June 9, 1970 J. H. LEMELSON Re. 26,904

ARTICLE MANIPULATION APPARATUS

Original Filed Jan. 14, 1963 6 Sheets-Sheet 1

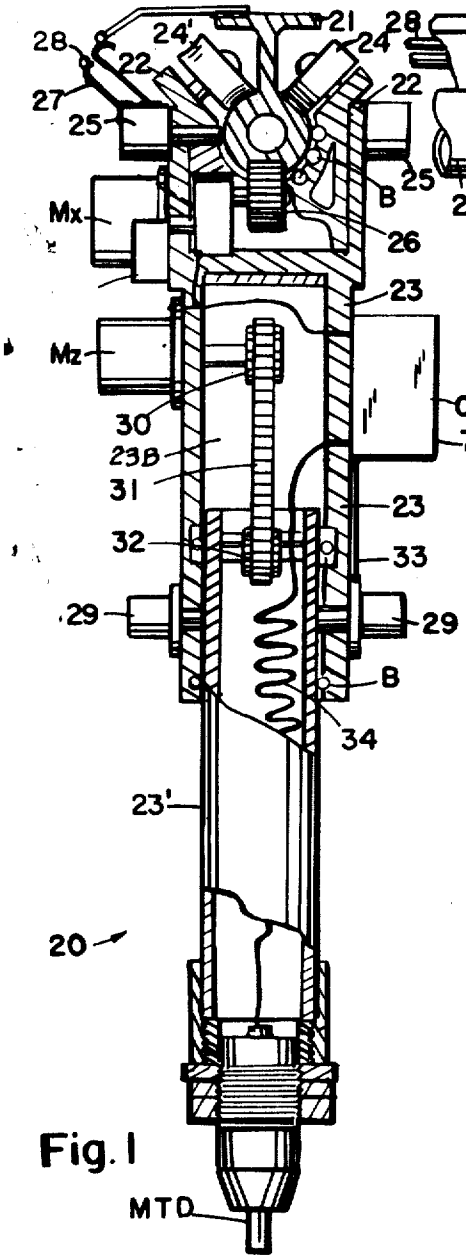


Fig. 1

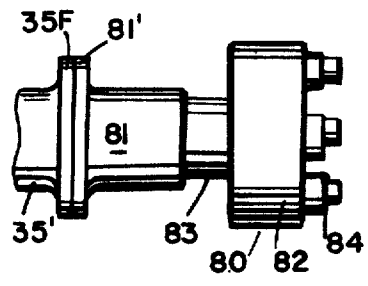


Fig. 3

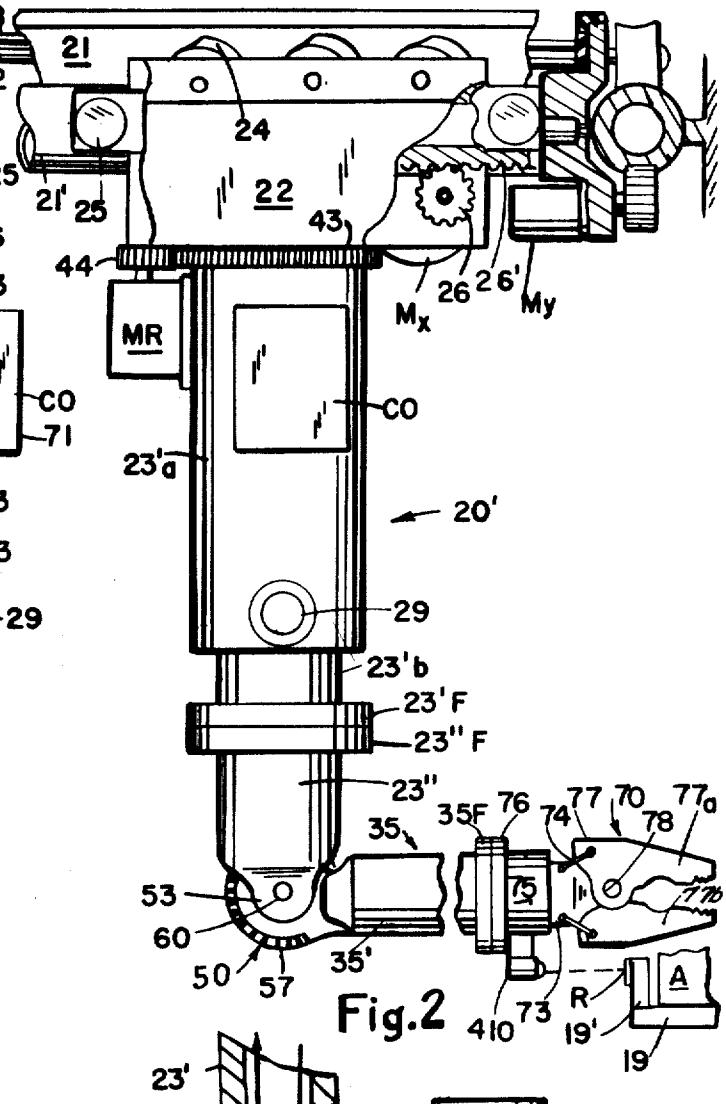


Fig. 2

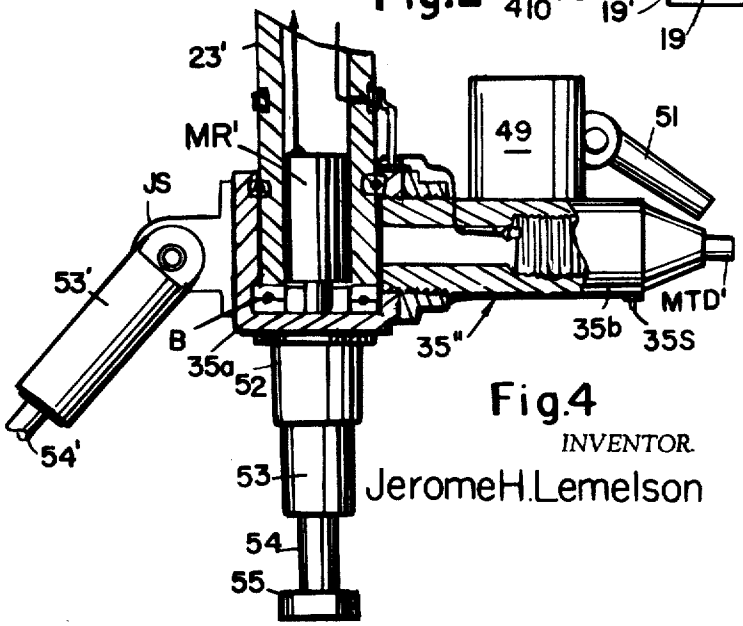


Fig. 4

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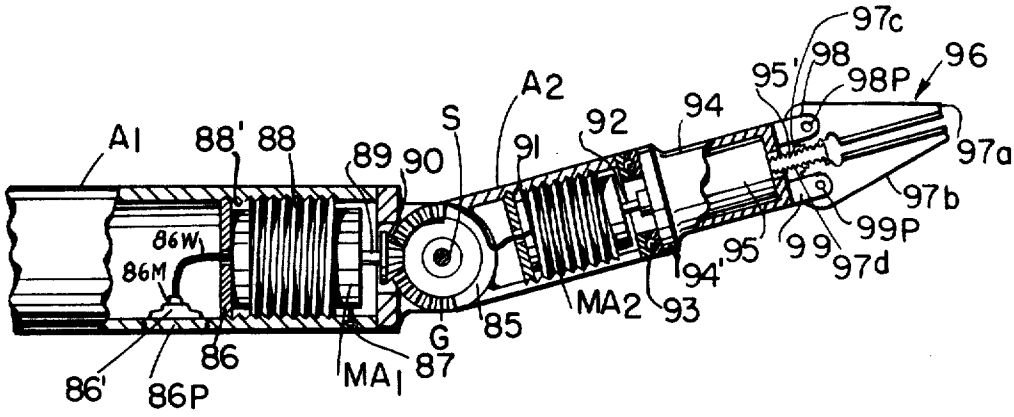


Fig. 2'

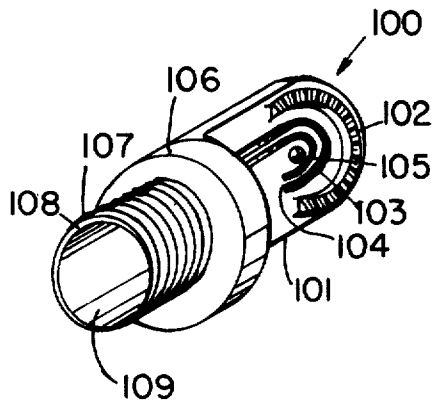


Fig.5

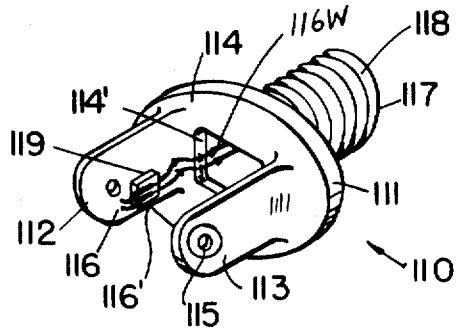


Fig. 6

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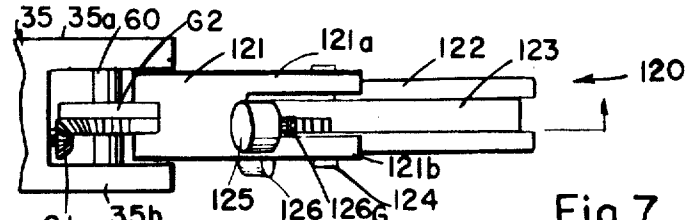


Fig.7

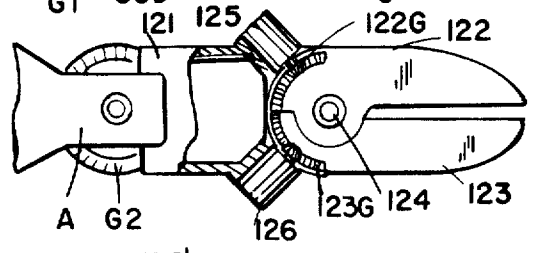


Fig.8

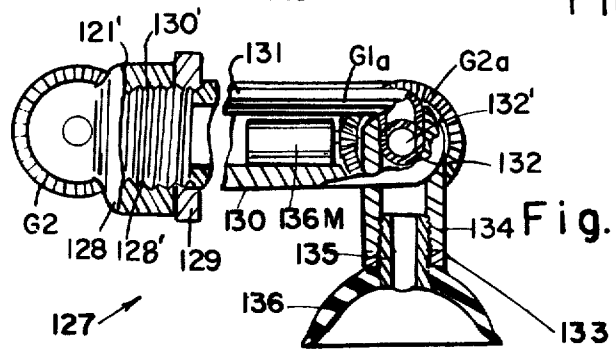


Fig.9

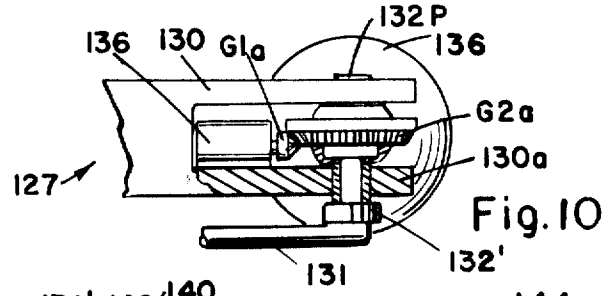


Fig.10

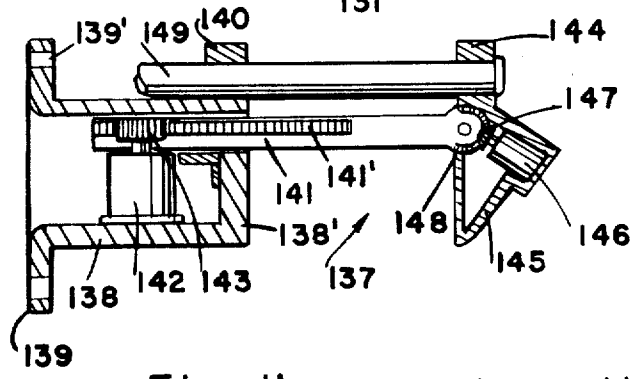


Fig. 11

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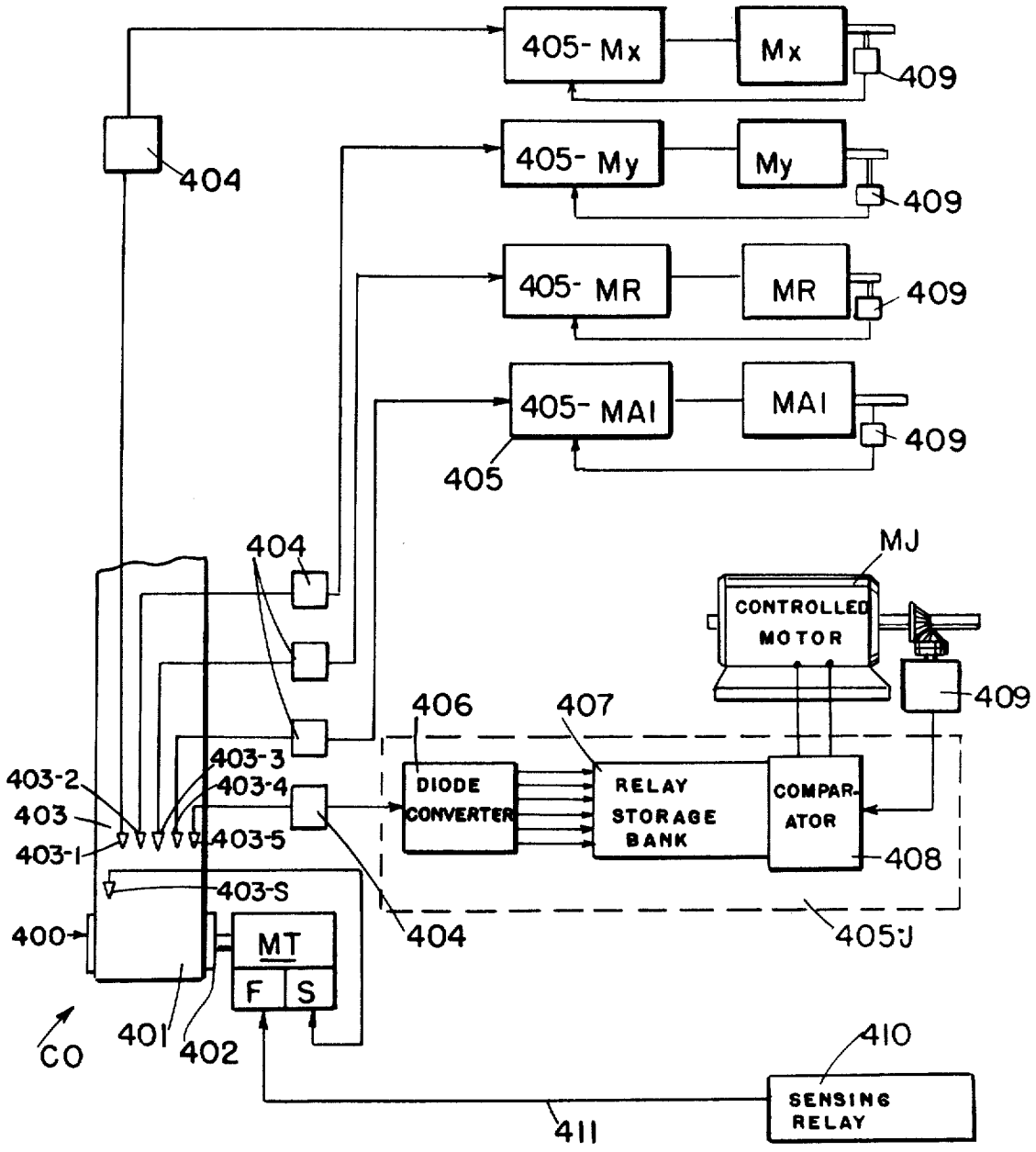


Fig. 12

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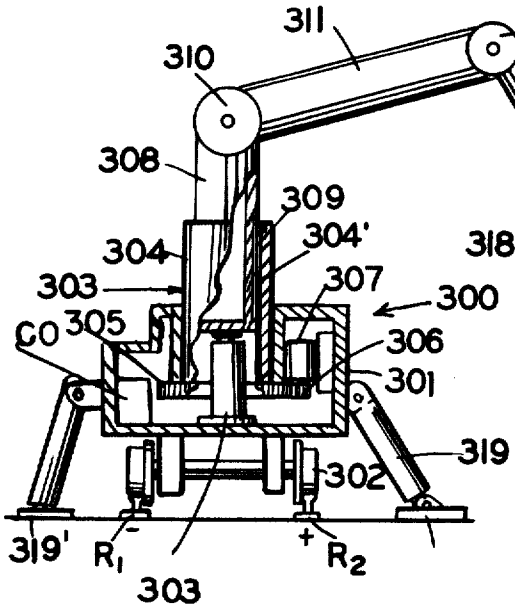


Fig.13

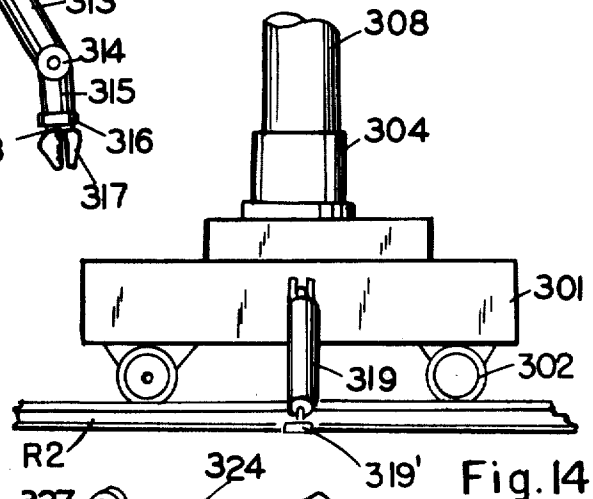


Fig.14

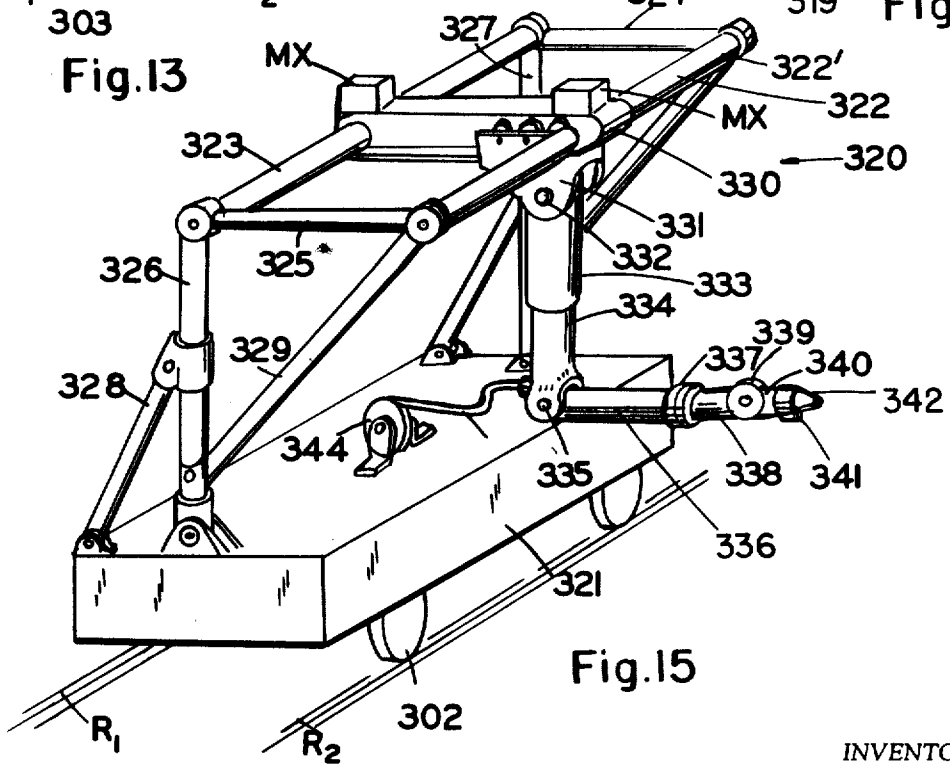


Fig.15

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ARTICLE MANIPULATION APPARATUS

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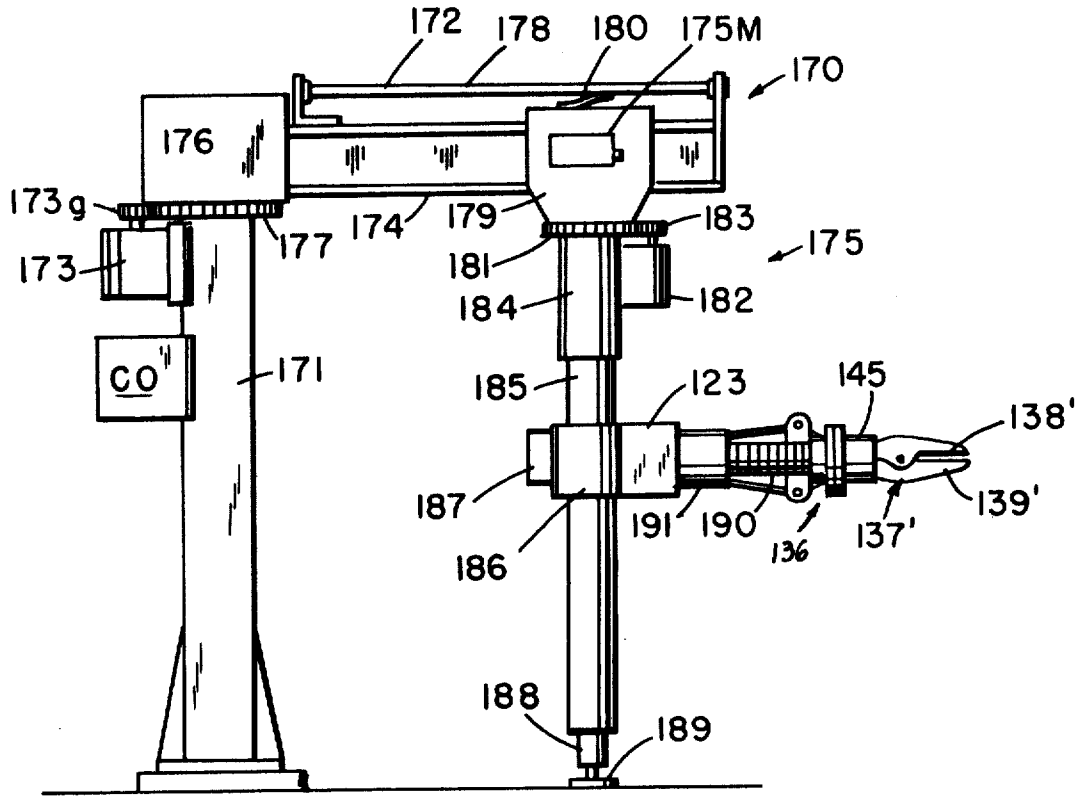


Fig. 16

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Reissued June 9, 1970

26,904

ARTICLE MANIPULATION APPARATUS

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Original No. 3,272,347, dated Sept. 13, 1966, Ser. No. 251,410, Jan. 14, 1963. Application for reissue Sept. 12, 1968, Ser. No. 796,237
Int. Cl. B25j 9/00
U.S. Cl. 214—1 13 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

A manipulating device for performing a plurality of manufacturing functions automatically controlled by a programming means. A sensing means is mounted on the manipulator to sense the prepositioning of an article which is to be manipulated and initiate the programmed operation.

This invention relates to an automatically controlled manipulator and is a continuation-in-part of my copending application entitled, Automation Devices, Ser. No. 477,467, which was filed December 24, 1954, now abandoned.

In the performance of many production and maintenance operations, manual labor is frequently required to pre-position a tool, device, or probe relative to a work piece and to manipulate it thereafter in order to perform a given function. Not only is the cost of such labor substantially high but other factors such as quality and production rate are limited by and dependent on the skill of the operator. Frequently, it is impossible for one or more operators to handle a particular tool and specialized equipment must be designed, developed and constructed for the performance of certain routine functions. This equipment is quite often not flexible and is used to perform one or a few operations.

This invention is primarily concerned with manipulating devices for the performance of a plurality of manufacturing functions, which devices may be automatically of semi-automatically controlled to perform various movements in a given volume.

Another object is to provide an automatically controlled manipulator the motions of which may be controlled by a programming means, the program or sequential control of which is easily charged or varied.

Another object is to provide an improved, automatically controlled manipulator having components which are easily interchanged.

Another object is to provide an improved automatic manipulator and an improved joint therefor, a portion of which may be easily disassembled and interchanged with other joint portions.

Still another object is to provide an improved automatic manipulator including a power operated carriage therefor, which carriage may be automatically controlled to pre-position the manipulator at a given floor or spatial location in a large production area.

Another object is to provide an automatic manipulator having an automatic controller or computing mechanism mounted directly thereon whereby the need for remote control thereof is eliminated.

Another object is to provide an automatic manipulator and a conveyor therefor for prepositioning said manipulator at a given spatial location in a production area and an automatically controlled means for fixing or locking a portion of the manipulator at an attained position while

other portions thereof perform a given function whereby an operating base may be established for the tool of the manipulator and substantial precision in the control thereof may be effected.

Another object is to provide an automatic manipulator for perforfming functions which require the feeding of a material, which manipulator includes means mounted thereon for retaining a supply of said material and feeding it to a tool of the manipulator.

Other objects and additional features of the invention will be obvious from the accompanying drawings and the following specification.

In the drawings:

FIG. 1 is an end view with parts broken away for clarity of an automatic tool manipulation apparatus which is movable along an overhead trackway;

FIG. 2 is a side view with parts broken away for clarity of an article manipulation apparatus having many of the features of the apparatus of FIG. 1;

FIG. 2' is a side view with parts broken away for clarity of a manipulator arm assembly applicable to the apparatus of FIG. 2;

FIG. 3 is a partial view of a tool or article manipulation apparatus applicable to apparatus such as that illustrated in FIG. 2;

FIG. 4 is a partial view of a tool or article manipulation apparatus applicable to the apparatus of FIGS. 1 and 2 and showing means for stabilizing and supporting the apparatus above a floor;

FIG. 5 is an isometric view of a joint component;

FIG. 6 is an isometric view of a yoke shaped joint member adapted for assembly with the member illustrated in FIG. 5;

FIG. 7 is a top view of a jaw assembly for seizing and releasing articles and applicable to the apparatus of FIGS. 1–4;

FIG. 8 is a side view of the jaw assembly of FIG. 7 with parts broken away for clarity;

FIG. 9 is a side view with parts broken away for clarity of an automatic manipulator joint and suction retaining means at the end thereof;

FIG. 10 is a partial top view of the apparatus of FIG. 9 with parts broken away for clarity;

FIG. 11 is a side view with parts broken away for clarity of a manipulator clamping fixture applicable to the apparatus of FIG. 1;

FIG. 12 is a schematic diagram of a programmable automatic control means for automatically operating apparatus of this invention or the like;

FIG. 13 is an end view with parts broken away for clarity of an automatic manipulation apparatus mounted on a wheeled vehicle;

FIG. 14 is a partial view of the apparatus of FIG. 13; and

FIG. 15 is an isometric view of a further type of vehicle mounted automatic manipulation apparatus.

FIG. 16 is a side view of still another form of floor mounted apparatus incorporating the novel concepts of the instant invention.

FIGS. 1 and 2 illustrate details of an automatic article manipulation apparatus or tool, certain portions of which form part of this invention and are illustrated in the other drawings. Part of a typical automatic production apparatus **20** is shown in FIG. 1 and application of certain of the features of the apparatus of FIG. 1 to an automatic article manipulator apparatus **20'** is shown in FIG. 2.

The apparatus comprises an overhead support or trackway **21** along which a tool denoted MTD in FIG. 1 or manipulator may be conveyed and prepositioned by means of a carriage **22** and a plurality of movable linkages or arms. In FIG. 1 a first arm or column **23** is integrally

secured to the overhead carriage **22** and supports a plurality of components including a second arm **23'** which is a tubular cylinder adapted for vertical movement through the bore **23B** of the column **23**. A plurality of wheels **24, 24'** are supported in bearing by formations **22'** defining sidewall portions of the carriage **22** and ride along the lower cylindrical portion **21'** of the overhead track **21** for movement of the carriage assembly therealong. A reversible electrical gear motor Mx is secured to the sidewall of the carriage **22** and has its output shaft driving a toothed wheel **26** which enagages a toothed track **26'** cut in the lower surface of the portion **21'** of overhead track **21**. Thus by controlling the operation of motor Mx the position of the carriage **22** and its manipulator or tool assembly may be predetermined along track **21** for performing predetermined operations on work-in-process which is prepositioned or which follows a predetermined path relative to the overhead track. Electrical power for the servo motors associated with the assembly **20** or **20'** is derived from overhead wires **28** which are insulatedly supported off the overhead track and are swept by respective electrical brushes or sliding elements **27** which are insulatedly supported off the carriage **22** and extend to respective of the servo motors to be controlled or to a positional computing mechanism CO located in a housing **71** which is shown mounted along the side wall of the column **23**. Thus signals transmitted along the overhead wires may be utilized to preset or otherwise control the positional computer CO as well as to supply electrical energy for the operation of said computer and the servo motors to be described. Notation B refers to steel balls mounted within receptacles in the wall of the carriage **22** to provide rolling engagement with the cylindrical portion **21'** of the overhead track to simplify the movement of **22** therealong. Notation **25** refers to lineal actuators or servos mounted against the side walls of the overhead carriage **22** which, when activated, are adapted to project their respective actuating arms to engage the wall of the track and to lock the carriage in position.

A reversible gear motor Mz is shown secured to the side wall of column **23** and has a pulley or sprocket wheel **30** secured to its output shaft. A drive belt or chain **31** loops over the sprocket **30** and around a second pulley or sprocket **32** which is supported for rotation within the upper end of the column **23'**. The drive chain **31** is thus operative to raise and lower column **23'** within column **23** depending on the direction of rotation of the output shaft of motor Mz. Lineal actuators or solenoids **29** mounted on the side wall of **23** are utilized to engage the surface of the column **23'** and to lock it in place when **23'** is in a predetermined vertical position. Notation **33** refers to the wire connecting the locking actuators **29** with the positional computer CO which computer controls not only the position in which **23'** is stopped and locked but also the degree of operation of the other servos including the locking actuators **25**, Mx, Mz and those to be described.

Whereas in FIG. 1 column **23** is fixed relative to the overhead carriage **22**, in FIG. 2 the column **23'a** is rotationally supported by the overhead carriage. A large spur gear **43** is shown secured to the bottom wall of carriage **22** and the column **23'a** is supported on a vertical shaft and bearing (not shown). A reversible gear motor MR is secured to the wall of column **23'a** near the upper end thereof and has a small spur gear **44** secured to its output shaft and engaging the teeth of gear **43**. Thus as motor MR operates, the column **23'a** and the assembly therebelow will rotate in a direction depending on the direction of rotation of the output shaft of MR.

In FIG. 2 a second cylindrical column **23'b** is longitudinally movable within the bore of column **23'a** and has a flange **23'F** secured to the end thereof. A third column **23''** having an upper flange **23''F** is secured to the column **23'b** by retaining the two flanges together with fasteners. Thus various assemblies, arms and fixtures may be secured to the end of column **23'b** depending on the operation to be performed by the apparatus **20'**.

The other end of column **23''** is provided with a yoke formation **53**, shown in detail in FIGS. 5 and 6, which supports a pin or shaft **60** on which is rotationally supported a gear plate **57** which is secured to a further arm assembly including jaw means **77** at the end thereof for seizing and releasing an article. Notation **50** refers to the entire joint assembly, which will be described and **35** to the manipulator assembly depending outward from said joint assembly. Assembly **35** comprises a first arm **35'** of cylindrical tubular shape, a flange **35f** at the end thereof, a second arm **75** having a flange **76** and rotationally supported at the end of **35'** by means illustrated in FIG. 3 and forming a part of the assembly **70** which includes the jaws **77a** and **77b**. The jaws **77a** and **77b** are pivotally mounted on pin **78** supported at the end of a base **73** secured to arm **75** and are operated by respective or a single servo through linkages **74** as illustrated in application Ser. No. 477,467.

The apparatus illustrated in FIGS. 1 and 2 is subject to a substantial degree of variation. By providing simple assembly and disassembly means for the joints defined between components **23, 23'; 23'a, 43; 23'', 23'b; 35', 23''; 75, 35'** and the jaw assembly base **73** and **75**, it is easily seen that devices and assemblies of the various configurations may be fabricated by varying the shape, length and configurations of said arms and the type of tool or article seizing means secured to the assembly.

It is also noted that the overhead track travelling manipulators **20** and **20'** may be mounted on floor travelling vehicles or trucks to further increase their versatility or that the overhead mounted carriage itself may be replaced by a floor mounted base or a vehicle adapted to travel along a guideway or tracks mounted on the floor. Many structural variations are possible in which the single arm assembly, such as that shown supported and downwardly extending from arms **23'** or **23'b**, may be replaced by a plurality of arms mounted on a frame or other assembly as hereinafter described or illustrated in my said copending application.

Also illustrated in FIG. 2 is means **19** for prepositioning one or a plurality of articles or assemblies A relative to the overhead track **21** and the automatic conveying apparatus **20'** so that by referencing and automatically programming the manipulator, it may be controlled to open the jaws of the assembly **70**, preposition said jaws adjacent a predetermined portion of the article A, clampingly engage opposite surfaces of the article by predetermined closure of said jaws, lift the article off the prepositioning means **19**, retain and move the article through a predetermined spatial path, further preposition the article and/or release said article after work has been performed thereon. The prepositioning means **19** may comprise a gravity or power operated conveyor or any suitable means for aligning and locating the article relative to the manipulator. A sensing relay **410** mounted at the end of the manipulator arm **75** may be used to sense the presence of the article and energize the automatic controller CO or articles may be fed automatically to the end of **19** against a stop **19'** which prepositions each article.

Notation R refers to a reflective marker disposed at the end of the chute **19** or on the article A and adapted for energizing the photoelectric cell in sensor **410**.

FIG. 2' shows structural and component details of a manipulator arm assembly of the type illustrated in FIG. 2 in which a modified article handling device is provided. The assembly comprises a first arm **A1** which may be similar in position and structure to either the arm member **35'** of FIG. 2 or **23'** of FIGS. 1 or 2. The end of **A1** is provided with a pair of yoke members (not shown) but illustrated in FIG. 2 for supporting a shaft S in a

bearing which shaft retains the end of a second arm A2. The end of arm A2 is defined by a disc-like plate **85** having a semi-circular formation of tapered gear teeth G the axis of which formation is the axis of the shaft S. The end of arm A1 is provided with interior threading **88'** and a reversible servo motor MA1 having a housing with exterior threads **88** cut therein, which is screwed into the threaded bore of A1 until the end of the motor engages a plate **86** extending across the bore in A1. A set-screw **87** passes through a threaded opening in the wall of A1 and engages an unthreaded portion of the housing of motor MA1 to prevent its rotation. The shaft **89** of motor MA1 has a bevel gear **90** secured thereto which engages the teeth in the gear G cut in the end plate formation **85**. The motor MA1 is preferably a gear motor of sufficient power to rotate the assembly coupled to the shaft thereof when retaining an article of a certain maximum weight on the seizing head **96** provided at the end thereof. Notation **86'** refers to a disconnectible coupling member secured to a gate or door **86P** which forms part of the wall of member A1 and is removable to permit electrical coupling of the motor MA1 to wires extending along arm A1 should it be required to remove said motor for repair or maintenance purposes. Wires **86W** extend from the motor through an opening in plate **86** and have a male plug **86M** secured thereto for electrically connecting said wires to the connector **86P**. Removably secured within A2 is a motor MA2 having an exteriorally threaded housing, and assembly of said motor is effected in the manner illustrated in a third arm **94** which is supported by the shaft **92** of motor MA2 against a ball or roller bearing **93** and is rotatable thereby. A lineal actuator **95** is secured within **94** and has an actuator arm **95'** which is operative to open and close the jaws **97a** and **97b** of the clamping head **96** by engagement of respective toothed surfaces of **95'** with tooth formations **97c** and **97d** at the rear end of each clamp. Four brackets (referred to by the general notation **99**) are secured to the end wall **94'** of **94** and pivotally support the jaws as illustrated.

In FIG. 3 is shown a modified tool or manipulator head **80** applicable to the apparatus of FIG. 1. Secured to the flanged end **35f** of arm **35'** is a base **81** having flange **81'** abutting **35f**. A cylindrical arm or base **83** is rotationally mounted within and projects from the other end of **81** and mounts a cylindrical head **82** having a plurality of tools or manipulator mounts **84** arranged radially relative to the longitudinal axis of **83** so that rotation of **82** relative to **81** will position any of the tools or mounts **84** in alignment with a particular spatial position. Thus one of the mounts **84** may contain a first tool and the next a second tool each self-powered, and adapted to cooperate in performing different functions on the same area of a workpiece. Or each may contain the same fixture for seizing and releasing respective articles.

FIG. 4 illustrates modifications to the apparatus illustrated in FIGS. 1 and 2 including means for further stabilizing and retaining the manipulator or tool mount by the automatic projection of one or more actuators against the floor or adjacent walls, machinery or the like. While the apparatus of FIG. 4 is shown secured to and projecting downward from the vertical column **23'**, it may also be secured to and projectable from one or more of the arm assemblies such as **35'** illustrated in FIG. 2.

The lower end of column **23'** is shown having a fixture secured thereto in the form of a collar **35a** which is rotatable thereon and is adapted to rotate the latter arm assembly **35''** by means of a motor MR' secured within the cylindrical column **23'**, the shaft of which motor is secured to the end wall of collar **35a**. The motor is preferably automatically controlled by signals from the positional command computer CO and is operatively connected to an output thereof. Secured to the end wall of collar **35a** is a mount **52** for a lineal actuator **53** having a shaft **54** which is projectable against the floor below the production apparatus. Notation **55** refers to a shoe at the end of shaft **54** which engages the floor and forcibly retains the upper assembly in place when **54** is projected as the actuator **53** is operated. The actuator is preferably automatically controlled by the positional computer CO and may comprise a motor driven device, solenoid, or fluid cylinder. A further actuator **53'** is shown secured to a bracket JS which is secured to the side wall of the fitting **35a**. The actuator **53'** may project against the floor or against a wall or support adjacent the work area to further stabilize the assembly and is preferably operated in a predetermined sequence with the operation of the other servos driving the various components of the apparatus **20'** to project and stabilize and thereafter release the assembly for movement for prepositioning relative to another workpiece. It is noted that the actuator **53'** has the primary function to stabilize the rotatable assembly which includes **35a** whereas the actuator **53** is utilized to stabilize the column **23'** so that shoe **55** may be retained against the floor while the arm **54'** of actuator **53'** is retracted to reposition the arm **35''** and/or tools or other arms secured thereto relative to different portions of a workpiece.

As stated, the arm **35''** may have various tools or article seizing fixtures removably secured thereto for the performance of various operations and in accordance with such structures as provided elsewhere in this application. In FIG. 4 a motor operated tool MTD' is shown secured within the end **35a** of the laterally projecting fixture and is operatively connected to a tool MTD' which may comprise any power operative device for operating on or relative to a workpiece which is prepositioned relative to the apparatus **20** or **20'**. Notation **49** refers to a housing secured to **35b** which may contain a fluid such as a cutting fluid, compressed gas or the like for cooperatively performing on the work provided within housing. **49** may also be other devices such as a viedo camera, a radiation generating apparatus for inspecting or performing operations on the work such as X-ray generating means, electron beam generating means or means for generating other forms of radiation and directing said radiation against a surface of the work. Notation **51** refers to a nozzle or probe extending from housing **49** which may be utilized to direct a fluid against the area of the work positioned **35b** or to direct radiation thereagainst. The device **51** may be power operative to assume various attitudes relative to **49** and positionally controlled by signals generated by positional computer CO to which it is operatively connected. Another feature of the apparatus illustrated in FIG. 4 includes a limit switch **35S** secured to the arm of fixture **35b** and having a long actuator arm which projects therefrom for sensing and indicating when actuated by a surface such as the surface of a workpiece which the apparatus **20'** is positionably controlled to the vicinity of. Actuation of switch **35S** may be utilized to provide a feedback signal to the computer CO to which it is operatively connected for indicating the prepositioning of the assembly **35''** relative to said work and initiating cyclic action thereafter under the control of said computer.

FIGS. 5 and 6 illustrate details of components of a manipulator or tool joint of the type provided in FIGS. 2 and 2'. In FIG. 5 a first joint member **100** is shown which is preferably made of a unitary casting or welded assembly of a tubular portion **107** which is provided with exterior threads **108** and extends from a flange or shelf portion **106** the other face of which is secured to or integrally formed with a plate **101** the outer end of which is circular and has a semi-circular formation **102** of gear teeth therein. A hole **105** extends normal to the faces of **101** through which a pin or axle may be passed to permit the pivotal rotation of **100**. Extending in a semi-circular formation around one face of **101** are a pair of conducting strips **103** and **104** which are insulatedly supported off the metal base and provide continuous electrical contact with brush elements extending from the as-

sembly **110** when assembled with **100**. The threaded plug-like formation **107** at the other end of **100** is provided with a bore **109** therethrough through which wires extending from the surface conducting elements **103** and **104** may pass to the manipulator arm into which the end **107** of **100** is threadably secured.

In FIG. 6, fitting **110** is provided with a substantially cylindrically shaped end portion **117** which is exteriorally threaded and has a bore therethrough through which wires may pass to the manipulator arm member the end of which is threadably engaged by the threads **118** of **117**. Integral with and of a greater diameter than the threaded portion **117** of the fitting is a circumscribing flange or shelf **114** which supports integral, longitudinally extending bracket formations **112** and **113** which define a yoke for providing bearing support for a pin or shaft (not shown) which passes through the opening **105** in formation **101** of the fitting **100** and provides pivotal support of **100** relative to **110**. In other words, both members **100** and **110** are removably securable to threaded end portions of respective tubes or pipes which may comprise respective manipulator arms and are so designed such that they may be easily assembled and disassembled with each other for replacement or in order to change the manipulator arm configuration, length, etc.

To provide electrical coupling across the joint consisting of the assembly of **100** with **110**, brushes **116** and **116'** are insulatedly supported against the inside face of the leaf or bracket formation **112** and are so designed that they will compressively yet slidably engage respective of the flat conducting elements **103** and **104** which are secured to one face of the gear shaped portion **101** of the member **100**. The elements **116** and **116'** may comprise string strips of a spring copper alloy and are shown mounted adajacent each other on a sheet **119** of insulating material secured to the inside face of **112**. Notation **115** refers to aligned holes through formations **112** and **113** through which the pivot pin supporting member **100** passes. Notation **114'** refers to an opening in the shelf formation **114** through which wires **116w** extending from the brush contactors **116** and **116'** pass to the bore through **17**. Said wires are preferably provided with a disconnectable coupling for connecting respective wires extending along the interior of the manipulator arm with the brush contactor elements, which coupling may be disconnected when it is desired to remove the fitting from the end of the manipulator arm.

In another form of the invention, the threaded tubular portions **107** and **117** of the respective fittings **100** and **110** may be eliminated whereupon the shelf formations **106** and **114** will serve as flanges which may be secured by means of fasteners to respective flanges extending outward from the ends of the manipulator arm or tubing with which the fitting is to be assembled. Assembly of the threaded fittings illustrated in FIGS. 5 and 6, is preferably accomplished by means of an adjustment nut or washer which threadably engages the threads of the tubular formations **107** and **117** and locks the assembly against the face of the end of the manipulator arm when tightened thereagainst although the fitting may be merely tightened into the threaded bore in the manipulator arm per se or held in position by means of a set screw.

FIGS. 7–11 illustrate various article seizing devices applicable to the automatic article manipulation apparatus hereinabove described. In FIGS 7 and 8 a clamping assembly **120** is provided which comprises a base **121** having a fork-like pair of projecting portions **121a** and **121b** at one end thereof which provide bearing support for a pair of jaws **122** and **123** which are pivotally mounted for rotation on a shaft **124** supported by the formations **121a** and **121b**. The other end of the base **121** is provided with a large bevel gear **G2** which is welded or integrally cast thereon and which is supported for rotation about or on a pin or shaft **23b** which is supported by the fork-like formations **35a** and **35b** extending from the manipulator arm **35**. Supported within **35** is a reversible gear-motor (not shown) having a bevel gear **G1** which engages the teeth of gear **G2** for rotationally driving said gear and the clamp assembly **120** about the axis of pin **23b**.

Either or both of the clamping jaws **122** and **123** may be pivoted relative to the other to open a predetermined degree and clamp against a workpiece or article to be held by the assembly by the operation of respective reversible gear motors **125** and **126** which are supported against the wall of base **121**. The motors **125** and **126** have respective output shafts containing small bevel gears which engage the teeth of respective gear formations **122G** and **123G** provided along the rear, circular edges of the respective jaw members **123** and **122** for pivotally rotating said members about the axis of a pin or shaft **124** which supports them.

If the servo motors hereinabove described as well as the motor operatively coupled for rotating gear **G2** and the two motoors **125** and **126** are respectively program controlled by a positional computer or multi circuit controller, the assembly **20** may be prepositioned in space relative to the prepositioned workpiece and the jaws may be controlled to open and clampingly engage a predetermined portion of the workpiece whereafter the assembly may be moved to cause the workpiece to assume a predetermined attitude or to move through a predetermined path in space in the act of effecting predetermined transfer or assembly operations relative thereto.

FIGS. 9 and 10 illustrate details of a suction holding apparatus or assembly **127** applicable to the article manipulation apparatus hereinabove described. The apparatus **127** includes a base or manipulator arm member **128** having a large bevel gear **G2** integrally provided at one end thereof and having a second assembly or arm **130** removably secured to the other end thereof. The rear end of **130** is provided with a threaded formation **130'** which is shown threadably engaged within a threaded bore **128'** in the arm or base **128** and is secured thereto by means of a locking plate or nut **129** engaging the threads of **130'** and locking the assembly, when tightened, against the front face of **128**. An assembly **133**, containing a suction cup **136**, is pivotally secured to the end of arm **130** for positioning the suction cup **136** at any attitude relative to **130**. An arm **134** extends to the suction cup and is secured to a hollow threaded tube **134** which is directly secured to the suction cup. The upper end of **134** is provided with a bevel gear **G2a** secured thereto having a center which is the axis of rotation of **133** about **130**. Suction is applied to the interior of suction cup **136** through hollow fitting **135**, the interior of arm **134** and a rotary coupling **132** which includes the hollow shaft or pin **132P** on which the assembly **133** pivots. Notation **132'** refers to the rotary coupling itself which is located exterior of the fork formation **130a** and connects the pivotable pin **132P** with a tube or pipe **131** extending parallel to the arm **130** to a similar assembly at the next joint of the manipulator. Thus, control of the various servo motors hereinabove described as well as the operation of motor **136M** and the servo means controlling suctions and positive pressure on line **131**, may be utilized for effecting the prepositioning of the assembly of FIGS. 9 and 10 and the suction cup **136** relative to the surface of the workpiece, the engagement and retention of the workpiece thereby and the movemnet of said workpiece through a predetermined spatial path followed by release of the workpiece upon the automatic release of pressure from the suction cup.

In FIG. 11 is shown an article seizing assembly **137** comprising a base member **138** having a flange **139** at one end thereof which is removably securable to a manipulator arm flange as hereinabove described by means of fasteners passing through holes **139'** in said flange. A clamping means is provided between the end face **138'** of **138** and a jaw member **145** by inward and outward controlled and predetermined movement of said jaw member. Pivot-

ally secured to and extending from the jaw member is a long spur gear member and guide **141** which extends through an opening in the end wall of **138** and is driven in and out of said fitting by means of a reversible gear motor **142** having a small spur gear **143** secured to its outward shaft which engages the teeth of gear **141'** cut in the member **141**. Further support for the jaw **145** is provided by means af a shaft or rod **149** which is secured to the upper end of a base **144** about which **145** pivots and extends through a hole bored in a projection **140** from **138**. Jaw member **145** is also shown pivotally supported at the end of **141** to provide a further degree of flexibility in clamping engagement with the surface of a workpiece. A small servo motor **146** situated within **145** has an output shaft with a gear **147** engaging a bevel gear formation **148** in the end of member **141** so that **145** may pivot about **141** while the formation **145** remains fixed relative to **141**.

It is briefly noted that the connecting ends of the assemblies illustrated in FIGS. 7–10 may each be provided with a flange formation such as flange **139** of FIG. 11 for directly securing the assembly to a flange at the end of a manipulator arm such as illustrated in the other drawings hereinabove described. Conversely the assembly illustrated in FIG. 11 may be provided with a bevel or spur gear secured to the end in place of the flange **139** for pivotally assembling said assembly **137** relative to a manipulator assembly of the types provided elsewhere herein. Various other manipulator or automatic tool assemblies may be provided for removable assembly with the apparatus of this application as shown and described in my application Ser. No. 477,467.

It has been noted that the apparatus hereinabove described may be automatically controlled to seize, proposition and release an article of manufacture in a manufacturing operation or to perform other operations relative to work-in-process by prepositioning a tool or inspection device, by applying an automatic controller referred to by the notation CO which is operative to control the various servo motors described. While the automatic controller may comprise a simple multi-circuit recycle timer operatively connected to energize and de-energize the various servo motors illustrated in FIGS. 1 and 2, a more precise and easily adjustable or changeable programming means may be derived by reproducing command recordings from a recording member such as a card or tape.

A complete description of the control apparatus for controlling the various manipulator components to move along predetermined paths or to swing predetermined arcs during predetermined intervals in an operational cycle is brief since it is not claimed specifically herein. However, one form of such automatic control is illustrated schematically in FIG. 12. This system utilizes stored digital command recordings which are converted to analog for sequentially coordinated servo controlled movement of the various drive motors previously described. The specific control circuitry may be of various forms well known to those skilled in the art, with, however, reference being made to Mergler, A Digital-Analog Machine Tool Control System, National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratory, Cleveland, Ohio, Proceedings of the Western Joint Computer Conference, February 9, 1954, for the details of one such servo-controlled system. It should be recognized that such a system is merely representative of my invention's application and is not intended as a limitation thereof.

In FIG. 12 the automatic controller CO derives command signals by reproducing digital command recordings from a magnetic or punched tape **401** which is driven in a predetermined path, preferably a closed loop, about a tape transport referred to by the general notation **400** which transport includes a drive wheel or sprocket **402** which is rotated at constant speed by means of a tape drive motor MT having forward drive controls F and S. A bank of reproduction heads **403** is operatively coupled to reproduce the pulse codes recorded on the tape **401**, each of which heads is operatively connected to the input of a respective converter controller **405** which controls the operation of a respective servo motor. Reproduction transducer **403–1**, for example, is operatively connected through a reproduction amplifier **404** to a control circuit **405**–Mx which is operative in response to the train of pulses reproduced by **403–1** to control the motor Mx to operate in a predetermined manner to effect positioning of the entire manipulator **20** along the overhead trackway **22** relative to a particular work area spatial volume. Similarly reproduction head **403–2** is connected through its reproduction amplifier to the input of a control circuit **405**–My and the signals reproduced thereby are operative to control the motor My in a predetermined manner. The other servo motors illustrated which are operatively controlled by signals reproduced by respective eproduction heads of the bank **403** include a motor MR such as illustrated in FIGS. 1 or 2, a second servo motor MA1 which is operative to effect pivotal rotation of an assembly such as the arm assembly illustrated in FIG. 2' relative to the remainder of the manipulator assembly and servo motor MJ is operative to operate an article seizing device such as any of those illustrated in FIGS. 7–11 in response to signals reproduced by reproduction head **403–5**.

The controller **405–J** is illustrated in further detail in FIG. 12 and will be described. It is assumed that the other controllers having the servo notations Mx, My, MR and MA, preceded by the numerical notation **405–** are similar in construction to **405–J**. The binary code pulse output of the reproduction head **403–5** is first passed to a series-to-parallel diode converter **406** where each code command is converted to a parallel code which code is transmitted to a relay storage bank **407** containing precision resistors. The contacts of the storage unit relays set up the resistance bank in **407** so that the resistance is proportional to the digital information recorded on the tape **401**. Thus the relay storage introduces a resistance proportional to the numerical value of the signals reproduced from the tape into a self-balancing bridge which forms part of a comparator device **408**. A feed back signal is generated during the operation of the servo motor MJ being controlled by means of a response potentiometer **409** which is coupled to the shaft of the control motor and provides an error signal at the output of the comparator **408** which is used to control the operation of said motor until the bridge is balanced or a null condition exists whereupon the motor will stop with the jaws or article seizing device controlled thereby being at a predetermined open or closed condition. The position of the command signals recorded on the tape **401** will determine just when the jaws will open or close in a cycle of operation and will similarly provide effective control for the other servos of the manipulator to control movement of the various components or assemblies, by providing binary code command signals at the inputs to each of the control circuits **405** of each of the motors.

It is noted that the tape drive motor MT may be operated continuously to provide automatic recycle operation of the manipulator if the articles to be seized and transferred or operated on thereby are continuously fed to a predetermined spatial location as determined by, for example, the end of a chute or conveyor or by movement along a conveyor adjacent the manipulator assembly. Recycling may also be effected by providing means for sensing the appearance of an article at a predetermined spatial location as, for example, it is fed to the end of a chute or travels along a conveyor whereby the sensing means provides a pulse signal for energizing the start control F of motor MT which motor has been previously stopped by energization of the stop control S thereof. The stop control S of MT may be energized, for example, by reproduction of a signal from a further channel of the tape **401** at the end of the cycle.

The arrangement of servo motors illustrated in FIG. 12 is only illustrative and variations in the number and type of said servos will be provided in accordance with variations in both the physical arrangement of manipulator components and servos operative to drive said components. For example, the motor Mx may be eliminated from the control cycle if the manipulator apparatus is manually prepositioned relative to a predetermined spatial location. Similarly, any of the other servo motors may be eliminated or may be multiplied in number depending on the particular physical arrangement of manipulator arms, rotatable assemblies and columns. Notation **410** in FIG. 12 refers to a sensing relay, preferably mounted on the manipulator in a position to sense the presence of an article or assembly immediately adjacent said manipulator. In FIG. 2, the sensing relay **410** is illustrated as a photoelectric cell mounted on the arm **75** immediately adjacent the jaw assembly **70**. The output **411** of the sensing relay **410** is operatively connected to the start control F of motor MT to transmit a pulse thereto to effect recycling of the tape **401** when said sensing relay becomes energized upon sensing the surface of an article or assembly in alignment with the manipulator. The relay **410** may comprise any type of suitable sensor capable of generating an output signal when an article is in the immediate vicinity of said device and may comprise a photoelectric cell with or without a light source immediately adjacent thereto for beaming light against the surface to be sensed which is reflected thereby back to the cell, and infra-red detector for detecting the surface of the article to be seized or operated on, a limit switch operative to generate an output signal upon contact with the surface of the article or assembly, an electro magnetic or other type of proximity switch etc. Notation **403–S** refers to a pick up head operatively connected to a sixth channel of the tape **401** for reproducing a stop-signal recorded at the end of the cycle recordings which is transmitted to energize the stop control S of motor MT which stops until the start control F is energized upon activation or energization of the sensing relay **410**. Power supplies are not illustrated in FIG. 12 for the purpose of simplifying the diagram and it is assumed that they are provided on the correct sides of all relays, amplifiers and other circuits.

FIGS. 13 and 14 illustrate details of an automatic manipulator which, unlike the manipulators illustrated in FIGS. 1–4, is mounted on a carriage or vehicle which is movable along the floor of a work area, preferably on tracks **R1** and **R2** secured to the floor. The manipulation apparatus **300** comprises a rigid vehicle body **301** having at least four wheels **302** rotational supported and depending downwardly from said body for movement along the rails **R1** and **R2**. Centrally disposed and projecting upwardly from said body is an assembly **303** comprising a plurality of manipulator elements including a first vertical cylindrical column **304** rotationally supported within the vehicle body **301** and rotatable by means of a large spur gear **305** secured to the end thereof which is driven by a second smaller circular gear **306** secured to the shaft of a reversible gear-motor **307** which is shown retained against the side wall of the vehicle body. Slidably movable within column **304** is a second vertical column **308** secured at its lower end to the shaft of a lineal actuator **303** which is preferably driven by an electric motor. The column or arm **308** defines one end of an assembly of manipulator arms which is movable vertically within **304** but restrained against rotation therein by means of a pin or key **309** projecting outwardly therefrom which rides in a vertical slot **304'** in the vertical column **304**. Thus as motor **307** rotates column **304**, the upper assembly defined by **308** rotates therewith but is vertically movable within **304** by the vertical movement of the shaft of lineal actuator **303**.

Notations **310**, **312** and **314** refer to pivoting joints of the type hereinabove described which respectively connect arms **308**, **311**, **313** and **315**. The end of arm **315** is provided with a rotary joint **316** similar to that defined near the end of the manipulator of FIG. 2 and an article seizing head or jaw assembly **317** is secured to the end-most arm **318** situated beyond the rotary joint **316**.

It is thus seen that the article manipulator head **317** may be rotated and pivoted by the automatic controlled operation of the various servos such as **307** and those operating device **303**, joints **310**, **312**, **314** and **316**. A sequential controller or positional computer CO is shown secured within the body of the vehicle **301** which body may also contain a power supply for operating the various servos and the controller CO. Notations **319** and **319'** refer to lineal actuators which are mounted at the sides of the vehicle body **301** and may be automatically operated to project arms against the floor to stabilize the body of the vehicle in a predetermined position. A motor for driving and prepositioning the vehicle at different locations in a work area is mounted within the body **301** although not illustrated and may also be automatically controlled by the positional controller CO to define the location of the apparatus **300** relative to articles or work to be handled thereby.

Variations in the particular arm arrangement protruding upwardly and outwardly from the vehicle body **301** are possible and it is to be understood that the arrangement provided in FIGS. 13 and 14 is merely illustrative. The various fittings and article seizing means illustrated in FIGS. 7–11 may be removably secured to the fixture or arm at the end of the manipulator assembly of FIGS. 13 and 14.

FIG. 15 shows another arrangement in an automatic vehicle mounted manipulation or tool apparatus referred to by the general notation **320**. The apparatus includes a vehicle body **321** mounting preferably a power supply, positional controller CO, fluid pressurizing means **344** for propulsion or effecting the operation of various production tools, etc. Projecting upwardly from the body **321** is a frame **322** including longitudinal tubular members **322'** and **323** held together by end members **324** and **325** and supported by verticals **326** and **327** as well as other frame members **328**, **329**, etc. A carriage **330** is movable along the longitudinal members **322'** and **323** and is power operated by means of a motor Mx. A second carriage **331** is movable longitudinally along the carriage **330** and is power operated by its own motor (not shown) for driving a manipulator assembly **20''** therealong. The assembly **20''** is preferably similar in most respects to the manipulator assembly **20'** of FIG. 2 and may contain either an article seizing head or a tool at the end thereof. In FIG. 15 a tool or inspection device **342** is provided at the end of the end-most arm **340** which is pivotally mounted on a joint **339** which extends from a further arm **338** which is rotationally mounted on rotary joint **337** relative to a further arm **336** which is rotationally mounted on the arm **334** corresponding to **23'** of FIG. 2. Notation **341** refers to a surface sensing device such as a limit switch, electro magnetic or photoelectric relay mounted adjacent the tool or clamping head **342** for sensing the surface of an article or assembly immediately adjacent the apparatus **320**. The operation of **341** is similar to the device **410** of FIGS. 2 and 12 which is operative to initiate an automatic cycle of operation. Thereafter the control computer or cycle controller is operative to start, stop and otherwise control the various servos in accordance with the preset program thereof.

In order for the apparatus illustrated in FIGS. 13–15 to perform automatic article or tool manipulation functions, the articles, equipment or machines to be operated on thereby must be prepositioned relative to the track or guideway for the vehicles mounting said manipulation apparatus or means must be provided for sensing or otherwise identifying the surface of an article or assembly adjacent the trackway. Accordingly, articles or equipment may be prepositioned adjacent the floor mounted track-

way or rails R1 and R2 and the vehicle may be automatically controlled to stop at a predetermined location along its track which location is either determined by sensing the surface of an article or machine by means of a sensor such as **410** of FIG. 2 or **341** of FIG. 15 located on the manipulator or vehicle body or by means of sensing the distance travelled along the trackway or rails. In the latter case, the motor effecting movement of the vehicle along the track may be controlled to stop the vehicle at a predetermined distance therealong by the means illustrated in FIG. 2 or by counting rotations of said motor and generating feedback signals to a predetermining controller such as a presettable predetermining counter. In a simpler form of the invention, the vehicle may be prepositioned relative to a machine, assembly, articles or the like by an operator and thereafter automatically controlled by means of the controller CO to perform predetermined manipulation functions.

FIG. 16 illustrates a floor mounted apparatus **170** employing an arm assembly **136'** of the type described for performing various transfer or production operations relative to work-in-process. The apparatus includes a first stationary vertical column **171** preferably secured to or fixedly maintained against the floor and having an assembly **172** secured to the upper end of **171** and including an overhead track **174** extending horizontally outward from **171**. The overhead track **174** forming part of the overhead assembly is secured to a mount **176** which is shown rotationally mounted at the upper end of **171** and rotatable by means of a circular gear **177** secured thereto which is engaged by a smaller circular spur or bevel gear **173** which is part of the gear frame associated with a gear-motor **173** secured to **171**.

A manipulator assembly **175** is supported on an overhead carriage **179** which is movable along track **174** and power operated by means of an electric motor **175M** secured to the carriage. Depending downward from **179** and rotationally supported thereon is a first column member **184** having a gear motor **182** secured thereto, the drive gear **183** of which engages a large circular spur or bevel gear **181** secured to **179** so that a reversible motor **182** operates, it will cause rotation of **184**. Supported by and extending vertically downward from **184** is a cylindrical track **185** which supports a fixture **186** containing the manipulator arm assembly. Fixture **186** and the arm assembly are movable vertically up and down column or track **185** by means of a reversible drive motor **187** secured to **186**. A lineal actuator **188** is secured to the lower end of **185** and is operative to project a ram or plate against the floor to support the assembly **175** from the load.

The manipulator arm assembly **136'** includes a flexible arm unit **190** secured to a base **191** which is removably secured to fixture base **186**. Retained against the other end of **190** is a jaw assembly **137'** of the type illustrated in FIG. 3 but having a modified base **145'** containing a single servo such as a lineal actuator for opening and closing the individual jaws **138'** and **139'** in response to an input signal or signals to the control or said actuator. Details of such a lineal actuator operated jaw assembly are shown in my said application Serial No. 477,467. A presettable programming device or positional computor CO is provided in a housing **171'** shown secured to the vertical column **171** and preferably contains a plurality of output circuits connected to each of the described servos for sequentially controlling their operation to preposition the assembly **172** at a predetermined angular attitude relative to **171**, the carriage **179** at a predetermined location along overhead track **174**, the assembly **175** in a predetermined attitude relative to **179**, the fixture base **186** at a predetermined location along the vertical column **185** and the flexible deflectable arm **190** in a predetermined deflected attitude and to move thereafter through a predetermined arc to predetermine the path of movement of the jaw assembly **137'** and the movement of an article retained thereby. Electrical coupling is attained between the outputs of CO and the assembly **172** by means of conventional brush contacting means having components secured to the upper end of **171** and to **176** in sliding engagement with each other, by means of a plurality of slide wires **178** insulatedly supported above **174** which are engaged by a plurality of respect brushes shown at **180** which are insulatedly supported on and project upward from the carriage **179** and by further brush-slide contact means electrically coupling **184** to **179**, **186** to **185** and assembly **36'** to **191**. The laterally extending arm **190** which pivots about base **191**, is provided with a flange **135** at the end thereof and the assembly **136** may be fixedly mounted on or rotationally mounted relative to arm **190** and power operated by the reversible motor secured within **145'** but not shown. Details of such a structure will be hereinafter described. The jaws **138'** and **139'** are automatically opened and closed to seize and preposition a workpiece there-between by means of one or more lineal actuators secured within the base **145'** which directly supports said jaw members. It is noted that each of the hereinabove described servos including the locking servos **25** and **29** of FIGS. 1 and 2 are preferably automatically controlled by the positional control or computing mechanism situated within the housing CO by wires or other conductors extending to each of the movable components with coupling preferably being made by means of brushes sliding across stationary contacts or slip rings at each of the joints as will hereinafter be more fully described.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) sensing means mounted on said manipulator and movable therewith for sensing the presence of an article prepositioned relative to said manipulator, said sensing means including means for generating a signal upon sensing an article adjacent said manipulator,

and initiating predeterminedly responsive operation of said programming means.

2. An article manipulator in accordance with claim 1, wherein:

said seizing means comprising jaw means for clampingly engaging said retaining an article on said manipulator arm assembly and including a movable jaw having a pair of clamp members, at least one of said clamp members being movable for compressively engaging an article against the other clamp member.

3. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said articles seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) including means for prepositioning an article relative to said manipulator and means mounted on said manipulator and movable therewith for sensing the presence of said article, said sensing means including means for generating a signal upon sensing an article adjacent said manipulator, said programming means being of the recycle type and having control means for initiating an operational cycle, said control means being operatively connected to said sensing means for effecting the initiation of a control cycle when said sensing means senses the presence of an article aligned with said automatic manipulator.

4. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including suction means for engaging and retaining an article against said assembly for transferring said article with the movement of said assembly,

(b) a base member operatively connected to said arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said assembly,

(d) first servo means for driving said manipulator arm assembly a predetermined path relative said base member,

(e) said suction means comprising at least one suction cup,

(f) means for applying suction to the volume defined by said suction cup,

(g) second servo means operative to apply and release suction by operating said suction applying means,

(h) controls for said servos,

(i) a variable programming means operatively connected to said servo controls and including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(j) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and the sequence and duration of application of suction to said suction means to automatically effect the seizing of an article, the movement of said article through a predetermined spatial path and the release of said article at its predetermined position along the path of the movement of said arm assembly,

(k) sensing means mounted on said manipulator and movable therewith for sensing the presence of an article prepositioned relative to said manipulator, said sensing means including means for generating a signal upon sensing an article adjacent said manipulator, and initiating predeterminedly responsive operation of said programming means.

5. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence.

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) including a normally inoperative starting control for activating said programming means to control movement of said article seizing means in said predetermined sequence of motions, a storage location including means for prepositioning a workpiece, sensing means mounted on said article manipulator, and operatively connected to activate said starting control when energized, position indicating means associated with said storage location, said sensing means being operative upon alignment with said indicating means to activate said starting control of said program control means to initiate said predetermined sequence of motions of said article seizing means.

6. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical

means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) said programming means being of the self resetting recycle type operative to become deactivated at the end of a control cycle, means mounted on said manipulator for sensing a surface of a normally inoperative starting control for activating said programming means to control movement of said article, seizing means in said predetermined sequence of motions, said sensing means being operatively connected to activate said starting control when energized upon sensing the surface of an article to be seized and transferred whereby said programming means is operative to effect a cycle of automatic operation of said article seizing means.

7. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) means for prepositioning an article relative said article seizing means, means mounted on said manipulator for sensing a surface of said positioning means, a normally inoperative starting control for activating said programming means to control movement of said article seizing means in said predetermined sequence of motions, said sensing means being operatively connected to activate said starting control when energized upon sensing the surface of said prepositioning means whereby said programming means is operative to effect a cycle of automatic operation of said article seizing means.

8. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) means mounted on said manipulator for sensing a surface of a normally inoperative starting control for activating said programming means to control movement of said article seizing means in said predetermined sequence of motions, said sensing means being operatively connected to activate said starting control when energized upon sensing the surface of an article to be seized and transferred whereby said programming means is operative to effect a cycle of automatic operation of said article seizing means.

9. An article manipulator for handling work-in-process comprising in combination:

(a) a manipulator arm assembly including mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) manipulation means between said base member and said arm assembly for moving and guiding said arm assembly,

(d) first servo means for driving said manipulator arm

assembly in a predetermined path relative said base member,

(e) said seizing means comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(f) second servo means connected for operating said article seizing means,

(g) controls for said servos,

(h) a variable programming means operatively connected to said servo controls including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(i) said programming means being operative to control said servos and to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(j) start-cycle control means for said programming means, light reflecting means disposed adjacent said manipulator apparatus, a light source and photoelectric sensing means mounted on said manipulator arm assembly adjacent said article seizing means head and operatively connected to said start cycle control means, said photoelectric means being energizable upon sensing said reflecting means to energize said start-cycle control means to start a cycle of automatic transfer operations.

10. An article manipulator for handling work in process comprising in combination:

(a) a manipulator arm assembly having mechanical means disposed at one end thereof for seizing and retaining an article,

(b) said mechanical means including a separately operable seizing head mounted for rotation at the end of said manipulator arm assembly,

(c) a base member operatively connected to said arm assembly for supporting said assembly,

(d) manipulation means for moving and guiding said arm assembly,

(e) first servo means for driving said manipulator arm assembly in a predetermined path relative to said base member,

(f) said seizing head comprising means for engaging and retaining an article on said manipulator arm assembly and including at least one member movable for grasping and releasing said article,

(g) second servo means for operating said seizing head to cause said movable member to grasp and release articles,

(h) third servo means for rotating said seizing head about a fixed axis defined at the end of said manipulator arm assembly,

(i) controls for said servos,

(j) a variable programming means operatively connected to said servo controls and including means for generating a plurality of control signals of predetermined characteristics in a predetermined sequence,

(k) said programming means being operative to control said servos to predetermine the movement of said manipulator arm assembly and said article seizing means along a predetermined path in a sequence of movements including predetermined rotation of said article seizing head at the end of said manipulator arm assembly during at least a portion of the operating cycle so as to automatically effect manipulation of an article retained by said manipulator, the movement of said article through a predetermined spatial path and the release of said article at a predetermined position along the path of movement of said arm assembly,

(l) said programming means being of the self-resetting recycle type operative to become deactivated at the end of a control cycle,

(m) start cycle control means for reactivating said programming means,

(n) means for prepositioning an article with respect to said article manipulator, and

(o) signal generating means connected to said start cycle control means and operative for generating a signal upon prepositioning an article relative to said manipulator whereby said programming means is operative thereafter to predeterminately activate and deactivate the controls for said servos to cause a repetition of the previous cycle of movements of said manipulator and seizing head to properly seize, transfer and release said article in a predetermined sequence of motions.

11. An article manipulator in accordance with claim 10, having a plurality of different seizing heads each operatively connectable to the end of said arm assembly, and removable coupling means connected to said arm assembly and each of said seizing heads to permit the rapid assembly and disassembly of a seizing head on the manipulator and its replacement with another seizing head.

12. An article manipulator for handling work in process comprising in combination:

(a) a manipulator arm assembly including first and second arm means,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) said first arm means being rotationally supported on said base member and said second arm means being rotationally supported on said first arm means,

(d) first servo means for rotating said arm means on said base member,

(e) second servo means for driving said second arm assembly on said first arm assembly,

(f) an article seizing head supported at the end of said second arm means,

(g) third servo means for operating said article seizing means for grasping and releasing an article disposed adjacent thereto,

(h) controls for said servos,

(i) a variable programming means operatively connected to said servo controls and including means for generating a plurality of control signals of predetermined characteristics and in a predetermined sequence,

(j) said programming means being operative to control said manipulator in an article transfer cycle by first activating the control for said servo means to operate said seizing head to seize an article, thereafter control one of said first and second controls to effectuate the movement of the seizing head and article along a first path, thereafter control the other of said first and second servo controls to effectuate the movement of the seizing head and article along a second path, thereafter control said third servo means to effectuate the release of the article, and thereafter control said first and second control means to return the seizing head to that position at which it was located prior to initiating the described cycle so as to preposition that seizing head just prior to initiating another similar transfer cycle.

13. An article manipulator for handling work in process comprising in combination:

(a) a manipulator arm assembly having mechanical means disposed at one end thereof for seizing and retaining an article,

(b) a base member operatively connected to said manipulator arm assembly for supporting said assembly,

(c) said manipulator arm assembly including a first arm assembly movably supported on said base member and a second arm assembly movable supported on said first arm assembly,

(*d*) *said seizing means being rotationally mounted at the end of said second arm assembly,*

(*e*) *first servo means for moving said first arm assembly on said base member,*

(*f*) *second servo means for moving said second arm assembly on said first arm assembly,*

(*g*) *third servo means for operating said seizing means to seize and release articles,*

(*h*) *controls for said servos,*

(*i*) *variable programming means operatively connected to said servo controls,*

(*j*) *said programming means comprising a plurality of separate control loops and including at least one loop operatively connected to each of said servo controls for predeterminately controlling the operation thereof, and*

(*k*) *reading means for a plurality of recordings including at least one reading transducer operatively connected to each of said control loops for predeterminately varying the control of each loop whereby the servo controlled by each loop may be predeterminately varied in its operation,*

(*l*) *means for synchronously reproducing command control signals recorded on each of said channels in a manner whereby each of the control loops is predeterminately varied in the proper sequence to predeterminately, sequentially operate the servos effecting movements of said manipulator arm assemblies and said article seizing means to effect a cycle of automatic operation of said article seizing means.*

References Cited

The following references, cited by the Examiner, are of record in the patented file of this patent or the original patent.

UNITED STATES PATENTS

1,140,839	5/1915	Moore.	
1,837,718	12/1931	Kendall et al.	212—127
2,428,856	10/1947	Sinclair	214—16.1
2,475,245	7/1949	Leaver et al.	318—162
2,537,770	1/1951	Livingston et al.	318—162
2,580,472	1/1952	Smith	214—147
2,679,940	6/1954	Goertz et al.	
2,691,448	10/1954	Lontz.	
2,696,921	12/1954	Desjardins	214—16.1
2,697,529	12/1954	Hubbel et al.	214—147
2,822,094	2/1958	Greer	212—127
2,623,626	12/1952	Dittola	198—21
2,861,700	11/1958	James.	
2,861,701	11/1958	Bergsland et al.	
2,988,237	6/1961	Devol	214—11

OTHER REFERENCES

Mergler: A Digital-Analog Machine Tool Control System, National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratory, Cleveland, Ohio, Proceedings of the Western Joint Computer Conference, Feb. 9, 1954.

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