is distorted so that it arrives simultaneously at a number of points 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. This device, which is described in U.S. Patent 2,774,306 (N. A. MacLeod, Dec. 18, 1956), effects the requisite initiation but suffers from the complexity of design, the number of components in the device resulting in complications of fabrication. As is apparent, the provision of an effective line wave generator of simplified design is highly desirable.

Accordingly, an object of the present invention is the provision of an improved device wherein the detonation front generated at a point source is made to arrive simultaneously at a plurality of points along a curved line or one or more straight lines. Another object of the present invention is the provision of a line wave generator characterized by simplicity of design. A 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 points along its surface is induced simultaneously in an efficient manner. Other objects will become apparent as the invention is further described.

I have found that the foregoing objects may be achieved when I provide as the line wave generator a continuous sheet-like matrix of a high explosive, the matrix being defined by a plurality of aperatures of dimensions sufficient to prevent the propagation of the detonation wave across the aperture, the apertures delimiting a series of paths from the initiation point to each of a plurality of finish points, each of the paths being of sufficient cross-sectional area to support the detonation wave, the shortest detonation path being equal for each initiation point-finish point route.

In order to describe more fully the nature of the present invention, reference now is made to the accompanying drawings in which:

Figure 1 is a visual consideration of the theory involved in the present invention,

Figures 2A–G represent various embodiments of the line wave generator of the present invention, which embodiments are constructed in accordance with the principles illustrated in Figure 1.

Referring now to the figures in greater detail, Figure 1 represents a hypothetical case in which a sheet-like charge of a high-velocity detonating composition, completely irregular in its shape, is provided with numerous, irregularly shaped apertures randomly disposed within the sheet. The explosive composition constitutes a continuous matrix. When the charge is initiated at point P_0, the starting point, the detonation proceeds outwardly at a given velocity along various routes R, indicated by the dotted lines in the figure, between point P_0 and the finish points, P_1, P_2, P_3 . . . P_n, constituting line L along the periphery of the charge. The routes, R, taken by the detonation wave are delimited by the position and size of the randomly spaced apertures, and, in all cases, the routes are along a path of cross-sectional area, W_0, equal to or greater than the minimum required to prevent the detonation from dying out. As is well-known in the art, for every high-explosion composition, there is a certain minimum dimension (width or thickness), most conveniently expressed as the cross-sectional area, required to support a detonation, and the detonation has been found to travel midway of the edges of this minimum

size area, as indicated by the dotted lines of the figure. The fact also must be considered that for every high explosive of given cross-sectional area a certain air gap exists over which the detonation wave cannot propagate.

As illustrated in Figure 1, the detonation wave travels along various routes which are of sufficient cross-sectional area to support the detonation, the wave crossing over those air gaps sufficiently small in magnitude and by-passing those air gaps of a size sufficient to prevent the propagation of the detonation. Thus, it can be readily seen that the detonation wave can be forced to take a predetermined and desired path. When the air gaps, regardless of their shape, are of sufficient dimension to control the diversion of the detonation wave and are so disposed that the shortest path for any starting point-finish point route is equal in length to all other shortest starting point-finish point routes, the detonation wave arrives simultaneously at all the finish points, regardless of the exact configuration of the paths taken by the wave.

In Figures 2A–G are described various configurations constructed in accordance with the principles of Figure 1. In all the configurations, the apertures are of sufficient dimension to prevent the propagation of the detonation across them and they delimit paths of sufficient cross-sectional area to support the detonation.

Figure 2A illustrates an embodiment of the present invention wherein the detonation front generated at point P_0 travels down routes R and arrives simultaneously along a series of points P_1–P_8 in a straight line. The sheet-like high explosive is triangular in form and is perforated with a number of apertures such that the matrix of explosive thus defined comprises a series of parallel elongated, diagonal strips bounded on all sides of the high explosive.

The embodiment shown in Figure 2B comprises an equilateral triangle provided with a regular hexagonal array of circular apertures, the apertures being centered at points of intersection of a rectangular coordinate grid. In this embodiment, the detonation front generated at point P_0 travels routes R and arrives simultaneously at a plurality of points also in a straight line, some of the finish points being indicated by P_1–P_6.

In Figure 2C, the sheet-like high explosive is in the form of an ogival triangle provided with a distorted hexagonal array of circular apertures, the apertures being centered at points of intersection of a polar coordinate grid. The detonation front traveling from point P_0 along routes R arrives simultaneously at a plurality of points in a straight line, some of which points are indicated by P_1–P_4.

The device of Figure 2D also is triangular in shape and also produces a straight-line wave front, the detonation front arriving simultaneously at points P_1–P_{10} which are located along a straight line. In this case, the triangular sheet of high explosive is perforated with rows of nested chevron-shaped apertures, the rows being so disposed as to form straight columns of the apertures.

In Figure 2E, the line wave generator comprises an approximately semicircular sheet of a high explosive provided with rows of apertures so disposed that the detonation wave generated at point P_0 after by-passing one aperture is immediately confronted with another aperture which must be by-passed, the shortest start point-finish point path for each finish point (some of which are indicated by P_1–P_7) being equal to every other shortest start point-finish point path, so that the detonation front arrives simultaneously at the finish points which constitute a straight line.

Figure 2F illustrates a line wave generator wherein a detonation front generated at one point is made to arrive simultaneously at a plurality of points along a circle. In this embodiment, the matrix of high explosive constitutes a ring defining a circular hole, the points along the inner edge of the ring being the finish points, some of which are represented by P_1–P_8. The apertures defining the matrix are positioned such that the detonation wave after being diverted around one aperture encounters and must by-pass another aperture, the shortest detonation path being equal for each start point-finish point route.

In Figure 2G showing an embodiment wherein the detonation front generated at one point arrives simultaneously at a number of points delineating a rectangle, the outer edges of the high-explosive matrix form a polyhedron and the inner edges define a rectangle. The apertures within the matrix are so located that the detonation front generated at point P_0 must, after by-passing one aperture, by-pass another, so that the shortest detonation path from the start point to each of the finish points (generally indicated by P_1–P_5) delineating the rectangle is equal for each start point-finish point route.

The following example serves to illustrate a specific embodiment of the device of the present invention. However, it will be understood to be illustrative only and not as limiting the invention in any manner. The explosive composition used in the example was flexible and sheet-like and comprised an 85/15 mixture of PETN and a binder consisting of 50% butyl rubber and 50% of a thermoplastic terpene hydrocarbon resin ("Piccolyte" commercially available from the Pennsylvania Industrial Chemical Corporation and composed essentially of polymers of β-pinene). The explosive composition is described in detail in co-pending application Serial No. 666,221 (C. J. Breza and C. O. Davis, filed June 17, 1957, and assigned to the present assignee).

Example

A 4.3-mm.-thick sheet of the explosive composition having an explosive loading of 4 grams per square inch was made up into the triangular form illustrated in Figure 2B. The circular apertures were 6 mm. in diameter and were provided on 9.25-mm. centers in a regular hexagonal array. The sheet was initiated at the apex by means of a standard electric blasting cap, and the detonation front traveled through the sheet to give a straight line detonation front.

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 high explosive must be in the form of a continuous matrix, (2) that the apertures must be of sufficient dimension to prevent the propagation of the detonation wave across the aperture, (3) that the initiation point-finish point paths must be of sufficient cross-sectional area to support the detonation, and (4) the shortest detonation path must be equal for each of the initiation point-finish point routes. Upon the basis of these considerations, many variations of the line wave generator, in addition to the afore-described 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 at high velocity and can be formed into the necessary continuous sheet-like matrix. The exemplified composition of a cap-sensitive crystalline high explosive, e.g. PETN, and elastomer-resin binder detonates at a velocity of 6000–7000 meters per second and is readily formed into the desired sheet for conversion into the continuous matrix. As disclosed in the aforementioned application, this composition generally contains 92.5–77.5% of the high explosive, the binder containing 25–75% of the elastomer. Although this composition constitutes the preferred high-velocity explosive, the use of other high-velocity sheet-like explosives, e.g. sheets of blasting gelatin, is completely within the scope of the present invention.

The dimensions of the apertures naturally are dependent upon the specific high-velocity detonating explosive constituting the matrix, since the air gap necessary to

prevent the propagation of the detonation wave is a function of the explosive. For example, the apertures in the exemplified explosive composition must have a minimum minor dimension of 0.020 inch, in order to provide the requisite air gap. Of course, this value will be different when other explosives, such as blasting gelatin, are used, and, hence, the exact minimum minor dimension of the aperture is not a fixed value.

Similarly, the minimum cross-sectional area required to support the detonation is a function of the specific explosive forming the matrix. For the exemplified explosive material, this minimum area is 7.8 square millimeters. Since the cross-sectional area is dependent upon the width of the web and the thickness of the explosive sheet, the minimum quantity of explosive required to support the detonation may also be expressed by the relationship:

$$\frac{1}{T}+\frac{1}{W_0}=K$$

wherein: T is the sheet thickness, W_0 is the minimum dimension (width of web) for support of detonation, and K is a constant. For the exemplified explosive composition, K is 0.72 $mm.^{-1}$. However, as stated previously in regard to the aperture size, the specific value for the cross-sectional area, and also for constant K of the thickness-width equation if use of the latter is desirable, will vary with the specific explosive used, the exact minimum cross-sectional area or constant not being a fixed value.

In many instances, for a given configuration of the line wave generator a mathematical expression correlating the required dimensions of the paths with the air gap, or aperture size, may be formulated. As an example, for this configuration of 2–B, i.e. a triangular sheet of explosive provided with a regular hexagonal array of circular holes, a perfectly straight detonation front is produced when:

$$\frac{2(W-W_0)}{2R+W_0}=0.122$$

W being the width of web of explosive between adjacent holes, W_0 being the minimum width of web which will support a detonation, and R being aperture radius. However, sufficiently straight fronts for many purposes can be obtained when the following equation is satisfied:

$$0.05\leq\frac{2(W-W_0)}{2R+W_0}\leq 0.9$$

Although the invention has been described in detail in the foregoing, it will be apparent to those skilled in the art that many variations are possible without departure

from the scope of the invention. For example, a number of the line wave generators may be assembled, e.g. stacked, to give a plane wave detonation front, and the specific explosive used and the configuration and dimensions of the line wave generator may be varied. I intend, therefore, to be limited only by the following claims.

I claim:

1. A line wave generator wherein the natural detonation front generated at one initiation point is distorted to arrive simultaneously at a plurality of finish points along a straight line which consists of a continuous sheet-like matrix of a high-velocity detonating explosive, said matrix being defined by a plurality of apertures of dimensions sufficient to prevent the propagation of the detonation wave across the aperture, said apertures delimiting a series of paths from the said initiation point to each of a plurality of said finish points delineating said straight line, all of said paths being of sufficient cross-sectional area to support the detonation wave, the shortest such path from said initiation point to all of said finish points being equal.

2. A line wave generator according to claim 1, wherein said matrix consists of a triangular sheet comprising a series of parallel, elongated diagonal strips bounded on all sides by said high-velocity detonating explosive.

3. A line wave generator according to claim 1, wherein said matrix consists of a triangular sheet provided with a regular hexagonal array of circular apertures, said apertures being centered at points of intersection of a rectangular coordinate grid.

4. A line wave generator according to claim 1, wherein said matrix consists of an ogival triangular sheet provided with a distorted hexagonal array of circular apertures, said apertures being centered at points of intersection of a polar coordinate grid.

5. A line wave generator according to claim 1, wherein said matrix consists of a triangular sheet provided with rows of nested chrevon-shaped apertures, said rows being so disposed as to form straight columns of the apertures.

6. A line wave generator according to claim 1, wherein said matrix consists of a semicircular sheet provided with rows of apertures so disposed that the detonation wave after by-passing one aperture encounters and must by-pass another aperture.

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