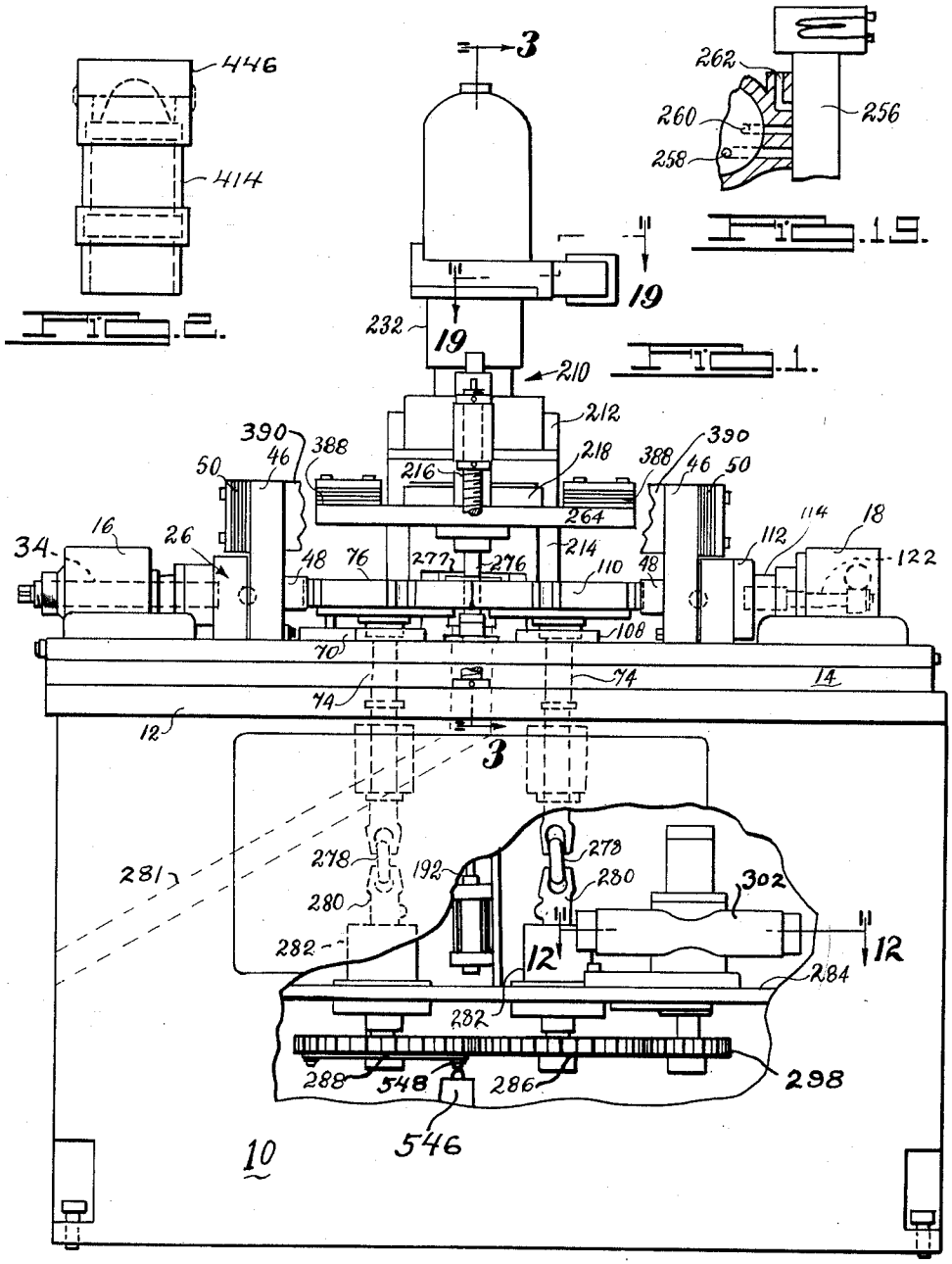
May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

Filed Dec. 30, 1957 14 Sheets-Sheet 1



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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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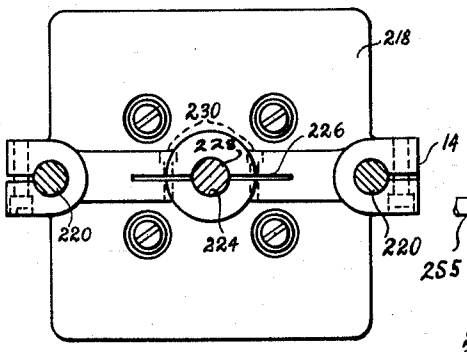


FIG. 4.

FIG. 3.

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FUSING MACHINE

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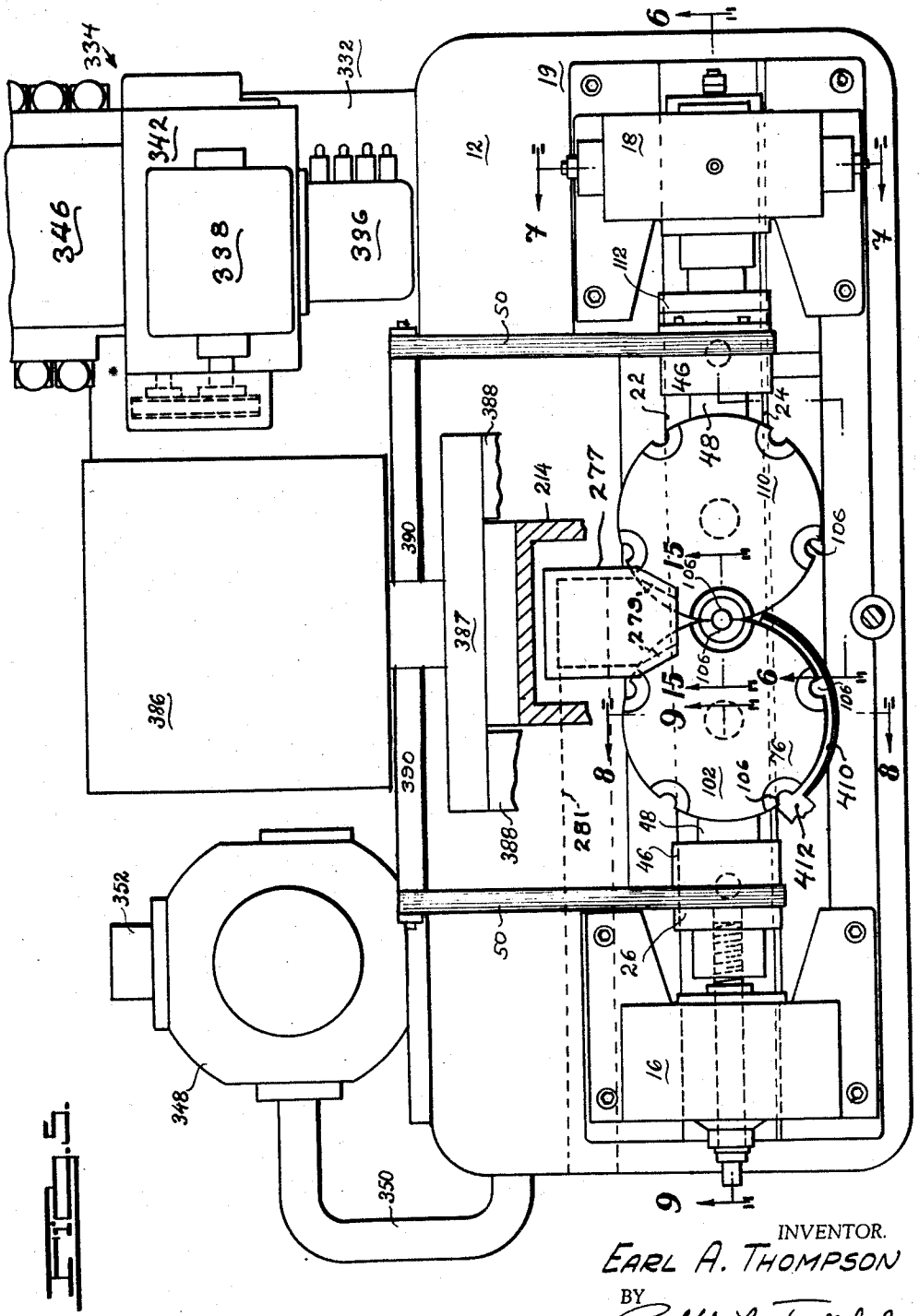


FIG. 5.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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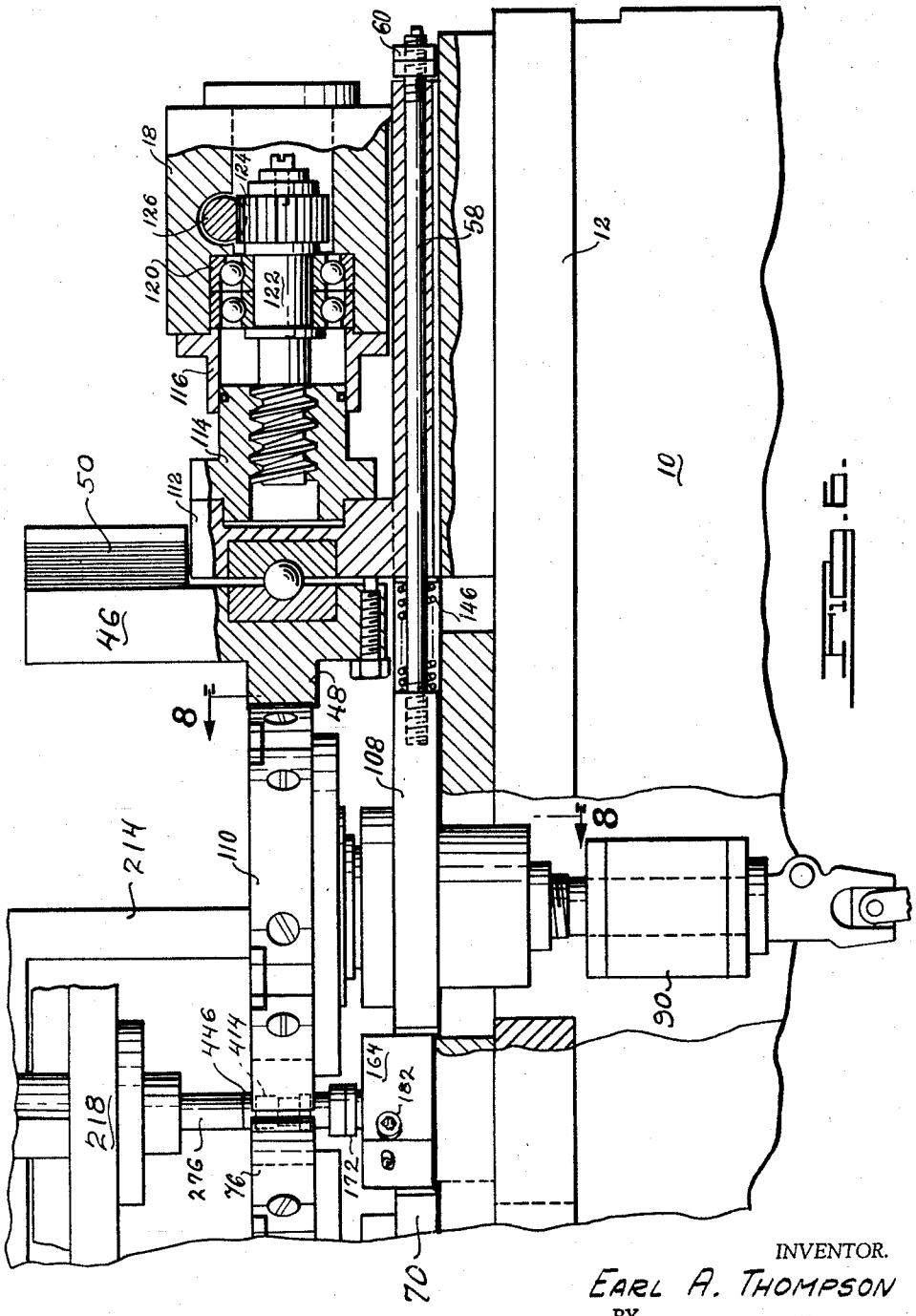


FIG. 6.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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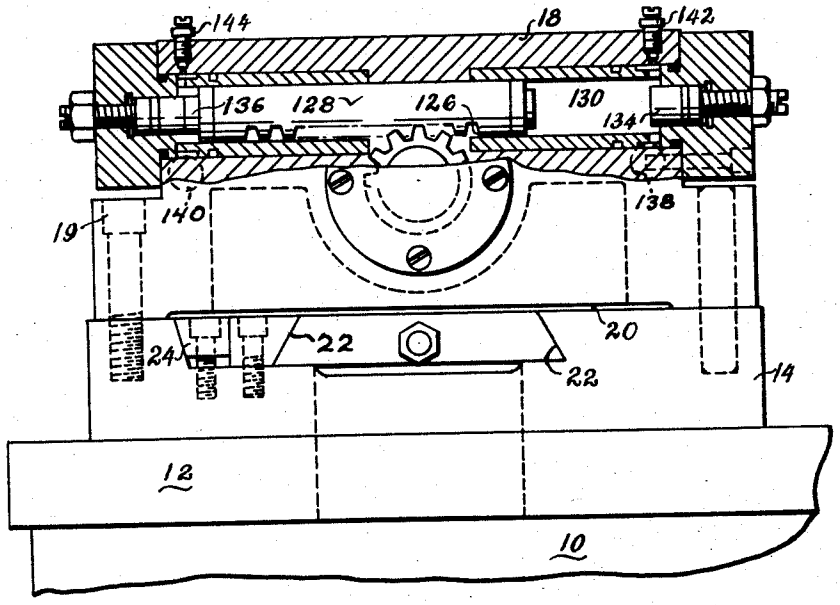


FIG. 7.

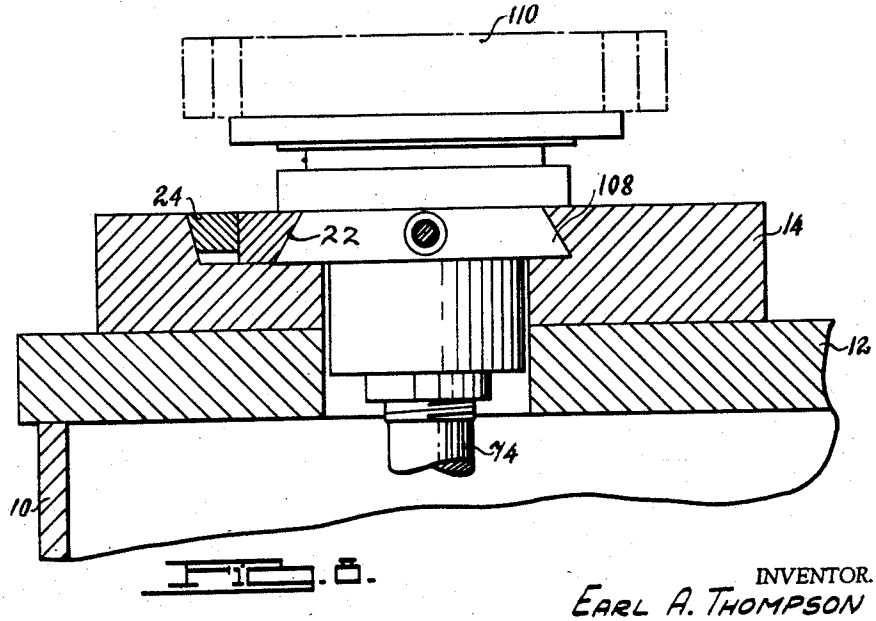


FIG. 8.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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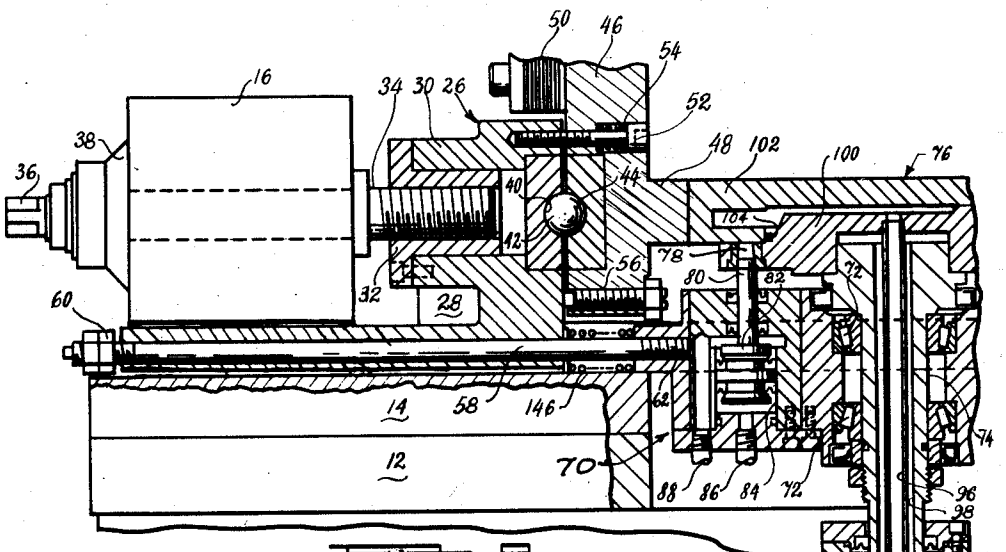


FIG. 9.

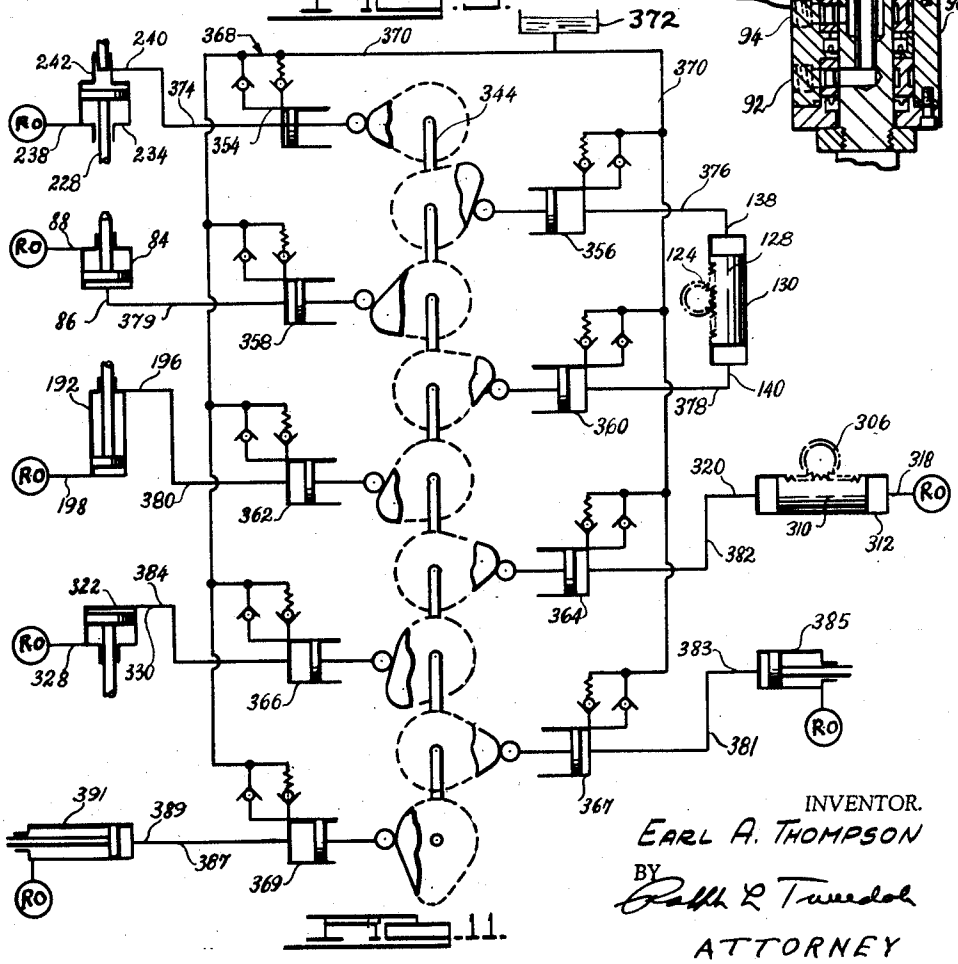


FIG. 11.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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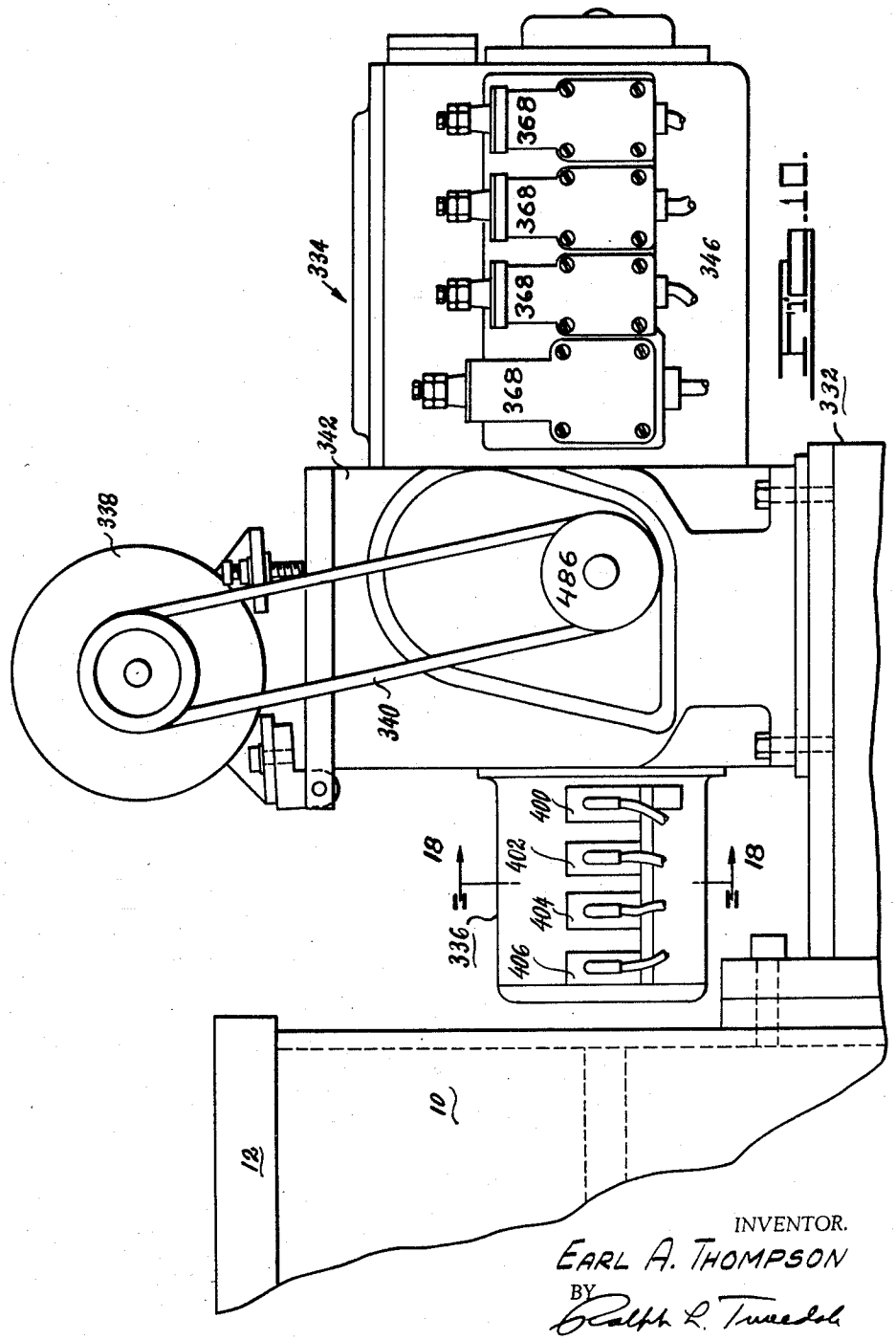


FIG. 10.

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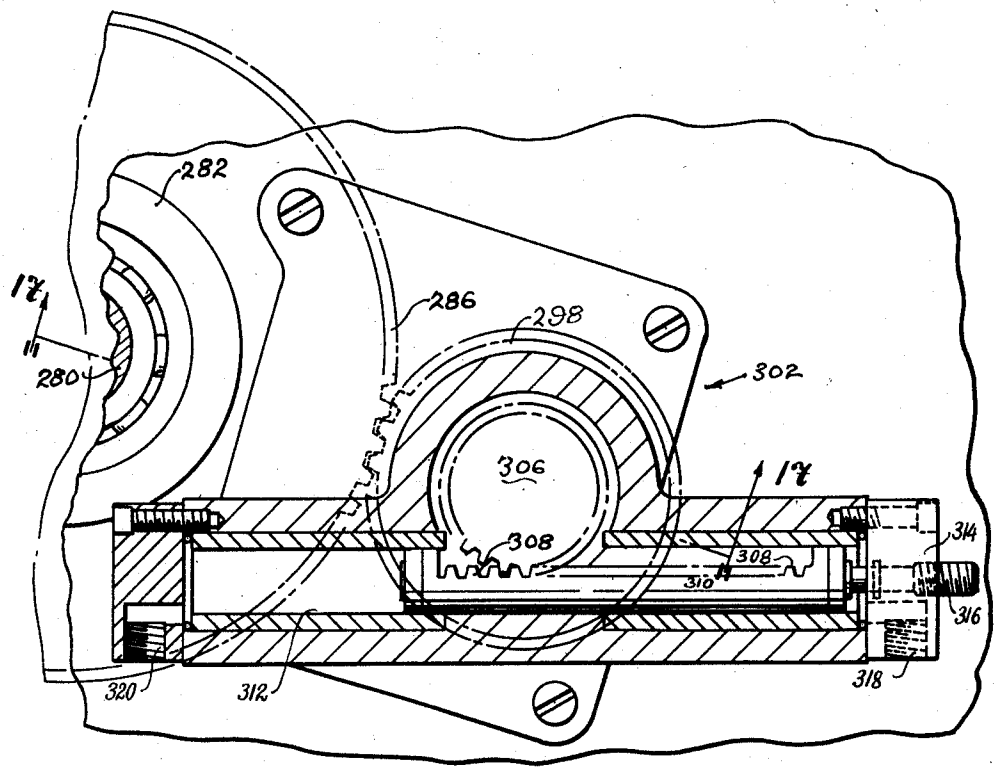


FIG. 12.

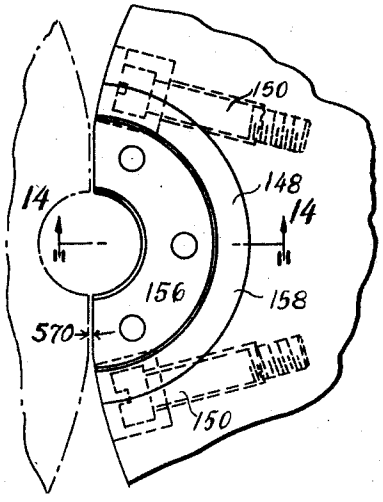


FIG. 13.

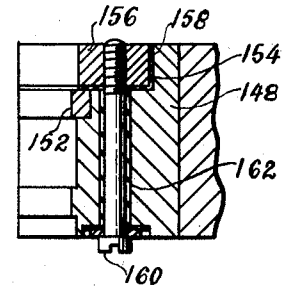


FIG. 14.

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FUSING MACHINE

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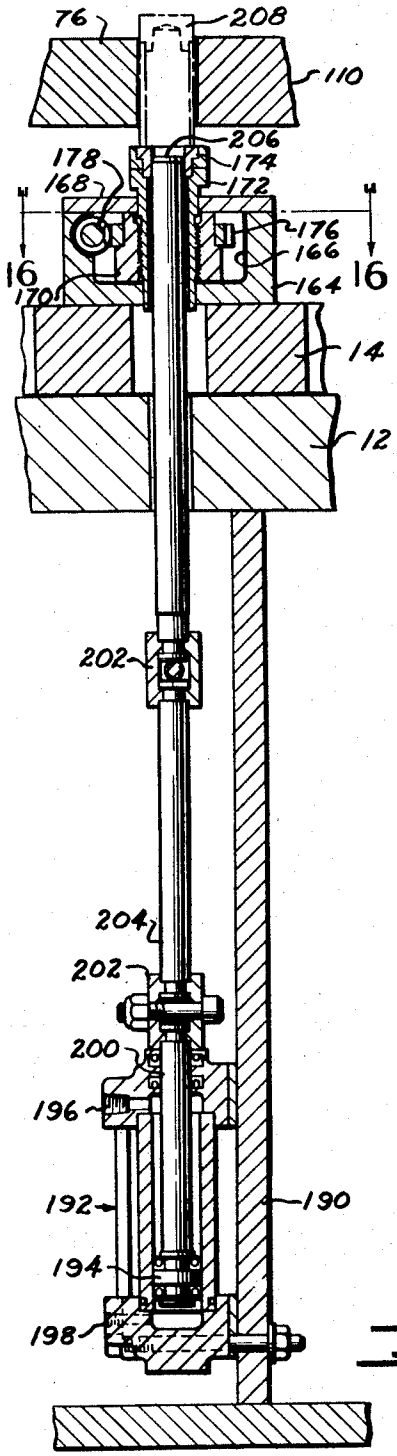


FIG. 15.

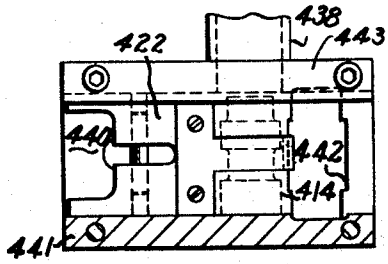


FIG. 32.

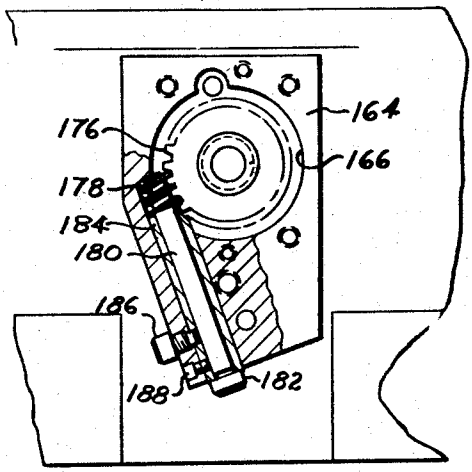


FIG. 16.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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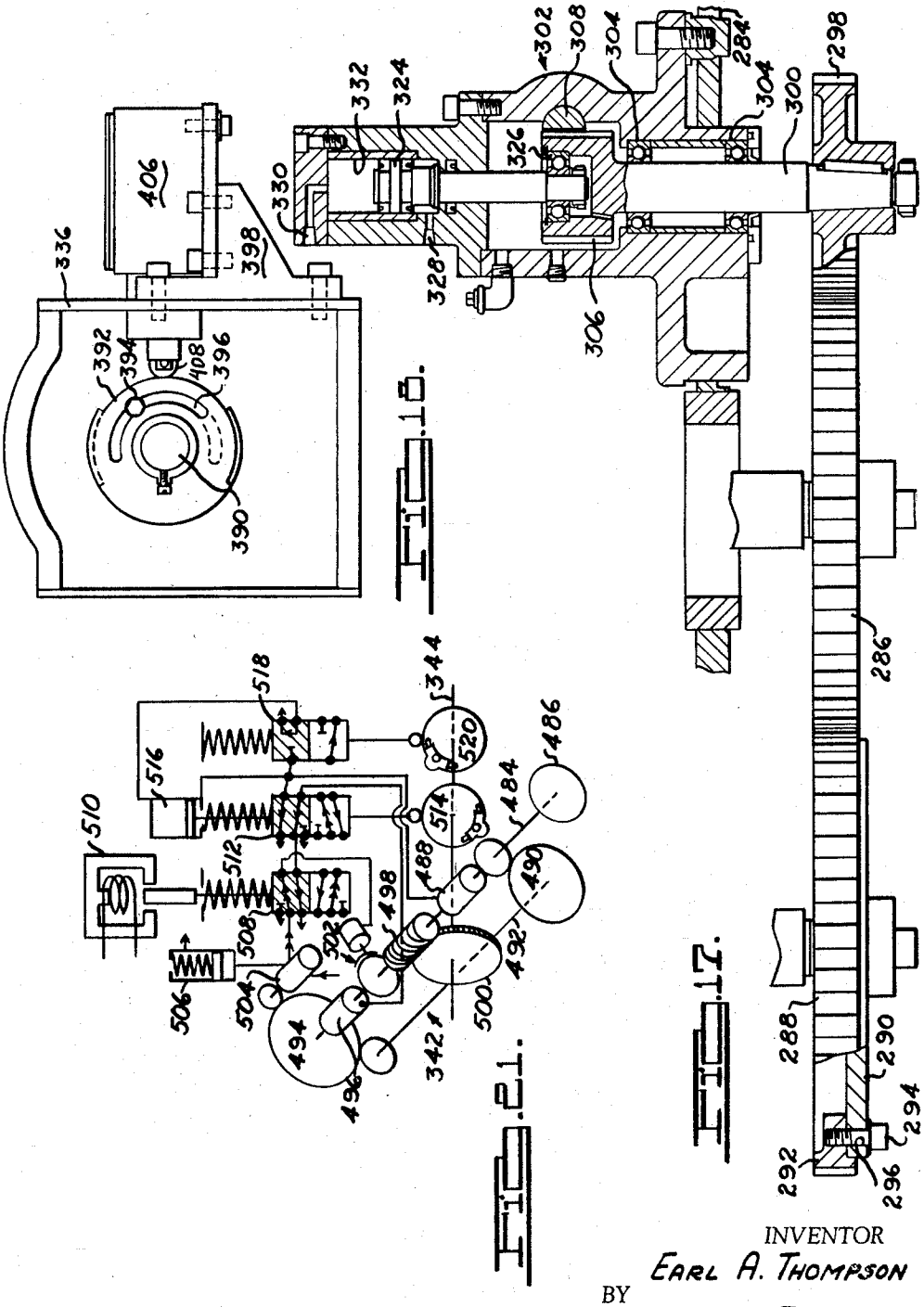


FIG. 15.

FIG. 17.

FIG. 21.

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May 3, 1960 E. A. THOMPSON 2,935,596

FUSING MACHINE

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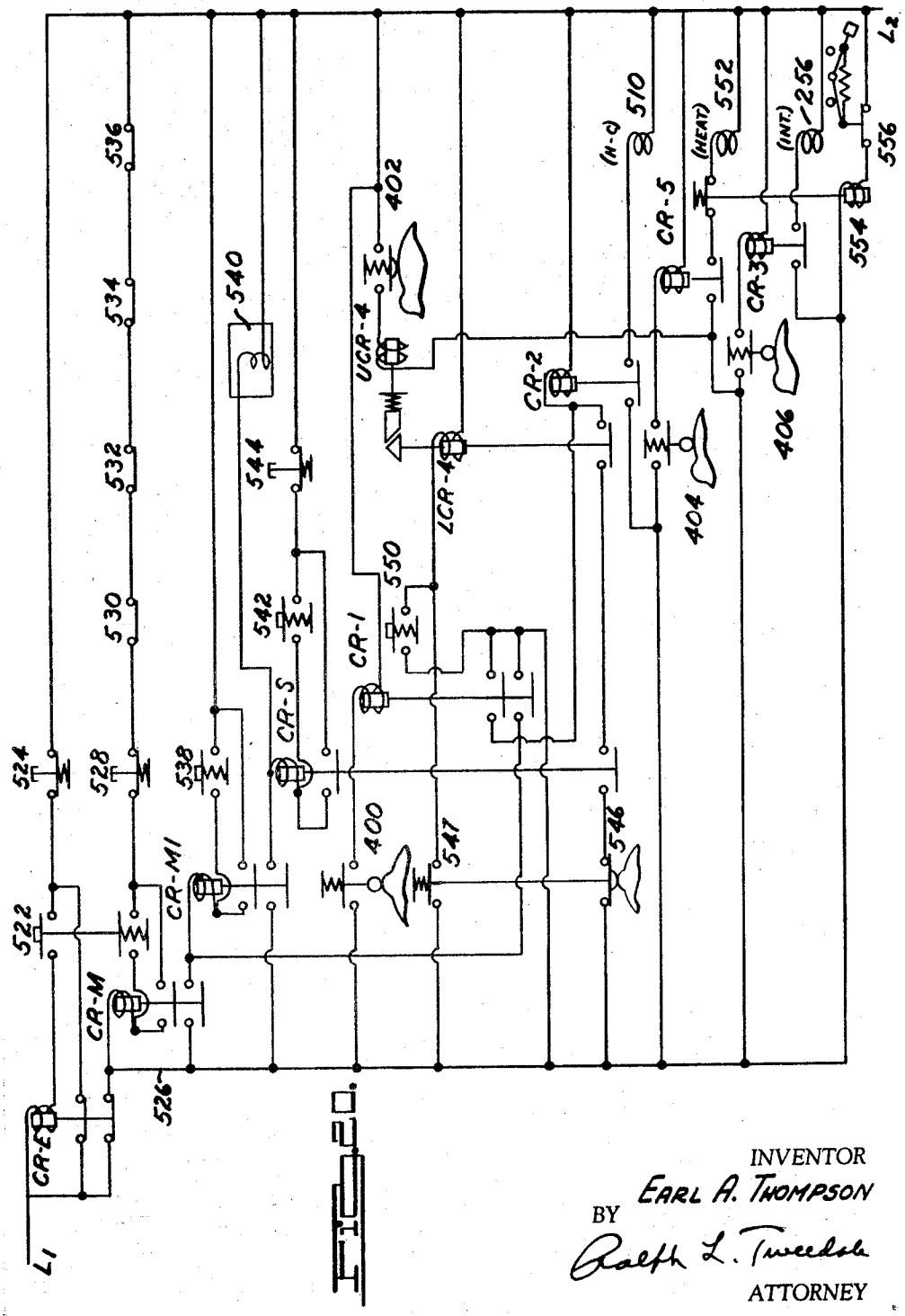


FIG. 20.

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FUSING MACHINE

Filed Dec. 30, 1957 14 Sheets-Sheet 12

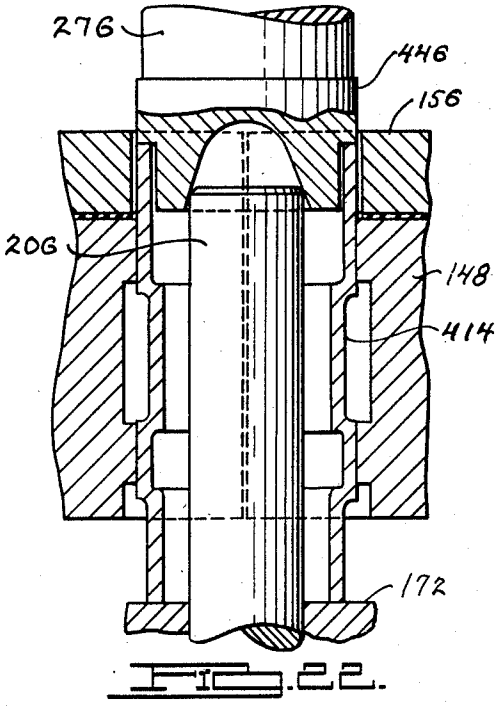


FIG. 22.

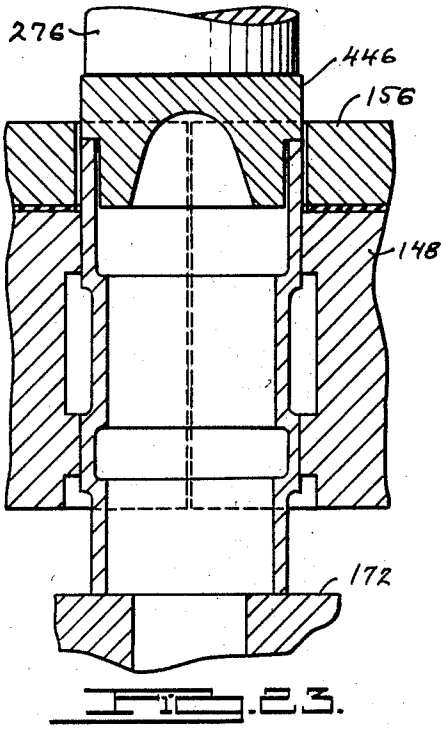


FIG. 23.

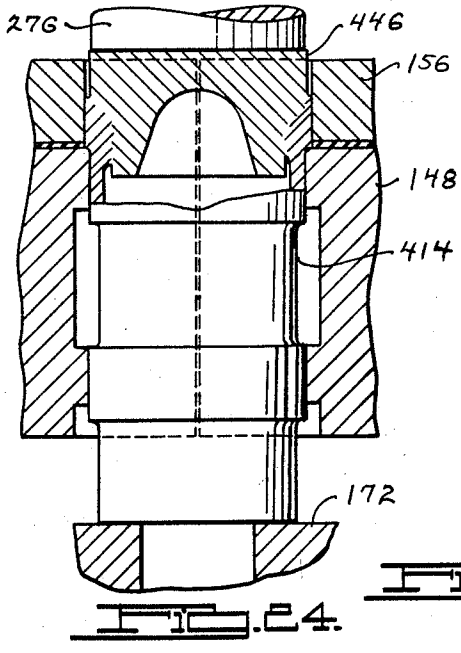


FIG. 24.

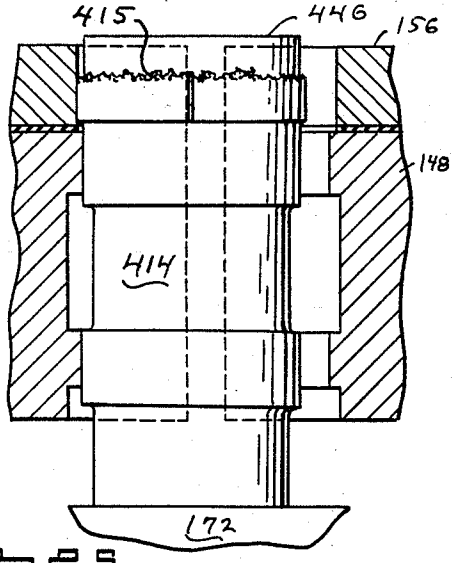


FIG. 25.

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FUSING MACHINE

Filed Dec. 30, 1957 14 Sheets-Sheet 13

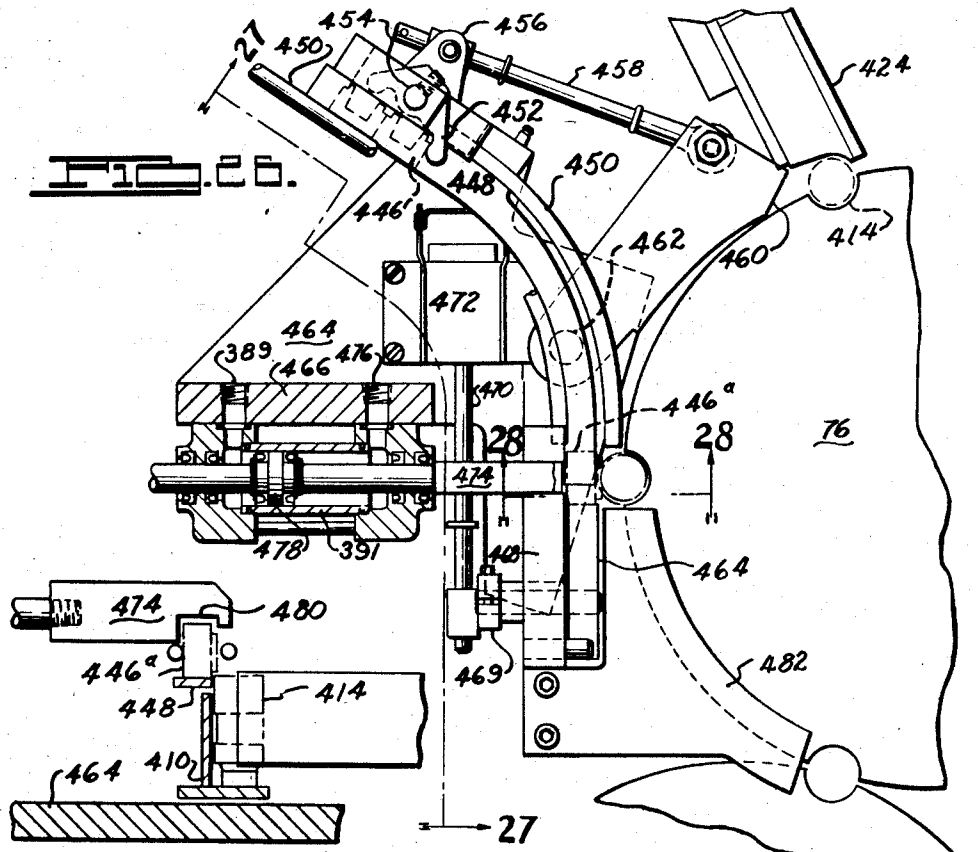


FIG. 26.

FIG. 26.

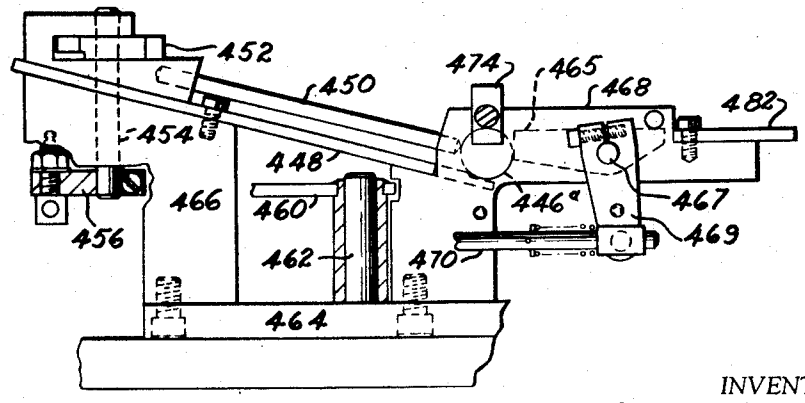


FIG. 27.

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FUSING MACHINE

Filed Dec. 30, 1957 14 Sheets-Sheet 14

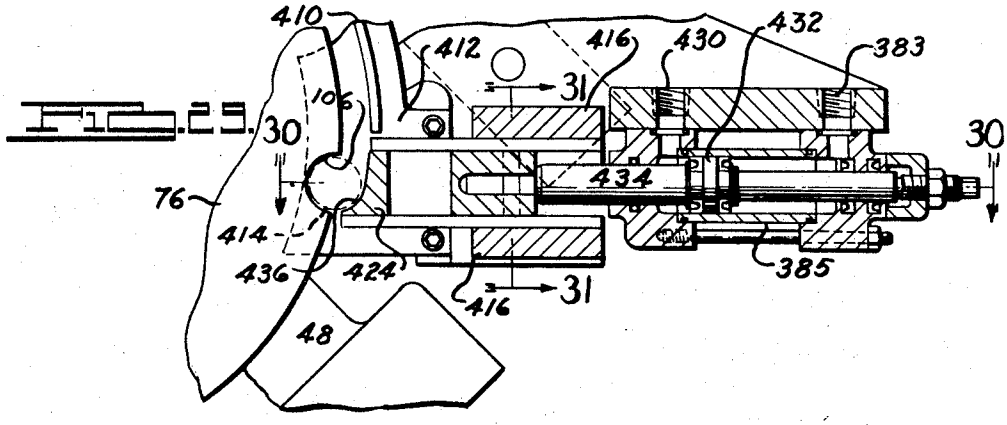


FIG. 29.

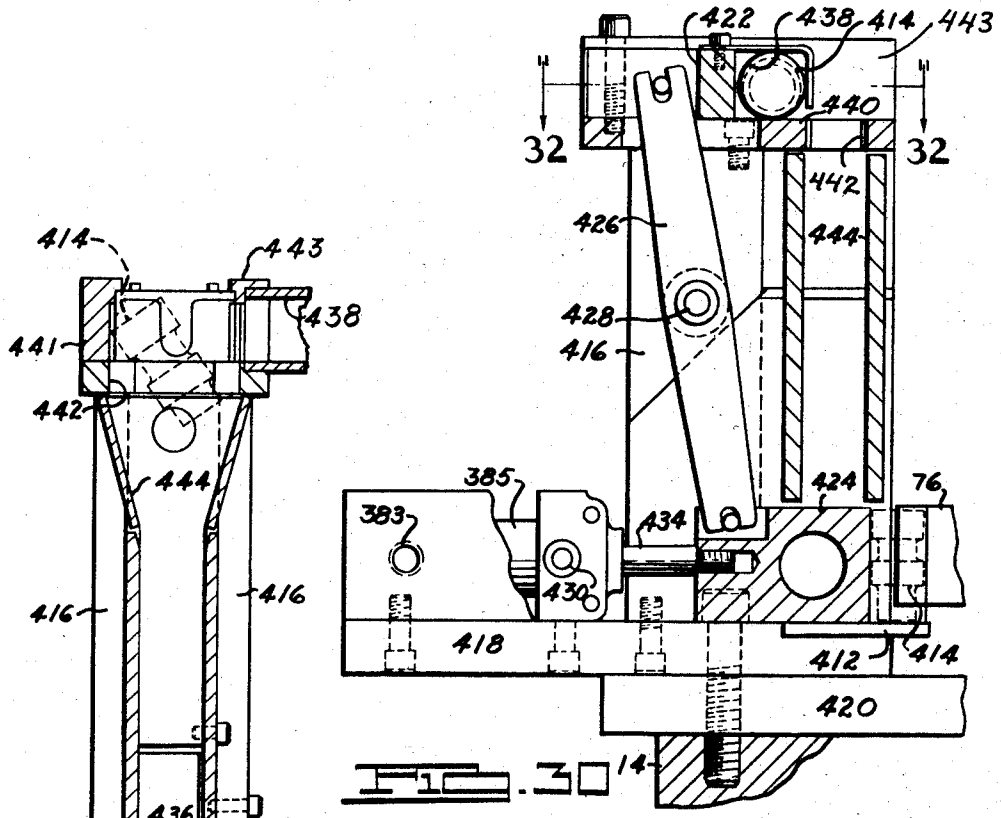


FIG. 30.

FIG. 31.

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United States Patent Office

2,935,596

Patented May 3, 1960

2,935,596

FUSING MACHINE

Earl A. Thompson, Ferndale, Mich.

Application December 30, 1957, Serial No. 706,116

12 Claims. (Cl. 219—101)

This application is a continuation-in-part of my co-pending application, Serial No. 637,589, filed January 31, 1957, for Tappet or Cam Follower and the Art of Making Same, which, in turn, is a continuation-in-part of my application, Serial No. 407,005, filed January 29, 1954, for Tappet or Cam Follower and the Art of Making Same, both now abandoned.

This invention relates to apparatus for the electric fusion of metal parts. The invention is more particularly concerned with apparatus for producing fused cast iron and steel tappets for automotive engines in which a cast iron base is directly joined to a tubular steel sleeve or body in a single short application of heat and pressure.

It has long been recognized that the wearing properties of cast iron are well suited for service as a follower member in direct contact with an automotive camshaft and that the body portion of a tappet is most desirably formed of steel. Such two-piece tappets have heretofore been difficult to manufacture because of the problems of forming a reliable joint between the cast iron and the steel which will stand the impact forces involved and which can be produced in quantity at reasonable cost. Various proposals have been made for joining the cast iron and steel directly by an electric heating process without, however, achieving a commercially satisfactory machine or method for producing a thoroughly reliable junction economically. One difficulty involved resides in the difference in melting points between cast iron and steel. When a heating current high enough to melt the iron is applied, the steel does not melt but the molten iron will flow as a liquid which instantaneously leaves the zone of juncture, preventing adherence of the two pieces.

It is an object of the present invention to provide an improved apparatus for effectively forming a direct fusion joint between a piece of cast iron and a piece of steel having a higher melting point than the cast iron.

A further object is to provide such an apparatus which will form the joint rapidly by a brief pulse of heavy electric current in a manner somewhat similar to a butt welding apparatus.

Another object is to provide an improved apparatus for directly joining a cast iron piece to a steel piece having a higher melting point.

A further object is to provide such an apparatus in which a pulse of electric heating current, together with the application of a strong compressive force will serve to both fuse the cast iron to the steel at one place and upset the steel into mechanical contact with solid cast iron at another place.

A further object is to provide such an apparatus in which the flow of the molten iron is confined and in which the upsetting of the steel takes place in a manner to eliminate the formation of irregularly projecting nodules of metal so that the finished joint presents a comparatively smooth and regular surface which needs no snagging and may be finished by conventional grinding methods.

It is also an object of this invention to provide an improved apparatus for joining cast iron directly to steel by both fusion of the cast iron and mechanical upsetting of the steel wherein the line of demarcation between the two metals in the finished joint is a more intimate bond than has heretofore been possible to obtain and which, when the edge of the joint is machined, is invisible to the unaided eye.

Another object is to provide an improved electric fusion apparatus for joining a cast iron part to a steel part in which a die mold is utilized for confining the molten and softened metals to the situs of the joint.

A further object is to provide an apparatus of this character in which cast iron parts may be joined to steel parts with great rapidity automatically.

It is also an object to provide such an apparatus wherein a part to be joined may be clamped between a pair of rotating electrodes.

Another object of the present invention is to provide an improved work handling and current conducting electrode system as a part of such an apparatus.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawing wherein a preferred form of the present invention is illustrated.

In the drawings:

Figure 1 is a front view of an electric fusion apparatus embodying a preferred form of the present invention.

Figure 2 is a view of a finished valve tappet incorporating a preferred form of the present invention.

Figure 3 is a vertical cross section on line 3—3 of Figure 1.

Figure 4 is a cross section on line 4—4 of Figure 3.

Figure 5 is a plan view of the machine shown in Figure 1 partially broken away.

Figure 6 is a partial sectional view taken on line 6—6 of Figure 5.

Figure 7 is a partial end view partly in section on line 7—7 of Figure 5.

Figure 8 is a fragmentary cross section taken on line 8—8 of Figure 5.

Figure 9 is a fragmentary sectional view on line 9—9 of Figure 5.

Figure 10 is an end view of the machine shown in Figure 1 illustrating the mechanico-hydraulic drive mechanism.

Figure 11 is a diagrammatical view of a mechanico-hydraulic drive mechanism forming part of the machine of Figure 1.

Figure 12 is a fragmentary sectional view taken on line 12—12 of Figure 1.

Figure 13 is a fragmentary view of a portion of Figure 5 on a larger scale.

Figure 14 is a fragmentary sectional view on line 14—14 of Figure 13.

Figure 15 is a fragmentary sectional view on line 15—15 of Figure 5.

Figure 16 is a cross sectional view on line 16—16 of Figure 15.

Figure 17 is a sectional view on line 17—17 of Figure 12.

Figure 18 is a sectional view on line 18—18 of Figure 10.

Figure 19 is a fragmentary sectional view taken on line 19—19 of Figure 1.

Figure 20 is an electrical circuit diagram for the machine in Figure 1.

Figure 21 is a diagrammatic view of a portion of the mechanico-hydraulic control mechanism.

Figure 22 is a fragmentary sectional view illustrating the parts of a two-piece tappet in position in the machine of Figure 1 and ready for fusing.

Figure 23 is a view corresponding to Figure 22 showing the starting stage in the fusing operation.

Figure 24 is a view corresponding to Figure 22 showing the complete fused tappet at the conclusion of the fusing operation.

Figure 25 is a view of the fused tappet ready for removal from the machine.

Figure 26 is a top view, partly in section, of a work feeding mechanism forming part of the machine of Figure 1.

Figure 27 is a developed front view of the work feeding mechanism shown in Figure 26, developed along the line 27—27 of Figure 26.

Figure 28 is a fragmentary sectional view on line 28—28 of Figure 26.

Figure 29 is a top view, partly in section, of another portion of the work feeding mechanism.

Figure 30 is a front view, partly in section, on line 30—30 of Figure 29.

Figure 31 is a sectional view on line 31—31 of Figure 29.

Figure 32 is a top view partly in section on line 32—32 of Figure 30.

Sliding heads

The machine illustrated in the drawings comprises a main box-like base **10**, having a generally flat top plate **12**. Secured rigidly to the top plate **12** is a way bed plate **14** extending the full width of the machine for the purpose of carrying a plurality of horizontally shiftable heads. At each end of the bed **14** there is rigidly secured to the top surface thereof a pair of vertically extending thrust brackets **16** and **18**, respectively. These brackets are mounted by bolts **19** (Figure 7) and are provided with a small vertical clearance space **20** over most of the central portion of the bed **14**.

The bed is provided with a dovetail way **22** having an adjustable gib **24**. Slidable within the way **22** are four heads for the purpose of carrying suitable electrodes. At the left-hand end of the way, a head **26** (Figure 9) has a dovetail base **28** slidable in the way **22** and carries an upstanding vertical bracket **30** which has a horizontal arranged nut **32** in its left-hand face. A threaded shaft **34** is rotatable but axially immovable in the thrust bracket **16** and has wrenching flats **36** and a graduated dial **38** at its left end for the purpose of adjusting the position of the head **26** in the way **22**.

The bracket **30** carries on its right-hand face a hardened steel hemispherical socket **40** in which is mounted a mating steel ball **42**. Opposing the socket **40** is a similar socket **44** carried in an electrode jaw member **46**, which has a horizontally extending jaw **48** and has a flexible laminated ribbon bus bar **50** secured to its upper portion.

The universal motion permitted by the ball and socket connection **42** is restrained by a plurality of cap screws **52** having springs **54** under their heads and by a corresponding number of adjustable stop bolts **56**. Preferably the bolts **52** and **56** are distributed alternately around the axis of the adjusting shaft **34**, there being, for example, three of the spring retainer bolts **52** and three of the stop screws **56**.

The base **28** has a horizontal bore which receives a rod **58** having adjusting nuts **60** at its left-hand end. The right-hand end of rod **58** is secured in a threaded socket **62** formed in a first turret slide or head **70**.

The head **70** has dovetail sides which slidably fit the way **22** and carries anti-friction bearings **72** for journaling a vertical turret shaft **74**. The shaft **74** carries at its upper end a turret **76**. On its lower surface, the turret **76** carries a plurality of tapered indexing holes **78** for cooperation with a slidable bolt **80** which has a piston **82** at its lower end, reciprocable in a fluid cylinder **84**. Suitable fluid pressure connections **86** and **88** may be provided for operating the piston **84**.

The turret **76** and shaft **74** are arranged with circulating water passages to cool the electrodes. Thus, a two-way fluid swivel joint **90** is positioned at the lower end of shaft **74** having an inlet passage **92** and an outlet passage **94**. These communicate, respectively, with a central tube **96** and a concentric annular passage **98** in the shaft.

The turret head is hollow and arranged with suitable passages for directing the incoming cooling liquid around the circumference of the turret and back to the outlet passage. The turret head **76** comprises a lower base member **100** upon which an upper electrode member **102** is slidably fitted and sealed at **104**. The member **102**, as well as the jaw **48** and member **46**, are formed of highly conductive material such as a copper alloy. The periphery of the member **102** is cylindrical and mates with the corresponding face of jaw **48** when the turret is positioned as shown in Figure 5. The cylindrical periphery is interrupted in five or more places to form work piece receiving cavity halves later to be described.

A third slide, or head, **108** is mounted in the way **22** and carries another turret **110**. The head **108** and turret **110** may be similar to head **70** and turret **76** except that the indexing holes and pin may be omitted. The fourth movable slide is indicated at **112** and may be similar to slide **26** except for its connection with thrust bracket **18**.

The construction of the latter is illustrated in Figures 6 and 7 and includes a nut block **114** secured to the head **112** at its right-hand end. The block **114** may have a cylindrical exterior slidably fitted in a stationary sleeve **116**, which is secured to the end face of thrust bracket **18**. Journaled upon anti-friction thrust bearings **120** is a screw shaft **122** threaded in the nut block **114** and having a pinion **124** at its right-hand end. A rack **126** meshes with pinion **124**.

As illustrated in Figure 7, the rack **126** is formed upon a cylindrical double acting piston **128** which is slidable in cylinder **130** formed in the thrust block **18**. Suitable adjustable stops pins **134** and **136** limit the stroke of the piston **128**. Fluid connection ports **138** and **140** are provided at each end of the cylinder as well as necessary air bleed valves **142** and **144**.

The arrangement of the four heads **26**, **70**, **108**, and **112** is such that the first head **26** remains in a stationary position which may be adjusted by the threaded shaft **34**. The head **70** is biased to the right by a spring **146** (Figure 9) tending to separate the turret **76** from the jaw **48** by a small distance. The adjusting nuts **60** determine this distance and limit the expansion of the spring **146**. As shown in Figure 6 a similar construction is employed between the heads **108** and **112** and, once the spring **146** has expanded to bring the nuts **60** into contact with head **112**, the two heads **112** and **108** may be shifted to the right as a unit by the action of the threaded shaft **122** in the nut **114**. Movement of the head **112** to the left, however, will apply a compressive force to bring all four heads into abutment, compressing the springs **146** and serving to hold a work piece between the pair of cavity halves **106** which are facing each other in the turrets **76** and **110**.

The cavity halves may be identical on both turrets and are shown in detail in Figures 13 and 14. They are preferably formed as half-annular liners of welding electrode alloy as indicated at **148**. These may be retained by cap screws **150** at either edge of the liner **148**. Preferably one or more contact rings **152** of special electrode alloy material are brazed into the liner halves **148** for the purpose of contacting the work piece to transfer the heavy current thereto.

Positioned in an annular groove **154**, formed in the liner **148**, is an annular die member **156**, which is formed of stainless steel. The die **156** is insulated from the liner **148** by insulation **158** and retained by screws **160** which are also insulated from jaw **148** by insulation **162**. Mica, fiberglass or similar material may be used for insulation.

The bed plate **14** carries at its mid portion a stationary block **164**, Figures 15 and 16, which has a cylindrical

recess 166 closed by a cover 168. Within the recess is a rotatable nut sleeve 170 within which is threaded a hollow work piece abutment 172 having a hardened, wear resistant insert 174 at its upper end.

The nut 170 is provided with ring gear 176 which meshes with a worm 178 mounted on a shaft 180 which is rotatably secured in the block 164 and has a hexagon socket head 182 for purposes of turning the same. The shaft 180 is journaled in a bushing 184 which is retained in the block 164 by a set screw 186. A second set screw 188 serves to lock the shaft 180 in any adjusted position.

The base 10 is provided with a fore and aft vertical bulk head 190 upon which is mounted a hydraulic motor 192 having a piston 194 and suitable fluid connections 196 and 198. The rod 200 of piston 194 carries, by means of couplings 202 and rod 204, a vertically reciprocating centering pin 206. The upper end of pin 206 is slidably received in the hollow nut 172 and insert 174. The upper end of pin 206 is chamfered to act as a centering media for a work piece part having a hollow tapered cavity as indicated in dotted lines at 208.

Head

As shown in Figures 1 and 3, the base 10 carries a central upright pressing head, generally designated 210. This comprises a stationary frame member 212 which is supported at the rear by a pedestal 214 and at the front by a post 216. A movable platen 218 has a pair of vertical guide bars 220 securely clamped thereto and reciprocable in bushed bores 222 in the member 212. The platen 218 has a threaded bore 224 at its central portion and is slotted as indicated at 226 (Figure 4) for the purpose of adjustably clamping a thrust rod 228 to the platen 218 by means of clamping screws 230.

The frame member 212 carries an operating cylinder assembly 232 centrally on its upper portion. This may comprise a first hydraulic cylinder 234 in which a piston 236 is slidable. The piston 236 is connected to the thrust rod 228. Suitable hydraulic connections 238 and 240 connect with the lower and upper ends of cylinder 234, respectively. The connection 240 enters through a plurality of radial ports in a bushing 242 within which is slidably mounted an intensifier plunger 244. The bushing 242 opens at its lower end directly into the cylinder 234.

The plunger 244 carries an air piston 246 at its upper end. The piston 246 is of considerably larger diameter and is slidable in a cylinder 248, the lower end of which has a vent opening 250. The upper end of cylinder 248 is closed by a disc 252 which also forms the base of an air accumulator or pressure reservoir indicated at 254. This may receive compressed air from any suitable supply, such as a shop airline 255.

As shown in Figure 19, a solenoid operated three-way air valve 256 controls communication of the upper end of cylinder 248 with accumulator air pressure and exhaust. A conduit 258 connects between the accumulator 254 and the valve 256. A conduit 260 communicates between the cylinder 248 and the valve, while a conduit 262 provides an exhaust from the valve.

On the lower face of the platen 218 there is secured a bus bar 264. The bar is insulated from the platen at 266 as are the holding screws 268. Suitable cooling water inlet and outlet connections are provided at 270 and 272. Secured to the lower face of the bus bar 264 is an electrode holder 274 having a hollow cylindrical electrode 276 projecting downwardly and located centrally above the cavity halves 106 at the point of tangency of the turrets 76 and 110.

As shown in Figures 3 and 5, a finished work ejector guide 277 overlies the turrets 76 and 110 to the rear of the electrode 276. This includes a pair of inclined camming surfaces 279 which lie in the path of the cavity halves as they leave the tangent point, and thus serve to clear a finished work piece from whichever of the cavity halves it may happen to cling. An exit chute 281, which is inclined downwardly to the left of the machine, serves to carry finished pieces out to a convenient receptacle or conveyer.

For clarity of illustration, the pipelines and hoses which supply cooling fluid and motive fluid to the various parts described and shown have been omitted from the drawings, it being understood that these connections are established by usual plumbing procedures. Likewise the complete electrical bus bars for supplying fusing current to the electrodes are not shown since they in turn may be arranged according to conventional electrical construction practice.

Turret index

For the purpose of intermittently rotating the turret heads 76 and 110, their operating shafts 74 are provided with universal joint coupling shafts indicated at 278. These connect with stationary stub shafts 280 journaled in stationary bearing blocks 282 which are secured to a mezzanine base plate 284 in the base 10. The lower end of shafts 280 carry meshing gears 286 and 288 of equal size.

The gear 286 has a separate web 290 (Figure 17) which is secured to the rim 292 by several bolts 294, which operate in arcuate slots 296 for providing angular adjustment of gear 286 relative to shaft 74.

The gear 286 is driven from an indexing pinion 298 which is keyed to the lower end of a shaft 300. This shaft is arranged having both rotary and reciprocating motion so that the pinion may be lifted up to disengage the gear 286 for performing an idle reverse rotation of the pinion. For this purpose an indexing drive assembly, generally designated 302, is mounted on the plate 284. This includes a pair of anti-friction bearings 304 within which the shaft 300 is slidable and which serve as rotary mountings for the shaft as well.

At its upper end the shaft 300 is provided with a pinion 306 which meshes with a rack 308 formed on a double-acting piston 310 (Figure 12). The width of pinion 306 is substantially double that of the rack so that meshing engagement is not interrupted by vertical translation of the shaft 300. The piston 310 is mounted in a double ended cylinder 312 having end caps 314 provided with adjustable stop screws 316 and with fluid terminal connections 318 and 320.

Positioned in the top of index mechanism 302 is an operating cylinder 322 having a piston 324, the rod of which is connected to shaft 300 through a thrust bearing 326. Connection terminals 328 and 330 are provided for motive fluid.

Work piece feeders

For the purpose of feeding work pieces to the machine, a guide rail of L-shaped cross section is shown at 410 in Figure 5 and underlies the forward periphery of the left-hand turret 76. The work guide 410 has a flat entry shelf 412 lying under one of the cavity halves 106 where a tubular work piece component may be received. Such a component is indicated at 414 in Figure 29.

An automatic work feeding mechanism for feeding tubular components is shown in Figures 29 through 32. This tube feeder comprises a vertical frame structure 416 mounted upon a base 418 which is secured by a spacer 420 to the base plate 14 of the machine. Associated with the frame structure 416 is a pair of alternately reciprocating shuttles 422 and 424, which are connected for operation by a lever 426 pivoted at 428 on the frame 416. The shuttles may be operated by a fluid motor 385 having fluid connections 383 and 430. The piston 432 has its rod 434 connected to the shuttle 424 for this purpose.

The shuttle 424 has a J-shaped pusher face 436, which, in its projected position as shown in Figures 29 and 30, holds a work piece component 414 in the cavity halves 106, having slid it to this position with its bottom face

resting on the guide plate 412, as shown in Figure 30. The upper shuttle 422, in its retracted position shown in the drawings, receives work piece tubes 414 from a gravity or other conveyer tube 438 (Figure 32), which has a horizontal terminus. A horizontal plate 440 supports the work pieces in this position. Suitable vertical side plates 441 and 443 are secured to the plate 440 to form guides for the shuttle 422 and to receive the end of conveyer tube 438. When the shuttle 422 is projected forwardly, it pushes the work piece 414 horizontally along the plate 440 until it falls through a hole 442. The shuttle 422 also blocks entry of the next work piece from the tube 438 until the shuttle returns to the position shown in the drawings.

The hole 422 cooperates with a chute 444 to orient and erect the work pieces with their large ends at the top. Thus, as shown in Figure 32, the end portions of hole 442 are narrower than the central portion so that they permit the small end of the tube to pass, but not the large end. Accordingly a piece presented large end first from the tube 438 will fall through the opening 442, as shown in dotted lines in Figure 31.

The chute 444 completes the erection of the work piece so that it will stand on the guide plate 412 in front of the shuttle 424, which recedes as the shuttle 422 advances. Work pieces which are presented small end forward from the tube 438 will start to drop through the hole 442 at the left-hand end in Figure 31 and will erect themselves with their small ends down in an otherwise similar manner.

For the purpose of feeding the second work piece components, such as the cast iron buttons 446 shown in Figure 26, there is provided a button feeding mechanism illustrated in Figures 26 through 28. This may comprise a curved gravity track 448 having side rails 450 and which is inclined, as shown in Figure 27, for the purpose of guiding buttons, one at a time, into a position shown at 466*a*. A rocking escapement lever 452 is pivoted at 454 and has an operating lever 456 connected by a link 458 with a tripping cam 460 which is pivoted at 462 on a base plate 464 fastened to the base of the machine. Suitable vertical frame plates 466 and 468 are secured to base plate 464 to carry other parts of the button feeding mechanism. The tripping cam 460 is engaged by a tubular component 414 as the turret 76 rotates and operates the escapement lever 452 to release the foremost button 446 in the stack while holding the second button against release.

The buttons may be fed to the escapement lever 452 by a suitable gravity or other conveyer running through a preheating oven. Buttons are held in the position 446*a* by a retractable stop 465 which is pivoted at 467 and has an operating lever 469 connected by a rod 470 to a solenoid 472. The solenoid 472 may be arranged to be actuated through a time delay mechanism, not shown, each time the machine is started up, after having been at rest for a sufficient time for a button to lose its preheat, thus rejecting the first one or more cold buttons.

Mechanico-hydraulic control system

For the purpose of moving the various parts of the machine in a proper sequence and for controlling the supply of fusing current, there is mounted on a bracket 332 (Figure 10) at the rear of the base 10 a mechanico-hydraulic driving and control unit, generally designated 334, and having an electrical controller section 336. The unit 334 comprises a drive motor 338 connected by a belt 340 to a two-speed transmission gear box 342. The output of the transmission 342 is a single camshaft 344, shown diagrammatically in Figure 11, and running horizontally from left to right in the cam case 346 in Figure 10. The camshaft carries cams which operate hydraulic pulsator transmitters for operating the pistons and various fluid motors connected to the movable parts of the machine. For the purpose of achieving maximum efficiency of motion, it is desirable to operate the master camshaft 344 at both a rapid speed and a slower feeding speed during different portions of a single revolution thereof. This may be accomplished by a suitable self-controlling two-speed transmission 342, the mechanism of which is shown diagrammatically in Figure 21. Thus, an input shaft 484 may be driven by a pulley 486 from the belt 340 (Figure 10) and drives a hydraulically engageable clutch 488. Reduction gearing 490 connects between input shaft 484 and a countershaft 492, which, at its opposite end, drives by additional reduction gearing 494, a second hydraulically engaged clutch 496. The driven elements of the clutches 488 and 496 are connected to opposite ends of a worm 498 which meshes with a worm wheel 500 secured to the camshaft 344. A hydraulically engageable brake 502 may hold the worm 498 stationary. For the purpose of controlling the clutches and brake, there is provided a hydraulic control system in the transmission 342 which includes a pump 504 driven from the gearing 494 and having a combined accumulator and relief valve 506 connected to its delivery line. A solenoid operated start-stop valve 508 is controlled by a solenoid 510 and serves in its normal position to establish the connections shown in the cross-hatched upper rectangle and, when energized, to establish the connections shown in the lower rectangle. In this diagram, double-headed arrows indicate pressure fluid from the pump delivery line, and single-headed arrows indicate exhaust to the reservoir, which may be formed by the housing for transmission 342.

The start-stop valve 508 also controls the fluid supply to a speed shifting valve 512, which is spring biased to establish the connections shown in the cross-hatched rectangle. Valve 512 may be shifted to establish the connections of the lower rectangle by an adjustable tripping cam 514 on the camshaft 344. A hydraulic holding cylinder 516 holds the valve 512 in its shifted position until it is released by a reset valve 518, which is controlled by an adjustable cam 520 on the camshaft 344. It will be seen that, in the position shown in Figure 21, valve 508 maintains the brake 502 applied with hydraulic pressure from the pump and accumulator, and, together with the valve 512, maintains the slow speed clutch 496 disengaged by exhausting the same. Valve 512 alone exhausts the high speed clutch 488.

If solenoid 510 is energized, brake 502 is released and slow speed clutch 496 is engaged by pressure from the pump through valves 508 and 512, with the high speed clutch 488 remaining disengaged. When the cam 514 shifts valve 512, the slow speed clutch 496 will be disengaged and the high speed clutch 488 will be engaged. This condition will maintain until cam 520 operates the reset valve 518 to bypass the holding cylinder 516 and reset valve 512.

The camshaft 344 also carries an extension camshaft running into the electrical controller 336 for operating electric switches which control the application of fusing current and control the stopping of the transmission 342.

The base 10 also carries on its rear wall (Figure 5) a liquid reservoir or accumulator 348 for maintaining a plenary supply of oil under pressure which may be utilized to bias the various motive cylinders in one direction. For this purpose a return oil manifold 350 leads from the reservoir 348 and has branches leading to the various connection ports of the motive cylinders. The reservoir 348 may be a closed chamber containing a body of liquid together with a body of air under pressure above the liquid. Such air may be supplied from any convenient source such as a shop airline, and if the shopline pressure is not maintained high enough, a self-actuated intensifier of known construction may be utilized as shown at 352.

The hydraulic connections for the cam unit 334 are indicated diagrammatically in Figure 11. Here the return oil connections are indicated by a circle containing the letters RO, it being understood that although these are

shown separately, a common manifold and accumulator, as disclosed at 350 and 348, is preferred for all such return oil connections. The camshaft 344 carries a plurality of cams, each of which actuates one of the single-acting pulsator units 354, 356, 358, 360, 362, 364, 366, 367, and 369. These comprise a single-acting piston and cylinder operated by its respective cam and follower. The contours of the cams and displacements of the pulsators are chosen to produce the particular program of motions, speeds, accelerations, sequences, and overlappings desired for the machine parts to be motivated.

A balancing valve in the form of a combined relief and replenishing valve, such as indicated at 368, is provided for each pulsator and serves to blow off a slight excess of transmitter displacement at the end of a motor stroke and to replenish the liquid column at the end of the retraction stroke of the transmitter piston. For this purpose the valve 368 communicates through a passage 370 with an oil reservoir 372 positioned immediately over the transmitter cylinder.

The pulsator unit 354 connects by a liquid column line 374 with connection 240 leading to the motor cylinder 234 for the vertical electrode platen. The pulsator unit 356 connects by a liquid column line 376 with the connection 138 to the cylinder 130 for the electrode clamping screw. Unlike the other motive cylinders, the cylinder 130 is not connected at its opposite end with the return oil accumulator manifold 350, but instead the connection 140 is connected by a liquid column line 378 with the pulsator unit 360. The contour of the cams for the pulsators 356 and 360 is arranged so that the receding portion of each cam recedes slightly ahead of the advance of the other cam. The pulsator 358 is connected by a liquid column line 379 to the connection 86 of the turret lock bolt cylinder 84. The pulsator 362 is connected by a liquid column conductor 380 with the connection 196 of the cylinder 192 which operates the centering pin 206. The pulsator 364 is connected by a liquid column line 382 with the connection 320 of indexing cylinder 312, while pulsator 366 is connected by a liquid column line 384 with the connection 330 of cylinder 332.

The pulsator 367 connects by a liquid column line 381 with connection 383 of cylinder 385 of the work feeding mechanism. Likewise, pulsator 369 connects by liquid column 387 with connection 389 of cylinder 391.

Mounted on the rear of the base 10 (Figure 5) is a transformer 386 which is of conventional form such as used in electric welding machines and has a bus bar 387 which connects by a pair of flexible laminated ribbon connectors 388 with the bus bar 264 (Figure 1) on the platen 218. The other output terminal of the transformer is connected by a bus bar 390 with the flexible connectors 50 leading to the electrode clamping jaws 46 and 48.

Electric control system

The electrical controls may comprise a suitable panel of relays and a welding current control of the usual type for initiating and terminating the supply of current to the electrodes. A suitable electric circuit is shown diagrammatically in Figure 20 whereby operation of the mechanico-hydraulic unit and of the heating current control may be accomplished through the action of the cam operated circuit controllers in the cam box 336.

The latter is illustrated in Figure 18 wherein the extension 390 of camshaft 344 carries a plurality of cams 392 which are adjustable angularly on the shaft and which are formed of two leaves adjustably clamped together by screws 394 which extend through slots 396. A bracket 398 on the side of the cam case 336 carries a plurality of limit switches 400, 402, 404 and 406, each of which has a roller plunger 408 for cooperating with its respective cam 392.

The machine also includes a system of switches and relays for control of the over-all functions as illustrated diagrammatically in Figure 20. This system may be located in a suitable electric panel box, not illustrated, and may incorporate therein suitable heating current controls for the transformer 386.

Referring now to Figure 20, there is shown a suitable power supply, designated L–1 and L–2, and emergency relay CR–E of the holding type manually controlled in the usual fashion by a start switch 522 and a stop switch 524. CR–E controls the current supply to a principal conductor 526 feeding the remainder of the circuit. A master relay CR–M is similarly under the control of start switch 522 and a master stop switch 528. In addition, automatic stop switches 530, 532, 534, and 536 may be provided and controlled, respectively, by flow of cooling water to the electrodes, by pressure in the return oil accumulator 348, by air pressure in the intensifier supply chamber 254, and by electrical overload.

Relay CR–M controls one of two alternate preparatory circuits for relay CR–M1, which may be energized by a normally open manual start switch 538 having the usual holding circuit in shunt therewith. Relay CR–M1 has an additional preparatory circuit controlled by the lower contacts of a relay CR–1. Thus, relay CR–M1 may be manually energized if either of the relays CR–M and CR–1 are deenergized and can be deenergized only by opening both CR–M and CR–1. Relay CR–1 is under the sole control of the cam operated limit switch 400 in the electrical cam box. This switch 400 is opened only when the camshaft 344 reaches a predetermined position, which is the starting and ending point of a cam cycle. Thus, unlike relay CR–E, the relay CR–M, if dropped out by the master stop switch 528, will not deenergize CR–M1 immediately, but this action will be deferred until cam switch 400 is opened at the end of a cam cycle.

Relay CR–M1 controls a cycle relay CR–S and also a motor relay 540, which, when energized, energizes the electric motor 338 for the mechanico-hydraulic drive and control unit 334. Relay CR–S has the usual holding type start and stop circuit under the control of manual start switch 542 and manual stop switch 544. The start solenoid 510 (Figure 21) for the mechanico-hydraulic unit is under the control of a relay CR–2, which in turn is controlled by two alternate energizing circuits. The first is the upper contacts of relay CR–1. This insures that relay CR–2 remains energized until the end point of the cam cycle as determined by the limit switch 400.

The other energization circuit for relay CR–2 includes an index interlock switch 546 having a set of normally open contacts in series with the lower contacts of relay CR–S. Interlock switch 546 is arranged to be actuated by any one of five cam dogs 548 (Figure 1) which are located on the bottom of gear 288 so as to actuate the switch 548 each time the turret 76 is brought into properly indexed position. The purpose of this switch is merely precautionary in the event that a malfunction of the apparatus should prevent the turrets from indexing. Also in the alternate energization circuit for relay CR–2 are the lower contacts of a latching type relay LCR–4 which is unlatched by a coil UCR–4.

The latching coil LCR–4 is energized by a set of normally closed contacts 547 on the index switch 546 and may be also manually energized by a switch 550. The unlatching coil UCR–4 is energized once each revolution of the camshaft 344 by the switch 402 of the electrical cam box 336. This may occur at some point after completion of a turret indexing motion.

Thus, relay CR–2, which starts and stops the camshaft, is held energized by the relay CR–1 continuously except for an instant as the camshaft rotates through its normal stopping position. During this instant cam switch 400 deenergizes relay CR–1. However, in normal operation, relay CR–2 and the cam driving solenoid 510 remain energized through the alternate circuit, including the index switch 546, the lower contacts of relay CR–S, and the contacts of latching relay LCR–4. On the other

hand, during the progress of a camshaft revolution, the latching relay is unlatched by cam switch **402**, which energizes unlatching coil UCR–4, thus assuring that the camshaft will stop at the end of that revolution, unless the turret thereafter indexes. If the turret does not index, then the upper contacts **547** of index switch **546** will prevent the latching relay from being reclosed by LCR–4 and CR–1 will deenergize CR–2 as the end of a cam cycle is reached.

For the purpose of controlling the application of heating current, a relay CR–5 is provided and is energized by switch 404 in the electrical cam box **336** at the appropriate time in the machine cycle. Relay CR–5 operates a relay **552** provided in the control circuit, not shown, for the transformer 386. This control relay is also in series with contacts controlled by a relay **554**, which in turn is under the control of a manually operated "weld-no weld" switch 556. The solenoid valve **256** for admitting air to the intensifier **232** is under the control of a relay CR–3, which in turn is energized once each cam revolution at the proper point by the fourth switch **406** in the cam box 334.

Operation

In operation with the mechanico-hydraulic unit **334** stopped in its normal stopping position, with the turrets indexed to the cavity meshing position shown in Figure 5, and with a supply of tubular components available in the tube feeder and a supply of buttons available for the button feeder, a cycle may be started by first operating the start switch 522 to close relays CR–E and CR–M, start switch **538** to start the electric motor **338**, and then operating start switch **542** to energize relay CR–S. With no parts in the cavity halves of the turrets **76** and **110** to start with, the cam for liquid column **381** operates motor **385** through a forward and return stroke, starting and ending at the position shown in Figures 29 and 30. Thereupon the liquid column **387** operates the motor **391** for the button pusher **474**. As explained hereafter, this takes place during an interval sometime after the normal starting point of a cycle and while the camshft **344** is rotating at its rapid speed. A convenient time may be just prior to the starting of the turret unclamping motion of the piston **128**.

During the initial few cycles, while the first parts are going into the machine to fill the three stations on turret **76**, the machine goes through the motions of performing fusion operations. These motions and the further motions of feeding work pieces to the proper stations on turret **76** will be described starting at the appropriate point in the rotation of camshaft **344** where the fusing operation would normally be completed and the speed shifting cam **514** (Figure 12) shifts the valve **512** causing the camshaft to rotate at rapid speed. At about the same time the cams for the liquid columns **376** and **378**, which operate the fluid motor **130** for the turret clamping screw **122**, begin to move the piston **128** so as to retract the head **112**. Its first motion to the right separates jaw **48** from turret **110** until it picks up the nuts **60** at the right-hand end of the machine, thus beginning to move the head **108** for turret **110**. During the first part of this motion, the spring **146** at the left end of the machine pushes the head **70** for the turret **76** to the right until nuts **60** are contacted, thus separating turret **76** from its jaw **48**. Thereafter the further travel of head **112** to the right separates the turret **110** from the turret **76** at the meshing point.

After the turrets are thus separated, the cam for the indexing rack motor **312** operates the rack piston **310** through the liquid column **382**, moving it from its left-hand position to the right-hand position shown in Figure 12. This, through the gearing **286**, **288**, and **298**, indexes the turrets **76** and **110** through a fifth of a revolution so that the five work piece cavity halves advance one step. Since the tube feeder mechanism has positioned a tubular component **414** in the cavity half **106**, as shown in Figures 26, 29, and 30, the first motion of the turret will cause the work piece **414** to actuate cam **460** counterclockwise in Figure 26, thus tripping the escapement lever **452** and allowing a button **446** to roll down to the position **446***a*. The first one or more of such buttons to roll down will be permitted to roll off the end of the track because stop **465** (Figure 27) will have been raised by its solenoid **472** and the first one or more of the tubes **414** will pass through the machine without receiving a button. Liquid column **379** for the lock pin motor **84** will thereupon raise the lock pin **80**.

On the next indexing cycle after the stop **465** is lowered, the button released by cam **460** will stop in position **446***a*. In the meantime, the appropriate cam will have driven the shuttle motor **385** and the button pusher motor **391**, feeding another work piece **414** and causing the pusher **474** to tip the button **446** into position on top of the work piece tube **414** and then to return and retract the pusher **474**.

At about the same time the cams for the turret clamping rack operate the piston **128** to reclamp the turrets between the two heads **26** and **112**, thus holding the tubular work piece between the cavity halves and establishing good electric contact through the ring **152** (Figure 14) and positioning the insulated die **156** along side the crack between the two work piece components, as shown in Figures 22 and 23. For tight contact, a clearance as shown at **570** in Figure 13 is allowed.

Since there is considerable diametral play between the button and the tube where they telescope together, it is desirable to center the button with respect to the tube. For this purpose the cam for the centering pin motor **192** (Figure 15) raises the piston **194** to bring the centering pin **206** upwardly to the position shown in Figure 22, where its tapered end centers the button **446** by means of its tapered interior configuration. This may complete the rapid portion of the cam cycle and the transmission may be tripped into slow speed by cam **520**.

At about the same time, the turret indexing mechanism may return, and for this purpose the appropriate cam operates the disengaging motor **322** in Figure 17 to lift the drive pinion **298** out of engagement with gear **286** so that the indexing motor **312** may be returned to the position shown in Figure 12. While the centering pin **206** remains up, the cam for the electrode cylinder **234** lowers the electrode **276** into contact with the button, and thereafter the centering pin is lowered by the recession of its cam. Thereupon the electrical cam switch **406** closes to energize relay CR–3, which in turn energizes the solenoid valve **256**. This operates the intensifier piston **246** and its ram **244** descends closing the port **240** and applying intensifier pressure in the upper end of cylinder **234**. Very shortly thereafter the electrical cam switch **404** closes to energize relay CR–5, which energizes the control relay **552** to apply the fusing heat through the transformer **386**.

Joint fusion

The tubular work piece rests upon the adjustable stop **174**, shown in Figure 15, and the intensifier applies a high pressing force, pushing the button into the end of the tube. The application of the heating current along with the pressure causes the upper end of the steel tube to soften, but not melt, and results in a swaging, or upsetting, of the tube wall, both inwardly and outwardly in a radial direction. Thus, the steel is swaged into mechanical contact with the side wall of the telescoping portion of the button and is also swaged outwardly into contact with the insulated die **156**.

At the same time the cast iron is heated above its melting point locally adjacent the contacting faces of the two parts. The molten cast iron tends to flow away from the joint face at first, but is prevented from flowing inwardly by the mechanical seal established by the inwardly upset end of the tube. Thus, the molten cast iron may only

flow outwardly into contact with the die **156**. Here it is blocked against downward flow by the outward upset of the steel tube and can only flow upwardly. That flow is stopped almost as soon as it starts by the chilling effect of the die **156** leaving a random edge formation as shown at **415**. This remains relatively cool at all times because of the waiting time allowed while each die moves on around the turret stations, waiting for its next turn to be utilized in a fusing action.

It will be understood that the characteristics of the joint obtained may be varied depending upon a number of factors. Thus, for example, if the buttons are preheated to 400° F. or 500° F., the iron melts sufficiently soon during the swaging that the iron flows out to contact the die and solidify in the manner described. On the other hand, if the buttons are utilized at room temperature, or with considerably less preheating, the swaging of the steel may continue before the iron melts so as to extrude a portion of the steel upwardly past the boundary of the cast iron and into the clearance space between the button and the die before the cast iron can reach that space. In either event, a fusion of the iron to the red-hot, but unmolten, steel is obtained at the junction plane of the two pieces. This is supplemented by a mechanical bond through swaging or upsetting along the lower telescoping protuberance of the cast iron button.

The intensity of the heating current and the time of application are subject to some variation depending upon the size of the parts to be joined and the composition of their metals. In a typical automotive tappet of ⅞ diameter tubular stock with about 1/16 wall thickness, a heating time of about 30 cycles of 60 cycle current is suitable. The power usage may be of the order of magnitude of 75 kva. If desired, the heating current may be applied in stages, first at a low value for pre-heating the pieces. During the pre-heating step the upper end of the tube **414** and the adjacent facial region of the button, which is in contact with the tube, may be brought to a temperature which is just below the melting temperature of cast iron, that is, around 2000° F. When the tube **414** is a steel tube, the top end will be brought, during the pre-heating step, to a forging temperature of about 1800° F. The current will take the shortest path between the turret cavities **106** and electrode **276**, and therefore, only the upper end of the tube **414** between turret cavities **106** and electrode **276**, as well as the button **446** will be heated any substantial amount. After the pre-heating stage and at about the same time that the intensifier piston **244—246** descends the final fusing current of high value may be applied to raise the temperature of the cast iron button above its melting point locally adjacent the interfacial areas between the tube and button as previously described. With the use of a pre-heating stage, the steel tube may be brought to a higher forging temperature and thus a more extensive upset, or forging thereof, may be obtained.

Cycle completion

The cam switch **404** opens to cut off the heating current at the proper time. At about the same time the indexing drive pinion is engaged by operation of motor **322**, the lock pin is lowered, and the turret clamping screw is started in the releasing direction, as previously described. Also the cam switch **406** opens to deenergize the intensifier valve, allowing return oil in the lower end of cylinder **234** to start raising the piston **236**. Only a small travel upwardly of piston **236** is required to return the intensifier ram **244** upwardly past the port **240**, thus exhausting the air from the upper end of intensifier cylinder **248**.

At about the same time the appropriate cam for electrode cylinder **234** begins to recede, allowing return oil to continue the upward movement of the electrode. As previously described, the speed shifting cam **514** may operate at about this point, causing the further motion of the electrode to take place more rapidly and the completion cycle to take place.

It will thus be seen that the parts are fed automatically as each cavity half in turn passes the tube feeder **424** and a button pusher **474**, respectively. The finished fused pieces are ejected by one or the other of the ejector cams **279** as the cavity halves pass their inclined surfaces. Should a part become jammed in any stage of its progress through the machine, the liquid column drive for the blocked part of the machine merely passes its displacement over its own individual relief valve on the drive stroke and replenishes from the reservoir on the return stroke. Thus, damage to the machine is avoided. In the case of a jam-up preventing any indexing of the turrets, the index interlock switch **546** controls the action of relay CR–2 so as to stop the drive of the master camshaft **344** when it next reaches its normal stopping position.

While the parts are described as being directly joined, the use of that and like expressions is intended to include joining parts which may have thin coatings on them of a different metal or other material and which may become embedded or alloyed in the metal forming the zone of juncture.

It will thus be seen that the present invention provides an improved automatic machine which may receive parts from two hoppers or conveyers in a continuous stream and bring them together in the fusing station to produce a fusion bond between a steel piece and a cast iron piece having different melting points. The method performed by the machine through the use of a chilling die adjacent the faces of pieces to be joined produces an improved joint in the final product which has a high mechanical strength and which is of a homogeneous nature in that there is no extraneous material separating the two metals. Due to the migration of carbon from the cast iron to the steel, the joint has a zone of significant width across which the carbon content varies from a high value in the cast iron to a low value in the steel. The joint is formed with such an intimate bond between the two metals that there is no line visible, except under a microscope, when the edge of the joint has been machined smooth, and the fused piece looks, when finished, as though made from a single body of metal.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted all coming within the scope of the claims which follow.

What is claimed is as follows:

1. An electric fusing machine comprising in combination a frame, a pair of rotary turrets rotatable on spaced axes and in a tangential relation and provided with a plurality of die halves in their periphery, means mounting the turrets for relative motion through a short distance toward and away from each other along their common diameter, means for indexing the turrets to bring successive die halves into facing relation, a pair of relatively movable clamping abutments positioned on the ends of the common diameter of the turrets, means for shifting the abutments to clamp the turrets together and to provide a current conducting connection to the turrets, and means including a transformer for supplying current to the abutments whereby a fusing current may be applied to parts carried between the die halves.

2. An electric fusing machine comprising in combination a frame, a pair of rotary turrets rotatable on spaced axes and in a tangential relation and provided with a plurality of die halves in their periphery, means mounting the turrets for relative motion through a short distance toward and away from each other along their common diameter, means for indexing the turrets to bring successive die halves into facing relation, a pair of relatively movable clamping abutments positioned on the ends of the common diameter of the turrets, means for shifting the abutments to clamp the turrets together and to provide

a current conducting connection to the turrets, an electrode mounted for motion perpendicular to the common tangent of the turrets and in line with the facing die halves, means for shifting the electrode toward a work piece held between the die halves and means for providing current to the electrode and the turrets for fusing parts held by the die halves.

3. An electric fusing machine comprising in combination a frame, a pair of rotary turrets rotatable on spaced axes and in a tangential relation and provided with a plurality of die halves in their periphery, means mounting the turrets for relative motion through a short distance toward and away from each other along their common diameter, means for indexing the turrets to bring successive die halves into facing relation, a pair of relatively movable clamping abutments positioned on the ends of the common diameter of the turrets, means for shifting the abutments to clamp the turrets together and to provide a current conducting connection to the turrets, an electrode mounted for motion perpendicular to the common tangent of the turrets and in line with the facing die halves, means including a fluid operated intensifier for shifting the electrode toward a work piece held between the die halves and means for providing current to the electrode and the turrets for fusing parts held by the die halves.

4. An apparatus for joining by fusion a cast iron piece and a steel piece comprising a first electrode means for contacting one piece with a current conducting engagement, a second electrode for contacting the other piece, a die mold member positioned adjacent the junction of the pieces and extending along and slightly spaced from the surface of both pieces and electrically insulated from the electrodes, means for supplying heating current to the electrodes, and means for forcing the pieces together whereby the iron may be melted and the steel upset adjacent the junction to flow into contact with the die mold to limit the outflow of metal from the junction by chilling action of the die mold.

5. An apparatus for joining by fusion a cast iron piece and a steel piece comprising a first electrode means for contacting one piece with a current conducting engagement, a second electrode for contacting the other piece, a die mold member positioned adjacent the junction of the pieces and extending along and slightly spaced from the surface of both pieces, means for supplying heating current to the electrodes, and means for forcing the pieces together whereby the iron may be melted and the steel upset adjacent the junction to flow into contact with the die mold to limit the outflow of metal from the junction by chilling action of the die mold.

6. An apparatus for joining by fusion a cast iron piece and a steel piece comprising a pair of electrode halves for clamping one piece with a current conducting engagement, a second electrode for contacting the other piece, a die mold member positioned adjacent the junction of the pieces and extending along and slightly spaced from the surface of both pieces, shiftable means to position the unclamped piece laterally relative to the clamped piece, means for supplying heating current to the electrodes, and means for forcing the pieces together whereby the iron may be melted and the steel upset adjacent the junction to flow into contact with the die mold to limit the outflow to metal from the junction by chilling action of the die mold.

7. An apparatus for joining by fusion a steel tubular piece and a cast iron end piece comprising a pair of electrode halves for clamping the tubular member adjacent the juncture with a current conducting engagement, means for opening and closing the electrode halves, an electrode shiftable to engage the end piece, means for shifting the last named electrode endwise to press the pieces together, a cylindrical die mold surrounding the pieces at the juncture and spaced therefrom by a small distance, and means for supplying electric current to the pieces through the electrodes to raise the temperature of the junction zone above the melting point of the cast iron and below the melting point of the steel whereby the molten iron and the softened steel may be caused to flow into the space between the original pieces and the die mold to be chilled by the die mold.

8. An apparatus for joining by fusion a steel tubular piece and a cast iron end piece comprising a pair of electrode halves for clamping the tubular member adjacent the juncture with a current conducting engagement, means for opening and closing the electrode halves, an electrode shiftable to engage the end piece, means for shifting the last named electrode endwise to press the pieces together, a cylindrical die mold surrounding the pieces at the juncture and spaced therefrom by a small distance, and means for supplying electric current to the pieces through the electrodes to raise the temperature of the junction zone above the melting point of the cast iron and below the melting point of the steel whereby the molten iron and the softened steel may be caused to flow into the space between the original pieces and the die mold to be chilled by the die mold, and means providing at least one additional die mold alternately shiftable with the first die mold between a position for fusion and an inoperative position for cooling purposes.

9. In an electric heating machine for heating individual work pieces in automatic sequence the sub-combination of a combined work feeding and work heating electrode system which includes a pair of generally circular electrode turrets formed of highly conductive metal, each turret having a plurality of work cavity halves and being mounted for conjoint rotation and for limited diametral translation and a pair of clamping electrodes positioned at the ends of the common diameter of the turrets and having faces matching the periphery of the turrets and shiftably mounted to press the turrets toward and away from each other to clamp a work piece between the cavity halves which are in register.

10. In an electric heating machine for heating individual work pieces in automatic sequence the sub-combination of a combined work feeding and work heating electrode system which includes a pair of generally circular electrode turrets formed of highly conductive metal, each turret having an odd number of work cavity halves and being mounted for conjoint rotation and for limited diametral translation and a pair of clamping electrodes positioned at the ends of the common diameter of the turrets and having faces matching the periphery of the turrets intermediate the cavity halves and shiftably mounted to press the turrets toward and away from each other to clamp a work piece between the cavity halves which are in register.

11. In an electric heating machine for heating individual work pieces in automatic sequence the sub-combination of a combined work feeding and work heating electrode system which includes a pair of generally circular electrode turrets formed of highly conductive metal, each turret having a plurality of work cavity halves and being mounted for conjoint rotation and for limited diametral translation and a pair of clamping electrodes positioned at the ends of the common diameter of the turrets and having faces matching the periphery of the turrets, and means including a spherical abutment adjacent each clamping electrode and a reciprocating actuator for pressing the clamping electrodes and the turret electrodes into tight engagement.

12. In an electric heating machine for heating individual work pieces in automatic sequence the sub-combination of a combined work feeding and work heating electrode system which includes a pair of generally circular electrode turrets formed of highly conductive metal, each turret having a plurality of work cavity halves and being mounted for conjoint rotation and for limited diametral translation, a die mold half mounted adjacent to and insulated from each cavity half, and a pair of clamping electrodes positioned at the ends of the common diam-

eter of the turrets and having faces matching the periphery of the turrets and shiftably mounted to press the turrets toward and away from each other to clamp a work piece between the cavity halves which are in register.

References Cited in the file of this patent

UNITED STATES PATENTS

1,119,553	Vaughan	Dec. 1, 1914
1,544,272	Pancoast	June 30, 1925
1,691,778	McDonald	Nov. 13, 1928
1,898,814	Charlton	Feb. 21, 1933
1,977,538	Armstrong	Apr. 9, 1935
2,005,375	Jones et al.	June 18, 1935
2,014,240	Tarbox et al.	Sept. 10, 1935
2,055,342	Schneider	Sept. 22, 1936
2,150,444	Hoern	Mar. 14, 1939
2,178,724	Hoern	Nov. 7, 1939
2,293,247	Fentress	Aug. 18, 1942
2,352,754	Andersen et al.	July 4, 1944
2,358,090	Longoria	Sept. 12, 1944
2,473,543	Randolph	June 21, 1949
2,524,369	Tiedemann	Oct. 3, 1950
2,647,979	Knight	Aug. 4, 1953
2,656,445	Svenson	Oct. 20, 1953
2,816,211	Hutchins	Dec. 10, 1957
2,816,212	Fleischmann	Dec. 10, 1957