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HIGH-IMPACT PORTABLE RIVETING APPARATUS

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Fig. 1.

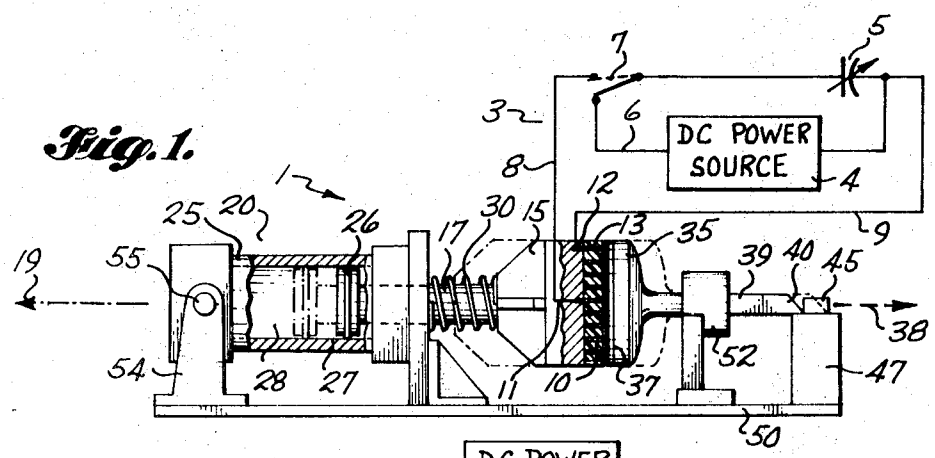


Fig. 2.

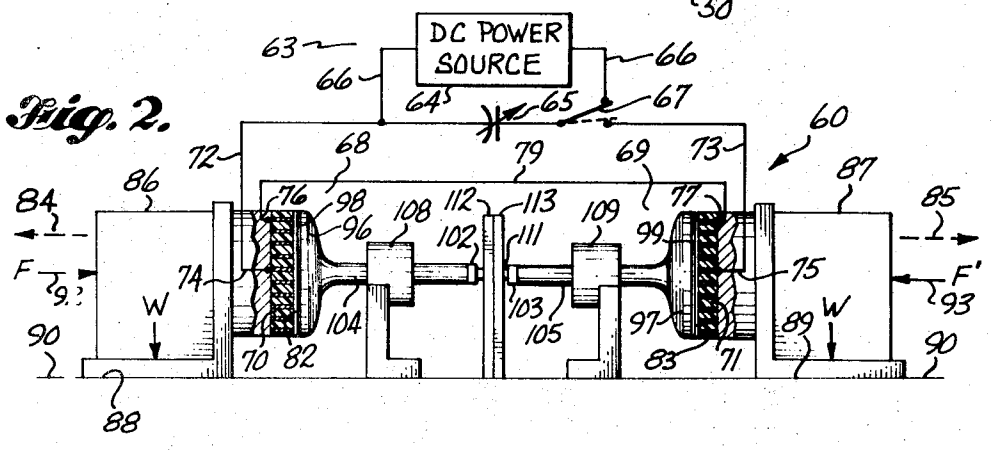
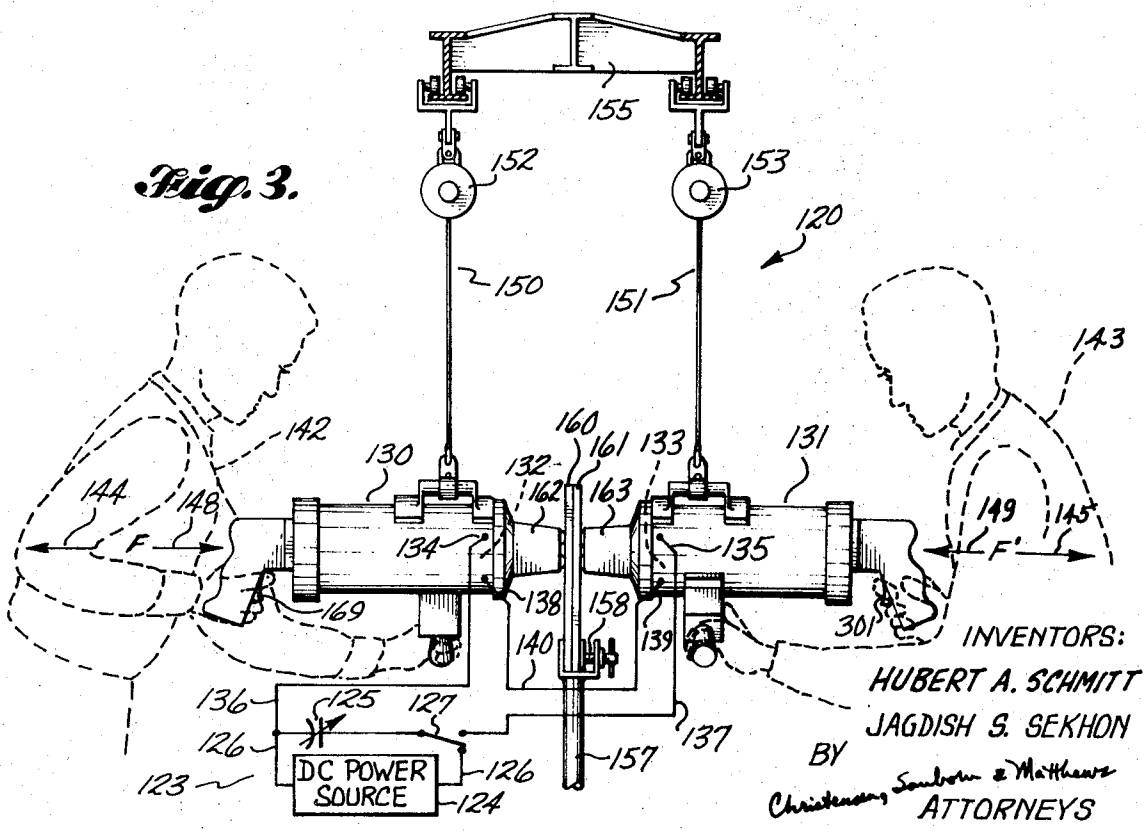


Fig. 3.



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HIGH-IMPACT PORTABLE RIVETING APPARATUS

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Fig. 4.

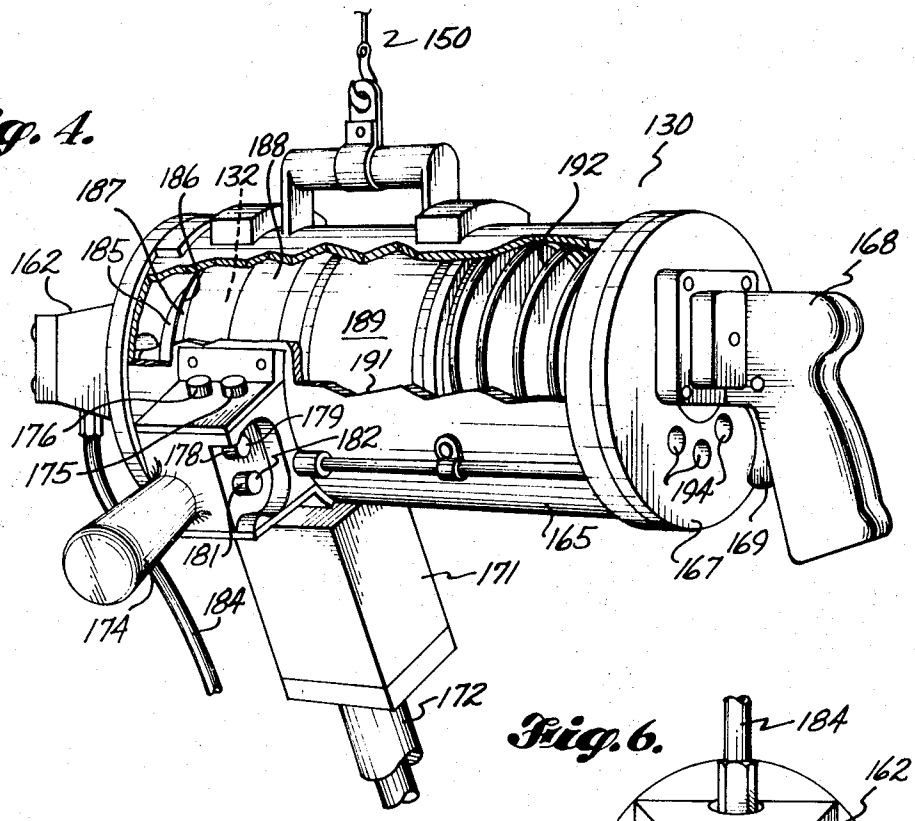


Fig. 6.

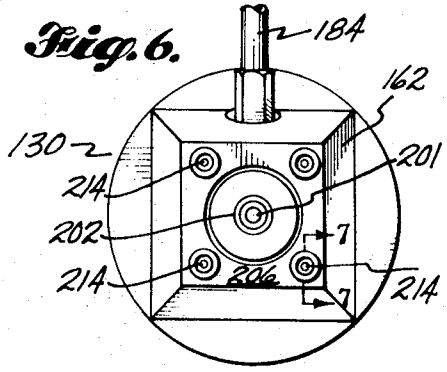


Fig. 5.

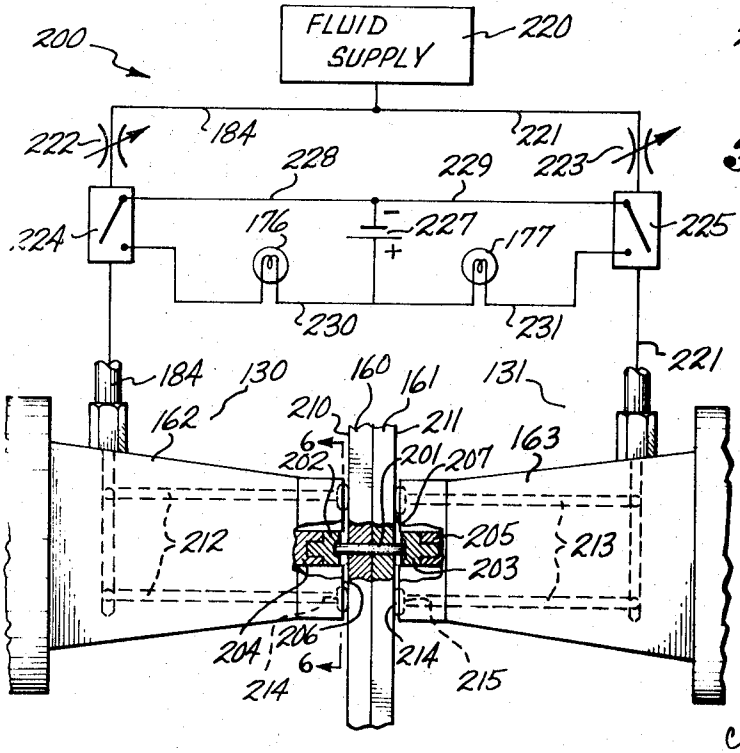
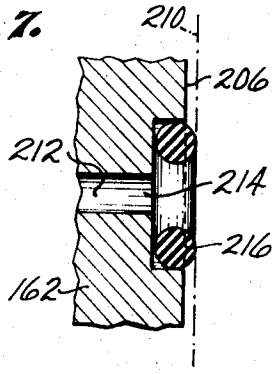


Fig. 7.



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HIGH-IMPACT PORTABLE RIVETING APPARATUS

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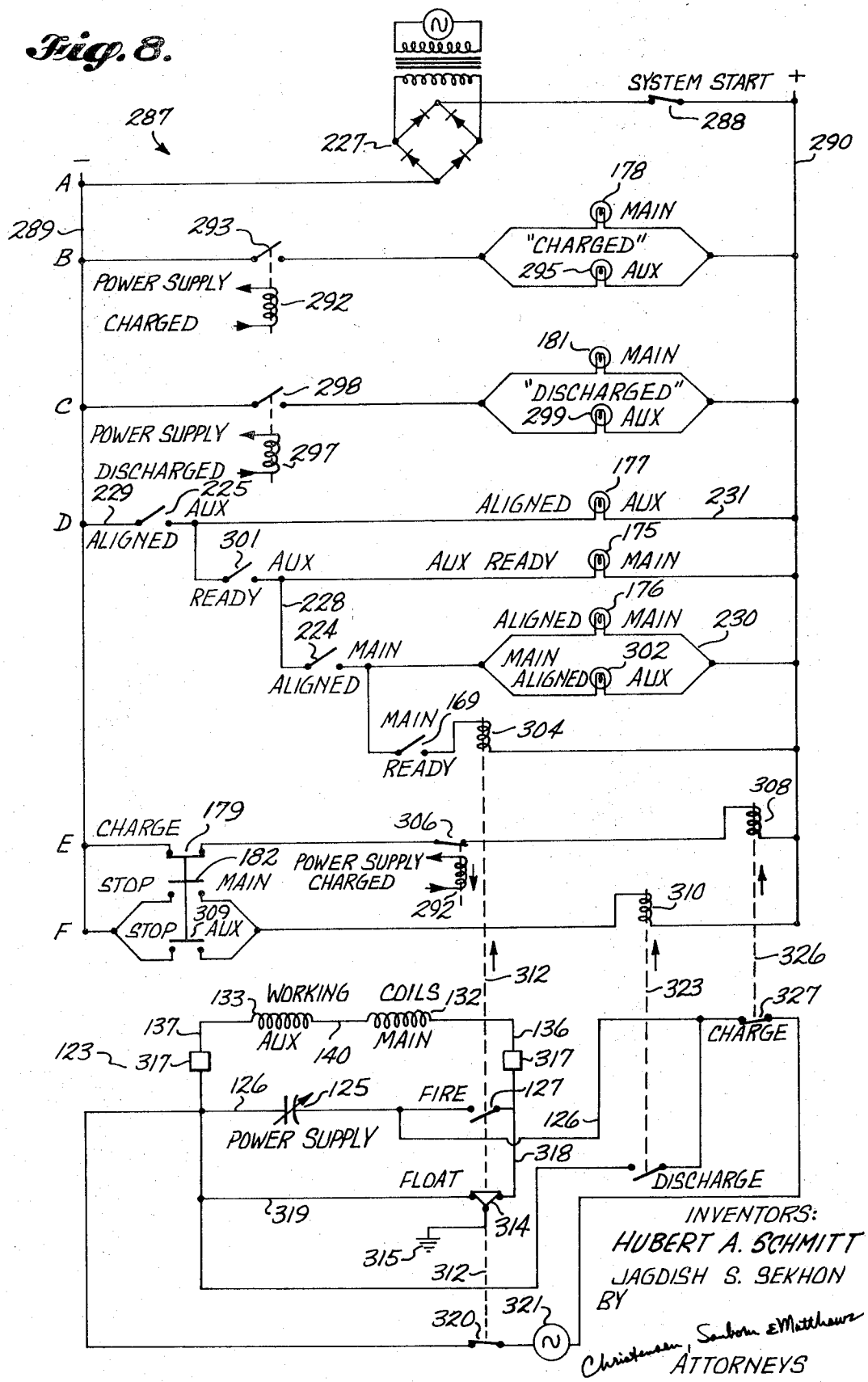
Fig. 8.



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3,559,269

HIGH-IMPACT PORTABLE RIVETING APPARATUS

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Int. Cl. B23p 11/00
U.S. Cl. 29—243.54 16 Claims

ABSTRACT OF THE DISCLOSURE

A high-impact tool is disclosed as part of a ram component of an electro-mechanical gun, as shown in FIG. 1, which converts a rapidly changing electric current passing through its coil into a mechanical force acting between a conductor plate on the ram and the coil to propel the ram and its forming surface against a workpiece to form it. A pair of portable electro-mechanical riveting guns, as shown in FIGS. 3–7, is described along with an electrical system, shown in FIG. 8, which interlocks their operation to insure a simultaneous ram impact on each end of the rivet. The power supply, for operator safety, is isolated from ground as it discharges through the coils. A system, shown in FIGS. 5–7, for proper gun alignment is disclosed wherein increased back-pressure of fluid or gas outlets, blocked by proper gun positioning against the workpiece, operates control switches permitting firing of the guns.

BACKGROUND OF THE INVENTION

This invention relates to apparatus for mechanically forming material and relates more particularly to a single-impact portable riveting apparatus.

DESCRIPTION OF THE PRIOR ART

In modern manufacturing operations there are many requirements for tools suitable for forming workpieces in a minimum time at a reasonable cost. Oftentimes the workpiece is quite large or already installed on a larger structure thereby establishing a requirement that the forming tool be portable so that it can be brought to the workpiece.

In the situation where metal parts or other high-strength materials need to be formed, the high energy requirement for the forming tool seems to dictate the need for a massive tool size. To produce high-quality structures it is important that the forming operations involved in fastening the structures together be of a high degree of uniformity.

In normal riveting processes wherein high-impact forces are required, these are generally applied by means of a repeated series of blows from the riveting tools against the rivet. Such rapid cycling of the impacting tool against the rivet puroduces a high noise level which becomes intolerable to those in the immediate vicinity after a short duration of exposure. Such noise fatigue reduces worker production and morale.

From the foregoing it is apparent that there is a need for a portable, high-impact tool which can be operated to produce a predictable and repeatable high-energy impact against workpieces with a minimum of noise.

In manufacturing operations involving the use of electrical tools wherein high currents and voltages are involved, shock hazards to the operators often prevent the wide use of such tools. Thus there is a need for means

which will reduce the shock hazard for operators of equipment utilizing surges of high voltage electric current in their operation.

For froming processes involving high forces applied in opposite directions to the workpiece the misalignment of the tools applying the forces may cause damage to the workpiece because of undesired distortion thereof. In addition the workpiece may be flexed and bent if the impacts on opposite sides do not occur simultaneously. Thus there is a need for means which will insure the proper alignment and simultaneous operation of high impact tools.

OBJECTS AND SUMMARY OF THE INVENTION

In view of the needs related above it is the principal object of the instant invention to provide a generally improved high-impact workpiece-forming apparatus.

It is another object of the instant invention to provide a high-impact apparatus having adequate components for producing workpiece-forming forces, but of a light enough construction to permit portability.

Yet another object of the instant invention is to provide in the electrical system for a high-impact tool a means for precisely controlling the impact force to yield repeatable predictable and highly uniform workpiece-forming operations.

A further object of the instant invention is to provide a generally improved single-impact riveting apparatus utilizing opposed rivet-driving tools and having an electrical system wherein the impact on one end of the rivet by one of the pair of guns is at substantially the identical instant that the other end of the rivet receives an impact from the other riveter.

A still further object of the instant invention is to provide in a portable high-impact tool a workpiece alignment sensing system which through suitable controls prevents the operation of the tool when it is improperly positioned relative to the workpiece.

It is another object of the instant invention to provide a control system which prevents an operating connection between an electrical energy source and a plurality of electrically operated tools until each of the selected set of said tools is in the proper operation alignment position and their respective operators are ready for the operation to take place.

A still further object of the instant invention is to provide a mans for isolating the electrical energy source for a high-impact tool during the operating cycle of its electrical components to thereby reduce the shock hazard for the tool's operator.

In accordance with the present invention a workpiece-forming ram member is propelled against the workpiece through the interaction between an electrically conductive surface of the ram and an electrically conductive coil when the coil carries a rapidly changing electric current. The apparatus in addition provides a guiding structure for the ram such that its workpiece-forming surface will be guided in its movement as the ram moves. A recoil mass includes and reinforces the coil moving with it in an opposite direction to the movement of the ram. The recoil mass is resisted in its movement by a recoil absorbing system. A restoration spring may constitute the recoil absorbing system as well as a mechanism for repositioning the recoil mass to its initial position adjacent the ram, awaiting another surge of rapidly-changing current through the coil. In a riveting operation two such apparatus are positioned to oppose one another such that the ram of one riveter moves in the exact opposite direction to the ram of the opposed riveter. A series connection between the propelling coil in one

riveter and the propelling coil in the other riveter is provided to insure simultaneous impacting of the rams on opposite ends of the rivet. The electrical system includes precisely controllable capacitors which are used in the power supply so that repeatable impacts result from preset voltage charges applied to the capacitors. Just before and during the passage of electrical current through the propelling coils, the supply of electric energy for the current is isolated from ground so that the operator's body does not become a part of the circuit due to an insulation breakdown.

To provide proper alignment between the path of the ram and the workpiece being riveted, a plurality of channels is formed in the working end of the portable riveting guns. The outlets of the channels are formed in the end of the gun positioned in contact with the workpiece in an array around the opening through which the rivet extends. Fluid or gas under pressure is supplied to the channels and exits from the outlets. The blocking of the outlets by the workpiece or its support, when the gun is properly aligned, increases the back-pressure on the fluid to a preset value which is sensed by a pressure-sensitive switch in communication with the channels. As the back-pressure reaches the amount which indicates that all of the outlets are blocked and the gun and workpiece are in proper alignment, the pressure switch is cycled providing a signal to the controls that the gun is in proper alignment.

These and other features and advantages of the invention will become more clearly apparent from the following detailed description thereof, which is to be read with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic view, with portions shown in cross section, of a generalized embodiment of a high-impact apparatus made in accordance with the instant invention;

FIG. 2 is a diagrammatic view similar to FIG. 1 but showing a simultaneously operated opposed pair of riveters made in accordance with the instant invention;

FIG. 3 is a side elevation view illustrating a riveting system utilizing an opposed pair of portable riveters made in accordance with the instant invention;

FIG. 4 is an isometric view, with some parts broken away for clarity, illustrating one of the portable riveters shown in FIG. 3;

FIG. 5 is a schematic view of the working end portion of the riveters shown in FIG. 3 illustrating the structure and control circuit for the alignment system made in accordance with the instant invention;

FIG. 6 is an end elevation view, taken from lines 6—6 of FIG. 5, illustrating the working end of one of the riveters;

FIG. 7 is an enlarged sectional view of one outlet of the alignment system as seen from lines 7—7 of FIG. 6;

FIG. 8 is a schematic view illustrating the electrical system for the riveting system shown in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

To provide a general understanding of the working principle of the several embodiments of the instant invention, reference is directed initially to the generalized embodiment of impact tool **1** illustrated schematically in FIG. 1. As shown, power supply **3** is connected to coil **10** which is structurally supported by recoil system **20**. In the initial position as shown in solid lines, ram **35** is positioned adjacent coil working face cover **13** so that the ram's workpiece-forming member **40** is properly positioned for forming workpiece **45** supported through workpiece holder **47** by frame strong-back member **50**.

Coil **10** may be formed of a continuous ribbon of conductive material such as flat copper wire and protected by nonconductive cover **13** positioned at its working end. Central terminal **11** of coil **10** is connected to power supply **3** by discharge lead **8** and outer terminal **12** is connected to power supply **3** by means of discharge lead **9**. Power supply **3** also includes power source **4** which is connected through charging leads **6** and normally closed control switch **7** to variable capacitor **5**. Once it is desired that the charge stored by capacitor **5** be permitted to discharge through coil **10**, control switch **7** is actuated to its dashed line position to connect discharging leads **8**, **9** to both sides of capacitor **5**. The quantity of electric energy is controlled for reliable repeatability of the impacts by varying the voltage stored by variable capacitor **5**. Although power supply **3** is described with reference to a control switch **7**, it should be understood that normal switches and relays would not be used for high current switching and that thyratrons are represented herein by switches for simplicity.

Surrounding the recoil end of coil **10** is a reinforcing structure which, along with the weight of coil **10**, is referred to generally as recoil mass **15**. As shown, rod member **17** projects in a first direction, as shown by the arrow **19**, from coil **10** toward recoil absorption system **20**. Fluid motor **25** houses piston **26** which is fixed to rod **17** and slides along cylinder **27** formed within fluid motor **25** to cause pressure fluid **28** to be compressed and forced around piston **26** as recoil mass **15** causes the rod **17** to move in the first direction **19** from the solid line position to the dashed line position. To restore recoil mass **15** including coil **10** to its solid line position from the dashed line position, restoration spring **30** is positioned to surround rod **17** and act between recoil mass **15** and fluid motor **25**.

Ram **35** is configured so that it includes a conductive surface, such as conductor plate **37**, having a size substantially equal to working face cover **13** of the coil **10** and is positioned initially adjacent to cover **13**. As coil **10** is subjected to the discharge from capacitor **5**, the rapidly changing electric current causes a repulsion between coil **10** and conductor plate **37** of ram **35**, thereby propelling recoil mass **15** including coil **10** in first direction **19** while ram **35** is propelled in a second direction, shown by arrow **38**, directly opposite to first direction **19**. Ram **35** includes stem member **39** extending from conductive plate **37** in second direction **38** and terminating at workpiece-forming member **40**, which is shown as being chisel-shaped. Member **40** may be joined to stem **39** by a detachable connection, such that various sizes and shapes of workpiece-forming members **40** can be utilized. For simplicity workpiece **45** has been shown as a simple stock member held in holder **47** which extends upwardly from frame strong-back **50**. Also rigidly connected to strong-back **50** is an upright structure forming ram guide **52** through which the ram stem **39** extends. At the recoil end of apparatus **1** there are positioned upright backstop members **54** secured at their lower ends to frame strong-back **50** and connected through suitable pin connectors **55** to fluid motor **25**.

In operation, the initial condition for embodiment **1** is shown in solid lines. Capacitor **5** is charged by means of its connection through charging lead **6** to a suitable power source **4**. Coil **10** is positioned adjacent to conductor plate **37** of ram **35**. Workpiece **45** is held in a selected position by workpiece holder **47**. Workpiece-forming member **40** is selected for the desired forming operation and secured to ram stem **39**. Restoration spring **30**, acting against fluid motor **25** and recoil mass **15**, holds coil **10** in the initial solid line position. When the impact operation is desired, the operator merely actuates control switch **7** to its dotted line position whereby the charge stored in variable capacitor **5** is discharged through

discharging leads 8 and 9 into coil 10 to produce a rapidly changing electrical current. A repulsion force between conductor plate 37 and coil 10 is developed of such a magnitude that ram 35 is propelled in second direction 38 with such force that workpiece 45 receives a tremendous impact from workpiece-forming member 40 positioned at the working end of ram stem 39. At the same time recoil mass 15 is subjected to a recoil force opposite to that propelling ram 35, such that recoil mass 15, including coil 10, moves to the dotted line position shown. This movement compresses restoration spring 30 as well as pressure fluid 28 trapped between the piston 26 and cylinder walls 27 of fluid motor 25 until the recoil energy has been absorbed. At this time restoration spring 30 restores recoil mass 15 to its initial solid line position with the ram 35 reaching its initial position as it rebounds from impacting workpiece 45. If a higher impact force is required variable capacitor 5 is changed to increase the voltage on the capacitor. In a like manner, if a lesser impact is needed, a lesser voltage will be stored by variable capacitor 5. Once a desired impact force has been obtained, the system can be recycled with very good repeatable and consistent forming results being obtained.

It has been found that one manufacturing operation, namely riveting, can be performed utilizing the principle of operation wherein a rapidly changing electric current in an adjacent coil is utilized for propelling the conductive surface of a rivet forming ram to form the rivets in a single impact. Such an operation reduces the noise of multiple impact riveters to that of a single impact. In addition the exact control available for producing impact repeatability obtained through the use of an adjustable power supply, results in improved and more uniform structural fastening.

As an example of one suitable riveting system utilizing this principle, reference is directed to FIG. 2 wherein second embodiment high-impact system 60 is shown Power supply 63 is substantially identical to power supply 3 of the embodiment 1 shown in FIG. 1. It includes power source 64 which is capable of charging variable capacitor 65 through charging leads 66 when control switch 67 is in the solid line position. Power supply 63 is used to provide a rapidly changing electric current to both left and right-hand opposed riveters 68 and 69. Left-hand riveter 68 includes coil 70 which is connected to power supply 63 by means of discharge lead 72 connected to its center terminal 74. Right-hand riveter 69 includes coil 71 which is connected to power supply 63 by means of a discharge lead 73 attached to its center terminal 75. The outer terminal 76 of coil 70 is connected to outer terminal 77 of coil 71 by means of series connector 79.

Coil 70 of left-hand riveter 68 is protected by insulated working surface cover 82 and surrounded by recoil mass 86 which extends to a first direction, as shown by arrow 84, from working surface cover 82. A friction surface 88 on recoil mass 86 makes contact with support surface 90. A resisting force "F" is schematically shown by arrow 92 pushing recoil mass 86 in the second direction, as shown by arrow 85, directly opposite first direction 84.

In a similar manner right-hand opposed riveter 69 protects its coil 71 by working surface cover 83 and recoil mass 87 which extends from the working surface 83 in second direction 85. Recoil mass 87 includes a friction surface 89 supported by support surface 90 and a right-hand resisting force "F" schematically illustrated by arrow 93, is shown pushing recoil mass 87 in first direction 94. Immediately adjacent to working surface cover 82 of the left riveter 68 is positioned conductor plate 98 of ram 96. At the opposite end of ram 96 is positioned the workpiece-forming tool shown as rivet die 102 secured to the ram stem 104. The movement of ram 96 is guided by means of ram guide 108 through which passes ram stem 104. A rivet 111 is shown in the path of rivet die 102 as its is moved in second direction 85. Rivet 111, at its other end, is in the path of rivet die 103 positioned at the end of ram stem 105 of righ-hand ram member 97. Initially ram 97 is positioned with its conductor plate 99 immediately adjacent working surface cover 83 of coil 71. The purpose of rivet 111 is to securely fasten together structural sheets 112 and 113 once it becomes formed by riveters 68, 69.

In operation rivet 111 is simultaneously deformed by receipt at its opposite ends of the simultaneous impact of rams 96 and 97 due to the simultaneous electric current flow through coils 70 and 71. This current flow is caused by the operator's movement of control switch 67 from its full line position to its dashed line position, whereat capacitor 65 discharges through coils 70 and 71 simultaneously because of the series connection provided between the coils by means of series connector 79. The rapidly changing electrical current causes the repulsion of ram 96 in second direction 85 and ram 97 in first direction 84 such that rivet 111 receives a simultaneous impact at each of its ends through the contact with rivet dies 102 and 103 against it. The recoil of left riveter 68 is absorbed by recoil mass 86 as the friction between friction surface 88 and support surface 90 absorbs a certain amount of the recoil energy while resisting force 92 is applied in second direction 85 to absorb the balance of the recoil energy. Similar recoil absorption occurs in right-hand riveter 69 as friction surface 89 slides along support surface 90 and resisiting force 93 is applied in first direction 84 directly opposite to the recoil direction of recoil mass 87. Once riveters 68 and 69 have reached equilibrium, resisting forces 92 and 93 are utilized to reposition coils 70 and 71 adjacent conductor plates 98 and 99 of respective rams 96 and 97. The repositioning of control switch 67 to its solid line position initiates the charging of capacitor 65 by means of power source 64 through charging leads 66. From this operation rivet 111 is properly deformed to securely fasten together structural sheets 113 and 112.

While the first two embodiments, 1 and 60, of high-impact tools have been shown in installations wherein the apparatus is mounted on a tool bench or other base support structure, the balance of this disclosure relates to a portable riveting system 120 which can be taken to the workpieces being joined rather than requiring them to be brought to the bench. As shown in FIG. 3, portable riveting system 120 includes power supply 123 having a power source 124 connected to a variable capacitor 125 through charging leads 126 when the control switch 127 is in the full line position shown. The left-hand gun, which will be hereinafter referred to as main gun 130, is positioned opposite to right-hand or auxilitary gun 131.

Main gun 130 includes coil 132. The center terminal 134 of coil 132 is connected to the power supply 123 by means of discharging lead 136. The outer terminal 138 of main coil 132 is connected through series connector 140 to the outer terminal 139 of auxiliary coil 133 positioned within auxiliary gun 131. Center terminal 135 of auxiliary coil 133 is connected by means of discharging lead 137 to power supply 123.

The main operator 142 is indicated in dotted lines as he applies first resisting force 148 to resist the recoil acting in the first direction, shown by arrow 144. In a similar manner auxiliary operator 143 applies a resisting force 149 to oppose the recoil of auxiliary gun 131 in the second direction, indicated by arrow 145. In normal usage the quantity of resisting forces 148 and 149, ranges between 20–35 pounds and is therefore easily within the capability of most operators including female operators. To avoid worker fatigue vertical supports 150 and 151 are used to hold up main and auxiliary guns 130 and 131. Through the utilization of counterbalance pulleys 152 and 153 suspended from overhead support 155 operators 142 and 143 can easily maneuver main and auxiliary guns 130 and 131 with the minimum of effort.

In the construction to be described in greater detail hereinafter, portable guns, such as main gun **130**, have been constructed having as little weight as 35 pounds and with additional equipment more recent models weigh less than 75 pounds. In a simplified form FIG. 3 illustrates the use of workpiece support **157** having a clamp **158** for securely holdingworkpiece sheets **160** and **161** in a convenient position for the placement against the sheets of working end **162** of main gun **130** and working end **163** of auxiliary gun **131**. It is of course understood that different shapes, sizes, and locations of workpieces may require the operators to position their guns **130** and **131** in something other than the horizontal plane shown in FIG. 3. For example, the plan in which both guns **130** and **131** lie might be vertical or inclined from either the vertical or horizontal plane as necessary to properly install the rivets into the workpieces.

For a more detailed description and appreciation of the features involved, reference is directed to FIG. 4 wherein a larger showing of main gun **130** illustrates its major internal as well as external structural components. For simplicity main gun **130** utilizes a cylindrical housing **165** which is closed at the rear end by closure plate **167**. Attached to closure plate **167** is a pistol grip **168** which accommodates one hand of operator **142** for easy operation of trigger switch **169** mounted thereupon. To make the necessary electrical connection between the power supply **123** and main coil **132** a power cable connector structure **171** is slidably supported on gun housing **165** in a manner which permits power cables **172** attached to connector **171** to be rapidly cycled rearwardly as coil **132** recoils.

Additional guidance and operator control of main gun **130** is provided by side handle **174** which extends radially outwardly from gun housing **165** and includes in the body portion a series of control and indicator elements. These include auxiliary ready light **175**, main alignment light **176**, red charged light **178** mounted within the transluscent charge button **179**, and green discharge light **181** mounted within green transluscent main stop button **182**. It should be noted that charge button **179** and stop button **182** are conveniently positioned for actuation by the operator's thumb as he steadies main gun **130** with the balance of his hand. While the working end **162** of main gun **130** will be described in greater detail with reference to FIGS. 5–7 it should be noted that it also includes an alignment fluid conduit **184**.

Mounted within housing **165**, which is typically constructed of nylon or lightweight material coated with an insulating material, ram **185** is positioned adjacent to and configured for guidance through working end **162**. Conductor plate **186** is attached to ram **185** such that it is positioned adjacent the working face cover **187** and coil assembly **188**. In addition to the coil assembly **188**, additional weight is provided by material extending rearwardly from coil assembly **188** to form recoil mass **189**. The outer peripheral surfaces of coil assembly **188** and the balance of recoil mass **189** slides along the inner surface **191** of housing **165**. Biased between rear end cover plate **167** and recoil mass **189** is positioned an absorption and restoration spring **192**. To permit easy egress of air which might be otherwise trapped within the chamber formed within housing **165** between recoil mass **189** and rear end cover plate **167** there are provided rear end air vents **194** defined by and projected through end cover plate **167**. Although they are not shown, working end **162** of main gun **130** may also include forward air vents to permit easy exit of the air displaced by ram **185** as it is propelled away from main coil **132**.

Because main and auxiliary guns **130** and **131** are independently positionable by their respective operators **142** and **143**, an alignment system **200** as shown in FIGS. 5–7 is provided to insure proper alignment so that the axis of the rivet being driven by the guns is coincident with the paths of the respective rams. As best shown in FIG. 5, forward end **162** of main gun **130** is positioned such that main die **202** secured to the end of ram stem **204** contacts one end of rivet **201**. The opposite end of rivet **201** is contacted by auxiliary die **203** which is secured to auxiliary ram stem **205**. The working surface **206** of main gun **130** is positioned in contact with the exterior surface **210** of workpiece sheet **160** and working surface **207** of auxiliary gun **131** is positioned in contact with the exterior surface **211** of workpiece sheet **161**.

Alignment channels **212** and **213** are formed in the working ends **162** and **163** of guns **130** and **131** to provide a pressure medium passage between main and auxiliary alignment outlets **214** and **215** and fluid or gas supply **220** through conduits **184** and **221**. The fluid or gas under pressure from supply **220** is conducted through supply conduits **184** and **221** as they pass through adjustable restrictors **222** and **223** and pressure sensitive switches **224** and **225**. The restrictors cause a pressure drop in conduits **184** and **221** when the fluid or gas flows. O-ring seals **216** and **217** are positioned, as shown in FIG. 7, in alignment outlets **214** and **215** such that as the working end **162** is positioned with working surfaces **206** in flush contact with working surface **210**, O-ring seals **216** prevent the escape of the fluid or gas under pressure. This blocking of the outlets **214** stops the gas or fluid flow through restrictor **222** and thus eliminates the normal pressure drop resulting in the supply pressure being sensed by pressure switch **224** causing it to close. When switch **224** is closed the electrical leads **228** and **230** carry the electric current from electrical potential **227**, causing the lighting of main alignment light **176**. This light remains lit as long as proper alignment is maintained with all of outlet **214** remaining blocked.

In a similar manner O-rings **217**, positioned in outlets **215**, will cause an increase in pressure in alignment channels **213** when auxiliary gun **131** is positioned with working surface **207** in flush contact with workpiece exterior sheet **211**. This increase in pressure causes the actuation of auxiliary pressure switch **225**, which through the electrical circuit established from electric potential **227** and electric leads **229** and **231**, causes auxiliary alignment light **177** to become lit.

It should be noted that any pressure medium could be used as an indicator of alignment. Good success has been obtained by using a generally available plant low-pressure air supply. As will be described with reference to the electrical system shown in FIG. 8, working coils **132** and **133** of the main and auxiliary guns **130** and **131** can not be energized if either of the alignment pressure indicating switches **224** or **225** are open.

FIG. 6 illustrates the array of outlets **214** positioned in working surface **206** of main gun **130**. Although some alignment information could be obtained by the use of a single outlet, a more reliable and more accurate alignment is represented by the blocking of a plurality of outlets with three or four being preferred. Somewhat greater detail as to the design of specific outlet **214** is shown in FIG. 7 wherein it is noted that alignment channel **212** opens into the outlet **214** which is surrounded by O-ring seal **216**, projecting a small amount outwardly from working surface **206** of working end **162** as it is positioned flush with exterior surface **210** of workpiece sheet **160**.

Because the rivets currently in use in aircraft industry requires tremendous forces to be adequately formed for fastening aircraft structures, it is necessary to provide very high voltages in the power supply and to conduct very high currents from the power supply to working coils **132** and **133**. In a typical installation the charge on capacitor **125** may vary between 2,000–10,000 volts, producing a current between 12,000 and 30,000 amps yielding 7,500–18,000 joules as the charge on capacitor **125** is discharged through the coils **132** and **133** in from 200–300 microseconds.

In view of the objects related above with regard to the interlocking operation between main and auxiliary guns **130** and **131**, reference is now directed to FIG. 8 for a

detailed description of the operating electrical system which provides the necessary means for obtaining the related objects. In essence the electrical system includes control circuit **287** shown in the upper portion of FIG. 8 which is interrelated with the power supply circuit **123** shown in the lower portion of FIG. 8. Control circuit **287** is basically a low voltage system wherein the input voltage is provided in circuit A by means of the electrical potential **227** establishing negative lead **289** and positive lead **290** when the system start switch **288** is closed. The condition of the electrical system shown in FIG. 8 is that in which power supply capacitor **125** is being charged. The sequence of operation therefore requires that initially the system start switch **288** is closed establishing the electrical potential between negative lead **289** and positive lead **290**. Circuit B is activated when the power supply charged coil **292** pulls closed the power supply charged switch **293**. This is indicated on the main gun by the lighting of the charged light **178** and on the auxiliary gun by lighting the auxiliary charge light **295**. Circuit C becomes activated when the power supply has been discharged causing the power supply discharged coil **297** to pull closed the power supply discharge switch **298**. This then is indicated on the main gun by the lighting of green light **181** and on the auxiliary gun by lighting the green light **299**.

With reference as necessary to the discussion of the alignment system shown in FIGS. 5–7, it should be noted that circuit D of FIG. 8 is actuated first by the closing of auxiliary pressure switch **225** which indicates that the auxiliary gun is aligned by lighting the aligned light **177** on the auxiliary gun. The auxiliary operator **143**, when he is ready, will actuate the ready trigger switch **301** which will be indicated on the main gun by lighting the auxiliary ready light **175** if auxiliary gun **131** is aligned closing switch **225**. When the main gun is aligned, pressure switch **224** becomes closed lighting main gun aligned light **176** on the main gun and main gun aligned light **302** on the auxiliary gun. When all of these conditions of circuit D have been met and the main gun operator **142** is ready he will close ready trigger switch **169** which will energize ready coil **304** sending a ready-to-fire signal **312** to the power supply **123**.

As previously indicated the condition shown in FIG. 8 is that of charging of the power supply capacitor **125**. Circuit E represents the means by which the depression of main gun charge button **179** will energize charge coil **308** to send a charge signal **326** to power supply **123** as long as the power supply charge switch **306** is not pulled open power supply charge coil **292** of circuit E. It should be noted that Circuit E is directly related to Circuit F in that the closure of either main stop button **182** or auxiliary stop switch **309** will open charge switch **179** of circuit E, and in addition will energize stop coil **310** sending a discharge signal **323** to power supply **123**.

With continued reference to FIG. 8 and particularly the power portion thereof it is noted that power supply circuit **123** has been schematically illustrated as being interconnected by means of signals to the control system **287**. Basically, however, the power supply **123** includes variable capacitor **125** which is shown as being charged by means of a closed connection provided by charging leads **126** from AC power source **321** through main line charge switch **327**. Once capacitor **125** has reached the desired charge a power supply charged signal will be supplied to coil **292** and control circuits B and E as noted above.

In circuit E the actuation of power supply charged coil **292** opens power supply charge switch **306** which de-energizes charge coil **308** sending a reverse charge signal **326** which opens mainline charge switch **327** dicontinuing the charging of power supply capacitor **125**. When all of the switches of circuit D have been closed the ready signal **312** will serve to close firing switch **127**, opening grounding guillotine switch **314** and open discharge disconnect switch **320**. While these operations have all been indicated as being performed by switches, they would most likely be performed by high voltage thyratron tubes useful in making and breaking circuits wherein high voltages are involved. In sequence, however, the opening of discharge disconnect switch **320** isolates AC power source **321** from any connection with power supply capacitor **125** since the other side of AC power source **321** was opened by means of opening main line charge **327** which occurred upon reaching the desired charge of capacitor **125**. The opening of grounding guillotine **314** isolates both sides of the output terminals **317** from ground and both sides of power supply **125** from ground. This is particularly important since the isolation of the charged power supply capacitor **125** from ground reduces the shock hazard to operators **142** and **143** since the potential on opposite sides of capacitor **125** is no longer related to ground and this condition exists during the short time in which the charge potential on power supply capacitor **125** is discharged through main coil **132** and auxiliary coil **133**. The discharging of the power supply through coils **132** and **133** is simultaneous since the coils are connected in series by series connector **140**.

Once power supply capacitor **125** has been discharged through working coils **132** and **133** the power supply charged coil **292** is no longer energized, permitting closure of power supply charge switch **306** in circuit E. If neither of the stop buttons **182** or **309** of circuit F have been closed then circuit E is completed causing the energizing of charge coil **308**. This causes a charge signal **326** to pull closed main line charge switch **327**. When either or both of the trigger switches **169** and **301** have been opened, the reverse ready signal **312** causes the restoration of the discharge disconnect switch **320** to its normal closed position permitting the charging of capacitor **125**. At the same time grounding guillotine switch **314** reestablishes the reference to ground **315** for power supply capacitor **125** and firing switch **127** resumed its normal open position.

We claim:

1. A high-energy impact apparatus comprising:
coil means adapted to be connected to an electric energy source for generating a rapidly changing energy field adjacent to said coil;
ram means including a conductor plate and a workpiece-forming tool;
recoil means including said coil and a body member extending in a first direction from said coil;
frame means including a backstop member and guide means for guiding the movement of said ram means from a first position whereat said conductor plate is positioned adjacent said coil to a second position whereat said forming tool impacts a workpiece as said energy field changes propelling said ram away from said coil in a second direction opposite to said first direction;
absorption means positioned between said backstop member and said recoil mass for resisting movement of said recoil mass in said first direction and including restoration means for restoring said coil to said first position adjacent said ram conductor plate.

2. The apparatus of claim **1** wherein:
said absorption means includes a spring biased between said backstop member and said recoil mass.

3. A riveting apparatus comprising:
a pair of riveting guns;
conductor means extending between each of said guns;
each of said guns including a rivet-forming ram, electromechanical means for receiving a rapidly changing electric current and converting it into mechanical energy for propelling said ram toward a rivet and operator control switch means for indicating that said gun is ready for receiving said current,
one portion of said conductor means providing an elec-

trical connection between said electrical connection between said electro-mechanic means of each of said guns for ensuring simultaneous operation of said guns once both of said operator ready indications are maintained.

4. The riveting apparatus of claim 3 including:
control means for operating said guns;
a second portion of said conductor means providing a connection between each of said guns and said control means for transmitting said gun-originated indication of being ready to said control means;
said control means including firing switch means connected between an electrical energy source and said electromechanical means, requiring the ready indication from both of said paired guns before permitting said rapidly changing electric current to pass through said electromechanical means of each of said guns.

5. The riveting apparatus of claim 3 including:
power supply means and power cable means connected between said power supply means and said guns for supplying said rapidly changing current thereto;
control means operatively connected among said guns and said power supply for selectively, upon receipt of both of said ready indications and the lack thereof, permitting and preventing the communication between said guns and said power supply means.

6. The riviting apparatus of claim 3 including:
power supply means and power cable means connected between said power supply means and said guns for supplying said rapidly changing current thereto;
control means operatively connected among said guns and said power supply for selectively permitting and preventing the communication between said guns and said power supply means;
said control means including ready means responsive to receipt of said operator-ready indication;
said guns each including means for signalling the proper gun to workpiece alignment condition;
said control means including alignment means responsive to receipt of said gun alignment signal;
said control means being structured to permit said communication between said power supply and said guns whenever both of said guns are properly aligned and said operator control switches indicate as indicated by the condition of said ready and alignment means and to prevent said communication whenever any one of said desired alignment or ready conditions is not indicated by said ready and alignment means.

7. The riveting apparatus of claim 3 wherein:
each of said guns also includes an alignment-sensing means having means for sensing the relative attitude of the path of said ram and the surface of the workpiece adjacent the hole in which the rivet is positioned;
said alignment means including alignment switch means adapted to prevent said indication of said gun ready condition at least until a preselected attitude of said ram path and workpiece surface has been reached.

8. The riveting system of claim 7 wherein:
said sensing means includes a plurality of pressure fluid channels provided in the ram end of said gun with outlets thereof formed in the surface of said gun adapted for flush contact with said workpiece surface and positioned adjacent the path of said ram;
said outlets being in communication with a source of said fluid under pressure;
pressure switch means positioned in communication with said channels adapted to change conditions upon sensing a preselected increase in said fluid pressure due to the blocking of said outlets.

9. The apparatus of claim 8 wherein:
said outlets include a compressible seal member positioned therein to extend around said outlets for providing, when compressed against said workpiece, a fluid-tight seal.

10. The riveting apparatus of claim 3 wherein:
one of said guns include means for sensing the proper alignment of said gun with said workpiece;
said alignment sensing means includes means for signalling said proper alignment;
second portion of said conductor providing means for communicating said alignment signal from one gun to the other of said guns;
indicator means positioned on said other gun and connected with said second conductor portion for indicating on said other gun the alignment of said first gun.

11. The riveting system of claim 10 wherein:
said conductor means includes a third portion for providing means for communicating the condition of the said operator control switch on said one gun to said other gun;
said other gun includes second indicator means connected with said third conductor portion for indicating on said other gun condition of said one gun operator control switch.

12. An impact tool apparatus comprising:
gun means including coil, ram and guide means;
said coil means providing means for generating a rapidly changing field;
said ram means including a conductor plate and workpiece plate and workpiece-forming tool;
said guide means providing ram guidance as it is propelled from its initial position whereat said plate is positioned adjacent said coil to an impact position whereat said forming tool impacts against a workpiece;
electrical means including power supply means, charging means, floating ground means, discharging means and firing means;
said charging means providing charge switch means for selectively connecting said power supply means with an electrical energy source for charging said power supply means;
said discharging means including a connection to ground and discharge switch means for selectively connecting said power supply with ground for discharge of said power supply;
said floating ground means including connections with isolation switch positioned in said charging and discharging means and responsive to the firing position of said firing means for isolating said power supply means from said charging and discharging means;
said firing means providing a connection and disconnection between said coil means and said power supply means for supplying a rapidly changing current to said coil means, with said connection being established when said firing means is in said firing position.

13. The apparatus of claim 12 wherein:
said gun means also includes alignment and operator ready indicating means;
said firing means including connections with said gun alignment and ready indicating means for preventing positioning of said firing means in said firing position until said indicating means indicates the desired alignment and readiness conditions for said gun.

14. The apparatus of claim 12 wherein:
said floating ground means operates to disconnect said power supply from said charging and discharging means before the firing connection between said

15. The apparatus of claim 12 wherein:
power supply and said coil is completed.
said gun means includes a discharge actuator for said

discharging means permitting said operator to discharge said power supply into said ground.

16. The apparatus of claim **12** wherein:

said gun means includes a charge actuator for said charging means permitting said operator to cause said connection between said energy source and said power supply.

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JAMES M. MEISTER, Primary Examiner

U.S. Cl. X.R.

173—117; 318—114, 130

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,559,269 Dated February 2, 1971

Inventor(s) H. A. Schmitt et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 11, Line 1 should read --trical connection--;

Column 11, Line 44 should read --and said operator control switches indicate ready as in- --;

Column 12, Line 5 should read --one of said guns includes means for sensing the proper--;

Column 12, Line 30 should read --said ram means including a conductor plate and--;

Column 12, Line 31 should read --workpiece-forming tool;--

Column 12, Line 73 should read --power supply and said coil is completed.--

Column 12, Line 74 should read --15. The apparatus of claim 12 wherein:--.

Signed and sealed this 20th day of July 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents