

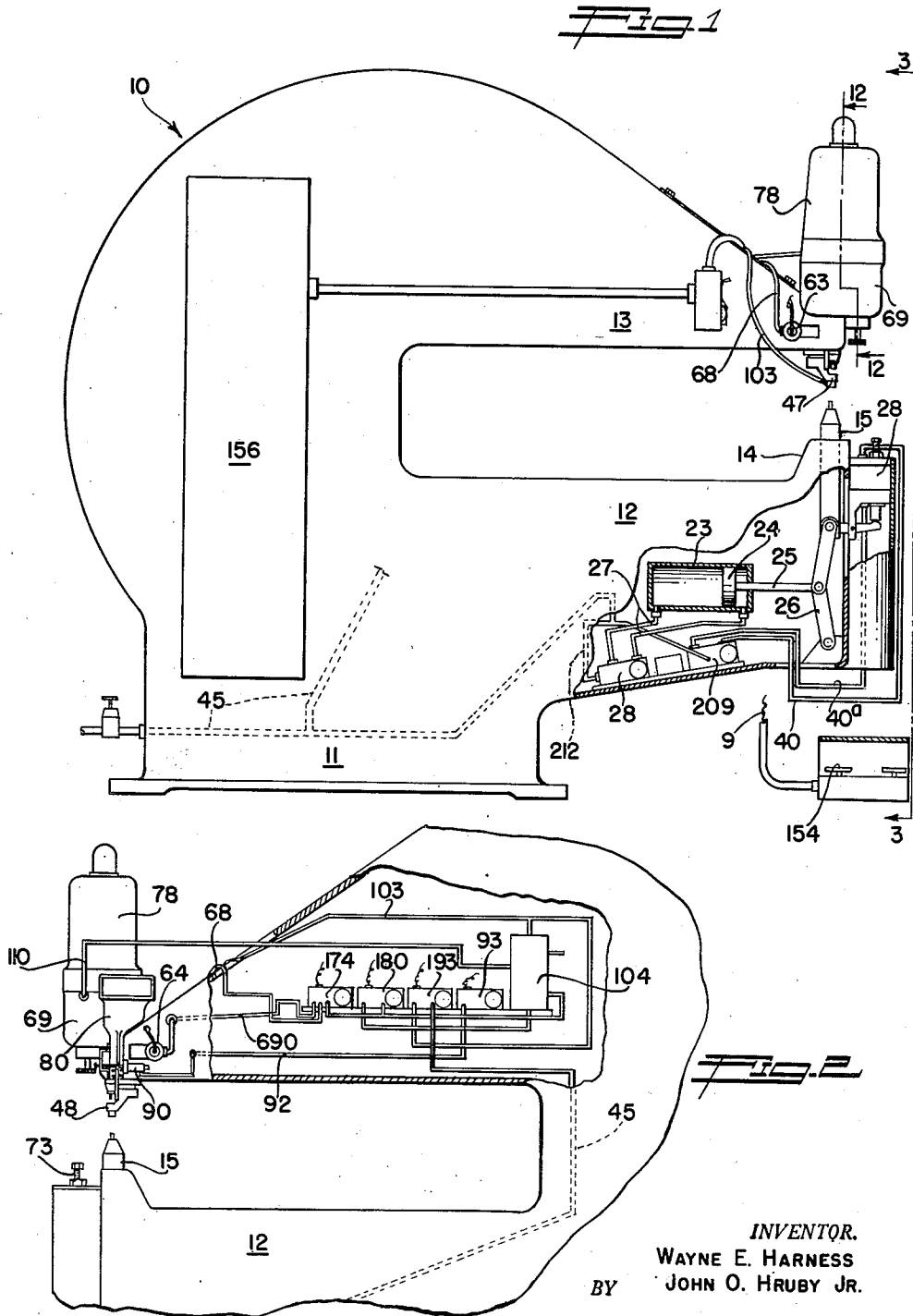
Dec. 9, 1952

W. E. HARNESS ET AL
AUTOMATIC RIVETING MACHINE

2,620,876

Filed July 1, 1946

7 Sheets-Sheet 1



INVENTOR.
WAYNE E. HARNESS
BY JOHN O. HRUBY JR.

George J. Sullivan
Agent

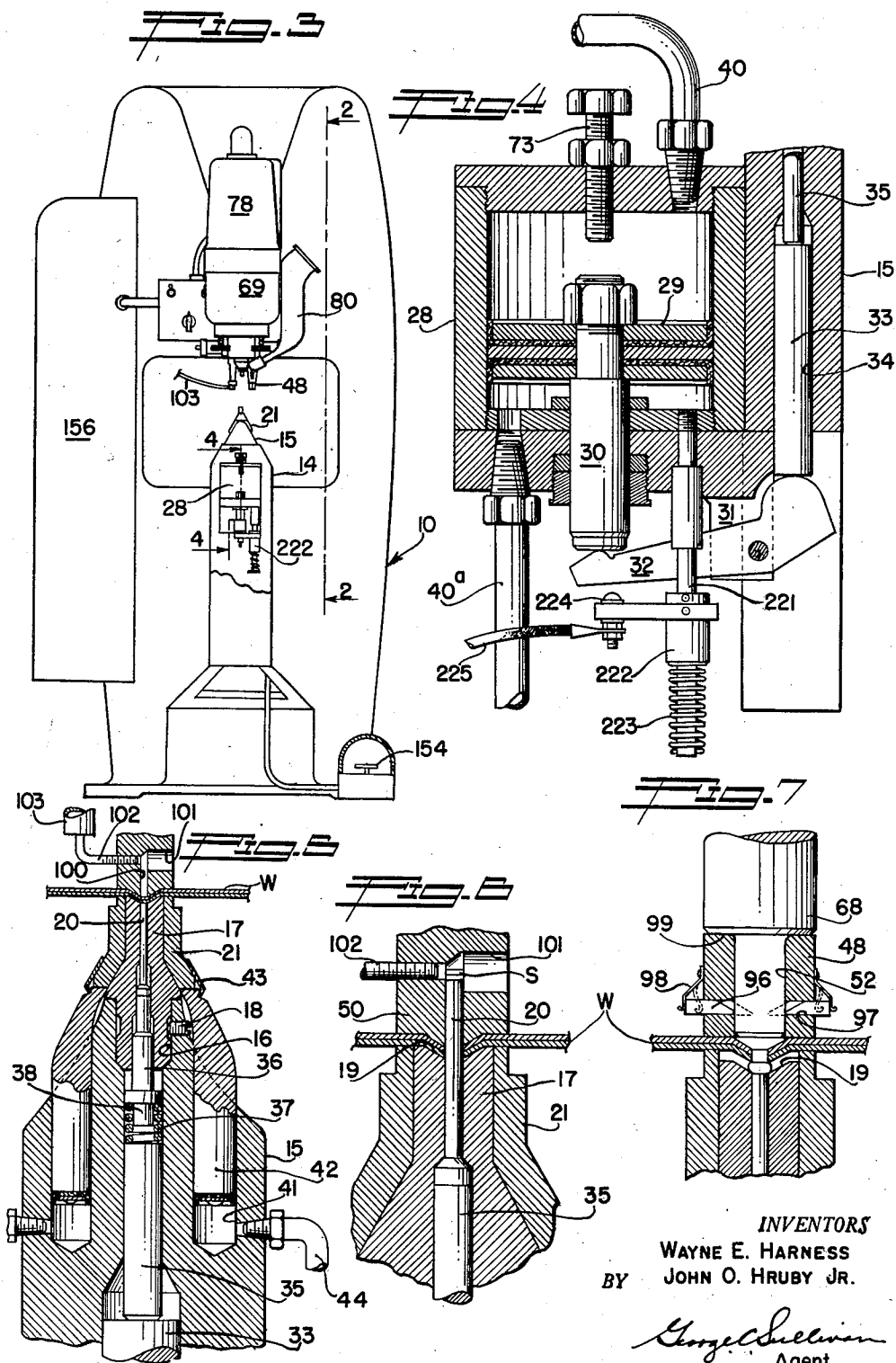
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INVENTORS
WAYNE E. HARNESS
JOHN O. HRUBY JR.
BY

George C. Sullivan
Agent

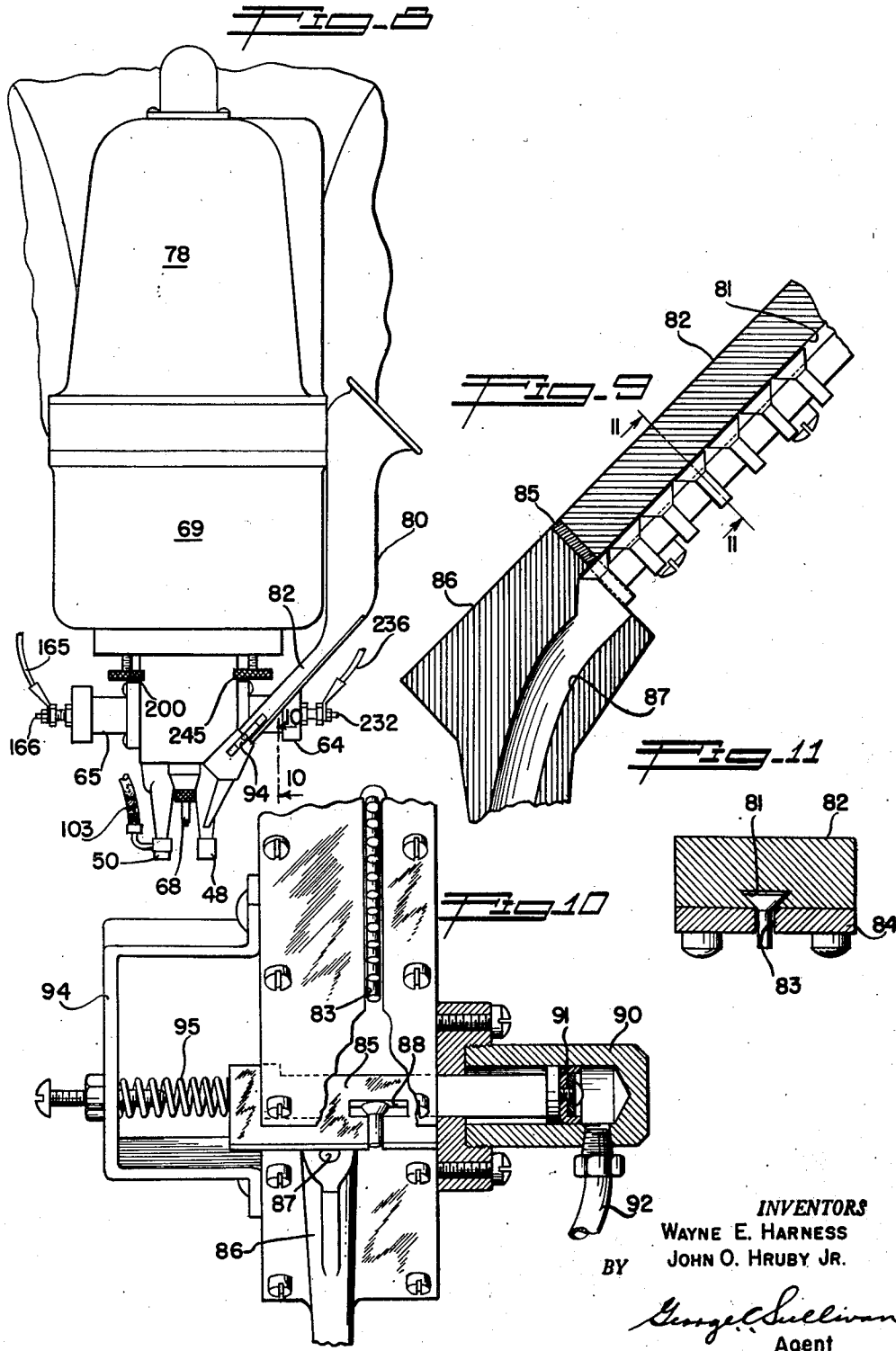
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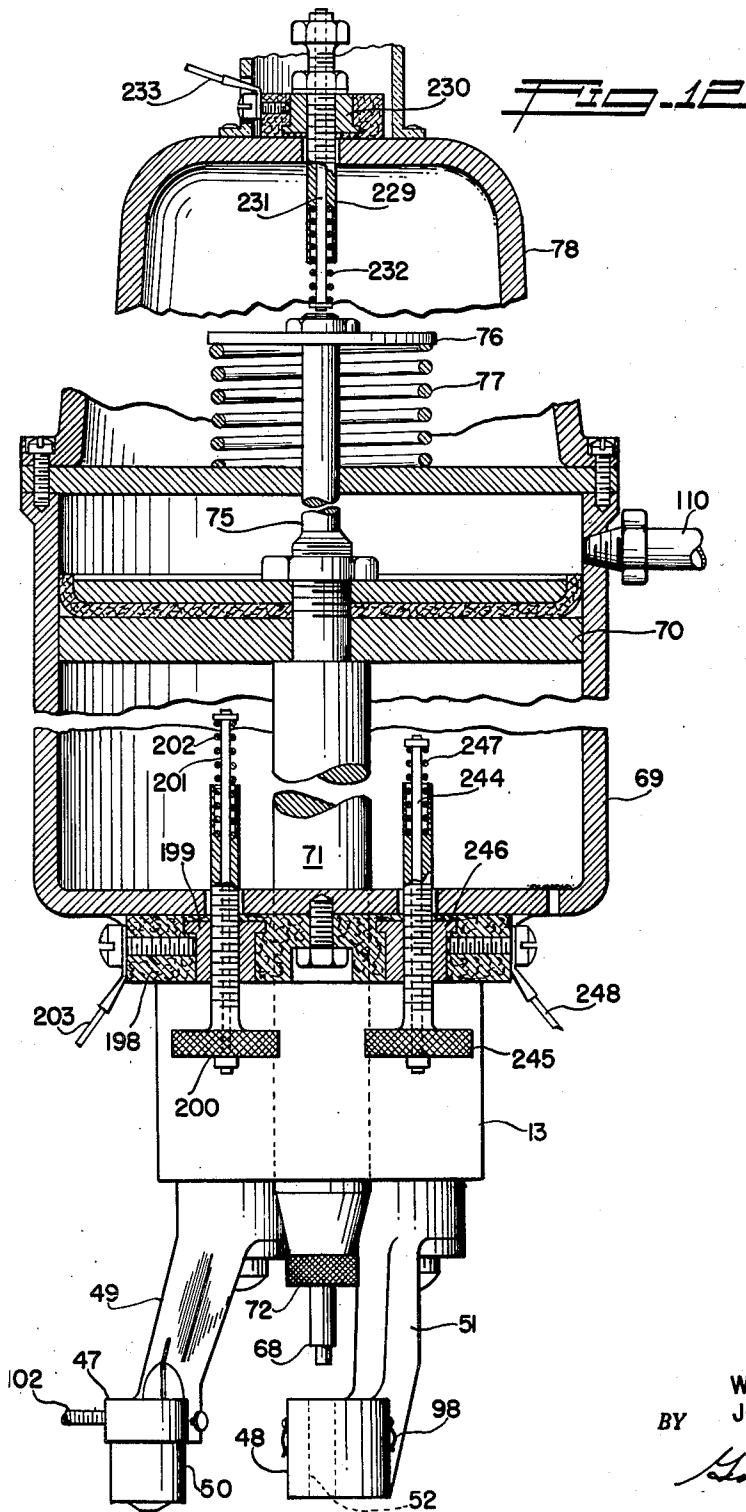
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INVENTORS
WAYNE E. HARNESS
JOHN O. HRUBY JR.
BY *George Sullivan*
Agent

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Fig. 13

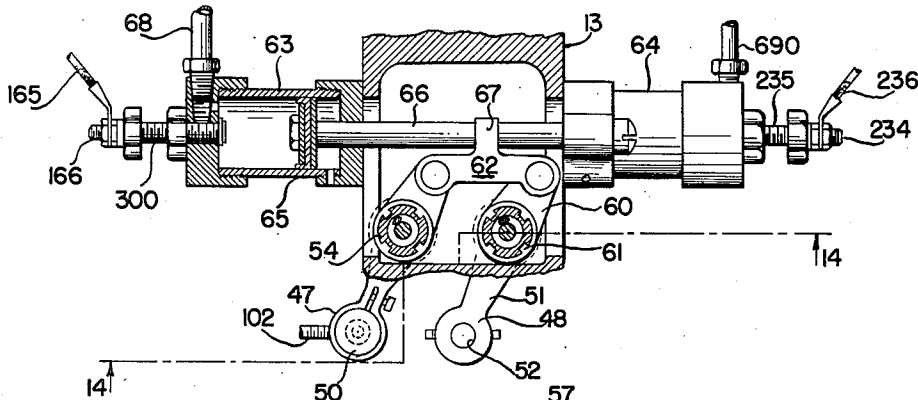


Fig. 14

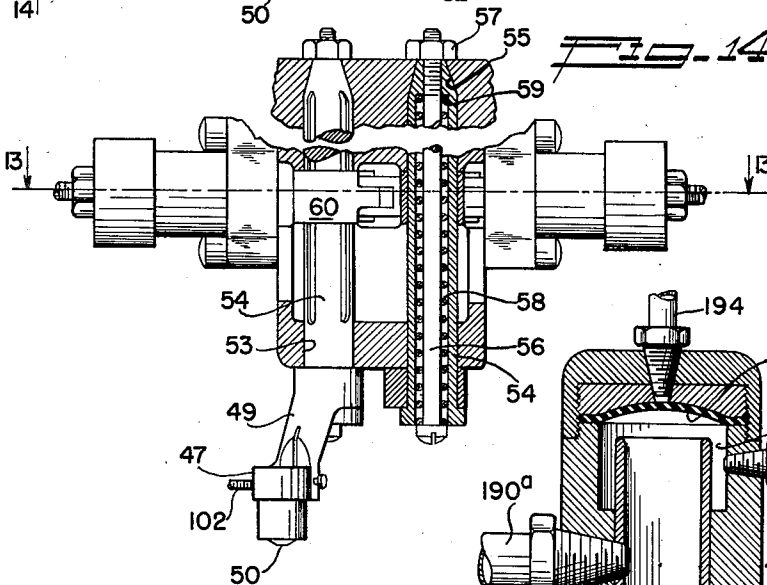
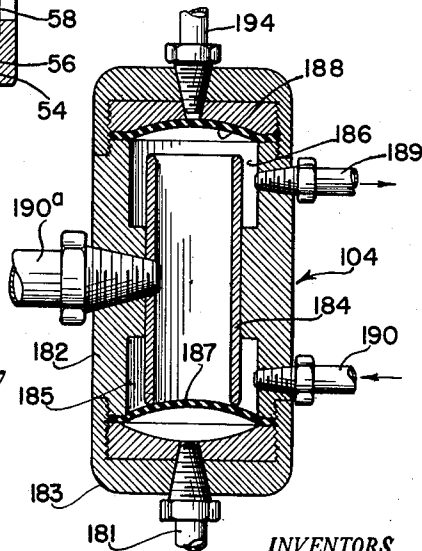


Fig. 15



INVENTORS
WAYNE E. HARNESS
JOHN O. HRUBY JR.
BY

George Sullivan
Agent

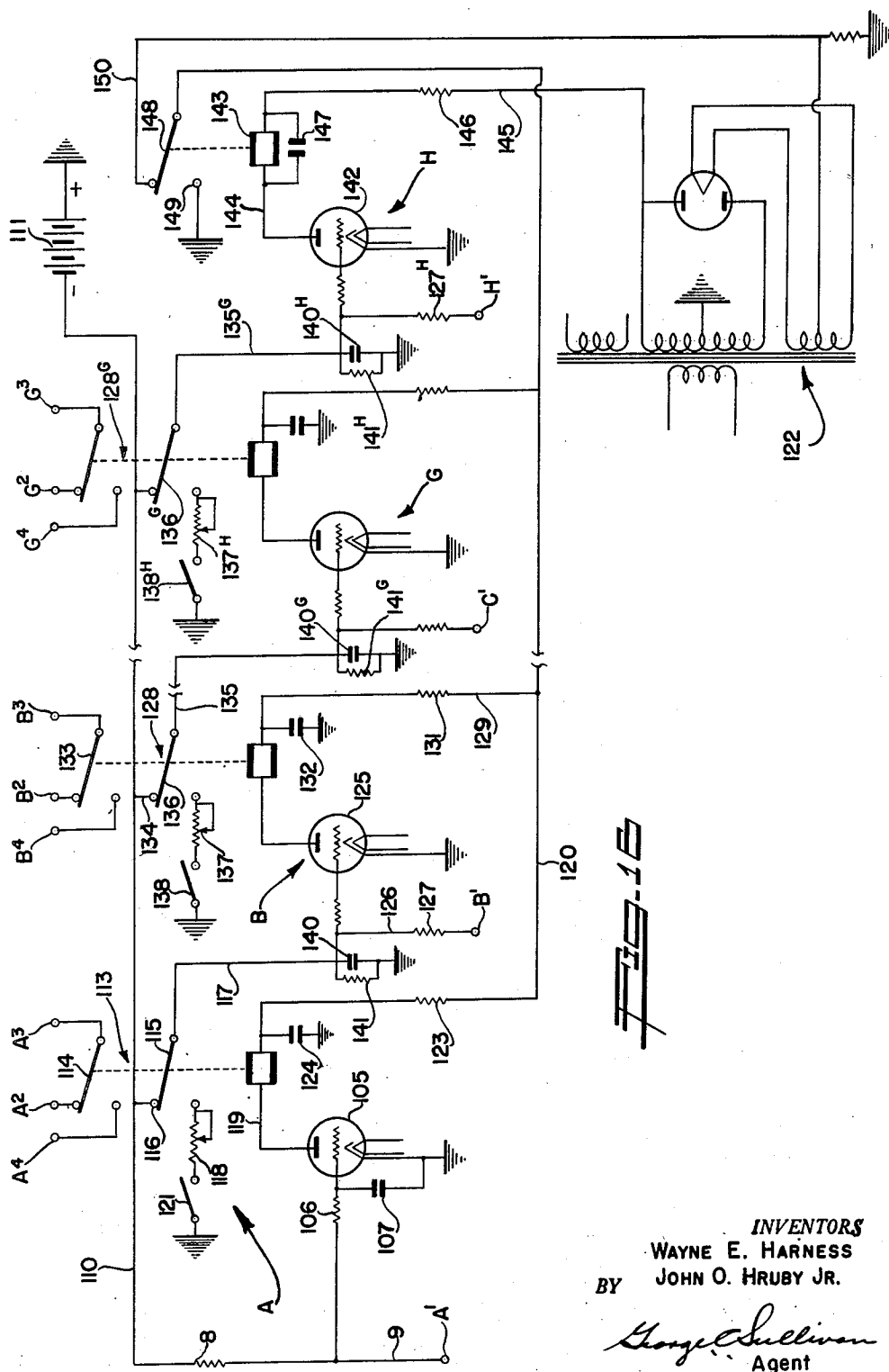
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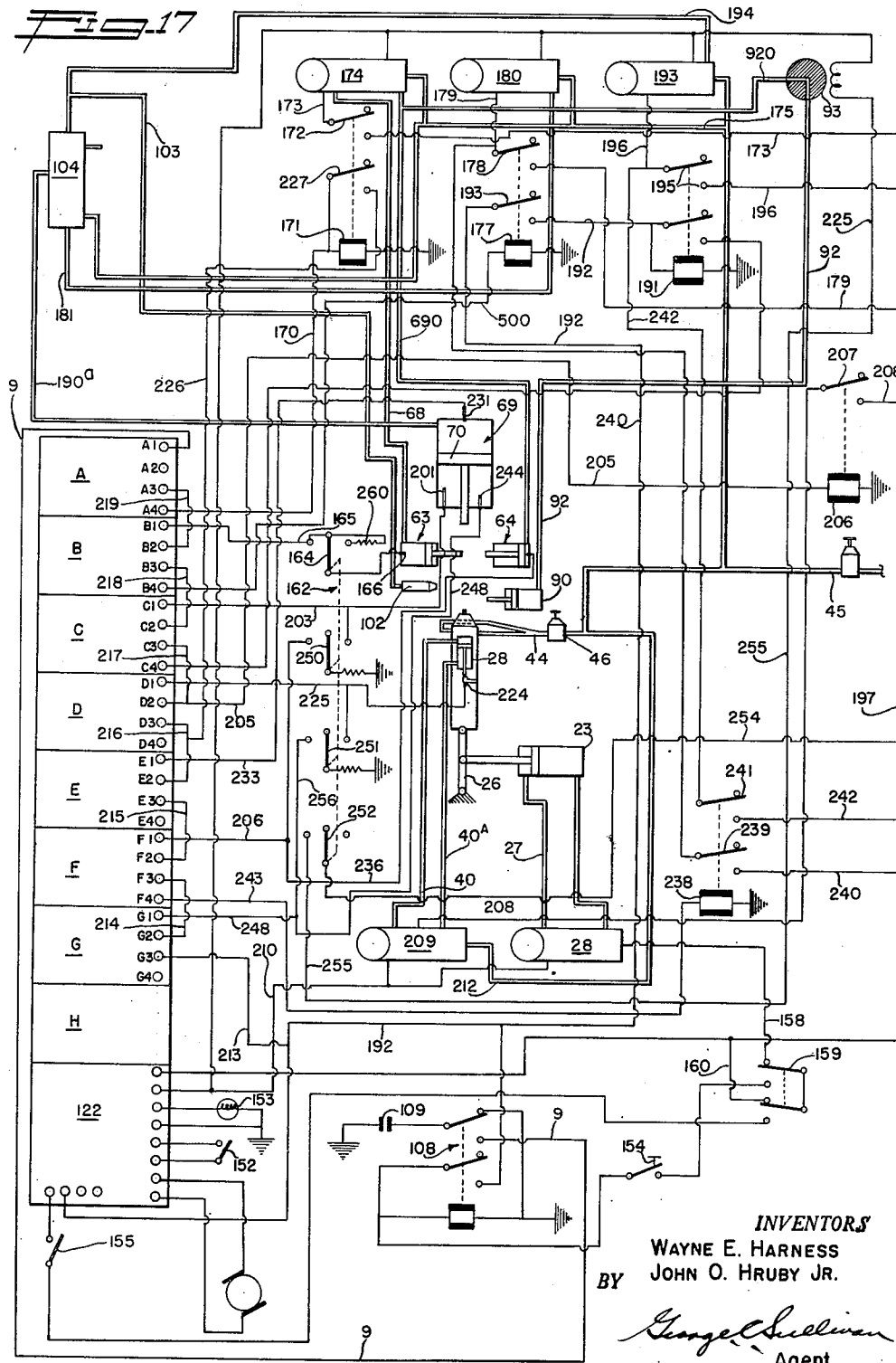
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AUTOMATIC RIVETING MACHINE

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UNITED STATES PATENT OFFICE

2,620,876

AUTOMATIC RIVETING MACHINE

Wayne E. Harness, North Hollywood, and John O. Hruby, Jr., Glendale, Calif., assignors to Lockheed Aircraft Corporation, Burbank, Calif.

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11 Claims. (Cl. 164—95)

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This invention relates to machines useful in the riveting of aircraft components and other objects and assemblies, the invention having particular reference to an improved machine of this class that is fully automatic in operation and low in maintenance cost.

Machines have been developed for performing automatic riveting operations and have found a wide application in many industries. However, the prior machines were designed and constructed in such a manner that they required frequent repair. For example, the life of the punches and dies was very short because the operating linkages allowed misalignment resulting in ultimate breakage. The wearing of the linkages and the breaking of the punches and dies necessitated frequent and prolonged shut-downs of the machines, and involved expensive repair expenditures. The prior machines referred to also lacked adequate provision for adjusting or setting the parts for the dimpling and riveting of material of different thicknesses, and much time was required in making these adjustments.

It is an important object of this invention to provide an automatic riveting machine that will operate at a low maintenance cost. The machine of this invention involves a minimum of mechanical linkages and parts subject to wear, and accurate alignment of the punch and dies is maintained indefinitely so as to practically eliminate the possibility of breakage. The several operating and shifting mechanisms are actuated directly by fluid pressure units, which in turn, are under control of an electronic system, there being no intermediate mechanism subject to wear and failure.

Another object of the invention is to provide a riveting machine that is operable to automatically perform an entire sequence of operations beginning with the dimpling of the material and ending with the heading-up of a rivet inserted in a punched hole in the material, and that may be selectively set or controlled to perform a single operation or an appropriate sub-sequence of operations. When set or conditioned to perform the full sequence of operations, the machine dimples the material, punches an opening therein, inserts a rivet in the opening and then heads up the rivet, this series of acts being entirely automatic and initiated by simple depression of a pedal, or the like. When less than this complete sequence is desired, the machine may be easily conditioned for successively performing the following individual or dual functions: (a) dimple and punch the work parts, or (b) insert and drive rivets.

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The selective control of the machine is effected by simply operating a conveniently located selector switch.

Another object of the invention is to provide a riveting machine of the character referred to which is operable to successively dimple hard and relatively hard alloys and materials. In the sequential operations, the sheets of material are first dimpled, and while the dimpled material is held under compression by the dimpling dies, the punch is operated to form or punch an opening in the material. The retention of the compression on the material at the dimple during the punching operation assures effective punching of the work without the development of cracks and without distortion of the material, even in cases where the material is tough and hard.

A further object of the invention is to provide an automatic dimpling machine wherein the depth of the dimple to be formed in the material or sheets, and the height of the driven rivets may be readily changed or adjusted to condition the machine for the riveting of material of various thicknesses. These adjustments are easily and quickly made by moving electronic contacts with respect to an actuating pneumatic ram, this movement being effected by adjusting knobs conveniently positioned at the front of the machine for this purpose.

A still further object of the invention is to provide an automatic riveting machine incorporating an improved and thoroughly reliable electronic control system which is easily selectively set by the operator to be sequentially operated by movement of the several pneumatic pistons or rams during machine operation.

Other objectives and features of the invention will be readily understood from the following detailed description of a typical preferred form of the invention wherein reference will be made to the accompanying drawings in which:

Figure 1 is a side elevation of a riveting machine incorporating the features of the invention with certain parts broken away to show internal parts in vertical cross section;

Figure 2 is a fragmentary elevation of the other side of the machine with a portion broken away to illustrate the valves and associated parts, being a view taken substantially as indicated by line 2—2 on Figure 3;

Figure 3 is a front view of the machine taken as indicated by line 3—3 on Figure 1;

Figure 4 is an enlarged vertical sectional view of the means for actuating the punch taken as indicated by line 4—4 on Figure 3;

Figure 5 is an enlarged fragmentary vertical section of the lower anvil assembly and associated parts showing a work piece being dimpled;

Figure 6 is an enlarged fragmentary vertical section of the die and punch assembly showing the punch in the actuated position;

Figure 7 is a view similar to Figure 6 showing a rivet being headed up;

Figure 8 is an enlarged fragmentary front view of the upper active assembly of the machine;

Figure 9 is an enlarged fragmentary vertical section of the rivet guide or feed means;

Figure 10 is a fragmentary elevation view with a portion in cross section taken substantially as indicated by line 10—10 on Figure 8;

Figure 11 is a transverse sectional view taken as indicated by line 11—11 on Figure 9;

Figure 12 is an enlarged vertical sectional view of the main cylinder taken substantially as indicated by line 12—12 on Figure 1;

Figure 13 is a horizontal sectional view taken substantially as indicated by line 13—13 on Figure 14;

Figure 14 is a vertical sectional view with certain parts in elevation taken substantially as indicated by line 14—14 on Figure 13;

Figure 15 is an enlarged sectional view of the diaphragm valve;

Figure 16 is a wiring diagram of the electronic circuit means; and,

Figure 17 is a combined wiring diagram and flow diagram of the principal circuits and fluid pressure actuating means of the machine.

The features of the invention are capable of embodiment in machines varying considerably in size, design and application. We will herein describe the preferred form of the machine illustrated in the accompanying drawings, it being understood that the invention is not to be considered as limited to the details of this particular embodiment.

As best illustrated in Figure 1, the machine includes a frame or body 10 of generally C shape having a base 11, a lower jaw 12, and an upper jaw 13. The forwardly extending jaws are spaced a substantial distance apart to receive the work and the body 10, or at least certain parts thereof, are hollow to contain working parts, etc. An upwardly projecting tubular boss 14 is provided on the lower jaw 12 adjacent its forward end to receive the lower anvil, die and punch assembly to be subsequently described. The active work-engaging elements of the machine are arranged on the forward portions of the jaws 12 and 13 and include a lower die and anvil carrier 15, best shown in Figures 1 and 5. The carrier 15 is guided for vertical movement in the tubular boss 14 and its upper portion is tapered or frusto-conical. A socket 16 is formed in the upper end of the carrier 15 to receive the shank of a die 17, which is removably secured therein by a set screw 18. The active upper end of the die 17 has a die cavity or recess 19 to aid in forming the dimples in the work piece and to serve as an anvil or abutment in setting up the rivets. The die 17 is tubular, having a central vertical opening for slidably receiving the punch 20.

The lower active assembly further includes a stripper 21 slidably on the exterior of the die 17. The stripper is a tubular part presenting a horizontal upper end face engaging the under side of the work piece W. The lower portion of the die 17 is externally flared as shown in Figures 5 and 6, and the stripper 21 is correspondingly

shaped so that downward travel of the stripper is limited by the cooperating flared parts. When the stripper is in its lowermost position, its upper surface is flush with the top surface of the die 17.

The carrier 15, punch 20 and stripper 21 described above, are each individually operated by fluid pressure actuated mechanisms, preferably in the form of pneumatic cylinder and piston means. The means for operating the carrier 15, that is, for moving the carrier vertically, comprises a cylinder 23, a piston 24 operable in the cylinder and linkage connecting the piston and carrier. In Figure 1 we have shown the cylinder 23 horizontally arranged within the lower jaw 12 so that the rod 25 of the piston extends forwardly for connection with a suitable toggle linkage 26. The linkage is anchored at one end in the jaw 12 and is secured at the other end to the die carrier 15. It will be seen that upon forward movement of the piston 24 the carrier with its die 17, moves upwardly, and upon rearward movement of the piston the carrier travels downwardly. Air pressure lines 27 extend from the opposite ends of the cylinder 23 to a four-way solenoid valve 28 mounted within the hollow frame jaw and controlled in the manner to be later described.

The means for operating the punch 20 includes a vertical cylinder 28 attached to the forward side of the carrier 15 and a piston 29 which operates in the cylinder and which is provided with a rod 30 extending downwardly through a gland in the lower head of the cylinder, as shown in Figure 4. Spaced lugs 31 on the cylinder head carry a pivoted lever 32. The lever 32 is arranged so that the piston rod 30 acts downwardly against its forward end and its rearward arm engages a rod 33 guided in an opening 34 in the carrier 15. An intermediate push rod 35 is slidable in the upper portion of the opening 34 and an upper push rod 36 slidably enters the lower end of the tubular die 17 to contact the enlarged lower end of the punch 20. The punch 20 is yieldingly supported for retraction, but upon actuation of the piston 29 the punch is positively forced upwardly. A helical spring 37 is engaged under compression between the upper end of the rod 35 and the enlarged lower end of the upper push rod 36. When the work piece W is placed on the die 17 preparatory to the dimpling operation or the punching operation, its weight presses the punch 20 downwardly to compress the spring 37. However, when the piston 29 is actuated downwardly the rods 33 and 35 move upwardly to compress the spring 37 until the upper end of the rod 35 engages a reduced stem 38 on the upper push rod 36, whereupon force is positively transmitted to the punch 20 to form an opening in the work piece. Upon the return or upward movement of the piston 29 the rods 33, 35 and 36 are free to return to the normal lower positions. Flexible lines 40 and 40^a deliver air under pressure to the opposite ends of the punch actuating cylinder 28. The lines extend to a solenoid operated valve 209 within the hollow jaw 12. The control for the valve 209 will be subsequently described.

The means for operating the stripper 21 serves to yieldingly urge the stripper upwardly so as to press against the under side of the work piece W around the female die 17. It is contemplated that spring means may be employed for this purpose, but we prefer to use pneumatic cylinder and ram units. Vertical cylinder bores 41 enter the tapering upper portion of the carrier 15 and plungers

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or rams 42 extend downwardly into the bores as shown in Figure 5. The projecting upper portions of the rams 42 curve upwardly and inwardly and are connected with the stripper 21 at diametrically opposite points by spring clips 43. The air pressure for supplying the bores 41 is carried by an air pressure line 44 extending from a main supply line 45 and the line 44 is branched to communicate with the lower ends of the bores. It is desirable to provide a suitable pressure regulating valve 46 in the line 44 as shown in Figure 17, which may be set or adjusted to maintain just sufficient pressure in the bores 41 to yieldingly urge the stripper 21 upwardly to free the work from the die 17 at the completion of the dimpling and/or punching operations.

The upper active assembly carried by the body jaw 13 includes a dimpling shoe 47 and a riveting shoe 48; see Figures 12, 13 and 14. The shoe 47 has an upwardly sloping arm 49 and its lower portion is offset and formed to removably carry a male dimpling die 50. The riveting shoe 48 has a similar arm 51 and is provided in its lower portion with a vertical opening 52. In the preferred construction, the two shoes 47 and 48 are mounted for individual vertical movement and for simultaneous horizontal shifting. The means for carrying the shoes includes shafts 54 slidably received in spaced vertical openings 53 formed in the forward portion of the jaw 13. The arm 49 of the dimpling shoe 47 is fixed to the lower end of one shaft 54 and the arm 51 of the riveting shoe 48 is secured to the lower end of the other shaft. The shafts are tubular, and their upper end portions are tapered to engage in correspondingly shaped seats 55 in the openings 53 so as to limit upward travel of the shafts. Spring means is provided to urge the shafts 54 to their uppermost portions where the respective shoes 47 and 48 are spaced clear of the work W and to return the parts to these positions after the several operations. These means include bolts or stems 56 extending through the tubular shafts 54 and provided at their upper ends with nuts 57 for engaging the top surface of the jaw 13. Helical compression springs 58 surround the stems 56 within the shafts 54 and are engaged under compression between the lower heads of the stems and internal shoulders 59 formed in the shafts. Figure 14 illustrates how the shoes 47 and 48 are normally held in the upper retracted positions by the springs 58.

Means is provided for shifting the shoes 47 and 48 between inactive positions and positions where they are in vertical alignment with the die 17 and the main ram 68. This mechanism includes lever arms 60 having sliding spline connections 61 with the shafts 54 so as to allow independent vertical shifting of the shafts while remaining in positive rotation transmitting relation to the shafts. The levers extend from the shafts in parallel relation and their ends are pivotally connected with a common link 62. As best shown in Figure 13, the lever arms 60 and the link 62 are housed in the hollow jaw 13 for free movement therein and piston mechanisms are supported on the jaw for shifting the link horizontally to move the shoes between their two positions. Horizontal cylinders 63 and 64 are secured to the opposite sides of the jaw 13 and contain pistons 65 provided with rods 66 which extend into the jaw 13. The shifting link 62 has a lug 67 extending between the opposing inner ends of the piston rods 66. An air pressure line 68 communicates with the outer end of the cyl-

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inder 63 and a similar line 690 supplies air under pressure to the outer end of the cylinder 64. The parts are constructed and related so that upon introducing air pressure to the cylinder 63 the riveting shoe 48 is brought to the active position in line with the main ram 68, and upon supplying air pressure to the cylinder 64 the dimpling shoe 47 is moved to its active position in alignment with the ram. It will be observed that shifting of one shoe to the active position simultaneously moves the other shoe to a remote or inactive position.

The work dimpling and punching mechanism further includes a main cylinder and piston unit for actuating the above mentioned main ram 68. This unit includes a vertical cylinder 69 mounted on the forward end of the jaw 13 where its central longitudinal axis is in coaxial relation to the die 17. A piston 70 operates in the cylinder and has a rod 71 extending downwardly through an opening in the jaw 13. The lower end of the rod 71 carries a chuck 72 for the ram 68. The lower end of the piston actuated ram 68 is engageable with the male dimpling die 50 to drive the same downwardly against the work W when the shoe 47 is in the active position, and is adapted to move downwardly through the riveting shoe 48 when the latter is in its active position to drive the rivet as shown in Figure 7. In this connection, it will be observed that the shank of the rivet is upset against the top of the punch 20 and the female die 17 so that vertical adjustment of the punch 20 controls the dimensions of the driven rivet. A stop screw 73, shown in Figure 4, is threaded through an opening in the top of the cylinder 28 and is engageable by the piston 29 to limit the downward travel of the punch 20. Thus adjustment of the screw 73 controls the position of the punch 29 for the riveting operations.

Referring again to the main cylinder, it will be seen from an inspection of Figure 12 that a reduced rod or stem 75 extends upwardly from the piston 70 and slidably passes through an opening in the upper head of the cylinder. A disc or washer 76 is secured on the upper end of the stem 75, and a helical spring 77 is arranged under compression between the cylinder head and washer to return the piston 70 and the punch 68 to the raised position when air pressure in the cylinder is released. The projecting stem 75, spring 77 and disc 76 are housed within a suitable hood or cap 78 on the cylinder 69.

It is desirable to incorporate a mechanism for feeding rivets to the riveting shoe 48 and for introducing the individual rivets to the shoe. In the drawings we have shown a simple rivet feed comprising a hopper 80 arranged adjacent the outer end of the body jaw 13 and designed to receive and contain a considerable supply of rivets. The hopper 80 discharges into a track defined by a groove 81 in a track member 82 and a slot 83 formed in a plate 84 attached to the track member. The member 82 slopes downwardly toward the shoe 48 and the rivets move by gravity through the track. The groove 81 is formed to receive the heads of the rivets, while the rivet shanks extend outwardly through the groove 83 as shown in Figures 9 and 11.

A rivet-selection or gate means is provided at the lower end at the above described track and includes a shiftable gate 85 slidably engaged between the lower end of the track member 82 and the upper end of a rivet discharging element 86. The element 86 has a passage 87 for receiving the rivets and for guiding them to the riveting

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shoe, when the shoe is in the retracted position. The entrance of the passage 87 is shaped so that the rivets swing or tilt to a position where their shanks lead or point downwardly, and the rivets remain in this position as they travel through the passage to the riveting shoe. As best shown in Figure 10, the passage 87 is offset horizontally from the lower end of the track groove 81 and slot 83, and the gate 85 operates to shift the rivets one at a time from the track to the entrance of the passage 87. The selector or gate 85 has a T-shaped notch 88 for receiving an individual rivet and this notch is adapted to register with the track to receive the rivet. Upon shifting of the gate, the notch comes into alignment with the passage 87 to discharge the rivet. In Figure 10 the gate 85 is shown in the receiving position where the notch 88 has just received a rivet from the track.

Cylinder and piston means is provided to shift the gate from this position to the discharging position where the rivet falls from the notch 88 and the passage 87. A cylinder 90 is attached to the track assembly, and the gate 85 has a rod entering the cylinder. A piston 91 on the rod operates in the cylinder 90 and an air pressure line 92 communicates with the outer end of the cylinder. The air line 92 extends to a solenoid operated three-way valve 93 shown in Figure 17, and an air line 920 continues from the valve 93 to the valve 174 to be later described. Air under pressure, supplied to the cylinder 90, moves the gate 85 from the receiving position of Figure 10 to the position where it discharges the individual rivet into the passage 87. Spring means is arranged to restore the gate 85 to the receiving position of Figure 10 when pressure is released from the cylinder 90. A yoke or bracket 94 is secured to the track assembly, and a helical spring 95 is engaged under compression between the bracket and an end of the gate 85. It will be seen how the spring 95 automatically restores the gate 85 to the position shown in Figure 10 when the valve 174 is operated to discharge pressure from the cylinder 90.

In conditioning the machine for each riveting operation a rivet is supplied to the riveting button or shoe 48 by the track and gate means just described. This rivet is retained in the shoe 48 while the shoe is shifted into alignment with the main ram 68 and until it is forced into the opening punched in the work piece W. Thus it is necessary to support the rivet in the shoe 48 in position for engagement by the main ram 68 so it will be guided downwardly into the punched opening. The means for temporarily supporting the rivet in the shoe 48 is illustrated in Figure 7 and comprises a pair of diametrically opposite dogs 96. The dogs 96 are shiftably supported in radial slots or openings 97 in the walls of the tubular shoe and are movable toward and away from the vertical axis of the shoe. The opening in the shoe 48 is proportioned to freely receive the head of the rivet and the inner ends of the dogs have sloping surfaces for engaging under the rivet head. The dogs are urged inwardly to normally occupy positions where they will catch and support the rivet introduced into the upper end of the shoe. Leaf springs 98 on the exterior of the shoe 48 urge the dogs 96 to the active positions indicated in broken lines in Figure 7. The full lines of Figure 7 show the dogs in their outermost positions with the ram 68 engaged in the shoe opening 52. Upon retraction of the ram from the shoe 48 the spring-

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urged dogs 96 return to the positions where they are operable to stop and support the next rivet. It will be observed in Figure 7 that the lower end of the main ram 68 is reduced in diameter to enter the shoe opening 52 and to have a downwardly facing shoulder 99 for contacting the shoe 48. The shoulder 99, acting on the upper end of the shoe 48, moves the shoe downwardly against the work piece W to the position illustrated in Figure 7.

As will be subsequently described, the work piece work W is securely clamped between the male and female dimpling dies 17 and 50 during the punching operation, and the punch 20 is operated upwardly to punch the opening in the dimpled material. Figure 5 shows the parts in position for the punching operation, and Figure 6 illustrates the punch in its fully operated position. It will be seen that the upper or male die 50 has a central opening 100 for receiving the punch 20 as it moves upwardly through the work part. The punch 20 displaces slugs S of material upwardly through the opening 100 as it forms the opening in the work piece. Means is provided for clearing the slugs from the opening 100 of the die 50. A lateral opening 101 joins the upper end of the opening 100 and an air pressure nozzle 102 is threaded in an aligned opening in the die 50 to discharge a stream of air across the top of the opening 100 and through the opening 101. As shown in Figure 6, the slugs S on the top of the punch 20 are carried to a position adjacent the nozzle 102 so that the jet of air blows the slugs out through the opening 101. An air line 103 leads from a four-way diaphragm valve 104, to be subsequently described, to the nozzle 102. The line 103, or at least the portion of the line adjacent the shoe 50, is flexible so that it does not interfere with free movement of the shoe.

The elements thus far described are fluid pressure operated in the embodiment illustrated being pneumatically actuated, and the invention provides a versatile, dependable electronic control system for obtaining automatic, sequential and independent actuation of the several mechanisms to perform the dimpling, punching and riveting functions. In Figure 16 we have illustrated what may be termed the internal electronic circuit which comprises an initiating stage A, a plurality of intermediate stages B, C, D, E, F and G, and a reset stage H. The initiating stage A includes a thyatron or gas filled triode tube 105 having a current limiting resistor 106 connected in its grid circuit and a surge protection condenser 107 tapped into the grid lead. A relay or switch means is provided to initiate firing of the tube 105. As shown in Figure 17, this means comprises a relay 108 which is initially or normally open, and a condenser 109 is connected with one pole of the relay. A lead 9 extends from another pole or contact of relay 108 to terminal A¹. The grid of tube 105 is connected with the lead 9. A D. C. power source 111 is provided to give bias for the control of the grids of the tubes in the various electronic stages. A common line 110 extends from the negative side of the bias source 111 to a limiting resistor 8 of high enough resistance to allow condenser 109 to temporarily bring the bias on tube 105 to a voltage low enough to render tube 105 conductive. Resistor 8 is connected between lines 9 and 110. When the relay 108 is in the open condition, its associated condenser 109 has a zero charge. Upon operation of the relay 108 which may be effected by depressing a foot pedal 154 (see Figure 17), the zero charge

is impressed on the grid of tube 105, firing the tube, or in other words, rendering the tube conductive.

The initiating stage A further includes a relay 113 having three posts or terminals A², A³ and A⁴ for connecting with external circuits, which will be later described. One side of the relay winding is tied into the plate of the tube 105 by line 119 and a lead 120 connects the other side of the winding with a suitable power supply 122 through a network 123—124 to be later described. One blade or contactor 114 of the relay is initially in a position where it electrically connects terminals A² and A³, and upon energization of the relay, this connection is opened and the contactor connects terminals A³ and A⁴. The second movable blade or contactor 115 of the relay initially makes electrical connection between a terminal 116 tied into the bias source 111 through lead 110 and a lead 117. Upon energization of relay 113, contactor 115 breaks this connection and moves to a position where it connects the lead 117 with the terminal of a potentiometer 118. The other terminal of the potentiometer is connected with a grounded timing switch 121. A voltage limiting resistor 123 is interposed in the power line 120 and a peak charge condenser 124 is tapped off the line 120 to ground at a point between the resistor and the relay 113. The function of the above described elements will later become apparent.

The initiating stage A is associated with the first intermediate stage B to control actuation thereof. Referring again to Figure 16, intermediate stage B comprises a thyratron tube 125 having a lead 126 extending from its grid and provided with a current limiting resistor 127. The lead 126 extends to a terminal B¹ which has connection with an external circuit to be later described. The relay 128 of the first intermediate stage B has one terminal of its actuating winding connected with the plate of tube 125 and a lead 129 connects the other terminal of the winding with the power line 120. A voltage limiting resistor 131 is interposed in the line 129 and a peak charge condenser 132 is connected to the line at a point between the relay coil and the resistor. The relay of stage B is similar to the relay of the initiating stage A and includes a blade or contactor 133 initially in a position where it connects terminals B² and B³. Upon energization of relay 128, the contactor 133 breaks this connection and electrically connects terminals B³ and B⁴. The second blade 136 of the relay initially makes connection between a terminal 134 in the bias line 110 and a line 135 extending to the timing resistor and condenser circuit of the next intermediate stage C. Upon energization of relay 128, the blade 136 breaks this connection and completes a circuit between said line 135 and a terminal of a timing potentiometer 137. A switch 138 is connected between the other terminal of potentiometer 137 and ground. The above described lead 117 extending from blade 115 of relay 113 connects with the grid lead of tube 125 and with a timing condenser 140. A maximum timing resistor 141 is associated with condenser 140. Condenser 140 and resistor 141 are operable to time-out the tube 125 as will be described below.

Now referring again to initiating stage A, it will be assumed that initiating relay 108 is operated to fire tube 105 as described above. In the event switch 121 is closed at this time, firing of tube 105 energizes relay 113 to complete a circuit through terminals A³ and A⁴ and to complete a circuit from condenser 140 through potentiometer 118 to

ground. Completion of the circuit through the potentiometer discharges the charge in condenser 140 to the extent that tube 125 of the intermediate stage B becomes conductive to energize relay 128 of stage B. This timing-out of tube 125 is controlled primarily by potentiometer 118, resistor 141 being of an extremely high value with respect to the potentiometer. Thus it will be seen that if switch 121 is closed when relay 113 is energized, timing-out of the tube 125 is determined by the setting of potentiometer 118. In the event switch 121 is open when tube 105 of initiating stage A becomes conductive, energization of relay 113 brings the maximum timing circuit comprising condenser 140 and resistor 141 into play. Because of the high value of resistor 141, the tube 125 of stage B is held nonconductive for a substantial period for the purpose to be later described.

Intermediate stages C, D, E, F and G may be identical with intermediate stage B just described, and are related one to the other in the manner in which stage A is related to stage B. Accordingly, in order to simplify the disclosure, the details of stages C, D, E, F and G are omitted from the drawings, and in referring to the elements of these stages, reference numerals will be used corresponding to the reference numerals applied to corresponding elements of stage B with the respective exponents C, D, E, F and G added thereto. However, in the case of the external terminals of stages C, D, E, F and G, these are designated C¹, C², C³ and C⁴, D¹, D², D³ and D⁴, and so on, as clearly appears in Figure 17.

When lead 120 is energized before the machine is operated, condensers 124, 132 and 132^C to 132^G inclusive are charged to the maximum peak voltage of power supply 122. When tube 105 becomes conductive, the peak charge of condenser 124 is available for quick energization of relay 113. Upon energization of relay 113, the charge is partially drained off from the condenser and resistor 123 becomes part of a dividing network lowering the continuous voltage applied to relay 115. This allows the relay to remain energized without overheating. The peak voltage networks 131, 131^C to 131^G, and 132, 132^C to 132^G of the several intermediate stages B to G inclusive, function in a similar manner when their respective tubes 125 and 125^C to 125^G inclusive become conductive.

The several stages A to G inclusive are interconnected in the following manner, as shown in Figure 17. A conductor or lead 213 extends from a power supply line 192 to terminal G³ of stage G. Relay 128^G normally connects terminal G³ with terminal G². An interconnecting line 214 connects terminal G² with terminal F³ of stage F. Relay 128^F normally connects terminals F³ and F², and an interconnecting line 215 joins terminals F² and E³. Relay 128^E normally connects terminals E³ and E² and an interconnecting line 216 joins terminals E² and D³. Relay 128^D normally connects terminals D³ and D², and a line 217 joins terminals D² and C³. Relay 128^C normally connects C³ and C², and a line 218 joins terminals C² and B³. Relay 128 initially connects terminals B³ and B² and a connecting line 219 joins terminals B² and A³. Terminal A³ is connected with terminal A² by the contactor 114 of relay 113 when the same is in its de-energized condition. It will be seen that this arrangement interlocks the several stages in such a manner that delivery of current to their respective terminals 2 and 4 depends upon the position of their relays.

The internal electronic circuit further includes

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a reset stage H for breaking the full wave D. C. voltage from the power source 122 to the tubes 105, 125, 125^C, 125^D, 125^E, 125^F and 125^G, and for discharging the several condensers 124, 132^C, 132^D, 132^E, 132^F, and 132^G to render the related tubes of stages A to G inclusive, non-conductive, thereby restoring these stages to their normal or initial condition. Reset stage H includes a gas-filled triode or thyatron tube 142 having a current resistor 127^H in the portion of its grid circuit extending to its terminal H¹. The lead 135^G from the relay blade 136^G of stage G taps into the grid lead, and extends to a timing condenser 140^H. A maximum timing resistor 141^H is associated with the ground condenser 140^H. It will be seen from an inspection of Figure 16 that tube 142 of reset stage H becomes conductive in the same manner as the tubes 125 of the intermediate stages, either through the timing-out action of potentiometer 137^H or resistor 141^H. The reset stage H further includes a relay 143 connected between the plate lead 144 of tube 142 and a lead 145 extending from the half-wave portion of power source 122. A current-limiting resistor 146 is interposed in lead 145 and a smoothing condenser 147 is connected in the lead across the winding of relay 143. The relay has a contactor or blade 148 connected with a terminal of above described line 120 and operable between a position where it engages a grounded pole 149 and a pole connected with a line 150 carrying full wave voltage from the power supply 122. When the relay 143 is in the de-energized condition, the blade 148 is in engagement with the terminal of line 150.

When the tube 142 is made conductive as described above, the relay 143 breaks the full wave D. C. voltage circuit to the tubes 105, 125 and 125^C to 125^G inclusive. Energizing of relay 143 also brings the blade 148 into engagement with the grounded post 149 to discharge condensers 124, 132 and 132^C to 132^G inclusive, rendering the tubes of several stages A to G inclusive, nonconductive and allowing their related relays 113, 128 and 128^C to 128^G inclusive, to restore to their initial positions. Restoration of relay 128^G applies full negative voltage from source 111 to tube 142 of stage H, making the tube nonconductive. This restores relay 143 and completes the full sequence cycle. It will be observed that the internal electronic circuit is automatic upon closing of the switch 154 to carry out a full sequence of operations throughout the several stages A to H inclusive. A case 156 mounted on a side of the body 10 contains the above described electronic stages A to H inclusive, and the power supply means 122.

The external circuits of the system include a master switch 152 for controlling delivery of current to the power supply 122. An indicator lamp 153 may be exhausted with the power supply to indicate the position of the master switch. The above described initiating relay 108 is connected in series with a pair of pedal operated switches 154 so related that depression of a common pedal closes both switches. A safety switch 155 is also connected in series with the foot switch 154 and relay 108, and is operated to allow heating of the tubes of stages A to H inclusive. The above described solenoid valve 28 for controlling delivery of air under pressure to cylinder 23 has one lead 210 extending to the power supply and has another lead 158 extending to a switch 159 connected with a second power lead 160. The switch 159 is a double pole switch and is also connected

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in series with the foot switch 154, safety switch 155 and relay 108. Thus in order to condition the machine for operation, the switch 159 must be closed to actuate the piston 24, which brings the anvil or carrier 15 to its raised operative position.

With the switches 155 and 159 closed, the foot switch 154 is closed to initiate operation of the machine. Closing of the switch 154 energizes relay 108, which applies D. C. current to all stages A to H inclusive, of the internal electronic circuit, and applies a zero charge of the condenser 107 to the grid of the tube 105 of initiating stage A. As above described, this fires tube 105 and actuates relay 113 of stage A. A lead 170 extends from post A⁴ of stage A to a relay 171 which has a pole and blade 172 interposed in a power line 173 extending to a solenoid operated four-way valve 174. Upon firing of tube 105 of stage A, relay 171 is energized and solenoid valve 174 is reversed or operated. Solenoid valve 174 is operable to connect an air pressure supply manifold 175 with the pipe 690 leading to the right-hand shifting cylinder 64 so that the piston therein is operated to shift the dimpling shoe 47 into alignment with the main ram 68. This actuation of solenoid valve 174 also supplies air under pressure from manifold 175 to lines 920 and 92 leading to the above described rivet gate or selector cylinder 90. It will be seen that energization of stage A results in shifting of the dimpling shoe 47 into alignment with the main ram and delivery of a rivet into passage 87 of the rivet feed means.

A selector switch 162 is provided to either condition the internal electronic circuit for the full sequence of operations of the machine or for punching only, or for riveting only as desired. The switch 162 is interposed between the posts or terminals B¹, C¹ and D¹ of stages B, C and D, and certain external contacts embodied in the machine. A line 163 extends from post B¹ to a post of the switch 162 and the related switch blade 164 is engageable therewith to complete a circuit through a line 165 extending to an external contact 166. As illustrated in Figure 13, contact 166 is in the nature of a post extending through a tubular insulating screw 300 which in turn is threaded through an opening in the head of the left hand shift cylinder 63. The inner end of the contact 166 is engageable by piston 65.

The next phase of the operation is effected by engagement of the left-hand shift piston 65 with the above described contact 166. Contact 166 is connected with terminal B¹ of the first intermediate stage through the medium of line 165 and selector switch blade 164 so that engagement of the piston with the contact 166 grounds the tube 125 conductive. The timing switch 121 of stage B is open at this time, and the maximum timing circuit 140—141 allows ample time for the grounding of circuit 164 and 165 as just described. The conductive tube 125 energizes relay 128 and contactor 133 comes into engagement with terminal B⁴. This energizes a relay 177 having a contactor 178 interposed in a lead 179 extending from a solenoid actuated four-way valve 180 to a common A. C. power lead 197. Valve 180 controls communication between the air pressure manifold 175 and a line 181, and communication between the line 181 and the atmosphere. Line 181 extends to one end of a diaphragm valve 104 illustrated in detail in Figure 5.

Diaphragm valve 104 includes a tubular body 182 provided at its ends with caps or heads 183.

A partial partition in the body carries a tubular seat member 184 and defines two end chambers 185 and 186. The member 184 extends into these chambers and its end surfaces constitute annular seats which oppose the heads 183. Flexible diaphragms 187 and 188 are secured against the ends of the body 182 to extend across the chambers 185 and 186. The diaphragms are movable into and out of engagement with the adjacent ends of the seat member 184. An exhaust port 189 communicates with the inner portion of chamber 186 and an air pressure supply line 190, leading from manifold 175, communicates with the inner portion of chamber 185. It will be observed that the effective areas of the diaphragms 187 and 188 exposed to pressure introduced into the outer ends of the chambers 185 and 186, are considerably larger than the areas of the diaphragms exposed at the interior of the seat member 184 and the areas exposed around the seat member. Accordingly, pressure admitted to the outer end of a chamber holds the related diaphragm 187 or 188 engaged with the seat member 184 and resists comparable pressure within the seat member 184 or within the annular space surrounding the seat member. Release of pressure from an outer end of a chamber 185 or 186 allows the related diaphragm to open away from the seat member. A pipe 190^a communicates with the interior of the seat member 184 and extends to the upper end of the main cylinder 69.

When relay 177 is energized to reverse the solenoid actuated valve 189, pressure is relieved from line 181 and the outer end of chamber 185. This allows diaphragm 187 to move to the open position so that air under pressure pipe 190 flows through pipe 190^a to the upper end of the main cylinder 69. Substantially simultaneously with this action, air under pressure is supplied to the outer end of chamber 186 to close the diaphragm 188 against seat member 184 and thus close off the exhaust 189.

The means for effecting reversal of diaphragm 188 includes a relay 191 energized upon actuation of relay 177. A lead 192 extends from the coil of relay 191 to the power supply 122 and the above described relay 177 has a contactor and pole combination interposed in lead 192. Thus, upon energization of relay 177, relay 191 is also energized. Relay 191 controls a four-way solenoid actuated valve 193. Relay 191 has a blade and pole 195 interposed in a lead 196 extending from the supply line 197 to the solenoid of valve 193 so that energization of the relay operates or reverses the valve. Valve 193 governs a pipe 194 leading to the outer end of diaphragm valve chamber 186 to either connect the same with air pressure supply manifold 175 or the atmosphere. Energization of relay 191 reverses valve 193 so that air under pressure is supplied to pipe 194 and chamber 186. It will be seen that upon firing of tube 125, valves 180 and 193 are reversed to reverse the diaphragm valve 184 so that air under pressure is supplied to the upper end of the main cylinder 69 to actuate the ram 68 downwardly.

In accordance with the invention, means is provided for limiting the initial downward stroke of the main ram 68 so as to control the depth of the dimple formed in the work W, and the stroke-limiting means serves to initiate operation of the intermediate electronic stage C. A dimple depth contact is provided in the lower portion of the main cylinder 69 to be engaged by the piston 70 as it descends. A plate 198 of dielectric mate-

rial is secured to the under side of cylinder 69 and carries a bushing 199. A tubular thumb screw 200 is threaded upwardly through the bushing and passes freely through an opening in the cylinder wall to enter the cylinder. An elongate contact stem 201 is slidable in the thumb screw 200 and has a head at its lower end for contacting the under side of the thumb screw knob. A spring 202 is engaged under compression between the screw 200 and a head on the upper end of the stem 201 to urge the stem upwardly. It will be seen that rotation of the screw 200 vertically positions or adjusts the contact stem 201. The knob of the screw 200 is conveniently accessible at the front of the machine so that the operator may readily vary or regulate the depth of the dimples to be formed.

A lead or conductor 203 is electrically connected with the contact stem 201 through the medium of the bushing 199 and screw 200, and extends to the post C¹ of the intermediate electronic stage C. When the main piston 70 moves into engagement with the contact stem 201, the grid circuit of stage C is grounded to make the tube 125^c conductive. This in turn energizes relay 128^c to bring the blade 133^c into contact with post C⁴. A line 205 extends from terminal C³ to a relay 206, a circuit for energizing relay 206 being completed through lead 205, contactor 133^c and post C³. Relay 206 includes a post and contactor 207 interposed in a lead 208 extending from power line 197 to one side of the solenoid of a four-way valve 209. The other side of this solenoid is tapped into line 210 extending to the power supply 122. Valve 209 governs the above mentioned pipes 40 and 40^a, which lead to the upper and lower ends respectively of the punch operating cylinder 28. When the solenoid of valve 209 is in the normal de-energized condition, the valve connects the pipe 40^a with an air pressure supply line 212 so that the piston 29 is held in the upper position. Upon reversal of the valve 209, effected by operation of relay 206, pipe 40 is put into communication with pressure line 212 and pipe 40^a is allowed to exhaust to atmosphere. This actuates piston 29 downwardly and the punch 20 is forced upwardly to form an opening in the dimpled work piece. It is to be observed that air pressure is maintained in the main cylinder 69 at this time and the work W is tightly clamped between the dies 17 and 50 as it is punched. This assures the production of a true clean opening in the work with a minimum of distortion.

As described above, slugs S of the sheets or work pieces W are pushed upwardly through the opening of die 50 when the punch is operated. The invention provides for the delivery of air under pressure to the nozzle 102 to blow these slugs free. The above mentioned line or pipe 103 supplying the air nozzle 102 is in communication with the pipe 194 which extends between solenoid operated valve 193 and diaphragm valve 184. When the valve 193 is reversed to close off the exhaust 189 of the diaphragm valve as previously described, air under pressure is also supplied to the nozzle 102 through line 103. A stream of air discharges from the nozzle 102 at a substantial velocity so long as the solenoid of valve 193 remains energized. Accordingly, the slugs S formed during the punching operation are blown clear through the opening 101 by the air blast as the punch approaches the upper end of its stroke.

At the instant the blade or contactor 133^c of

stage C is operated toward post C⁴, the circuit to the coil of relay of 177 is opened to de-energize the relay 177. The current to relay 177 is carried by relay 128, line 217, relay 128^C and a line 500 extending from post B⁴ to the winding of the relay. When relay 128^C is energized as just described, this circuit is broken between terminals C² and C³. De-energization of relay 177 causes reversal of solenoid operated valve 180, which in turn seals off both ends of the diaphragm valve 104 to lock the ram 68 in its down or dimpling position. When blade 133^C moves into engagement with terminal C⁴ a circuit is completed to the winding of relay 206 through lead 205. Energization of relay 206 energizes solenoid actuated valve 209 to supply air under pressure to cylinder 28 through line 40. This actuates the punch 20 to form an opening in the work pieces W.

The above described actuation of the punch 20 causes operation of electronic stage D, which in turn de-energizes relays 191 and 206. As shown in Figure 4, a rod 221 is attached to the cylinder 28 of the punch operating mechanism and a sleeve 222 is slidable on the rod. The sleeve is yieldingly urged upwardly by a spring 223. A projecting arm on the sleeve 222 carries an insulated contact 224 in position to be engaged by the lever 32 when the punch 20 reaches the upper end of its movement. A conductor 225 extends from contact 224 to the terminal D¹ of stage D. Upon engagement of the lever 32 with contact 224, the grid circuit of tube 125^D is grounded to discharge condenser 140^D and the tube is made conductive. This energizes relay 128^D to break the connection between terminals D² and D³. This in turn de-energizes relays 191 and 206. De-energization of relays 191 and 206 results in reversal of the solenoid operated valves 193 and 209 so that the spring 77 is free to restore the piston 70 to its raised position and to move the ram upwardly out of engagement with the die 50. Valve 209 is also reversed to cause the punch 20 to descend. Relay 171 remains energized at this time to hold valve 174 in the actuated position so that the dimpling die 50 remains in line with the ram 68. Relay 171 is locked in by a lead 226, tapped into the interconnecting line 216 and extending to a second contactor 227 of the relay, the contactor being connected with a pole of the relay winding.

The invention provides means whereby restoration of the ram 68 reverses the positions of the dimpling shoe 47 and the riveting shoe 48. A tubular screw 229 is adjustably threaded through a bushing 230 secured in a di-electric plate on the hood 78 of the main cylinder 69. A contact stem 231 is shiftable in the screw and extends downwardly into the hood. A spring 232 is engaged between the screw 229 and a head on the lower end of the stem 231 to urge the stem downwardly to its lowermost position. The stem 231 is engaged by the upper end of the rod 75 when the piston 70 returns to its upper position. A conductor or line 233 extends from a post on the bushing 230 to the terminal E¹ of stage E. When the contact stem 231 is engaged by the rod 75, the control grid circuit of stage E is grounded so that tube 125^E becomes conductive to energize relay 128^E. This breaks the connection between terminals E² and E³, and relay 171 is de-energized so that valve 174 is reversed. Reversal of four-way valve 174 exhausts air pressure from line 690 and cylinder 64, and supplies air under pressure to line 68 and cylinder 63. The resultant actuation of piston 165 shifts the dimpling

shoe 47 to an idle position and moves the riveting button or shoe 48 carrying the previously introduced rivet into alignment with the main ram 68. It will be observed that at this time all external relays are de-energized. The machine is now in condition for the riveting operation.

Shifting of the riveting shoe 48 to the active position is immediately followed by downward actuation of the main ram 68. The means for accomplishing this includes a contact 234 carried by an insulating screw 235 threaded through an opening in the end of the right-hand shift cylinder 64 so as to be engageable by the piston of that cylinder when it returns to the outer position. A conductor or line 236 is connected to contact 234 and extends to terminal F¹ of stage F. Engagement of the returning piston with contact 234 grounds the control circuit of stage E to render the tube 125^E conductive so that relay 128^E is energized. In accordance with the invention, this re-energizes or reverses the four-way valves 180 and 193. The means for accomplishing this operation includes a relay 238 having a blade 239 interposed in a line 240 extending from the A. C. power line 197 to one pole of the solenoid operated valve 180. The relay has a second blade 241 in a line 242 extending from the A. C. power line 197 to the line 196 of the solenoid operated valve 193. A conductor 243 extends from the terminal F³ to stage F to the winding of relay 238 so that energization of relay 128^E energizes relay 238 and operates valves 180 and 193. In accordance with the previous description of operation, actuation of the valves 180 and 193 supplies air under pressure to the upper end of the main cylinder 69 through the medium of the diaphragm valve 104. This operates the ram 68 downwardly to drive or upset the rivet releasably held in the shoe 48. As shown in Figure 7, the rivet is passed through the punched opening in the work W and its shank is upset against the upper end of the punch 20 and the surface of die 17.

The invention provides adjustable means for accurately determining the depth of the rivet and for initiating the next stage of operation. This means includes what we will term a rivet depth contact 244 positioned to be engageable by the main piston 70. A tubular thumb screw 245 is threaded through a bushing 246 in the insulating plate 198 and passes freely into the lower end of the cylinder 69 as best shown in Figure 12. The rivet depth contact 244 is in the nature of an elongate stem shiftable in the screw 245 and provided with heads at its upper and lower ends. A spring 247 is engaged between the upper head of the contact and the screw 245 to urge the contact to its upper position projecting a considerable distance beyond the screw. The contact 244 is at a lower elevation than the dimple depth contact stem 201 and is not engaged during the dimpling stroke of the ram 68. As the piston 70 moves downwardly during the riveting stroke, it engages and depresses the stem 201, but at this time the circuits associated with the stem are idle. A lead 248 extends from a screw or post on a bushing 246 to the terminal G¹ of electronic stage G. When the piston 70 engages the stem 244, the control grid circuit of tube 125^G is grounded and the tube is made conductive. This energizes relay 128^G so that its blade 133^G moves out of engagement with terminal G². As a result, the circuit to terminal F³ and line 243 is broken to de-energize relay 238. This de-energizes or reverses valve 180 and 193 so that the diaphragm

valve 104 operates to cut off the air supply to the main cylinder 69 and to exhaust air therefrom. The spring 77 restores the piston 70 and ram 68 to their upper positions. It will be observed that the operator may accurately time the operation just described by adjusting the thumb screw 245 and thereby regulate or determine the depth of the driven rivet. Upon operation of stage G, the blade 133^G of its relay 128^G moves out of engagement with terminal G². This clears D. C. current from all external relays 171, 177, 191, 206 and 238.

The reset stage H of the electronic system is operated substantially simultaneously with return of the ram 68. The switch 138^G of stage G is closed at all times, and upon energization of relay 128 as above described, timing circuit 137^G and 140^H times-out the tube 142 of stage H. When the charge in condenser 140^H is reduced to a given degree, the tube 142 becomes conductive to energize relay 148. Operation of relay 148 breaks the DC circuit 120-150 to de-energize the relays 113, 123, 128^C to 128^G inclusive, of the electronic system. The contactor of relay 148 moves to the pole 149 to apply full negative bias voltage to the timing condensers 124, 140 and 140^C to 140^G inclusive, to prevent the tubes of the several stages from becoming conductive when voltage is again applied to the system. Thus the electronic system is fully restored for the next operation.

The machine may be conditioned to perform given individual operations or a sequence of selected operations short of a full sequential cycle. For example, the machine may be set to dimple the work W and punch an opening therein for the subsequent reception of a rivet. The above mentioned selector switch 162 is embodied in the external circuit to provide for the performance of selected operations or sequence of operations. The selector switch includes the previously mentioned blade 164, and additional blades 250, 251 and 252. Figure 17 shows the selector switch in position for a full sequence cycle of the machine. When desired to only dimple and punch the work W, the selector switch is moved to a position where its blades 250, 251 and 252 function as described below.

In considering the following description of operation where the machine is employed for dimpling and punching only or for rivet inserting and driving only, the relationship between the resistances in the control grid circuits of the several electronic stages is of importance. When the relay 128 of a given stage is open or in the initial position, the resistance in the circuit from the condenser 140 to the line 110 is less than the resistance in the circuit from the condenser to the terminal B¹, C¹, D¹, etc., as the case may be. Accordingly, the tube 125 is not made conductive, even though this terminal is grounded by the operation of some external element of the machine. The relay 128 of a preceding electronic stage must be energized or closed to render the tube 125 conductive by the grounding of the control grid circuit through the related terminal B¹, C¹, D¹, etc. The resistance 127 adjacent the terminal is of such a value that upon grounding of the circuit, the related tube 125 is made conductive almost immediately by bleeding off the charge in the associated condenser 140.

The dimpling and punching cycle is initiated in the same manner as the full sequential cycle by closing switches 154, 155 and 157. This re-

sults in operation of electronic stage A to shift dimple die 47 into position between die 17 and ram 68. Stage B then operates automatically to supply air under pressure to the upper end of the main cylinder 69 to move the ram downwardly whereby a dimple is formed in the work W by the dies 17 and 59. The dimple depth contact 201 is engaged by the piston 70 to operate stage C at the completion of the dimpling operation. Actuation of stage C maintains air pressure in the main cylinder 69 and causes air under pressure to be supplied to cylinder 28 to actuate the punch 20. The punch 20 forms an opening in the material held by the dies 17 and 59. At the completion of the punching operation, lever 32 engages contact 224 to energize or fire electronic stage D, which in turn effects the return of the ram 68 and punch 20 to their idle positions. Piston 70 comes into engagement with contact 231 as the ram approaches its uppermost position, and electronic stage E is operated. This causes the rivet shoe 48 to move into position between the ram 68 and die 17. However, there is no rivet contained in the shoe 48 at this time, and the shoe is not brought into operation during the dimpling and punching sequence. Blade 252 of the selector switch 162 is connected between a lead 254 extending from power line 197 and a line 255 extending to one side of the solenoid operated three-way valve 93. When the selector switch is positioned for dimpling and punching only, the blade 252 closes the circuit just mentioned to operate the valve 93 to a position where the air pressure supply is cut off from the rivet gate cylinder 90. The rivet gate 85 is thus held in a position where rivets cannot feed into the shoe 48.

Electronic stage F is grounded by the selector switch to fire immediately upon the operation of the electronic stage E, and before the right-hand shifting piston engages contact 234. Electronic stage G is also fired immediately. Contact 251 of the selector switch is at this time positioned to ground a tap 256 from the line 248 extending to terminal G¹. Electronic stage G clears all the external relays of the system and serves to time-out tube 142 of stage H through circuit 137^G, 135^G and 140^H. This clears out the electronic circuits for the succeeding operation.

When the machine is to be used to insert rivets in previously dimpled and punched openings in the work piece and then to drive the rivets, the selector switch 162 is moved to the "rivet only" position where the blades 164, 250 and 251 control the related circuits. In carrying out the "rivet only" operation, electronic stage A is operated by closing switch 154 and the other switches in the initiating circuit. This fires or operates stage A as above described. With selector switch 162 in the "rivet only" position, the blade 164 engages a terminal to place a resistor 260 in the circuit 165 which connects terminal B¹ and contact 166 at the left-hand shift cylinder 63. The resistor 260 is of such a value that it delays firing of tube 125 of stage B for a sufficient time to allow the rivet to drop into the shoe 48 from the passage 87. The automatic "rivet only" cycle is substantially reduced in time by reason of the fact that stages C and D are immediately grounded out, as will be described below. This shortening of the cycle of operation is compensated for by the delay in the firing of stage B effected by resistor 260, and the rivet is given ample time to fall into the rivet shoe before the shoe is shifted. Engagement

of shift piston 65 with contact 166 results in firing of stage B as described above. This conditions stage C for operation, and blade 250 of the selector switch 162 grounds line 203 so that stage C fires immediately. This conditions stage D, which also fires immediately because blade 251 of the selector switch grounds line 225 leading to the terminal D¹. Thus stages C and D are operated in rapid succession and do not depend upon external circuit conditions established by machine operation for their actuation. Stage E of the electronic system operates as above described to cause the rivet shoe 43 carrying the rivet to be shifted into position in line with the main ram 68. Stage F then operates as previously described to actuate the main ram, and the rivet is driven. Electronic stage G operates at the completion of the rivet driving operation by reason of the engagement of piston 70 with the rivet depth contact 244 and actuation of stage G causes the main piston and ram 68 to return to their upper positions. Re-set stage H operates as in the previously described cycles, and the system is restored to the normal condition for the next "rivet only" sequence. The machine may be repeatedly operated to insert and drive rivets in previously dimpled and punched openings by merely actuating the foot switch 154.

Switches 121, 138 and 138^C to 138^F inclusive may be omitted if desired. However, they are illustrated in the preferred embodiment of the invention to indicate that the successive stages of the electronic system may be timed out to perform or permit the performance of special or selected machine operations as conditions may require.

From the above detailed description it will be seen that we have provided a fully automatic riveting machine that may be employed to carry out a complete sequence of operations, including the dimpling and punching of the work parts, the insertion of the rivets and the driving of the rivets. The machine may also be set to simply dimple and punch the work parts or to insert rivets in previously dimpled and punched openings and then drive the inserted rivets. Thumb screw 200 may be easily adjusted to regulate the depth of the dimples to be formed in the work pieces, and thumb screw 245 may be manipulated to regulate the depth of the rivets. The thumb screws 200 and 245 are located where they are conveniently accessible to the operator, and adjustment of the machine may be accomplished without any delay whatsoever. It is to be observed that the several primary or active elements of the machine are directly operated by cylinder and piston mechanisms, and there are no intervening linkages subject to wear and malfunctioning. The electronic control system assures properly timed sequential operation of the several machine parts and is such that simple setting of the selector switch 162 conditions the machine either for the performance of the full cycle of operations or for dimpling and punching only, or riveting only. The invention provides a trouble-free fully automatic machine capable of rapidly carrying out its several functions.

Having described only a typical form of the invention, we do not wish to be limited to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that may appear to those skilled in the art and/or fall within the scope of the following claims.

We claim:

1. In a riveting and dimpling machine, anvil

means carrying a die, a ram, a piston for moving the ram toward the die, a shoe shiftable between a retracted position and a position in alignment with said ram and die and capable of movement toward the die, a second die carried by the shoe, cylinder and piston means for shifting the shoe between said positions, means for initiating operation of the first named piston to cause the ram to move said second die against a work piece on the first named die including contact means associated with said cylinder and piston means and closed when the shoe reaches the position in alignment with the ram, and means for terminating movement of the ram toward the anvil to limit the effect of the dies on the work piece comprising an electric control means and contact means for the same operated by said first named piston.

2. In a dimpling machine, anvil means carrying a die, a ram, a first piston for moving the ram toward the die, a shoe shiftable between a retracted position and a position in alignment with said ram and die and capable of movement toward the die, a second die carried by the shoe, means for shifting the shoe between said positions including a cylinder and a second piston operable therein, means for initiating operation of the first piston to cause the ram to move said second die against a work piece on the first named die including contact means associated with said cylinder and said second piston and closed when the shoe reaches the position in alignment with the ram, means for terminating movement of the ram toward the anvil to limit the effect of the dies on the work piece including an electric control system for said first piston and a contact operated by said first piston to govern said system, and manual means for changing the position of the contact to vary the effect of the dies upon the work piece.

3. In a dimpling machine, anvil means carrying a die, a ram, a first piston for moving the ram toward the die, a shoe shiftable between a retracted position and a position in alignment with said ram and die and capable of movement toward the die, a second die carried by the shoe, cylinder and piston means for shifting the shoe between said positions, means for initiating operation of the first named piston to cause the ram to move said second die against a work piece on the first named die including contact means associated with said cylinder and piston means and closed when the shoe reaches the piston in alignment with the ram, means for terminating movement of the ram toward the anvil to limit the effect of the dies on the work piece including an electric control system, a contact in said system arranged to be engaged by piston to limit movement of said first piston, and an accessible screw threaded member manually operable to alter the position of the contact and thus alter the effect of the dies upon the work piece.

4. In a dimpling machine, a normally stationary die, a die supported for movement toward the stationary die, a ram vertically aligned with the movable die for moving the same toward the stationary die, a cylinder vertically aligned with the ram, a piston operable in the cylinder to actuate the ram, and means for controlling the piston to determine the stroke of the ram and therefore the effect of the dies upon a work piece engaged between them, said means including valve means for controlling the delivery of actuating fluid pressure to the cylinder, an electrical system for operating the valve means and a contact in the system arranged in the cylinder to be engageable

by the piston to cause closing the valve when the dies have produced a given effect upon the work piece.

5. In a dimpling machine having an anvil means carrying a tubular dimpling die and having a punch movable through the die, the combination of; a ram movable toward and away from the die, a dimpling shoe arranged for movement between a retracted position and a position in line with the ram and for movement toward and away from the die, cylinder and piston means for moving the dimpling shoe into alignment with the ram, a die in the dimpling shoe, cylinder and piston means for moving the ram toward the anvil means, means energized by the piston of the first named cylinder and piston means for supplying actuating fluid pressure to the cylinder of the second named cylinder and piston means to actuate the ram so that said dies form a dimple in a work piece, means controlled by the piston of the ram actuating means for operating the punch to form an opening in the work piece, and means controlled by the punch actuating means for moving the ram away from the anvil.

6. In a machine of the class described for dimpling and punching a work piece, a stationary die, a shiftable die, means for shifting the second die into alignment with the first die, a ram for moving the second die toward the first die to form a dimple in the work piece, a punch movable through the first die to form an opening in the dimple, and an electronic control for producing sequential operation of the die shifting means, ram and punch on the order named, said control including contact means rendered active upon said shifting of the second die, a first electronic stage operated by said contact means to cause actuation of the ram, contact means rendered active upon full actuation of the ram, and a second electronic stage operated when the second contact means becomes active to cause actuation of the punch.

7. In a machine of the class described for dimpling and punching a work piece, a stationary die, a shiftable die, means for shifting the second die into alignment with the first die, a ram for moving the second die toward the first die to form a depression in the work piece, a punch movable through the first die to form an opening in the depression, and an electronic control for producing sequential operation of the die shifting means, ram and punch in the order named, said control including a first electronic stage manually initiated to cause actuation of the die shifting means, a second electronic stage conditioned for operation upon operation of the first stage and operable to cause operation of the ram, contact means operated upon said shifting of the second die to cause operation of the second stage, a third electronic stage conditioned for operation by said second stage and operable to cause actuation of the punch, and contact means operated upon actuation of the ram to cause operation of said third stage.

8. In a machine of the class described for dimpling and punching a work piece, a stationary die, a shiftable die, means for shifting the second die into alignment with the first die, a ram for moving the second die toward the first die to form a dimple in the work piece, a punch movable through the first die to form an opening in the dimple, and an electronic control for producing sequential operation of the die shifting means, ram and punch in the order named, said control including a first electronic stage manually ini-

tiated to cause actuation of the die shifting means, a second electronic stage conditioned for operation upon operation of the first stage and operable to cause operation of the ram, contact means operated upon said shifting of the second die to cause operation of the second stage, a third electronic stage conditioned for operation by said second stage and operable to cause actuation of the punch, and contact means operated upon actuation of the ram to cause operation of said third stage, each of said stages including a relay controlling the element which that stage operates and also operable to condition the succeeding stage, a tube for energizing said relay and having a control grid circuit grounded by one of said contact means to render the tube conductive to energize the relay.

9. In a machine having a stationary die, a shiftable die and a ram for moving the shiftable die against a work piece on the stationary die the combination of; means for shifting the die into alignment with the ram, means for operating the ram, and a control system comprising a first electronic stage including a relay for operating the die shifting means, a tube for energizing the relay and having a control grid circuit, and manually operable means for controlling said circuit to render the tube conductive so as to operate the relay, and a second stage comprising a relay for causing actuation of the ram operating means, a tube having a control grid circuit conditioned by operation of the relay of the first stage and contact means operated upon shifting of the shiftable die to the position where it is aligned with the ram for grounding the grid to render the tube conductive.

10. In a machine having a stationary die, a shiftable die and a ram for moving the shiftable die against a work piece on the stationary die the combination of; means for shifting the die into alignment with the ram, means for operating the ram, and a control system comprising a first electronic stage including a relay for operating the die shifting means, a tube for energizing the relay and having a control grid circuit, and manually operable means for controlling said circuit to render the tube conductive so as to operate the relay, and a second stage comprising a relay for causing actuation of the ram operating means, a tube having a control grid circuit conditioned by operation of the relay of the first stage, said grid circuit including contact means actuated by said means for shifting the die to ground the grid circuit to render the tube conductive upon shifting of the shiftable die to the position where it is aligned with the ram.

11. In a machine having a stationary die, a shiftable die and a ram for moving the shiftable die against a work piece on the stationary die, the combination of; means for shifting the die into alignment with the ram, means for operating the ram, and a control system comprising a first electronic stage including a relay for operating the die shifting means, a tube adapted to be made conductive to energize the relay, a grid circuit for the tube normally imposing a negative bias to hold the tube nonconductive, manually operated means for controlling said grid circuit to render the tube conductive to produce actuation of the die shifting means, and a second stage including a relay for causing actuation of the ram operating means, a tube operable when conductive to energize the second stage re-

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lay, a control grid circuit for the second stage normally connected with a bias source by the first stage relay and disconnected therefrom upon operation of the first stage relay, a condenser in the second stage grid circuit maintaining a sufficient bias charge to hold the second stage tube non-conductive, and contact means for grounding the second stage grid circuit upon shifting of the shiftable die into alignment with the ram to bleed said charge from the condenser to render the second stage tube conductive.

WAYNE E. HARNESS.
JOHN O. HRUBY, JR.

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