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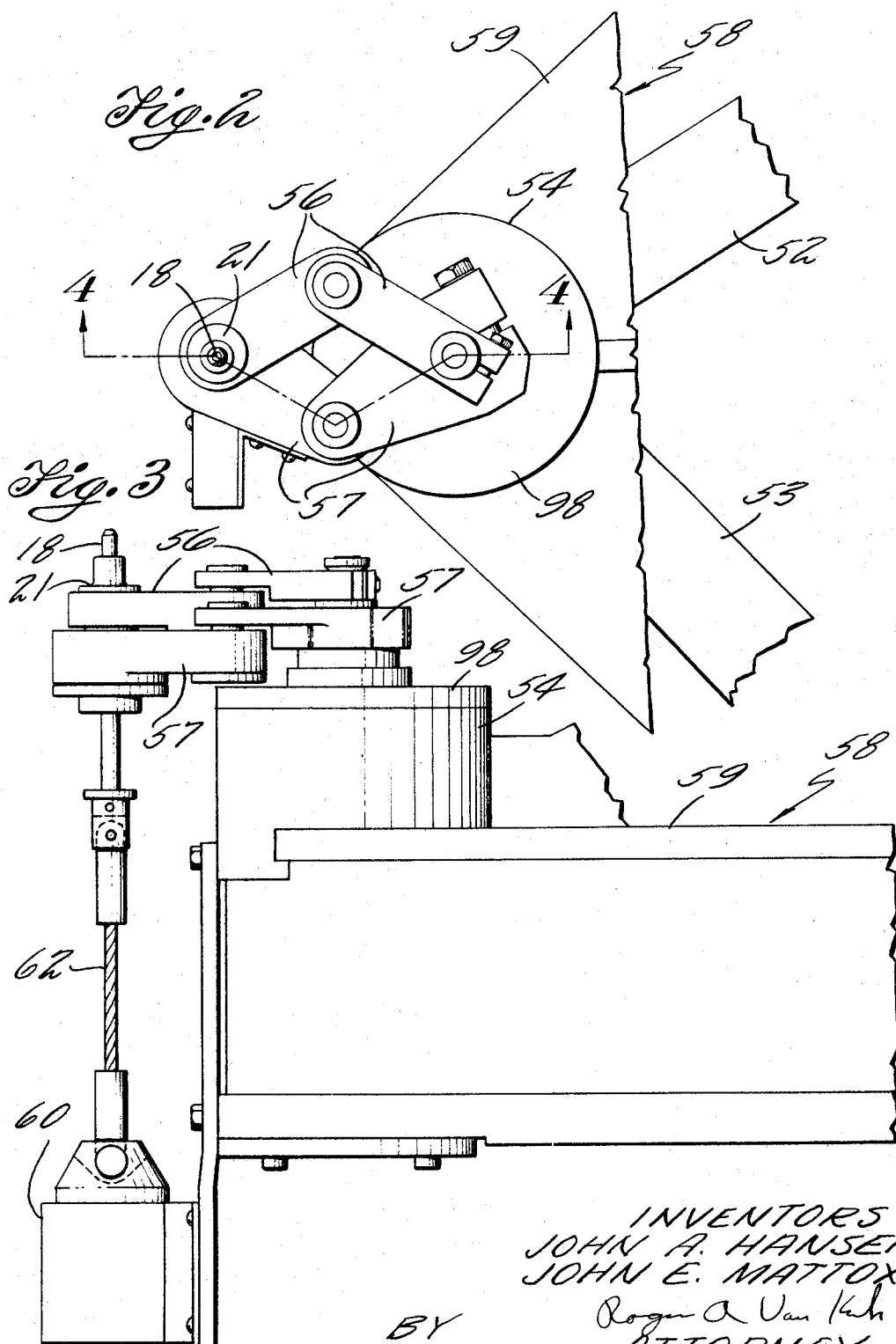
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ELECTRON BEAM PANTOGRAPH CONTROL

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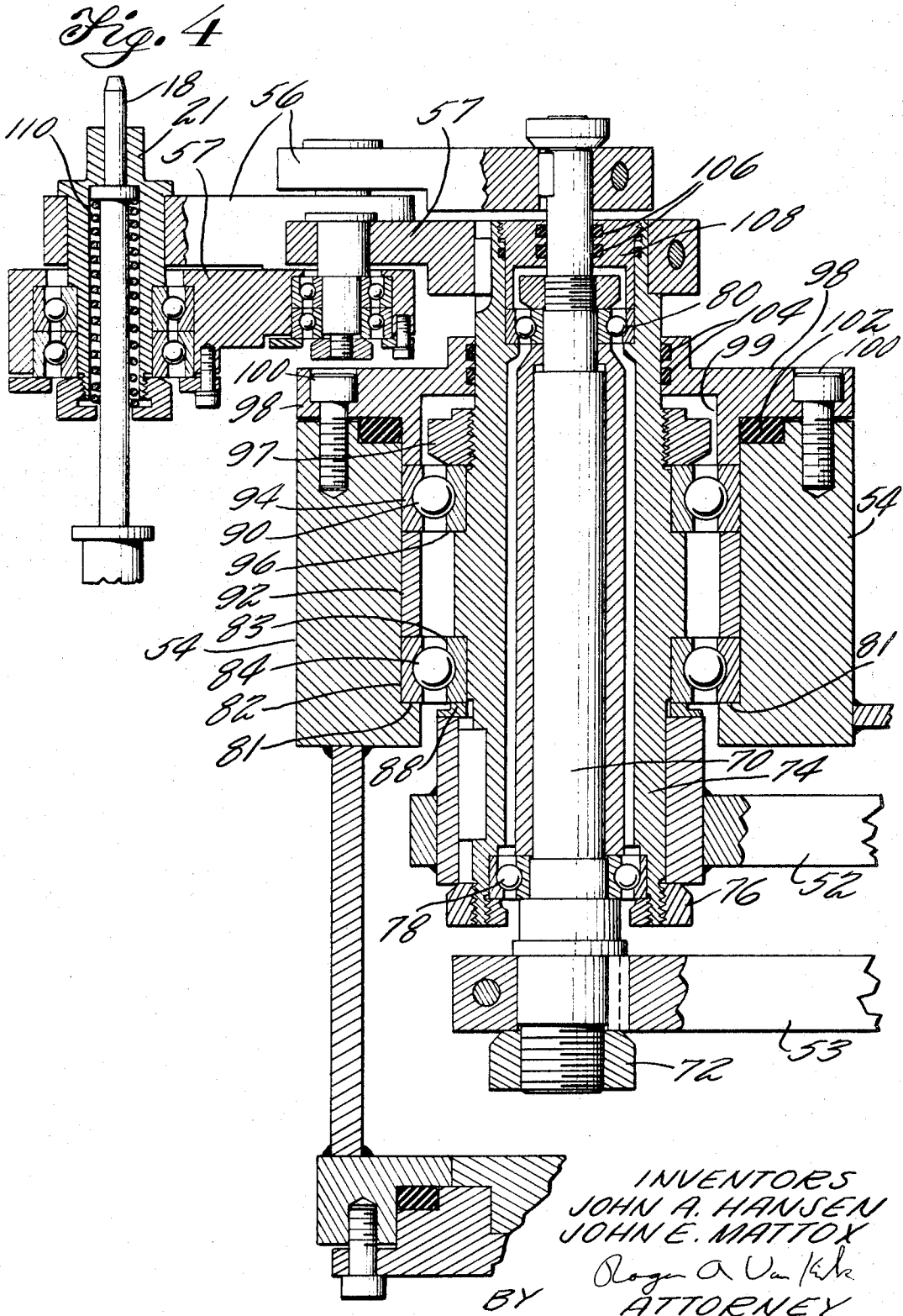
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ELECTRON BEAM PANTOGRAPH CONTROL

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ELECTRON BEAM PANTOGRAPH CONTROL
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ABSTRACT OF THE DISCLOSURE

Apparatus for serially positioning a plurality of objects to be electron beam welded in line with an electron beam generator and moving each object under the beam in accordance with a pattern, the pattern being in the form of a movable template, motion of a template tracer for the movable template being transmitted into the evacuated work chamber of the electron beam generator and coupled to an object supporting table via a pantograph having linkages interior and exterior of the evacuated chamber, motion of the template itself causing the supporting table to be engaged at a new location.

This invention relates to the automatic control of tools. More particularly, this invention is directed to a device which effects control over an operation which is to be performed in a location inaccessible to the operator of the tool.

While not limited thereto, this invention is thought to have particular utility and thus will be described in connection with the control of the positioning of a workpiece which is to be operated upon within the evacuated work chamber of an electron beam machine. Electron beam machines, as they are now generally known, are devices which use the kinetic energy of an electron beam to work a material. U.S. Patent No. 2,987,610, issued June 6, 1961, to K. H. Steigerwald, discloses such a machine. These machines operate by generating a beam of electrons having extremely high beam power density. An electron beam is a welding, cutting and machining tool which has practically no mass but has high kinetic energy because of the extremely high velocity imparted to the electrons. Transfer of this kinetic energy to the lattice electrons of the workpiece generates higher lattice vibrations which cause an increase in the temperature within the impingement area sufficient to accomplish work. As taught by the above-mentioned Steigerwald patent, once a minimum or threshold value for beam power density has been exceeded, the beam of electrons will penetrate deeply into the work producing a narrow, highly heated channel without reliance upon thermal conduction through the workpiece material.

It is, of course, necessary that the beam of electrons be generated in a low pressure environment. This requirement is dictated by, among other things, the fact that the elements which emit or otherwise cause production of the electrons, which are thereafter focussed into a beam, are highly susceptible to damage. In the usual instance the electrons are emitted by an incandescent, tungsten filament. Any oxygen in the chamber where the filament is located will cause almost instantaneous oxidation and failure of said filament. Once the emitted electrons have been focussed, by means clearly shown in the above-mentioned Steigerwald patent, into a beam, they will be accelerated and focussed at the desired point on the surface of the workpiece. Recent advances in the state of the art have permitted positioning of the workpiece outside of the low pressure environment and bringing the beam out of said low pressure region to perform its work in the atmosphere. While such out-of-vacuum electron beam material working unquestionably has great

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utility, particularly in the welding or machining of large workpieces, there are many instances where it is more desirable to locate the work in the same low pressure environment where the beam is generated. One particularly significant reason for placing the workpiece in a vacuum chamber is that, because of scatter of the beam due to collisions between the electrons and air molecules, greater power is required to achieve results outside the vacuum which are comparable with similar work performed in an evacuated chamber.

Many schemes have been proposed for the manipulation of workpieces positioned in inaccessible locations. These prior art schemes universally suffer from the same deficiencies. That is, they are relatively expensive, complex and, due in part to their complexity, have long down times when trouble develops. Examples of such prior art schemes are computed programming of work table position and the provision of plural manipulators which extend into the inaccessible region. It is the primary object of this invention to provide for the movement of a workpiece positioned in an inaccessible location by means which are inexpensive, reliable, fast acting and not unduly complex. In addition, this invention achieves the foregoing in automated fashion.

It is therefore an object of this invention to provide for the automatic control of a tool.

It is another object of this invention to automatically control the positioning of a workpiece in an inaccessible location.

It is also an object of this invention to provide for the automatic control of a process to be performed within an evacuated chamber.

It is a further object of this invention to automatically position a workpiece located within the work chamber of an electron beam machine.

It is yet another object of this invention to transmit motion from the exterior to the interior of a chamber without coincidence leakage of the fluid which comprises the exterior environment through the wall of the chamber.

These and other objects of this invention are achieved by a novel programming mechanism which employs a pantograph having an external parallelogram located outside of a chamber in which work is to be performed and having its follower linkage located within said chamber. A stylus or template tracer is attached to a first corner of the external parallelogram and is driven around a template. The motion imparted to the pantograph linkages is transmitted, by a novel arrangement of coaxial shafts, through the wall of the chamber so as to drive the linkages of the follower parallelogram. The corner of the second parallelogram engages, by means of a retractable pin, a table carrying one or a plurality of workpieces and thus causes movement of the work beneath the tool in accordance with the pattern being followed by the stylus. Means are also provided which permit the automatic positioning of a series of workpieces under the tool.

This invention may be better understood and its numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals refer to like elements in the different figures and in which:

FIGURE 1 is an isometric drawing of the control which comprises this invention.

FIGURE 2 is a plan view of the follower linkage employed in the apparatus shown in FIGURE 1.

FIGURE 3 is a side elevation view of the apparatus shown in FIGURE 2.

FIGURE 4 is a sectional view, along line 4—4 of FIGURE 2, of the means employed in the apparatus of

FIGURE 1 for transmitting motion through the wall of the chamber.

Referring now to FIGURE 1, the programming mechanism which comprises this invention is shown being utilized to control the positioning of workpieces beneath a stationary electron beam in the evacuated work chamber of an electron beam welding machine. The electron beam machine employs an electron beam forming column 10, only the bottom of which is shown, which comprises basically the same components as the beam forming column shown in FIGURE 1 of the aforementioned Steigerwald patent. The electron beam, which may be focussed to a diameter of .001 inch, exits from beam forming column 10 through tube 12. The beam thereafter impinges upon a workpiece located in work chamber 14 and aligned with the axis of the beam. Both chamber 14 and column 10 are evacuated by vacuum pumping means, not shown. In FIGURE 1, the pieces to be worked comprise a plurality of electronic devices which are to be hermetically encapsulated by the welding of cans thereover. These devices, with the cans in place, are positioned in a tray 16 carried in a rack 17 which is movable in the X and Y directions beneath the beam forming column. Tray 16 has apertures 19 in the bottom thereof for engagement with a drive pin 18 extending from a drive pin assembly 21 and which, in the manner to be described below, moves in accordance with a remotely located pattern. Rack 17 is slideably mounted on a pair of support rods 20 and 22 and thus can move freely in the Y direction. Rods 20 and 22 are fixed to members 24 and 26 and together therewith form a carriage which is freely movable in the X direction by rolling along a pair of rails 28 and 30. When drive pin 18 is withdrawn from tray 16, the entire assembly may be moved in either the X or Y direction by engagement of a solenoid operated alternate drive pin 32 carried by a movable table indicated generally at 34 which travels along guides mounted on the bottom of work chamber 14. The movement of mechanism 34 may be programmed but, in the most usual case, will be controlled by a pair of hand wheels, not shown, such as wheels 35 and 40 of FIGURE 1 of the abovementioned Steigerwald patent.

In the apparatus shown in FIGURE 1, welding motion is achieved by positioning each individual workpiece, one at a time, under the beam and then moving the entire tray through coordinated X-Y motion such that each portion to be welded on each device passes under the beam. This coordinated X-Y motion is programmed by driving a template tracer or stylus 42 around a template. Motion of the template tracer is transmitted, by means of a pantograph linkage, to drive pin 18. As will be discussed in more detail below, motion of the template tracer is reproduced on a reduced scale at the work tray to provide the X-Y motion. By adjusting the pantograph linkages, in a manner well known in the art, the demagnification may be selected and the welding contour thus adjusted to the desired value. In one embodiment, work tray 16 carried 140 pieces and the demagnification ratio was variable between 1:4 and 1:10.

In order to drive template tracer 42, a tracer drive motor 36 is mounted on a frame 38 above the template 40. Drive motor 36 drives the template tracer mechanism 42 through a constant velocity, double universal, telescoping shaft 44. Template 40 is mounted on a base 41 and is fabricated by forming a chain as the outside edge. Template tracer 42 comprises a sprocket which engages said chain to provide for positive drive action. The foregoing arrangement provides for constant speed movement of the stylus 42 about the template and this in turn provides the requisite constant speed movement of the work under the beam; even when the stylus is rotating about the corners of the template. As should be obvious, constant speed of movement of the work is necessary to produce uniform welds. For purposes which will be more fully explained below, the template and base as-

sembly are movable in the Y direction, along slides 46 and 48, under the command of air cylinder or actuator 50.

The operation of a pantograph is, of course, well known in the art. In the apparatus being described, pantograph linkages 52 and 53, which comprise the external large parallelogram, move in response to the tracing of template 40 by template tracer 42. Motion of linkages 52 and 53 is transmitted through the wall of chamber 14, without coincident leakage of air into the evacuated chamber, by means, located in a housing 54, which will be described in more detail below. Inside of chamber 14, motion of linkages 52 and 53 will cause corresponding movement of linkages 56 and 57 of the follower parallelogram. In order to facilitate the transmission of the motion of the pantograph linkage 52 to follower linkage 56, chamber 14 is constructed with a V-shaped depression, indicated generally at 58, in the side thereof. The pivot point of the external parallelogram is located adjacent the apex of this depression. As will be clearly explained below, movement of linkages 52, 53 will be transmitted vertically through to top wall 59 of depression 58 to the pivot point of the internal parallelogram.

Referring now to FIGURES 2 and 3, the internal parallelogram is shown in top plan and side elevation views respectively. FIGURE 3 most clearly shows the means, discussed above, by which the drive pin 18 may be retracted from tray 16 after welding of each individual device. As is most clearly seen from FIGURE 4, drive pin 18 is spring biased into engagement with the apertures 19 in the work tray during a welding operation. At the completion of a weld, pin 18 is retracted by energizing solenoid 60 which is connected to pin 18 by means of a flexible shaft 62. As will be explained in more detail below, pin 18 will thereafter move in such a manner as to engage the next aperture in the work tray and will move said tray in such a manner that the succeeding workpiece will be aligned with the axis of the electron beam. The foregoing manner of indexing constitutes a substantial improvement over the prior art because it eliminates accumulated tolerances. That is, by so moving the work in a stepwise fashion rather than programming the entire movement of tray 16 from a single starting point, accumulated errors are eliminated.

Considering now FIGURE 4, the means for transmitting the motion of pantograph linkages 52 and 53 of the external parallelogram through the wall 59 of depression 58 in vacuum chamber 14 is shown in detail. Pantograph linkage 53 of the external parallelogram is keyed to a first shaft 70 and is held by means of a locking nut 72. Pantograph linkage 52 of the external parallelogram is similarly keyed to a hollow shaft 74 and is held in place thereon by locking nut 76. Shaft 74 is coaxial with shaft 70 and, while serving to support the same, is capable of rotating thereabout on bearings 78 and 80. The assembly comprising coaxial shafts 70 and 74 is rigidly mounted to housing 54 which is in turn welded to top wall 59 of depression 58. The inside of housing 54 is constructed with a shoulder 81 which receives the outer race 82 of bearing 84. The inner race 83 of bearing 84 is retained on shaft 74 by means of a retaining ring 88. Between the lower bearing 84 and an upper bearing 90 is positioned a spacer ring 92. Spacer ring 92 supports the outer race 94 of bearing 90 and the inner race 96 of this bearing is also retained by a shoulder on shaft 74. The inner race 96 of bearing 90 is retained in position and thus rotatably supports shaft 74 by means of a locking nut 97 which engages threads on shaft 74. The bearings are also retained by means of the top 98 of housing 54 which has a projection 99 thereon which abuts outer race 94 and thus holds the bearing assembly in the proper position. Top member 98 is held into position on housing 54 by means of screws 100. Prior to bolting top 98 on member 54, a vacuum seal 102 is positioned on an inner shoulder of member 54. Tightening of screws 100 compresses seal

102 and thereby prevents leakage of air from without chamber 14 into the chamber around bearings 84 and 90. Also positioned between top member 98 and outer shaft 74 are a pair of vacuum seals 104. Seals 104 circumscribe and squeeze against shaft 74 thus preventing leakage of air into chamber 14 around the outside of shaft 74 while still permitting rotation of the shaft. To prevent leakage of air between shafts 70 and 74, another set of vacuum seals 106 is provided. Seals 106, as well as the outer races of bearing 80, are held in position by a locking nut and seal retainer 108. As with shaft 74, shaft 70 can rotate within seals 106. Follower linkage 57 is keyed to the upper end of shaft 74 and thus rotation of shaft 74 will cause movement of pin 18 which is similarly keyed to linkage 57. Linkage 56 is keyed to the upper end of shaft 70 and thus rotation of shaft 70 will also cause movement of pin 18 to which linkage 56 is also keyed. As mentioned above, pin 18 will engage the apertures in the work tray through the action of a spring. For this purpose, a spring 110 is provided internally of pin assembly 18. Thus, pin 18 will firmly engage the work tray until such time as solenoid 60 is activated whereupon shaft 62 will pull downwardly against the spring tension and cause retraction of pin 18. Upon deenergization of solenoid 60, pin 18 will be urged upwards and will engage an aperture in tray 16. Upon engagement of pin 18 with a pin aperture, a welding operation may be initiated.

Referring again to FIGURE 1, the operation of the disclosed invention is as follows. Assuming drive pin 18 is engaged in an aperture in tray 16, the operator will close a switch, not shown, to initiate welding. Upon closing of this switch, motor 36 will begin driving template-tracer or stylus assembly 42 about the template 40 in the clockwise direction from its starting position. The starting position is with the stylus 42 in contact with and thus causing closing of limit switch 112 which is mounted on the template support member 41. When the stylus moves out of contact with switch 112, the switch will open and, through the action of state-of-the-art electromechanical circuitry contained in a sequencer or logic unit 114, the electron beam generator will be gated on. Through the action of the pantograph, the workpiece will then be moved beneath the beam in accordance with the template pattern. The template tracer will rotate about template 40 one complete time. When stylus 42 contacts and thus closes switch 112 a second time, a timer in logic unit 114 will be actuated. The timer will prevent the second closing of switch 112 from deenergizing the beam generator and motor 36 and thus will produce a desired overlapping of the weld seam. The timer therefore functions as a holding relay for a predetermined interval and, when it has counted down to zero, will permit the deenergization of the beam generator. At this time, through relay circuits in unit 114, the motor 36 will be energized with a reverse polarity signal and will back up until switch 112 is contacted. Upon recontacting of switch 112 by stylus assembly 42, solenoid 60 will be energized thereby causing retraction of drive pin 18. Also upon reclosing of switch 112, air cylinder or actuator 50 will be energized and will drive the template and tracer assembly to the left as shown in FIGURE 1. During this period, switch 112, which travels with the template assembly, will act as an interlock and will prevent energization of motor 36 and the beam generator. The motion of template 40 and tracer 42 will be terminated by the contacting of a second limit switch 116, mounted on an adjustable stop 117, by the template support member 41. Closing of switch 116 deenergizes air actuator 50 thereby permitting the template and tracer assembly to return to its starting position. Closing of switch 116 also deenergizes solenoid 60 permitting spring 110 to cause pin 18 to engage a succeeding aperture in the row being worked. Return of the template assembly to its initial position thus causes a simultaneous movement of the work tray so as to position a second device to be welded in line with the axis of the beam. Upon return to its starting position, an extension on template

support 41 will contact and thus close switch 118. Closing of switch 118 will break the relay circuits held closed by switch 112 and thus will cause reenergization of motor 36 and the beam generator. Thereafter the entire procedure will be repeated until a complete row of devices on tray 16 have been worked. When a row has been completed, the machine operator will deactivate the sequencer and will engage alternate drive pin 32 with work tray 16. The operator will then drive table 34 in such a manner that a second row of devices to be worked is lined up with the beam axis. The operator will next cause retraction of pin 32, energize the sequencer and a second row may be automatically worked. It should be noted that the stepping from row to row need not be performed manually but can, through relatively straight-forward electromechanical logic circuitry which is controlled through limit switches on rack 17, be performed automatically. In moving of table 34 so as to position a new row on tray 16 in line for working, it is necessary that the tray 16 be moved in only one direction. By means of an interchange switch, not shown, on sequencer unit 114, the mode of indexing of the tray along a row can be reversed so that automatic operation up and down alternate rows is achieved. The foregoing is accomplished simply by alternating the sequence of retraction of drive pin 18 so that, after completing a row operating in the mode described above, the next row is worked with the drive pin being retracted, under command of switch 116, after movement of the template to the left, solenoid 60 being deenergized by closing of switch 118.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made without deviating from the scope and spirit of this invention. For example, with an electron beam machine employing a movable gun assembly, this invention may be employed to control movement of the gun relative to a stationary workpiece without the exercise of invention. Similarly, this invention may be utilized to control either the position of a device which generates a beam of coherent light or the objects to be worked with such a beam. It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

We claim:

1. Apparatus for automatically controlling the position and motion of a plurality of bodies to be worked with an electron beam within the evacuated work chamber of an electron beam machine comprising:
 - a template located outside of the evacuated work chamber of the electron beam machine,
 - a template tracer,
 - means for driving said template tracer about said template with constant speed,
 - means coupled to said template tracer for converting the linear motion thereof to rotary motion,
 - means for transmitting said rotary motion through a wall of the evacuated chamber without coincident leakage of air,
 - a movable table for supporting the bodies to be worked within the evacuated chamber,
 - means positioned in said evacuated chamber for engaging and driving said table,
 - means positioned in said evacuated chamber and coupled to said table engaging means and to said rotary motion transmitting means for reconverting said rotary motion to linear motion,
 - means for moving said template, and
 - means responsive to the motion of the template for causing said engaging means to engage said movable table at a new location whereby said plurality of bodies may be serially moved into position beneath the beam generator and thereafter moved under the beam in accordance with the pattern defined by the template.
2. The apparatus of claim 1 wherein said means for

causing engagement of the engaging means with the table comprises:

- first means responsive to the complete tracing of the template by the template tracer for causing disengagement of the engaging means from the table, 5
- second means responsive to the complete tracing of the template by the template tracer for generating a control signal for activating said means for simultaneously moving said template and tracer, 10
- means responsive to a desired degree of movement of said template for causing reengagement of said engaging means with the table at a new location, and means responsive to the return of the template to its starting point for causing said template tracer to begin retracing said template. 15
3. The apparatus of claim 2 wherein said means for transmitting rotary motion through said wall of the chamber comprises:
 - a pair of coaxial shafts arranged for rotation about each other, the outer of said shafts being rotatably mounted in said wall of the chamber, 20
 - first sealing means positioned between said inner and outer shafts,
 - second sealing means positioned between outer shaft and said wall.
4. Apparatus for automatically controlling the position and motion of a plurality of bodies in an environment unsuitable to the presence of a workman comprising:
 - means located in a friendly environment and carrying a pattern it is desired to have each of the bodies follow, 30
 - a pattern tracer,
 - means for driving said pattern tracer about said pattern with constant speed,
 - means coupled to said pattern tracer for transmitting the motion thereof into the unsuitable environment without coincident leakage of fluid between said unsuitable and friendly environments, 35
 - a movable table for supporting the bodies within the unsuitable environment, 40
 - means located within said unsuitable environment for engaging and driving said table,
 - means connecting said table engaging means to said motion transmitting means for coupling said transmitted motion to said table engaging means whereby said table and pattern tracer move simultaneously during the driving of said pattern tracer about said pattern, 45
 - means for simultaneously moving said pattern carrying and pattern tracing means and,
 - means responsive to said simultaneous motion of the pattern tracing and carrying means for causing said engaging means to engage said table at a new location. 50
5. Apparatus for automatically controlling the position and motion of a plurality of bodies to be worked in an environment unsuitable to the presence of a workman comprising: 55

- a template located in a friendly environment,
- a template tracer,
- means for driving said template tracer about said template with constant speed,
- a first parallelogram formed by the linkages of a pantograph coupled at one corner to said template tracer, means connected to the opposite corner of said first parallelogram for transmitting motion of the template tracer into the unsuitable environment without coincident leakage of fluid between said unsuitable and friendly environments,
- a movable table for supporting the bodies to be worked within the unsuitable environment,
- means for engaging and driving said table,
- a second parallelogram of said pantograph positioned within the unsuitable environment and connecting said table driving means to said motion transmitting means for coupling said transmitted motion to said said table,
- means for moving said template, and means responsive to motion of the template for causing said engaging means to engage said table at a new location.
6. Apparatus for automatically controlling relative motion in an evacuated chamber between an object to be worked with a beam of charged particles and the normal axis of the beam comprising:
 - means located outside of the evacuated chamber and carrying a pattern that it is desired to have the object follow, 25
 - a pattern tracer,
 - means for driving said pattern tracer about said pattern with constant speed,
 - means coupler to said pattern tracer for transmitting the linear motion thereof into the evacuated chamber as rotary motion without coincident leakage of air,
 - means within said chamber and operatively connected to said motion transmitting means for converting the transmitted rotary motion back into linear motion, and
 - means in said chamber responsive to said linear motion causing relative movement between the object to be worked and the axis of the beam of charged particles. 30

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