July 22, 1952 J. H. COOK 2,604,042

DETONATING EXPLOSIVE CHARGE AND METHOD OF IMPRESSING SURFACES EMPLOYING SAME

Filed July 30, 1948 3 Sheets-Sheet 1

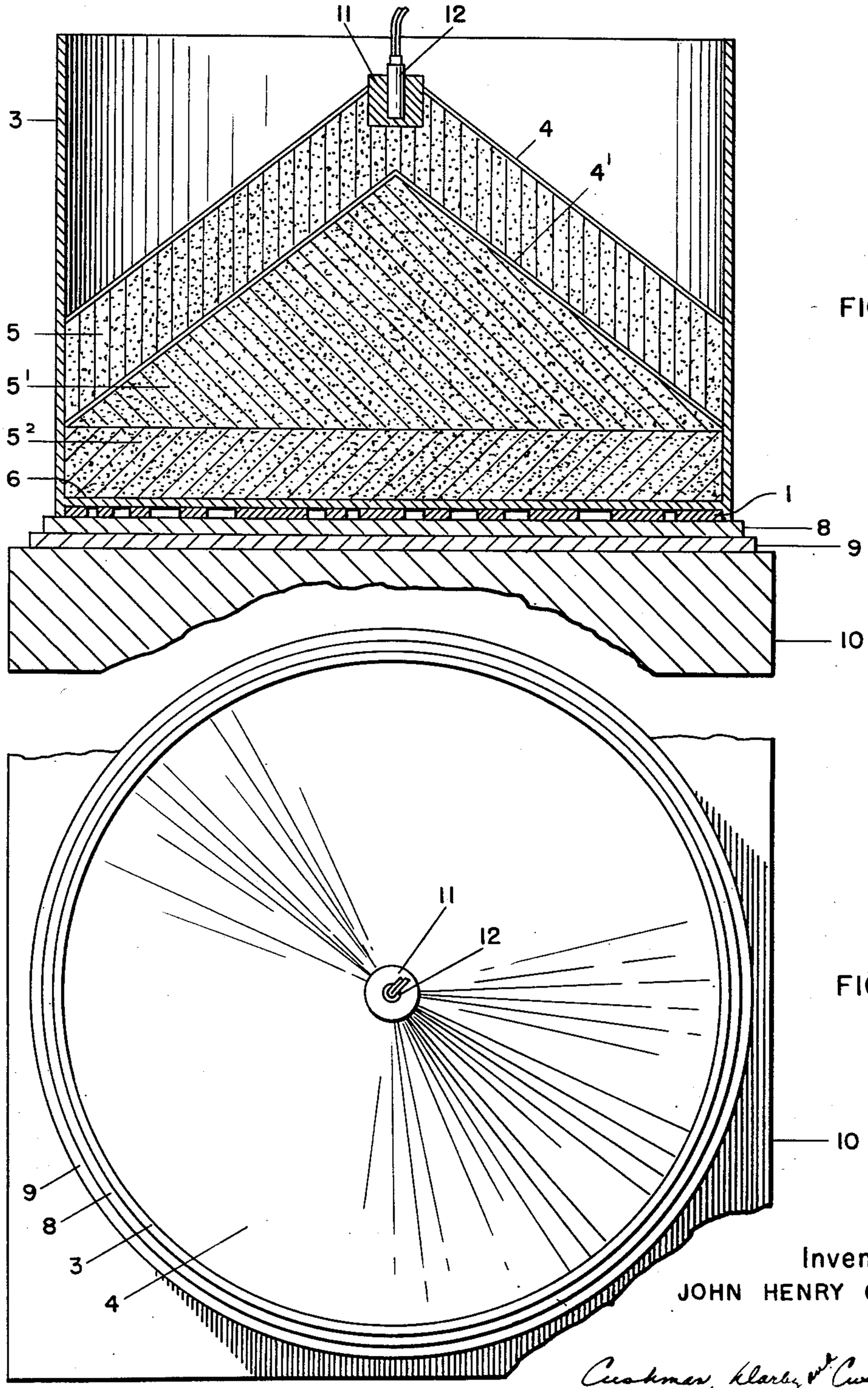


FIG. 1.




FIG. 2.

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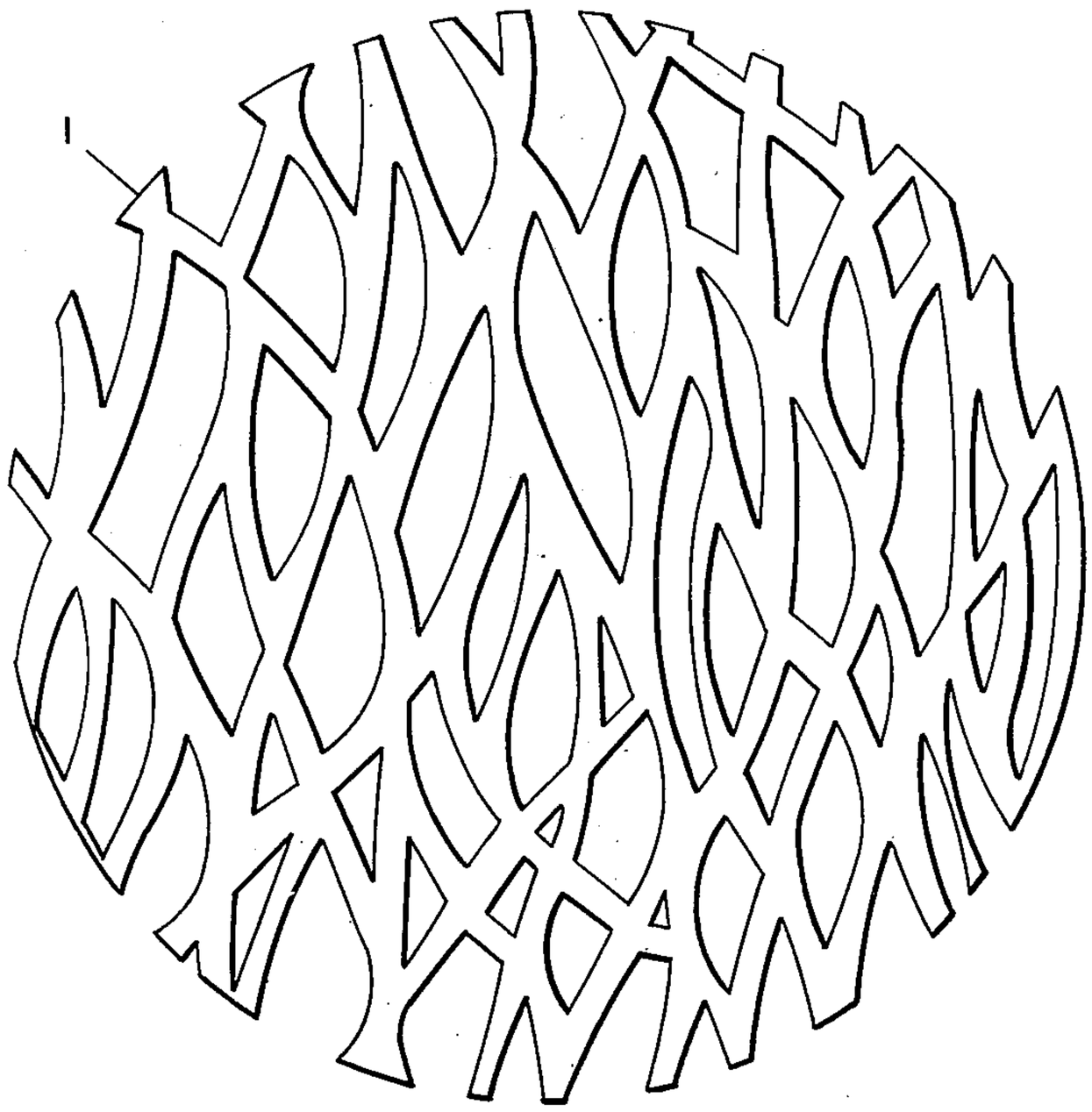


FIG. 3.

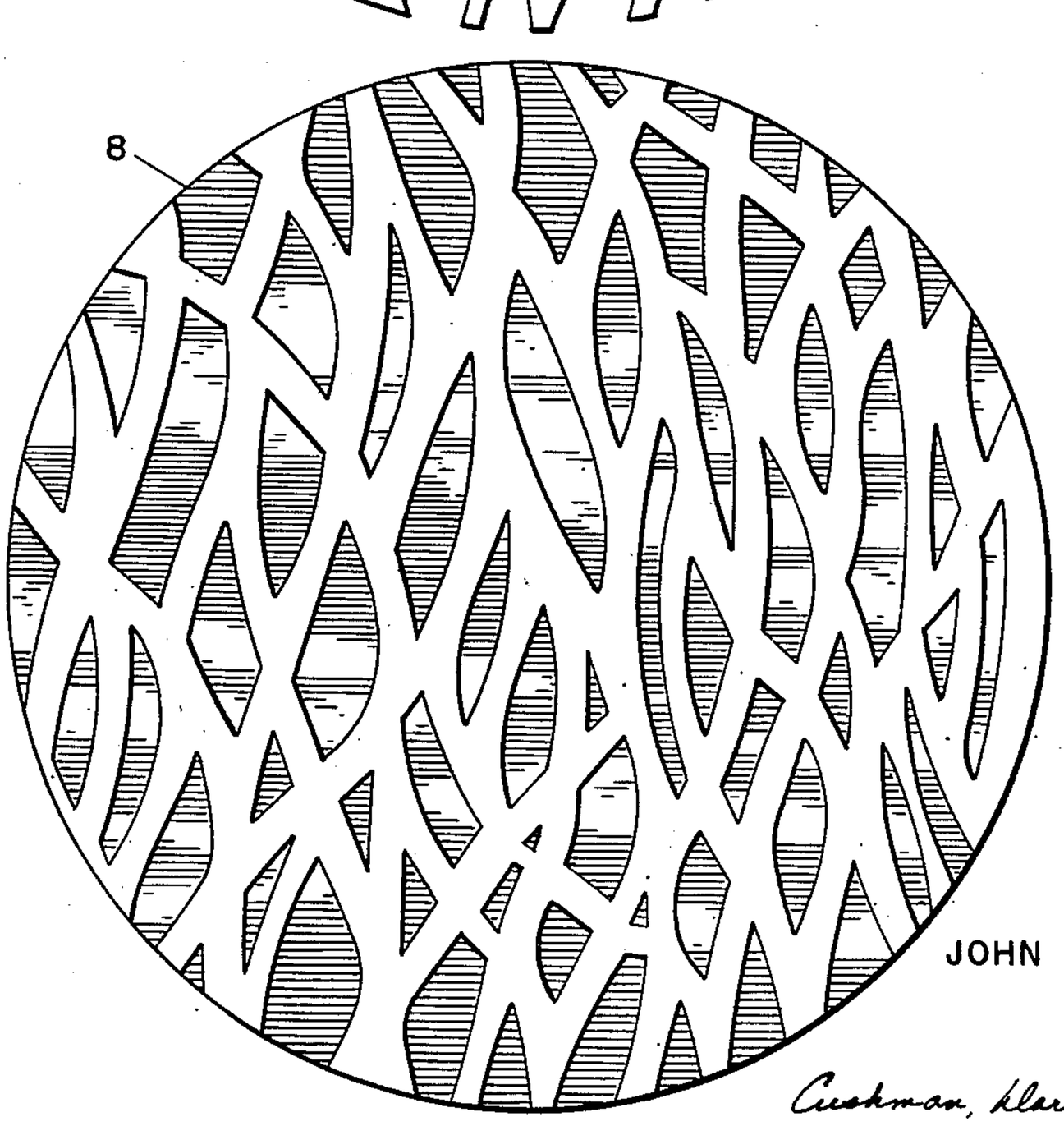


FIG. 4.

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Fig 5.

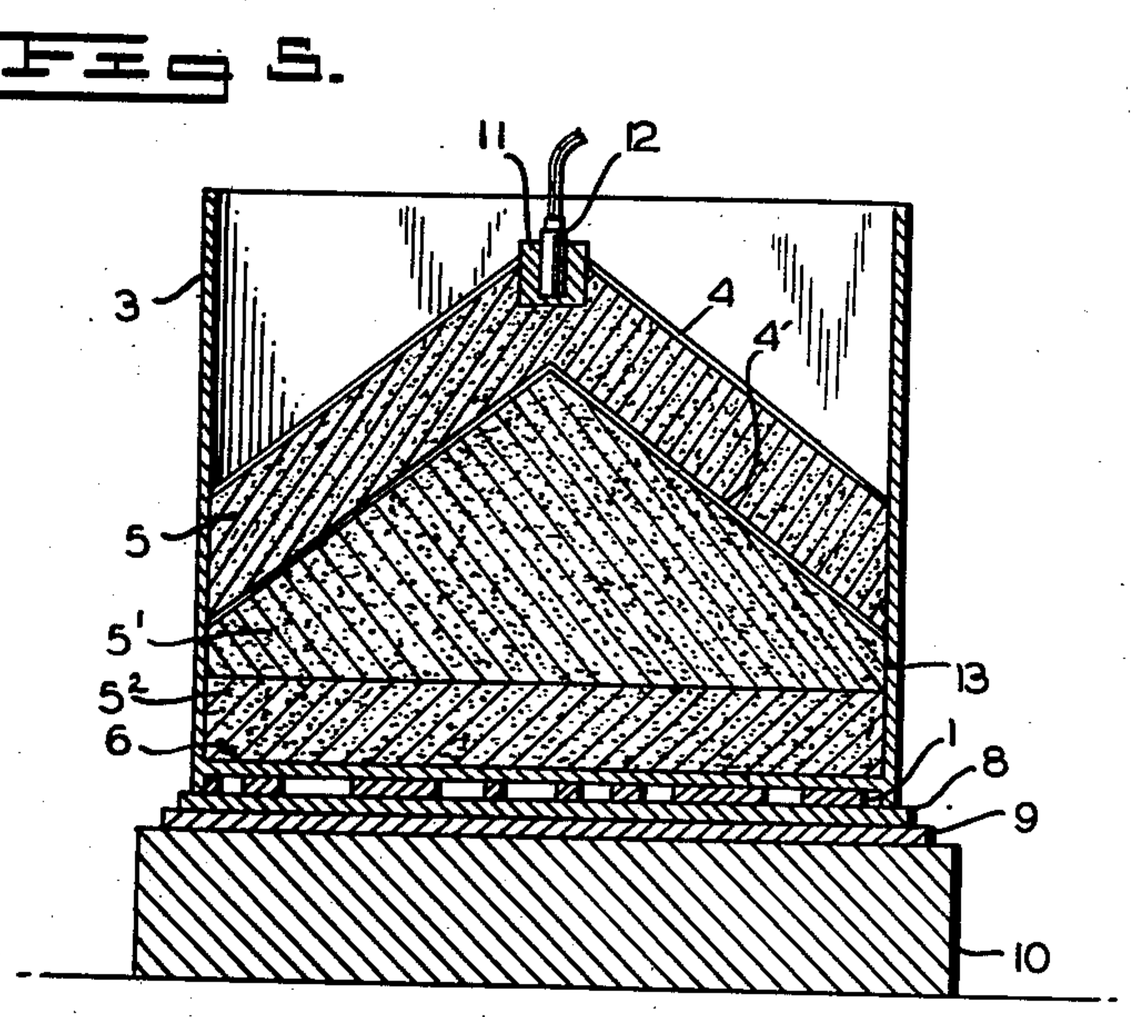
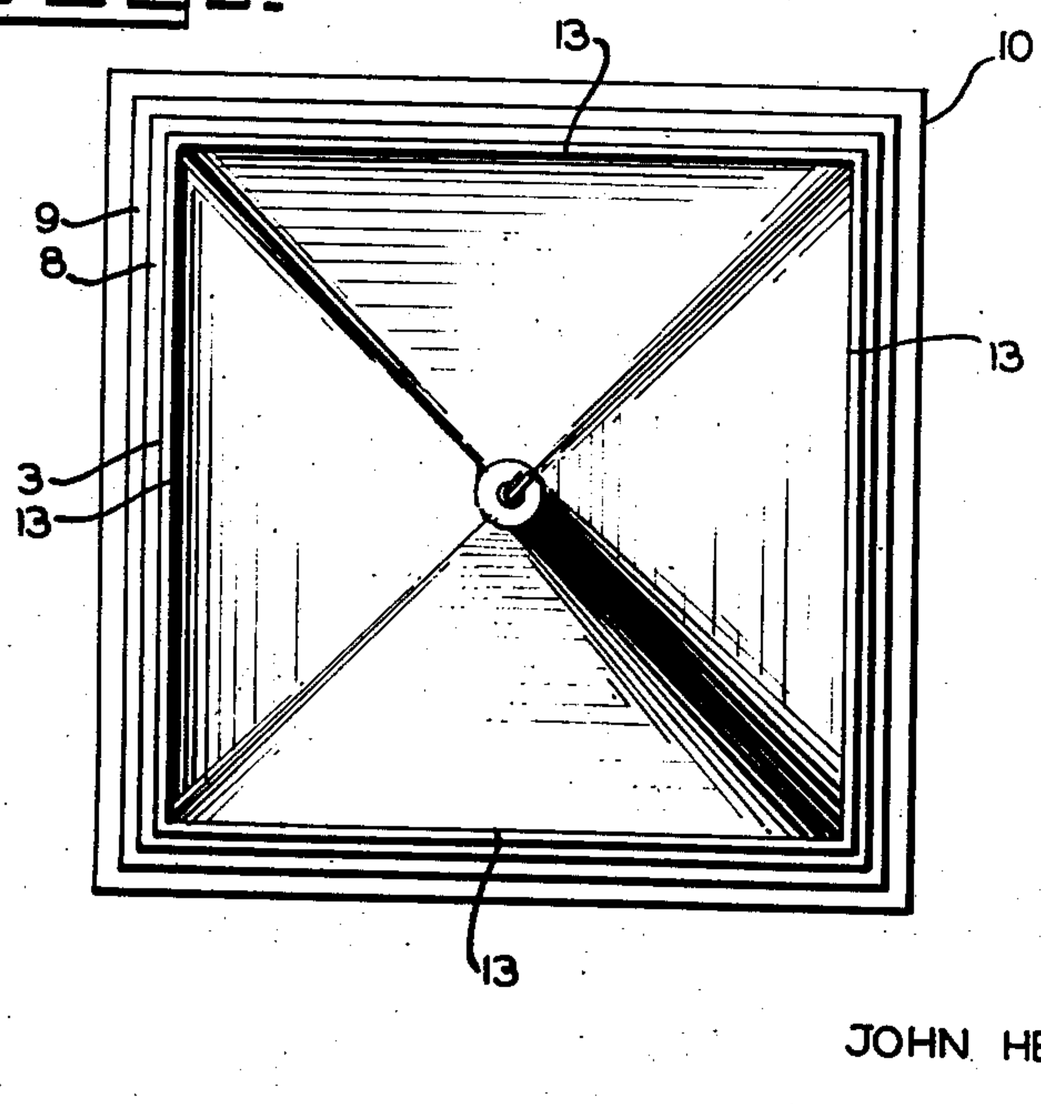



Fig 6.

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# UNITED STATES PATENT OFFICE

2,604,042

## DETONATING EXPLOSIVE CHARGE AND METHOD OF IMPRESSING SURFACES EMPLOYING SAME

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9 Claims. (Cl. 101—401.2)

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The present invention is concerned with a new and improved method of explosively impressing markings in low relief into a metal plate whereby impressed metal plates suitable for such purposes as embossing or printing sheet materials may be obtained. The invention further relates to a new form of explosive charge suitable for impressing in low relief on a metal plate markings simulating those provided by the boundaries between surfaces of differing relief in a template interposed between it and the metal plate.

It is an object of the invention to provide a practicable method for the production of metal plates of at least several square inches in area impressed with designs or other markings in low relief suitable for embossing, printing or the like in a more expeditious manner than by the usual methods. It is also an object of the invention to provide a new or improved form of explosive charge having a plane end of substantial area characterised in that when its detonation is initiated from its opposite end the detonation wave front at said plane end is substantially free from curvature.

Other objects of the invention will appear hereinafter.

It has long been known that by placing a coin on a metal plate and initiating detonation of an explosive charge superposed on the coin, the design on the face of the coin presented to the metal plate can be more or less faithfully reproduced on the plate in reverse; that is to say the hollow portions of the design on the coin will appear as raised portions in the plate, and the relief portions of the design on the coin will be indented in the plate. On the other hand the shape and markings of a leaf, a piece of lace, or like flat object of small area made of soft destructible material laid on a metal plate have been shown marked on a metal plate in positive image by detonating a plane-ended explosive cartridge superposed on the object. Hitherto however the so impressed plates have been regarded merely as scientific curiosities and no industrial application has been made of the possibilities of impressing metal plates with designs by means of explosives.

When a comparatively short cylinder or other plane ended columnar body of detonating explosive having an axis perpendicular to its ends and the same cross section throughout its axial length has its detonation initiated from a point at one end of its axis, the detonation wave front advancing through the column is convex. Owing to this convexity of the detonation wave front, no design

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impressed by means of an explosive column, whose detonation is initiated by a detonator at its remote end, on a metal plate from an interposed template or stencil cut with a design in low relief can be satisfactorily simulated, except in a small area immediately around the axis of the column; so that unless the cross sectional area of the explosive column and the design as a whole is small the rendering of the design becomes more and more noticeably indistinct as the periphery of the disc is approached, with the results that the impressed metal plate obtained is of no practical value.

This imperfection of impression presents a problem to which a practical solution is not easily found. Thus multiple initiation by means of detonators spaced at intervals over the area of the remote end of the explosive column does not usually effect the desired result, since the resulting design on the metal plate may be marred by blemishes representing the lines where the convex detonation wave front surfaces intersect, while the replacement of a portion of the length of the column of explosive by a disc of an explosive of higher velocity of detonation than that of the rest of the column only increases the radius of the area of reasonably clear definition of the design from say about 1 inch to about 1½ inches.

An explosive charge capable of giving a plane detonation wave front according to the invention comprises a core of a detonating explosive charge of conical form the surface continuity of whose plane base is uninterrupted by any recess or projection, said conical form being, if desired, truncated by one or more surfaces passing perpendicularly through its base, and in detonation inducing relationship with said explosive charge, a covering of a thickness of an explosive of a higher velocity of detonation extending over the whole of its conical curved surface, the detonation initiating means being at the apex, the sine of the base angle of the cone being equal to the quotient of the velocity of detonation of the explosive of relatively lower velocity divided by that of the explosive of relatively higher velocity.

The detonation wave front transmitted to and beyond the base of such an explosive charge is a plane parallel to said base. The longer time than would be otherwise required for an impulse to be transmitted from the apical region wholly or partly along the sloping length of the thickness of explosive of higher velocity of detonation covering the core explosive than directly along the axis of the cone is compensated for by the reduced thickness of the explosive of lower veloc-

ity of detonation through which the impulse must be transmitted before it can reach the base, so that at every point of the base of the cone, whether or not this is truncated as aforesaid, there arrives an impulse at the same instant of time.

In the method of explosively impressing low relief markings in a metal plate according to the present invention, the apically disposed initiating means detonates the composite explosive charge with a resultant plane detonation wave front. Between the base of the explosive charge and the metal plate there is interposed a sheet of destructible compressible material having predetermined local variations in its thickness or in the nature of the material composing it. The aforesaid destructible compressible material causes absorption of the energy of detonation directed through it in correspondingly differing degrees at the respective parts of its area. If desired, further cushioning sheet material of uniform absorption capacity over its area may be employed to absorb the energy to an additional degree. The higher energy absorbing portions of the sheet of destructible compressible material cause the metal plate portions beneath them to be subjected to less energy of detonation than those portions of the metal plate underlying the lesser energy absorbing portions of the destructible sheet material. As a result of this, as is explained more fully hereinafter, various designs may be impressed in the metal surfaces.

The aforesaid composite explosive charge preferably includes also as an element interposed between said first mentioned element and the sheet of destructible compressible material a parallel plane-ended column of uniform cross section, having its columnar axis perpendicular to its plane ends, of an explosive composition whose detonation is initiated from one of its plane ends through the base of said first mentioned element, whereof the core explosive has a velocity of detonation not exceeding and preferably lower than that of the explosive of said parallel plane-ended column. By the method of the present invention designs extending over areas ranging up to some hundreds of square inches may be satisfactorily impressed.

The invention will be further understood by reference to the diagrammatic drawings accompanying the provisional specification, whereof Figure 1 is a vertical axial section and Figure 2 is a top plan view of an assembly for executing a design on a metal plate according to one form of the invention, Figure 3 is a plan view of a sheet of destructible compressible material bearing an ornamental design forming part of the aforesaid assembly, Figure 4 is a plan view of the metal plate having the ornamental design in low relief obtained as a result of the detonation, Figure 5 is a vertical axial section of a modification of Figure 1, and Figure 6 is a top plan view of the modification of Figure 5.

In Figure 1, **10** is a steel anvil, **9** is a sheet of cushioning material such as cardboard, **8** is a brass plate, **6** is the smooth cardboard base and **3** the cardboard wall of a container. **1**, seen also in Figure 3, is a sheet of hard cardboard cut in stencil with the ornamental design shown in Figure 3. $4^1$ and **4** are thin partitions of stiff paper or the like. $5^2$ is a cylindrical charge of an explosive of a velocity of detonation about 3600 metres per second and $5^1$ is a conical charge of an explosive of velocity of detonation about 2300 metres per second capable of inducing the



detonation of the explosive $5^2$ when it is itself detonated by a charge **5** of a velocity of detonation abotu 5800 metres per second constituing a layer of uniform thickness covering the conical charge and capable of detonating the latter through the intervening thin sheet $4^1$. The base angle of the cone is 23° 22′. **11** is a tetryl primer and **12** is an electric detonator.

When the electric detonator **12** is fired the primer **11** is detonated and the latter radially initiates the detonation of the explosive charge **5**, which in turn initiates the detonation of the explosive charge $5^1$ across the intervening sheet $4^1$. The thickness of the explosive $5^1$ of lower velocity of detonation than that of explosive **5** that has to be traversed before the detonation impulse meets the explosive $5^2$ is greatest vertically below the apex of the cone, and the angle of the cone is such that the detonation impulse that has travelled down the outer layer explosive of higher velocity **5** arrives at the circumference of its base at precisely the same instant as that travelling axially arrives at the center of its base. At this instant a detonation impulse arrives at every point at the interface between the explosive $5^1$ and $5^2$, so that the detonation wave front at this interface is not convex but plane. Hence the detonation induced in the cylindrical explosive charge $5^2$ travels through it with a plane wave front and everywhere on the sheet **1** the detonation impinges normal to its surface. The upstanding parts of the design on the sheet **1** however, absorb more of the energy of the detonation than the blank portions, so that the metal plate **8** is more deeply impressed beneath the blank portions than beneath the upstanding portions. The base **6** of the container absorbs some of the detonation energy before it reaches the sheet **1**. The cushioning sheet **9** helps to prevent the plate **8** from being bent or broken. It is a remarkable fact, however, that the design rendered on the plate **8** is as a whole somewhat larger than that on the said sheet **1**, as is shown in Figures 3 and 4. The design is distinctly rendered on the plate over the whole area of the design.

The greater the difference between the velocities of detonation of the core explosive and of the outer explosive in the conical portion of the charge, the flatter may be the shape of the cone and hence the less the amount of explosive material required to produce a plane detonation wave front. It may therefore be preferable to employ as the core explosive one that would have a substantially lower velocity of detonation than is usually desirable for impressing the markings effectively on a metal plate—so long as it is capable of initiating the detonation of the parallel plane-ended column of the explosive of velocity of detonation suitable for impressing the markings. Thus the core explosive in the conical portion of the charge may advantageously have a velocity of detonation for instance of about 2,000–2500 metres per second and that of the explosive of the parallel plane-ended column may range up to about 3300–3800 metres per second or more depending on the depth of impression required, and the nature of the material of the metal plate and the extent to which the explosive charge is cushioned.

The velocity of detonation of the explosive on the conically curved surface should theoretically be as high as possible but economical and practical consideration will seldom permit the use of an explosive having a velocity of deto-

nation in excess of about 6,000 metres per second. While the use of the conical portion alone will produce a plane detonation wave front, it does not necessarily follow that the depth of the impressions all over the surface worked upon will be identical, since the two explosives present in the conical portion may differ markedly in power or density so that the energy transmitted from the base of this conical structure will not in general be the same in amount at all parts of its surface. This differential effect, however, is minimised when the conical portion is somewhat truncated by one or more surfaces normal to its base, and also when this portion is employed as the initiating means in conjunction with a parallel plane-ended cylindrical column of explosive in the aforesaid manner, especially when the explosive used for the core of the conical portion is of a substantially lower velocity of detonation than that of the explosive in said column and the velocity of detonation of the explosive on the conically curved surface is substantially higher than that of the explosive in said parallel plane-ended column.

In the case where a circular area is to be worked upon, the periphery of the base of the cone may be complete although it is usually desirable that the form of the charge, or portion of the charge should be truncated so that at least that portion of the cone lying outside the truncated surface perpendicular to the base of the complete cone and intersecting it at the junction between the two explosives comprising the cone should be omitted, and it is sometimes preferable that the truncation should be such as to omit an annular portion of the complete cone lying outside a cylindrical surface perpendicular to and intersecting the base somewhat nearer the axis of the cone. In the case where a non-circular area is to be worked upon, it will in general be advisable that the truncation of the cone should be such as to omit those portions of the complete cone that lie outside the surface or surfaces perpendicular to the base of the complete cone and intersecting it at the outline of the working area, the area of the base of the complete cone being large enough to circumscribe or even extend everywhere beyond the outline of the working area. This enables the base of this portion of the explosive to be superimposed on the plane end of a column of explosive of the required shape without overhanging it. Such truncations are without any adverse effect on the plane detonation wave front characteristics of the charge. An example of a composite explosive charge suitable for working on a non-circular area in accordance with this invention is shown in Figures 5 and 6, where like numerals as those used in Figures 1 and 2 represent like parts. The composite explosive charge of Figures 5 and 6 for working on a square area is formed by truncating the cone-shaped explosive charge $5^1$, so as to form four equal length surfaces **13** at right angles to each other and normal to the base of the conical explosive charge $5^1$.

The portion of the explosive charge in the form of the plane ended column may for instance consist of an 80:20 mixture by weight of trinitrotoluene and sodium chloride milled to a fine grist.

The explosive constituting the core of the coned portion may advantageously have a velocity of detonation not exceeding about 2300 metres per second and the explosive constituting the outer thickness a velocity of detonation



considerably higher, e. g. 5000 metres per second. The core explosive may consist for instance of "Denaby Powder" which consists of a mixture comprising 12% TNT, 59% ammonium nitrate, 6% sodium nitrate, 20% sodium chloride, and 3% cellulosic material and the outer thickness explosive may consist for instance of cyclotrimethylene trinitramine. The initiating means at the apex of the cone may be a primer adapted to receive a detonator, and may be included as a permanent part of the charge, or supplied separately like the detonator itself, to be assembled with the rest of the charge when it is to be exploded.

It will be understood that in making up the explosive charge a casing suitably compartmented by means of structures of light material is desirably employed, and that the base of the casing will serve as cushioning material between the explosive and the sheet of destructible compressible material which may, if desired, have the low relief markings penetrating through the whole of its thickness in the fashion of a stencil or through only a part of its thickness. The sharpness of the markings on the metal plate may be modified as desired by interposing further cushioning material preferably below the sheet of destructible compressible material. The sheet of destructible compressible material and further cushioning material should be of a character such that they will not become permanently attached to the metal plate after the detonation. Wood, paper, cardboard or the like may be used. A sheet of cushioning material may also be interposed between the metal plate and the anvil supporting it.

I claim:

1. A composite explosive charge capable of producing a plane detonation wave front comprising a right angle cone-shaped explosive charge arranged for detonation by a thickness of a priming charge of higher velocity of detonation extending over the whole of said conically curved surface, the apex of said thickness of charge of higher velocity of detonation being adapted for receiving detonation initiating means, and the sine of the base angle of the right angled cone-shaped explosive charge being equal to the quotient of the velocity of detonation of the charge of relatively lower velocity divided by the velocity of detonation of the charge of relatively higher velocity.

2. A composite explosive charge capable of producing a plane detonation wave front as set forth in claim 1 wherein the base surface of said cone-shaped explosive charge is arranged for initiating detonation of one end of an explosive composition in the form of a plane-ended column of uniform cross section having its columnar axis perpendicular to its plane ends, the velocity of detonation of said conical detonating charge being not greater than that of the velocity of said explosive of said plane-ended column.

3. A composite explosive charge capable of producing a plane detonation wave front as set forth in claim 1 wherein said composite charge is truncated by at least one surface normal to the base of the cone-shaped explosive charge.

4. A composite explosive charge capable of producing a plane detonation wave front comprising a right angle cone-shaped explosive charge arranged for detonation by a thickness of a priming charge of higher velocity of detonation extending over the whole of said conically curved surface and further arranged for

detonating through its base surface one end of a plane-ended column of uniform cross section having its columnar axis perpendicular to its plane ends, the velocity of detonation of said concial detonating charge being not greater than that of the velocity of said explosive of said column, and the sine of the base angle of said right angle cone-shaped explosive charge being equal to the quotient of the velocity of detonation of the charge of the right angle cone-shaped explosive divided by the velocity of detonation of the priming charge and having the apex of said thickness of said priming charge adapted for detonating initiating means.

5. A composite explosive charge capable of producing a plane detonation wave front as set forth in claim 4 wherein said composite explosive charge is truncated by at least one surface normal to the base of the cone.

6. A method of impressing low relief markings into a metal plate which comprises interposing a sheet of destructible compressible material having predetermined local variations of the kind to cause corresponding differences in energy absorption of a detonation directed through it between the metal plate to be impressed and a composite explosive charge, said composite explosive charge comprising a right angle cone-shaped charge arranged for detonation by a thickness of a priming charge of higher velocity of detonation extending over the whole of said conically curved surface, the sine of the base angle of said cone being equal to the quotient of the velocity of detonation of the charge of relatively lower velocity divided by the velocity of detonation of the charge of relatively higher velocity and having the apex of said thickness of charge of higher velocity of detonation provided with detonation initiating means, positioning the said explosive charge so that the said initiating means is furthermost removed from said metal plate, and detonating said initiating means.



7. A method as set forth in claim 6 wherein said composite explosive charge is truncated by at least one surface normal to the base of the cone.

8. A method as set forth in claim 6 wherein the composite explosive charge includes as a portion thereof nearest to the sheet of destructible compressible material a plane-ended explosive column of uniform cross section having its columnar axis perpendicular to its plane ends and one end thereof arranged for detonation by the base of said cone-shaped explosive charge, the velocity of detonation of said cone-shaped explosive charge being not more than that of the explosive of said column.

9. A method as set forth in claim 6 wherein cushioning sheet material is interposed between the composite explosive charge and the sheet of destructible compressible material.

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