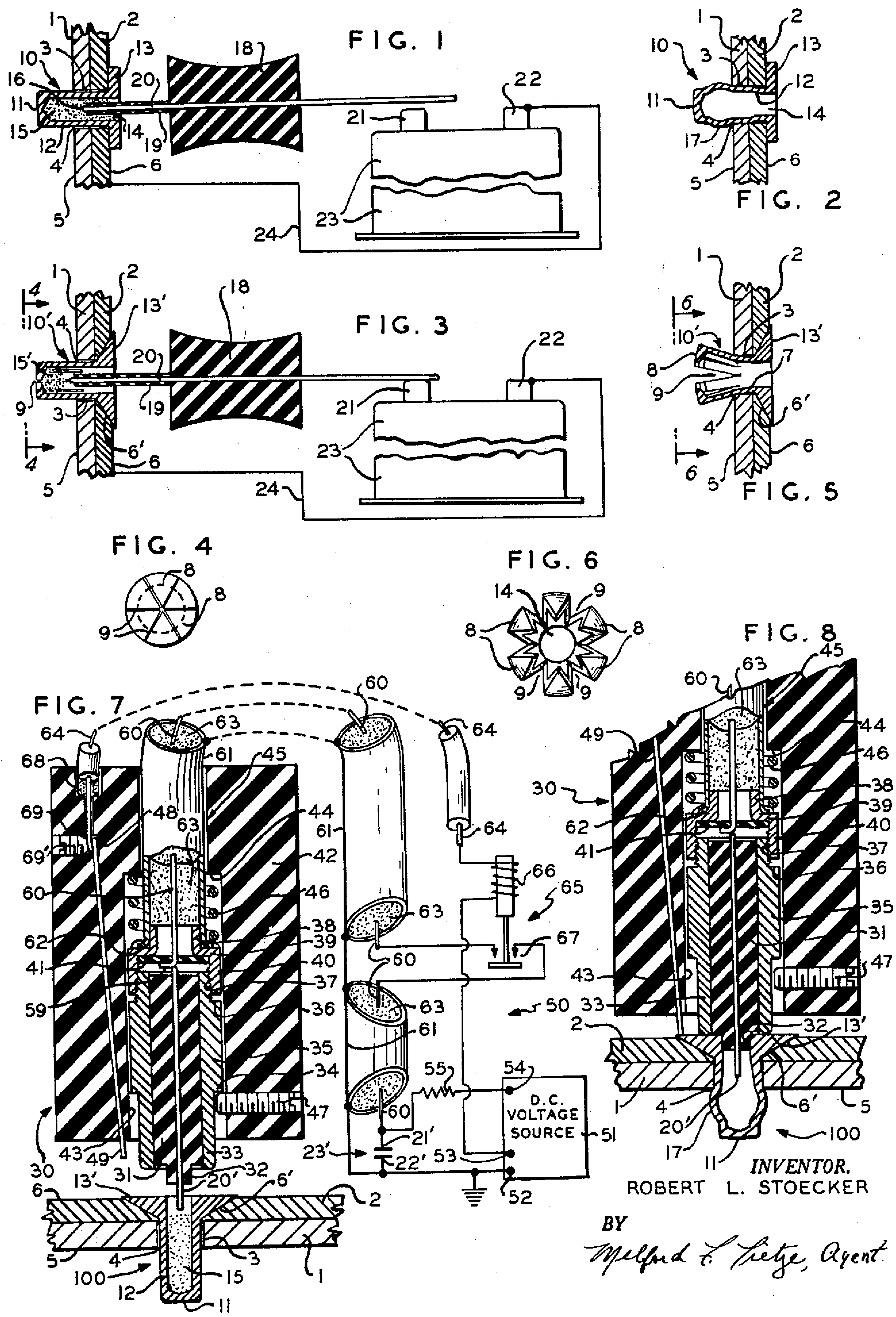
Aug. 27, 1963 R. L. STOECKER 3,101,859

RIVETING BY ELECTRIC DISCHARGE

Filed Aug. 15, 1961 2 Sheets-Sheet 1



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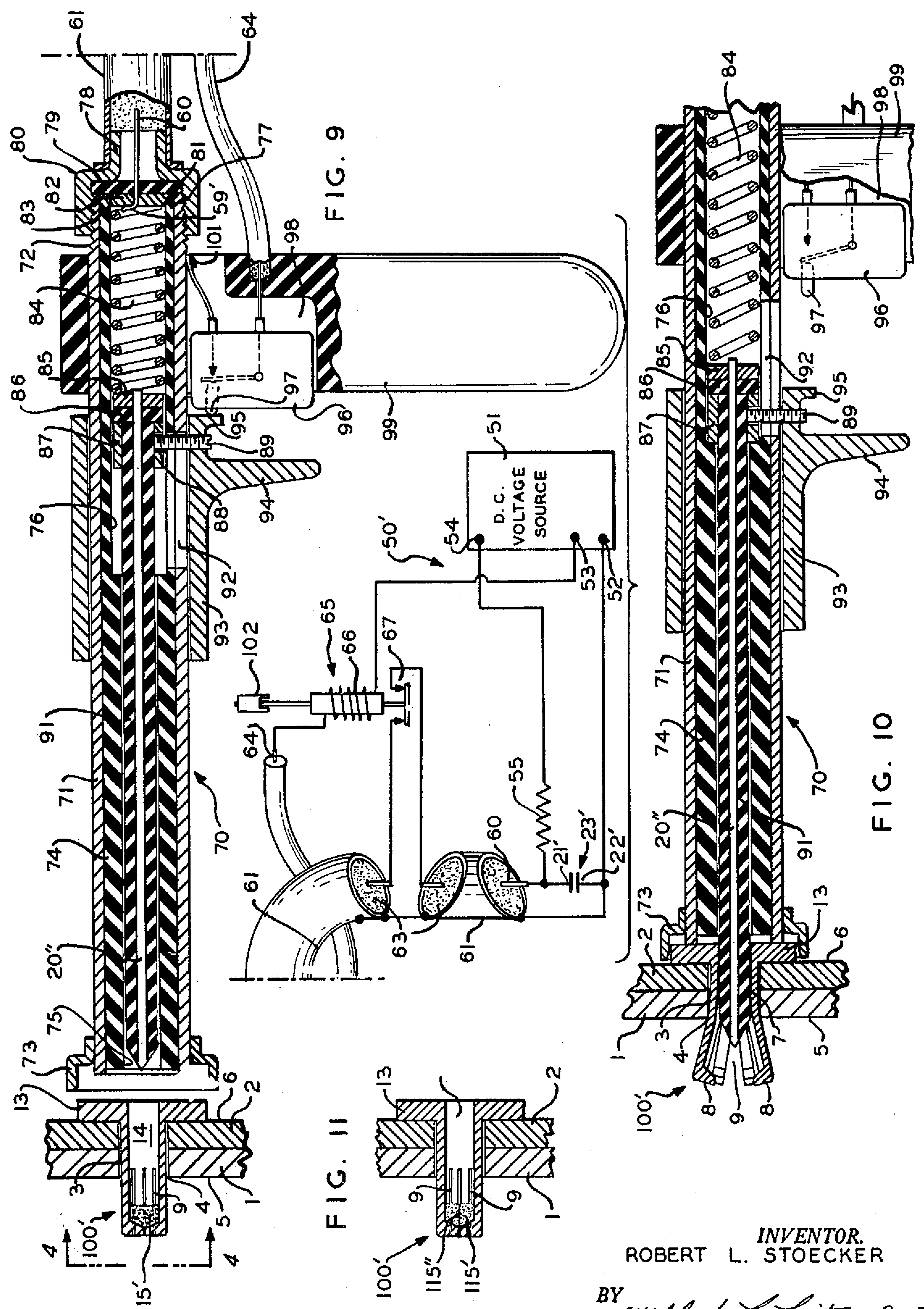

FIG. 9

FIG. 10

FIG. 11

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RIVETING BY ELECTRIC DISCHARGE

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This invention relates to riveting by electric discharge. It is especially concerned with improved methods and apparatus useful in blind riveting—i.e., the riveting of work of which one surface is exposed but the other is concealed or is at least inaccessible. This application is a continuation-in-part of my prior and copending application Serial No. 71,324, filed November 23, 1960.

Various methods of blind riveting, utilizing rivets of generally cup-like form, have heretofore been proposed. In one method there is placed at the inner extremity of the rivet cavity a charge of explosive which, after the rivet is seated in its aperture in the work to be riveted, is suitably provoked into explosion—i.e., the violent chemical reaction which gives that class of substance its name—to expand the inner portion of the rivet. In another method there is introduced into the rivet cavity an electrode which will carry to the far end of the rivet an electric current sufficient to melt that end region and thus to permit its material to flow into a new and presumably transversely enlarged configuration. Among still other methods are purely mechanical ones.

Each of these proposed methods, however, has involved some serious disadvantage or disadvantages. For example, the method involving explosives suffers from the obvious disadvantage of hazard, not merely as to each of the individual rivets but also as to their collective storage and transport. In the melting method there is the difficulty of control over the direction of flow of the melted material. In both the melting and various mechanical methods there is the unlikelihood of final significant clamping or binding pressure on the work longitudinal of the rivet. In some mechanical methods there is required the use for each rivet of a new tool which will be destroyed in the process of setting that rivet—and so on.

It is an object of my invention to provide a method of riveting, which may be blind riveting, which is free of the hazard inherently present in the use of explosives. It is an object to provide a method which imposes no need for special measures to control the direction of flow of material. It is an object to provide a method by the use of which there is developed a final large clamping or binding pressure, longitudinal of the rivet, on the work. It is an object to provide a method which, practiceable in an elementary manner essentially without any apparatus at all, also lends itself to a highly efficient manner of practice with a simple, single and permanent tool.

It is an object to provide a method of riveting, permissibly blind riveting, by the use of which there is developed not only a final large binding pressure longitudinal of the rivet on the work, but also a highly advantageous final substantial pressure of the wall of the rivet against confines of the aperture in which the rivet has been set.

It is a general object to provide a simple, inexpensive and otherwise improved method of riveting.

It is an object to provide a simple and otherwise improved means for deforming a rivet into highly effective relationship to work, of which one face may be concealed or inaccessible.

It is another object to provide a simple, inexpensive and otherwise improved rivet adapted to be blindly set into highly effective relationship to such work.

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Other and allied objects will appear from the following description and the appended claims.

In practicing the methods and in utilizing the means according to my invention I make use of the pressure developed, within matter inert as to chemical explosion, by the disruption thereof occasioned by effecting the abrupt discharge of a quantity of electricity therethrough. Typically and preferredly the discharge will be the discharge of an electrical capacitor previously charged to a voltage more than sufficient to effect the electric breakdown of that matter. Typically the discharge is an arc discharge.

There is of course already known the broad concept of metal deformation by discharge of a charged electrical capacitor. I have found, however, that in the setting of rivets this broad method of metal deformation produces unexpected advantageous results, beside affording exceptional simplicities. And my invention of course further involves various more specific features not at all contemplated or disclosed by the capacitor-discharge metal-deformation art of which I am aware.

In the description of my invention hereinafter set forth reference is made to the accompanying drawing, in which:

FIGURE 1 is a view, partly in vertical cross-section and partly in elevation, illustrating an elementary manner of practicing my invention;

FIGURE 2 is a cross-sectional view of the rivet of FIGURE 1 after its having been set;

FIGURE 3 is a view, partly in vertical cross-section and partly in elevation, illustrating an elementary alternative manner of practicing my invention;

FIGURE 4 is an enlarged elevational view of the end of the rivet, taken along the line 4—4 of FIGURE 3;

FIGURE 5 is a cross-sectional view of the rivet of FIGURE 3 after its having been set;

FIGURE 6 is an enlarged elevational view of the end of the set rivet, taken along the line 6—6 of FIGURE 5;

FIGURE 7 is a cross-sectional view of a tool which may be used for the more efficient practice of my invention in one manner, the tool being in position close to but still out of contact with the rivet to be set, together with a schematic diagram of the power supply to which that tool may be connected;

FIGURE 8 is a view similar in nature to part of FIGURE 7 but illustrating the tool and rivet immediately after the latter has been set;

FIGURE 9 is a cross-sectional view of a tool or gun which may be used for the more efficient practice of my invention in an alternative manner, the gun being in position close to but still out of contact with the rivet to be set, together with a schematic diagram of the power supply to which that gun may be connected;

FIGURE 10 is a view similar in nature to part of FIGURE 9 but illustrating the gun and rivet immediately after the latter has been set; and

FIGURE 11 is a cross-sectional view of a rivet generally similar to that of FIGURE 9 but illustrating a modification of my invention in respect to the loading of the rivet.

A typical rivet with which my invention may be practiced appears as **10** in FIGURE 1. It may be considered as generally cup-shaped, having the relatively thin side wall **12**, a "bottom" (in cup terms) end **11**, a flare or flange **13** at the "upper" end, and a cavity **14**. In FIGURE 1 the rivet is illustrated as having been already seated in an aperture **3** in work which may for example comprise inner and outer vertically disposed flat sheets, **1** and **2** respectively, of metal which are to be riveted together—the rivet, however, not yet being set (i.e., expanded into final binding relationship to the work) in that aperture. The rivet and its cavity are elongated (relative to most typical cup proportions) so that when the rivet is seated (i.e., when its flare 13 rests against the exposed face 6 of the work) the cavity 14 extends substantially beyond the inner or concealed face 5 of the work. The rivet will be of electrically conductive material having good ductility or at least exhibiting that characteristic under the impulsive action described below.

It may be appropriate here to stress that there is intended no limitation of the flare of the rivet to a flat flange such as shown in FIGURE 1. Thus by way of alternative example FIGURE 3 (the showing of which is hereinafter detailedly discussed) shows a different form of flare in a rivet which of course may still be characterized as generally cup-shaped. The priamry function of the flare, of whatever form, is of course the provision on the rivet of a shoulder or equivalent surface which will finally exert an inward force on the exposed face 6 of the work in opposition to an outward force to be exerted on the concealed face 5 as will be hereinafter described. Indeed, it is to be understood generally that the rivet may be altered within wide limits in respect of shape, proportions, etc. without defeating the applicability of my invention to the task of setting it.

The setting of the rivet by electrical-capacitor discharge in accordance with my invention contemplates the presence within the rivet cavity 14 of matter of some kind, inert as to chemical explosion but susceptible of electric disruption—and, preferably, of which undisrupted portions will serve effectively to transmit to the cavity wall pressure developed by the disruption. If the cavity be open at its outer end, as is true of the rivets above described, the cavity in the absence of special measures will initially contain air, and this is within the broad range of cavity contents which can be used in the practice of my invention. It is, however, true that the electric disruption of air requires relatively high voltages; it is furthermore true that the pressure-transmitting effectiveness of the undisrupted portions of an air cavity content is not as great as that characterizing some other forms of matter. Choice of preferred matter for presence in the cavity is more fully discussed near the end of this description; it will here be convenient to mention, as a simple initial example of preferred cavity contents, a loading of wax—of viscosity such that it is capable of being displaced under relatively light pressure but in the absence of pressure will remain in its position throughout various orientations of the rivet—into which has been mixed a quantity of common salt (NaCl) to lower its dielectric strength appropriately.

In carrying out my invention as contemplated in the illustration of FIGURE 1, a loading 15 of matter such as just described may be inserted into the cavity 14, initially almost but not necessarily completely filling the cavity. The insertion of the loading into the cavity is usually most conveniently carried out before the seating of the rivet in the aperture 3, though it may if desired be performed thereafter.

With the rivet resting in seated position in the aperture, I effect between points within the rivet an abrupt electric discharge through the cavity contents disposed between those points, disrupting such contents along the line taken by the discharge. Conveniently and desirably, though not indispensably, one of those points may be some point on the bounding surface of the cavity, and this is contemplated in the showing of FIGURE 1—the discharge therein being effected with the aid of a simple electrode introduced into the cavity, preferably approximately centrally thereof, to the other of the two points first mentioned above. Thus FIGURE 1 shows an electrode 20 in the form of a hard straight wire, for example of tungsten, of which the lefthand end portion is surrounded by a sheath 19 of insulation starting just to the right of the very extremity of the electrode; this lefthand end portion may be introduced approximately centrally

of the cavity to a point 16 therein which lies preferably within but relatively near the inner limit of the aperture 3 in the work. In the case of the loaded rivet of FIGURE 1 the introduction of the electrode may displace some of the material of the loading 15, and even though the cavity was not initially quite filled by the loading it may be assumed to be substantially filled after the introduction of the electrode.

The work of the rivet deformation to be performed by the discharge is of course inherently limited in magnitude, and furthermore its effective performance depends on initial abruptness of the discharge; it is accomplished in an extremely minute interval of time. It is therefore wholly unnecessary—and for obvious practical reasons of preservation of the rivet and work against destruction, safety to the operator, conservation of power consumption and the like it is altogether undesirable—that the discharge persist for any extended period of time. It is accordingly desirable that the quantity of electricity discharged be a pre-established quantity only—such as that stored in an electrical capacitor previously charged to a suitably selected voltage.

Accordingly in FIGURE 1 the other (righthand) end of the electrode 20 is shown as being in slight spaced relation to and above the lefthand lug 21 of a capacitor 23, of which the righthand lug 22 is connected to the rivet (for example through conductor 24 to the work portion 2 and through the latter to the rivet). The capacitor will have been charged to a voltage more than sufficient, when applied between the point 16 and rivet 10, to effect the electrical breakdown of the loading 15. Thus to effect the discharge, after having manipulated the electrode to the position in which it is illustrated in FIGURE 1, it is necessary only to lower its righthand end into contact with the lug 21. A generally cylindrical block 18 of insulating material secured about the electrode is shown as a finger piece by which the electrode may be manipulated in these manners.

The arc discharge effected as a result of bringing the electrode into contact with the lug 21 is an arc which disrupts the material of the loading 15 along the line taken therethrough by the discharge; under the circumstances illustrated in FIGURE 1 this line will be from the exposed lefthand tip end of the electrode 20 to some point on the side surface of the cavity (i.e., on the inner surface of the rivet wall 12) generally opposite that tip end. This disruption creates within the affected portion of the material an extremely sudden burst of energy, the expansive force of which is transmitted through the remaining portion of the material—and through any other matter which may be present in the cavity—to the entirety of the bounding surface of the cavity.

It is true that as shown in FIGURE 1 that bounding surface is discontinuous—i.e., the cavity is to a considerable extent open—at the outer end; the expansive force is so strong and abrupt, however, that it does its work on the various areas of the cavity surface with relatively little wasteful dissipation outwardly through the opening afforded at the outer end of the rivet. It is further true that the path of the discharge is not symmetrically positioned within the cavity, either longitudinally (which, of course, it cannot be, in view among other things of the inherent dissimilarity of the inner and outer end portions of the cavity) or even transversely (since it will occur to some one peripheral point or region on the side surface); I have, however, observed that notwithstanding these facts the effect of the energy burst is not only a highly useful one for its purpose in its longitudinal-distribution aspect, but also in its transverse-distribution aspect is remarkably close to symmetrical about the rivet axis.

There are some indications that the expansive force may consist of two components: the first, a high-intensity shock wave representing a tremendous compression of an extremely rapidly widening but always thin "shell" within the material; the second, an also tremendous, but relatively general and not thin-shelled, compression of the material outwardly against the boundary of the cavity. Whatever its precise nature may be, however, I have found that the expansive force generated as above described has served—as illustrated in FIGURE 2—both to create in the wall of the rivet a bulge 17 which exerts a longitudinal force component as well as a transverse one on the inner rim 4 of the aperture, and further to expand the wall of the rivet within the aperture 3 into a state of pressure against confines of the aperture—e.g., against the periphery of the aperture in the inner portion 1 of the work and in part of the outer portion 2. I have further found that the force components exerted by the bulge on the rim 4, and the state of pressure of the expanded wall against confines of the aperture, are continuing phenomena.

The inner rim 4 of the aperture is effectively a part of the inner face 5 of the work as well as being a part of the aperture 3, and accordingly the effect of the longitudinal force component thereon is to exert an outward pressure on the inner face 5 in opposition to the inward force exerted on the exposed face 6 by the flare 13 of the rivet—i.e., to effect a clamping of the work between the bulge and the flare. The effects of the transverse force component on the rim 4 are to preclude the rivet from "working" laterally within the aperture, and to minimize tendencies of the two portions of the work to "creep" transversely (i.e., in a direction parallel to their faces) relatively to each other. In these functions the transverse force component on the rim is aided by the expansion of the rivet wall into a state of pressure against confines of the aperture, which expansion and state of pressure in this case extend to be effective on those confines to a substantial longitudinal extent within the outer workpiece 2 as well as throughout the inner workpiece 1.

In the method above described with reference to FIGURES 1–2 the arc discharge is brought about by suddenly applying a suitable electric charge to an already positioned electrode. FIGURES 3–6 illustrate an alternative method of bringing about the discharge. They also illustrate the use of a rivet altered from that of FIGURES 1–2 in respect of the continuity of its inner end portion and in the nature of the bulge which will be produced by the discharge—and, for the primary purpose of showing the independence of my invention from specific rivet shapes, a different form of rivet flare.

Thus the rivet of these figures, designated as 10′, may have a flare in the form of truncatedly conical flange 13′ (for the receiving of which the exposed face 6 of the work will desirably be conically countersunk around the aperture, as indicated at 6′). The more basic alteration of the rivet 10′ from the rivet 10 of earlier figures is effected by the making of a number (for example, three) of very thin (for example, several mils thick only) longitudinal cuts through the rivet, preferably in planes each containing the rivet axis, from the inner end of the rivet for a distance outwardly, preferably to limits which when the rivet is seated will lie within the aperture 3 but relatively near its inner extremity; the effect of the making of these cuts is to create within the rivet wall and inner end a double number of slits 9 converging at the center of that inner end, as best seen in FIGURE 4, though leaving the inner end of the rivet and of its cavity still substantially closed and well proofed against loss of the loading therethrough.

In conformity both with the now-less-resistive rivet structure and with the altered method to be used in bringing about the arc discharge the loading of the rivet, which may, for example, be with the same material as in the case of FIGURES 1–2 but is now designated at 15′, may be confined to a region of the cavity adjacent the inner end—for example, from the inner end for a distance somewhat less than the diameter of the cavity. As before there will be employed the capacitor 23, again charged to a voltage more than sufficient when applied between a point in the loading and the rivet to effect the electrical breakdown of the loading, and against having its righthand lug 22 connected to the rivet as by the conductor 24 and the outer work portion 2.

In this case, however, before the introduction of the electrode into the cavity, or at least before its lefthand end comes into proximity with the loading 15′, its righthand end will have been brought into and thereafter maintained in contact with the lefthand lug 21 of the charged capacitor. While this contact is still being maintained the electrode will be moved progressively leftwardly, preferably substantially centered transversely of the cavity, FIGURE 3 illustrating the electrode at an intermediate position in the course of this movement. When the lefthand end of the electrode has reached at least the very close vicinity of the loading 15′ (the exact point depending on various parameters including the dielectric constant of the loading material) there will occur an abrupt discharge from the tip of the electrode to and through the loading—in this case to some point or region on the end surface of the cavity.

Again the discharge is an arc the effect of which is to disrupt the material of the loading along the line taken therethrough by the discharge, though that line has been seen to be specifically repositioned from that taken through the material of earlier figures. Again the disruption creates within the material an extremely sudden burst of energy, the expansive force of which is transmitted through the material. In this case, however, because of the limitation of quantity of the loading and because of the presence of the slits 9, the effect of that force will be principally confined to the several "jaws" 8 which have been formed by and between the slits 9.

The typical effect of the expansive force on the rivet 10′ is illustrated in FIGURES 5 and 6. As seen therein, that force has served to rock each of the jaws 8 away from the rivet axis, generally in the manner of causing each of them to pivot first about a bending region 7 at the outward extremity of the slits 9, and then to pivot further about the inner rim 4 of the aperture 3. The main part of each of the jaws 8 is of course a part of the rivet wall 12, and thus again it may be considered that in the rivet wall there has been created a bulge—though of course in this case the bulge is not reentrant to the original rivet configuration, and is peripherally interrupted by the now-triangularly-widened slits 9. Again the bulge exerts a longitudinal force component as well as a transverse one on the inner rim 4 of the aperture—through the further action, of earlier figures, of expanding the wall of the rivet within the aperture (i.e., substantially outwardly of the rim 4) is not usually performed to a very appreciable extent—and again those force components on the rim 4 are continuing phenomena.

It may be mentioned that the failure to effect any expansion at all, at a rim or otherwise, of the FIGURE 3 rivet within the portion 2 part of the aperture 3 is effectively substituted for, in preventing rivet "working" and work-portion "creeping," by the truncatedly conical flare 13′ and its seating against the corresponding countersinking at 6′ of the exposed face of the work.

From the figures (2, 5 and 6, as well as others not yet described) illustrating the loaded rivet after it has been set in the work by the discharge there has been omitted any showing of remnant material of the loading (15 or 15′). This has been purely for simplicity of illustration, and is not to be taken as implying that there will not be remnant material. There will be, since the breakdown will have consumed or altered the state of only a modest portion of the loading, the rest of which will have served the function of pressure transmission and may be harmlessly and unimportantly left within the rivet cavity (FIGURE 2) or at least partially adhering to the inner surfaces of the jaws 8 (FIGURES 5–6).

While the general method of my invention may indeed be carried out in various manners, such as those described above, without the aid of apparatus specially adapted thereto, nevertheless its practice can by the use of such apparatus be made more facile, safer for the operator, and more efficient. In FIGURES 7–8 and in FIGURES 9–10 I have shown two embodiments of such apparatus, and these may now be described.

Attention is first invited to FIGURES 7 and 8. Herein the rivet has the fully closed inner end of the FIGURE 1 rivet **10** yet, by way purely of example, has the truncatedly conical flare **13′** of the FIGURE 3 rivet **10′**; it is designated as **100**, and may, of course, be initially seated in the aperture 3 in the work 1—2 just like the rivet **10′** of FIGURE 3. It may be provided with an almost-full loading **15** of material, quite analogously to the rivet **10** of FIGURE 1. In these figures the apparatus specially adapted to the practice of my invention comprises a tool, designated generally as **30**, which may be manipulated in the vicinity of the rivet; a relatively stationary power supply, designated generally as **50**; and suitable cabling interconnecting that tool and that power supply. The functions of the tool, beside effecting an essentially complete closing of the rivet cavity, are those of aptly positioning the electrode both transversely and longitudinally of the cavity, and of controlling the supply of energy to the electrode; the tool may be most conveniently described starting with the electrode, which is centrally contained therein.

The electrode, designated as **20′**, may again typically be of material such as tungsten. It is surrounded by and secured in a relatively thick sleeve **31** of insulating material, which in turn is surrounded by and secured in a metallic jacket **33**. The outer (lower-shown) end of the electrode projects below the outer end of the jacket **33** by just the distance by which the electrode is to penetrate into the cavity **14** of the rivet; this is desirably a distance such that when the jacket **33** is brought into contact with the outer face of the rivet, the tip of the electrode will have been brought to a point within the cavity which lies within but relatively near the inner limit of the aperture **3** in the work. Immediately adjacent the jacket **33** the outer end of the sleeve **31** may be slightly inset, so as to insure that it will not interfere with intimate contact of the jacket 33 with the rivet; in its central portion, however, the sleeve **31** is provided with an outward extension **32** about the electrode, of diameter just freely to fit within the cavity **3**. The outward extent of this extension is desirably such as to bring its extremity, when the jacket **33** is brought into contact with the rivet face, only partially within the work-portion **2** part of the aperture **3**—i.e., to leave free of insulation the major part of the longitudinal extent of the cavity which lies within the entire aperture **3** of the work. The inner extremities of the jacket **33** and sleeve **31** may be substantially in alignment with each other, but the inner extremity of the electrode **20′** will extend slightly beyond that of the sleeve.

In its longitudinally central region the jacket **33** may be provided with an enlarged-diameter portion **35**, and inwardly beyond that portion it may be provided with external threading **37**. Onto this threading, though not fully into abutment against the shoulder **36** formed at the inward extremity of the central portion **35**, may be screwed an internally threaded metallic cap **40**, the central portion of which is formed into a reduced-diameter extension **38** directed away from the electrode, jacket and sleeve. In the space between the latter and the main part of the cap, and lying against the shoulder **39** of the cap formed between its threading and the cap extension **38**, there may be positioned a disc **41** of insulating material; through this disc there may project toward the electrode the extremity **59** of a cable conductor **60** hereinafter more fully referred to—that extremity being for example folded over against the disc, and being held in tight contact with the inner end of the electrode when the cap is screwed in place on the jacket.

The portions of the tool **30** thus far described will be recognized as not only a cavity-closing and electrode-positioning means, but as also a means for detachably securing the electrode in electrically connected relationship to the cable conductor **60**. The other extremity of the cable conductor **60** lies in the power supply **50**; there it serves to connect (subject to a control hereinafter described) the electrode with one terminal **21′** of a capacitor **23′**, of which the other terminal **22′** is connectible to the rivet in manner described below.

In the power supply there is comprised a D.C. source **51** of appropriately high voltage for charging the capacitor **23′**, the grounded (or groundable) terminal **52** of the voltage source being connected to the capacitor terminal **22′**, and the high-voltage terminal **54** of the source being connected to the capacitor terminal **21′** through the charging resistor **55**. It will be understood that the source will keep the capacitor charged through the resistor at all times excepting through each minute interval during which the capacitor is being discharged through the cable conductor **60** and through a brief recovery period (whose duration is, of course, established by choice of the value of the resistor) immediately following each such discharge.

For the purposes of my invention the effectiveness of the arc discharge of the charged capacitor is a function not only of the energy content of the charged capacitor, but also of the abruptness with which that energy is released through the discharge—i.e., the shortness of the period of time within which the discharge will be substantially completely effected. That abruptness is militated against the resistance, and even more by any inductance, effectively present in the series circuit through which the discharge occurs. It is true that the resistance effectively present in that circuit is usually most importantly contributed to by the effective resistance of the path of the arc proper, so that more than ordinary measures to reduce the resistance of conductor portions of that circuit are not called for. There exists, however, no such pragmatic limitation on the worth of minimizing to the greatest extent possible the effective inductance.

Even small values of effective inductance, although allowing the discharge to remain aperiodic as it should be, nevertheless lengthen the duration of its single pulse, while higher values not only lengthen that pulse further but when great enough render the discharge oscillatory—i.e., cause some of the energy to be withheld from the already-slowed initial pulse and to be released only in successive pulses of alternating directions—all to the serious detriment of the desired abruptness. In the preferred practice of my invention I minimize the inductance as much as possible—with a high preference, at least to the point of insuring aperiodicity of the discharge, and very desirably as much further as can be practically achieved.

This minimization may be accomplished by employing for the circuit from the capacitor to the electrode and rivet—or, stated reversely, for the circuit from electrode to rivet via the capacitor—a pair of coaxial conductors. Accordingly, in FIGURE 7 I have shown the conductor **60**, leading from electrode to capacitor terminal **21′**, as forming the inner one of a pair of such conductors, of which the outer one is a tubularly formed conductor **61**—the space between the conductors being filled with any suitable insulation **63**. To preserve the coaxiality of the circuit right to the electrode and rivet, the tubular conductor **61** may be mechanically and electrically connected to the cap extension **38**—it of course being readily observable that the cap, and the jacket **33** to which it in turn is mechanically and electrically connected, are in coaxial relationship to the electrode **20′** to which the conductor **60** is electrically connected as above described. The connection of the tubular conductor **61** to the cap extension **38** is readily effected by fitting the former about the latter with a slight flare as indicated at **62**, and for example soldering the flare to the exterior of the main part of the cap 40.

The connection from the capacitor terminal 22' to the rivet, above described as far as the jacket 33, is of course completed between the outer end of that jacket and the outer face of the rivet by the physical contact of those two elements effected by movement of the tool 30 to bring the electrode 20' into its above-described operative relationship to the rivet.

It is desirable that, as an adjunctive action to bringing the electrode into that operative relationship and completing the connection of capacitor terminal 22' to the rivet as just described, there be brought about the completion of the circuit from the capacitor terminal 21' to the electrode—which circuit it is desirable to maintain normally open. These two desderata are jointly accomplished by inserting into the conductor 60, within the power supply 50, the normally open contacts 67 of a relay 65 of which the coil 66 is arranged to be energized to close contacts 67 as such as adjunctive action. To accomplish such energization of the coil 66 it may be connected between a relatively low-voltage terminal 53 on the voltage source and a conductor 64 leading to the tool 30 and therethrough to a contact carried by that tool which is arranged to be automatically connected with the terminal 52 of the voltage source following the act of bringing the electrode into operative relationship to the rivet and completing the connection of the capacitor terminal 22' to the rivet.

To provide for the contact just mentioned the tool 30 may include, in freely surrounding relationship to the jacket 33 and the cap 40 and the outer end portion of the cable formed by the coaxial conductors 60 and 61, a cylinder 42 of insulating material. Through most of its length from its outer end inwardly this cylinder may be provided with an axial bore 43 just freely accommodating the jacket 33 and cap 40, and of a length somewhat greater than the combined length of those elements. Communicating with this bore 43 and passing through the remainder of the cylinder may be a somewhat smaller axial bore 45, between which the bore 43 there intervenes the shoulder 44, the outer end portion of the cable 60—61 lying partially within the bore 43 and partially within the bore 45. Within the bore 43 in surrounding relationshp to that cable portion there may be provided a helical compression spring 46 whose extremities bear respectively on the shoulder 44 and on the main portion of the cap 40 (permissibly through the flare 62 of the tubular conductor 61). The spring 46, of course, biases outwardly of the cylinder 42 the assembly consisting of the jacket, the cap, the end portion of cable 60—61 and the electrode 20' insulatedly carried within the jacket. A limit for the response of this assembly to this bias may be provided by one or more screws 47 threaded radially through the cylinder 42 near its outer end to extend slightly into its bore 43, there to intercept and be impinged on by the shoulder 34 forming the outer extremity of the enlarged central portion 35 of the jacket 33. This limit may establish a normal position, for the assembly relative to the cylinder, wherein the jacket 33 will extend a short distance outwardly from that cylinder.

The contact above discussed and to which the conductor 64 will be electrically connected may be formed by the outer extremity of a suitable stiff wire 49 passing, for example slightly diagonally, from a short distance outwardly of the outer extremity of the cylinder 42 through the cylinder to a region 48 therewithin relatively near the inner (upper-shown) extremity of the cylinder. This region 48 may form the inner end portion of a radial bore 69 in the cylinder, and from it to the inner cylinder extremity there may extend a further and stepped bore 68. The conductor 64 may extend into the bore 68 to overlap the wire 49 in the region 66, there to be clamped against that wire by the screw 69' threaded into the radial bore 69.

The point of emergence of the wire 49 from the cylinder may be close enough to the cylinder axis so that the contact formed by its extremity will be aligned with a marginal portion of the rivet face when the sleeve extension 32 is aligned with the rivet cavity 14. The distance of extension of the wire 49 outwardly from the cylinder will, however, be somewhat less than the normal such distance of the jacket 33; thus when the tool is manipulated merely to bring the end of the jacket into contact with the rivet (and the sleeve extension into the rivet cavity and the electrode into its operative position) the contact formed by the outer extremity of wire 49 will still be free of electrical connection with the rivet face. But if thereupon pressure toward the work be exerted on the cylinder 42, the spring 46 will be compressed and the cylinder and contact will move toward the work until the contact touches the rivet face—thereupon completing the circuit for energization of the coil 66, from that coil through the conductor 64, the wire 49, the rivet face, the jacket 33 and cap 40, and the conductor 61 to the grounded source terminal 52.

FIGURE 7 has illustrated the condition of the apparatus at a late point in the movement of the tool toward its final operative position. FIGURE 8 illustrates the condition immediately following the completion of that movement, and of the further movement of the cylinder 42 just described as serving to energize the coil 66. That energization will have caused the closure of the switch formed by the contacts 67 (which, although not appearing in FIGURE 8, would if appearing be shown closed), thus completing the connecting of the charged capacitor between the electrode and the rivet (analogously to the lowering of the electrode 20 into contact with the capacitor terminal 21 in the case of FIGURE 1) and bringing about the disruptive discharge of the capacitor through the loading 15. That discharge will in turn have brought about the setting of the rivet; that setting will be quite analogous to the setting of the rivet 10 in the case of FIGURE 1, with two exceptions. One is that the expansion of the rivet wall 12 into contact with confines of the aperture 3, though occurring as previously within the work-portion-1 part of the aperture, will have been precluded by the truncatedly conical flare from extending into the work-portion-2 part; that is a difference from which any unfavorable effects are precluded (as above brought out in a rather similar connection in the case of FIGURE 3) by the action of that flare itself in cooperation with the associated counter-sinking of the work face 6. The other exception is that the essentially complete closing of the rivet cavity 14 prior to the occurrence of the arc discharge will have created a slightly more efficient set of conditions, either resulting in the formation of a slightly greater bulge 17, or permitting the use of slightly less energy for the discharge, or the like.

It will be appreciated that the use of the specially adapted apparatus of FIGURES 7–8 carries out the method of my invention in a specific adaptation of the manner broadly disclosed in connection with FIGURES 1–2. FIGURES 9–10, to which reference is now invited, show specially adapted apparatus whose use carries out the method in a specific adaptation of the manner broadly disclosed in connection with FIGURES 3–6.

In FIGURES 9–10 the rivet is shown as having the thinly slitted inner end of the FIGURE-3 rivet 10' yet, by way of example, the flat flare 13 of the FIGURE-1 rivet; it is designated as 100', and may be provided with the limited loading 15' of material quite analogously to the rivet 10' of FIGURE 3. In these figures the apparatus specially adapted to the practice of my invention comprises a tool or gun designated generally as 70; again a power supply, which may be generally like that of FIGURE 7 but is designated generally as 50' because of one specific elaboration; and again cabling 60—61 and 64 interconnecting the tool or gun 70 and the power supply.

The gun 70 may be most conveniently described starting with its main exterior member. This may be a relatively long metallic barrel 71, for example of diameter slightly less than the outer diameter of the rivet flare. Secured immediately within the barrel may be a lining cylinder 74 of insulating material, having throughout a little over half its length starting with its outer (left-shown) end a bore 75 identical with that of the rivet cavity; its bore 76 throughout the remainder of its length may be somewhat enlarged. The outer extremity of the lining cylinder 74 may be slightly inset relative to that of the barrel 71; the opposite extremities of the two may, for example, be flush with one another.

At the last mentioned extremity of the barrel 71 the barrel may be provided with external threading 72; onto this threading may be screwed an internally threaded metallic cap 80, the central portion of which is formed into a reduced-diameter extension 78 directed away from the barrel. In the space between the extremity of the barrel (and lining cylinder) and the cap, and lying against the shoulder 79 of the cap formed between its threading and the cap extension 78, there may be positioned a disc 81 of insulating material; through this disc there may project to within the lining cylinder the end portion 59′ of the cable conductor 60, which conductor may be identical with that in FIGURE 7. In this instance the end portion 59′ may pass on through and be folded over against the surface of a metallic disc 82, whose periphery 83 may be bevelled to rest against corresponding bevelling 77 on, and just within the extremity of, the lining cylinder 74; the folded-over end portion 59′ of the conductor may be soldered or otherwise secured to the surface of the disc 82.

Within and having a free fit to the bore 75 there may be carried a sleeve 91 of insulating material, centrally within which is imbedded or otherwise secured the electrode 20″, again for example of tungsten wire. At their outer extremities the sleeve and electrode may for example be unitarily formed into a conical shape. FIGURE 9 illustrates the sleeve and electrode as inwardly withdrawn into the lining cylinder 74, for example so that the outer extremity of the electrode is just flush with the outer extremity of that cylinder; under these conditions the electrode will extend for a substantial distance into the enlarged bore 76 of the cylinder.

Closely adjacent its inner extremity the electrode may have secured thereon in flange relationship thereto, as by welding, the metallic disc 85; immediately outwardly of this disc, and lying thereagainst, there may be fitted about the electrode the insulating disc 86—it being into contact with this insulating disc that the insulating sleeve 91 extends. In turn just outwardly of the insulating disc 86 there may be secured about the sleeve 91 a collar 87, for example of metal. The diameters of discs 85 and 86 and of collar 87 will, of course, fit freely within the enlarged bore 76. The entire assembly of electrode, sleeve, discs and collar will be urged outwardly by a fairly powerful helical compression spring 84 contained within the enlarged bore 76 between, and having its extremities bearing against, the discs 85 and 82. The spring 84 will also serve electrically to interconnect those discs, and thus to connect the electrode with the conductor 60.

To arrange for externally controllable longitudinal movement of the internal assembly of electrode, sleeve, discs and collar, there may extend freely into a hole 88 in the wall of the collar, and freely through an elongated aperture 92 in lining cylinder 74 and barrel 71, a screw 89 threaded inwardly through a cylinder 93 which surrounds and is freely slidable along the barrel 71—the effect of the screw 89 being to interlock that assembly and that slidable cylinder as to longitudinal movement. FIGURE 9 illustrates that assembly and that cylinder as being held, against the force of the compressed spring 84, in a retracted position; such holding may be accomplished by outward finger pressure on a finger piece 94 extending for example downwardly from the cylinder 93. To facilitate the establishment and maintenance of that finger pressure a handle 99 may be secured about and extend downwardly from the barrel 71 a little inwardly from the retracted position of the cylinder 93.

As its outer extremity the barrel 71 may have secured coaxially thereabout an outwardly extending cup-shaped flange 73 of internal diameter shaped just freely to embrace the flange or flare 13 of the rivet 100′; the outward (i.e., leftward) extent of the flange will be limited so as not quite to abut against the work surface 6 when the outer extremity of barrel 71 is moved into contact with the rivet face and thus so as not to interfere with that contact.

The contemplated manner of mechanically manipulating the gun 70 is to move it, while maintaining the internal assembly and thus the electrode 20″ in retracted position, to bring the flange 73 into surrounding relationship to the rivet flare 13 and the extremity of the barrel 71 into contact with the rivet face—FIGURE 9 illustrating the gun in a position just prior to the completion of this movement—and then suddenly to release the finger pressure from the finger piece 94. Thereupon the internal assembly including the electrode 20″ will be abruptly propelled by the spring 84 into the rivet cavity 14—for a distance fixed by the impactive abutment of the outer end of collar 87 against the shoulder formed within the lining cylinder 74 by the inner extremity of the bore 75.

While the power supply 50′ may be generally like the power supply 50 of FIGURE 7, it is necessary in this case to control it in a somewhat different manner—since it is desired that the potential of the charged capacitor 23′ be already applied to the electrode at the time of release of the finger piece 94. Accordingly instead of an arrangement such as that of the contact wire 49 of FIGURE 7 there may be employed a switch which will be closed, to apply that potential to the electrode, when the internal assembly including electrode 20″ is retracted by finger pressure on the finger piece 94. Such a switch may be conveniently provided, for example by mounting, in a suitable slot 98 formed in the handle 99 immediately underneath the barrel 71, a small normally open switch 96 of encased variety throwable to closed condition, against the force of an internal over-center spring, by light pressure on a limitedly movable plunger 97. This switch may be mounted in the slot in an orientation such that the plunger 97 will be outwardly directed and may be impinged on, when the slidable cylinder 93 is retracted, by a small downward extension 95 formed from that cylinder—the plunger 97, when moved inwardly by the cylinder extension 95, constituting the limiting stop for retraction of the cylinder 93 and the internal assembly including the electrode 20″. One terminal of the switch 96 may be connected to the barrel 71—and therethrough and through the cap 80 and the tubular conductor 61 to the grounded terminal 52 of the power supply—as indicated at 101, while the other terminal may be connected to the outer extremity of the conductor 64 already described in connection with FIGURE 7.

In the illustration of the power supply in FIGURE 9 the contacts 67 of the relay 65 are shown closed; this is appropriate to the energization of the coil 66 taking place in response to the closed condition of the switch 96 which in turn is being maintained by the retracted finger piece 94, and is a condition desired to be continued at least until immediately after the completion of the abrupt prpulsion of the internal assembly including the electrode 20″ which will occur upon release of that finger piece. It will be appreciated, however, that in the absence of appropriate measures the coil 66 will be deenergized, and the contacts 67, therefore, constrained to open, forthwith upon the release of the finger piece. To preclude a premature opening of the contacts 67 the releasing action of the relay 65 may be delayed for a brief interval, following any opening of switch 96, sufficient to allow time for the completion of the propulsion just mentioned. Such a delay may be accomplished in any known manner, typical of which I have shown associated with the armature of the relay an air dash-pot **102** which will freely permit upward movement, but will appropriately retard any downward movement, of that armature.

It will already have been appreciated that in the apparatus of FIGURE 9 the barrel **71** and cap **80** perform the same functions as did jacket **33** and cap **40** of FIGURE 7, the outer tubular conductor **61** of the coaxial pair **60—61** being secured on and electrically connected to the cap **80** in manner quite analogous to that above described in connection with cap **40**.

FIGURE 10 illustrates the condition of the apparatus following the completion of the forward propulsion of the internal assembly including the electrode **20″** and the discharge of the capacitor **23′** to and through the loading **15′** which will of course occur at or minutely prior to that completion of propulsion. The action of that discharge will be fully understood from the above description of action presented in connection with FIGURES 3–6, there being in general only the distinctions that the movement of the electrode is now effected propulsively, at a much more rapid rate, and under uniformly duplicable conditions.

It will be understood that, in distinction to the limited dielectric strength possessed by the loading **15** or **15′** within the rivet cavity, the dielectric strengths of the various insulating members (e.g., sleeve **31**, disc **41**, insulation **62**, etc. in FIGURES 7–8; sleeve **91**, lining cylinder **74**, discs **81** and **86**, insulation **62**, etc. in FIGURES 9–10) which support and insulate the electrode and the conductor **60** in the apparatus of FIGURES 7–8 and 9–10 will each be high.

It is to be understood that the arrangements of apparatus of FIGURES 7–8 and 9–10 and the components thereof are typical only, and may be widely varied or elaborated upon. Simply as one example there may be mentioned the relay **65** which, while for conciseness of illustration shown as of a simple solenoid type (in one case, with mechanically delayed release), may of course be of any appropriate variety—for example, when utilizing quite high voltages, of an ignitron or other high-voltage-switch type (permissibly, in the delayed-release case, with purely electrical or still other release-delay means).

The capacity of the capacitor **23** or **23′** and the voltage to which it will be charged of course determine the energy which is available for release in the discharge of the capacitor—which energy will be understood, in accordance with well-known physical laws, to be proportional to the first power of that capacity and to the second power of that voltage. Choice of the magnitude of that energy, and thus in turn of the capacity and voltage, is determined by such factors as the ease with which the rivet to be set may be deformed, in turn involving the structural strength of its cavity, its ductility, etc.; the abruptness with which the discharge is effected, in turn influence by such factors as the inductance of the discharge circuit, discussed above; the significant losses of discharge energy, which in general are those represented by that serial part of the discharge which may occur not within the material of the loading but instead at the switch contacts in the process of their closure (in the case of the method as typified by FIGURES 1–2) or from the approaching electrode tip to the surface of the material (in the case of the method as typified by FIGURES 3–6); and the choice of the matter forming the contents of the cavity **14**.

I may give the following as examples of typical orders of magnitude of various parameters. With aluminum rivets of essentially maximum available ductility and of the type shown in FIGURES 9–10 and having a wall of approximately 1/32″ in thickness, and with the use of a simple petroleum-derived oil as the material of the loading **15′** (the rivet being seated in a substantially vertical position, as shown for the different form of rivet in FIGURES 7–8, to retain the oil at the inner end of the cavity) I have successfully expanded the rivets to such final state as disclosed in connection with FIGURES 3–6 or 9–10 by the discharge of a 54-microfarad capacitor previously charged to a voltage of 1,000 volts. Again, with rivets of similar material but of the type shown in FIGURES 1–2 and having a wall thickness of approximately 3/64″ and with the use of a saturated solution of common salt (NaCl) in water as the material of the loading **15** (the seating of course again holding the rivet substantially vertical to maintain the filling of the cavity by the material) I have successfully expanded the rivets to such final state as disclosed in connection with FIGURES 1–2 by the discharge of a 154-microfarad capacitor previously charged to a potential of 1,000 volts. The inductance of the discharge circuit has been sufficiently minimized so that the discharges have been aperiodic, and oscillographic observation of their durations has indicated substantial completion of their single pulse in a time period of the order of 50 micro-seconds.

It will already be appreciated that the choice of matter which is to form the contents of the rivet cavity is a very wide one, to say the least. That matter should of course have a dielectric strength low enough so that the voltage required to disrupt it, considered as supplied in the particular manner to the particular configuration of contents which will be used, is less than the voltage to which the condenser will be charged. It may consist of matter commonly considered single in nature, such as the air or the oil mentioned above; alternatively it may consist of a first component to which a second has been added for reduction of an otherwise excessively high dielectric strength (such as the water above mentioned for the FIGURES 1–2 type of rivet, with the addition of common salt). It may be a highly fluid material (such as the salt-saturated water), or a somewhat viscous but still fluid material (such as the oil), when the rivets may always be vertically or near-vertically seated; alternatively, to permit any orientation of the seated rivet, it may be a much more viscous material such as the salt- or otherwise-impregnated wax mentioned early hereinabove or a suitably impregnated grease. When two or more components are used, one or more may be in true solution in the other (such as the salt in the water); alternatively one or more may be merely dispersed through and in suspension in the other (such as the salt in the grease).

When two or more components are used with one or more dispersed in particle form through but not in true solution in the other component or "vehicle," the dispersed one or ones may be chosen to be electrically conductive, such as fine metallic particles; in this case, while some of the breaking down or disruption must and of course will be an arc occurring in the relatively non-conductive vehicle, the disruption considered as an entirety will in large measure include the vaporization, brought about by the momentary gross overheating, of the dispersed conductive particles.

A variation of the subject matter of the preceding paragraph which may be successfully employed is the constitution of the multi-component contents not by one or more components dispersed in particle form throughout the other, but rather by one in a suitably disposed solid and unitary form within the other. This variation I have illustrated in FIGURE 11, which shows a sealed but unset rivet alternative to that of FIGURES 9–10. The basic rivet proper may be quite identical to that of those figures and is, therefore, again designated as **100′**, and in the cavity of the rivet at its inner end may be a quantity **115′**, for example of pure grease or wax, similar in extent to the loading **15′** of those earlier figures—but to it there has been added, extending through it from the central region of the inner end of the cavity, for example to its outer surface, a conductive component 115'' consisting of a fine (for example, about 1-mill) wire. In this case the disruption will comprise principally the vaporization brought about by the momentary gross overheating, of the conductive fine wire 115''. It may be mentioned that the manner of securing this wire at the center of the inner end of the rivet is not critical; the wire may for example be cemented in the "hole" formed by the intersecting slits 9 since the cement, even though initially insulating the wire from the rivet, will of course itself be broken down in the discharge, which preferentially occurs therethrough.

In the FIGURE-11 loading material one of the components is of course wholly solid, and it will be understood that with any of the general categories of cavity contents mentioned above—i.e., whether consisting of a single component, or of a plurality with one or more either dissolved in or dispersed in particle form through the other, or of a plurality with one or more contained in unitary form or forms within the other—the entire contents may, but of course do not need to, be solid.

Disruption comprising vaporization of a solid of course ordinarily consists of two sequential phase changes—i.e., from solid to liquid and from liquid to very hot vapor—of which the second is invariably a useful source of pressure for the practice of my invention. It is however possible, by choice of a loading material which expands substantially in the change from solid to liquid phase, to take additional advantage of the first phase change and thereby to achieve two infinitesimally spaced shock waves instead of one. Typical of materials with which this acton may be achieved are hydrocarbon waxes, particularly those formed as by-products of petroleum-cracking processes. Wax cavity loadings for the practice of my invention therefore preferredly include loadings of such hydrocarbon waxes—permissibly, of course, with the addition of common salt or other agent to accomplish any desired reduction of dielectric strength.

It is my belief that among the aspects of my invention are not only a rivet specially adapted to be blindly set in the work by the abrupt discharge of a quantity of electricity, but also apparatus for deforming an appropriate rivet into effective binding relationship to the work—and true methods of rivet setting, practiceable by hand and essentially independent of specific apparatus.

While I have disclosed my invention with reference to particular examples thereof, I intend no unnecessary limitations thereby. Modifications in many respects will be suggested by my disclosure to those skilled in the art, and such modifications will not necessarily constitute departures from the spirit of the invention or from its scope, which I undertake to define in the appended claims.

I claim:

1. The method of riveting with a generally cup-like electrically conductive rivet whose cavity is elongated to extend through a receiving aperture in, to substantially beyond the inner face of, the work and contains matter inert as to chemical explosion but susceptible of electric disruption, which comprises seating the rivet within the aperture and against the work; and creating in the wall of the seated rivet at least principally beyond the work a bulge exerting both transverse and longitudinal continuing force components on the inner rim of the aperture by effecting between a point within and the side surface of the cavity the abrupt discharge of a previously stored quantity of electricity through and disruptive of said matter.

2. The method of riveting with a generally cup-like electrically conductive rivet whose cavity is elongated to extend through a receiving aperture in, to substantially beyond the inner face of, the work, which comprises seating the rivet within the aperture and against the work; and creating in the wall of the seated rivet at least principally beyond the work a bulge exerting both transverse and longitudinal continuing force components on the inner rim of the aperture by effecting between a point within and the bounding surface of the cavity, through a cavity-contained loading of material inert as to chemical explosion and comprising two components of respectively different electric properties, the abrupt and material-disrupting discharge of a previously stored quantity of electricity.

3. The subject matter claimed in claim 2 wherein a second of said components is dissolved in, and renders the dielectric strength of said material substantially lower than that of, the first of said components.

4. The subject matter claimed in claim 2 wherein a second of said components is dispersed in finely subdivided form throughout, and renders the dielectric strength of said material substantially lower than that of, the first of said components.

5. The method of riveting with a generally cup-like electrically conductive rivet whose cavity is elongated to extend through a receiving aperture in, to substantially beyond the inner face of, the work, which comprises seating the rivet within the aperture and against the work; and creating in the wall of the seated rivet at least principally beyond the work a bulge exerting both transverse and longitudinal continuing force components on the inner rim of the aperture by effecting between a point within and the bounding surface of the cavity, through a cavity-contained loading inert as to chemical explosion and comprising material characterized by substantial expansion in its change from solid to liquid phase, the abrupt and material-disrupting discharge of a previously stored quantity of electricity.

6. In riveting apparatus for use with a generally cup-like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption: means for deforming the seated rivet into binding relationship to the work, comprising in combination an electrode temporarily insertible to within the rivet cavity and at least substantially into contact with said matter; an electrical capacitor; means for charging the capacitor to a voltage more than sufficient, when applied to said matter, to effect the disruptive electric breakdown thereof; and means effective electrically to connect the charged capacitor between the electrode and the rivet.

7. The subject matter claimed in claim 6 further including means fixing the distance of insertibility of the electrode into the cavity.

8. The subject matter claimed in claim 6 further including means secured to the electrode for at least substantially closing the cavity of the rivet when the electrode is inserted into the cavity.

9. In riveting apparatus for use with a generally cup-like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption: means for deforming the seated rivet into binding relationship to the work, comprising in combination means temporarily positionable at least substantially to close the cavity; an electrode carried by said last-mentioned means and arranged for insertion to within the cavity transversely intermediately thereof and at least substantially into contact with said matter; an electrical capacitor; means for charging the capacitor to a voltage more than sufficient when applied to said matter, to effect the disruptive electric breakdown thereof; and means effective electrically to connect the charged capacitor between the electrode and the rivet.

10. The subject matter claimed in claim 9 wherein said temporarily positionable means when positioned at least substantially to close the cavity leaves freely exposed to the matter within the cavity the side surface of the cavity throughout the major part of that portion of its longitudinal extent which is within said aperture.

11. In riveting apparatus for use with a generally cup-

like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption: means for deforming the seated rivet into binding relationship to the work, comprising in combination an electrical capacitor; means for charging the capacitor to a voltage more than sufficient, when applied to said matter, to effect the disruptive electric breakdown thereof; and means for applying the electric charge of the capacitor to said matter, said means comprising a manually manipulable tool having an electrode which is insertible into the rivet cavity and into substantial contact with said matter.

12. In riveting apparatus for use with a generally cup-like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption: means for deforming the seated rivet into binding relationship to the work, comprising in combination an electrical capacitor; means for charging the capacitor to a voltage more than sufficient, when applied to said matter, to effect the disruptive electric breakdown thereof; means for applying the electric charge of the capacitor through said matter, said means including a tool having an electrode positionable at least substantially in contact with said matter; and means carried by, and movable with respect to other portions of, the tool for controlling said charge-applying means.

13. In riveting apparatus for use with a generally cup-like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption; means for deforming the seated rivet into binding relationship to the work, comprising in combination an electrode; a sleeve surrounding the electrode, at least that portion of the sleeve which is immediately adjacent the electrode being of insulating material, the sleeve being provided with an end portion of limited length and of reduced diameter which is adapted to enter and at least substantially to close the cavity of the rivet and which then exposes the electrode within the cavity; an electrical capacitor; means for charging the capacitor to a voltage more than sufficient, when applied to said matter, to effect the disruptive electric breakdown thereof; and means effective electrically to connect the charged capacitor between the electrode and the rivet.

14. In riveting apparatus for use with a generally cup-like electrically conductive rivet seatable within an aperture in the work and whose cavity is elongated to extend substantially beyond the inner face of the work and contains matter inert as to chemical explosion but susceptible of electric disruption: means for deforming the seated rivet into binding relationship to the work, comprising in combination an electrical capacitor to one terminal of which the rivet is electrically connected; means for charging the capacitor to a voltage more than sufficient, when applied to said matter, to effect the disruptive electric breakdown thereof; an electrode, electrically connected to the other terminal of the charged capacitor, temporarily and progressively moveable toward a position whereat it will have reached at least the vicinity of said matter and will have invoked the disruptive electric breakdown thereof; and means effective to align the electrode transversely of the rivet.

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