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Harper et al.

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[54] AUTOMATIC WORK-REPEATING MECHANISM

[72] Inventors: Kenneth B. Harper, Winnetka; Hubert J. Tremblay, Roselle, both of Ill.

[73] Assignee: Harper Associates, Inc., Winnetka, Ill.

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[52] U.S. Cl. 318/568, 318/162, 214/1

[51] Int. Cl. G05b 19/42

[58] Field of Search 318/162, 568; 214/1

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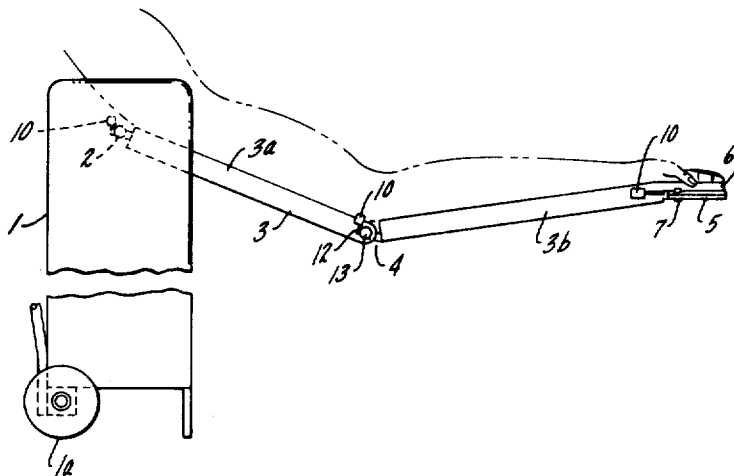
Primary Examiner—Benjamin Dobeck

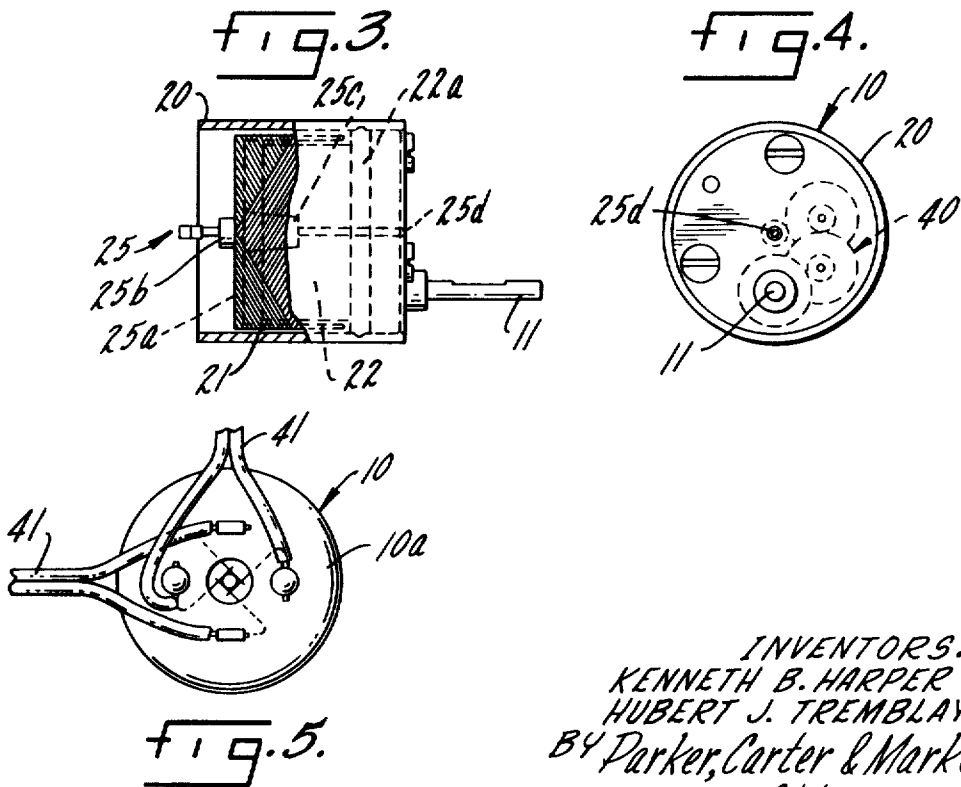
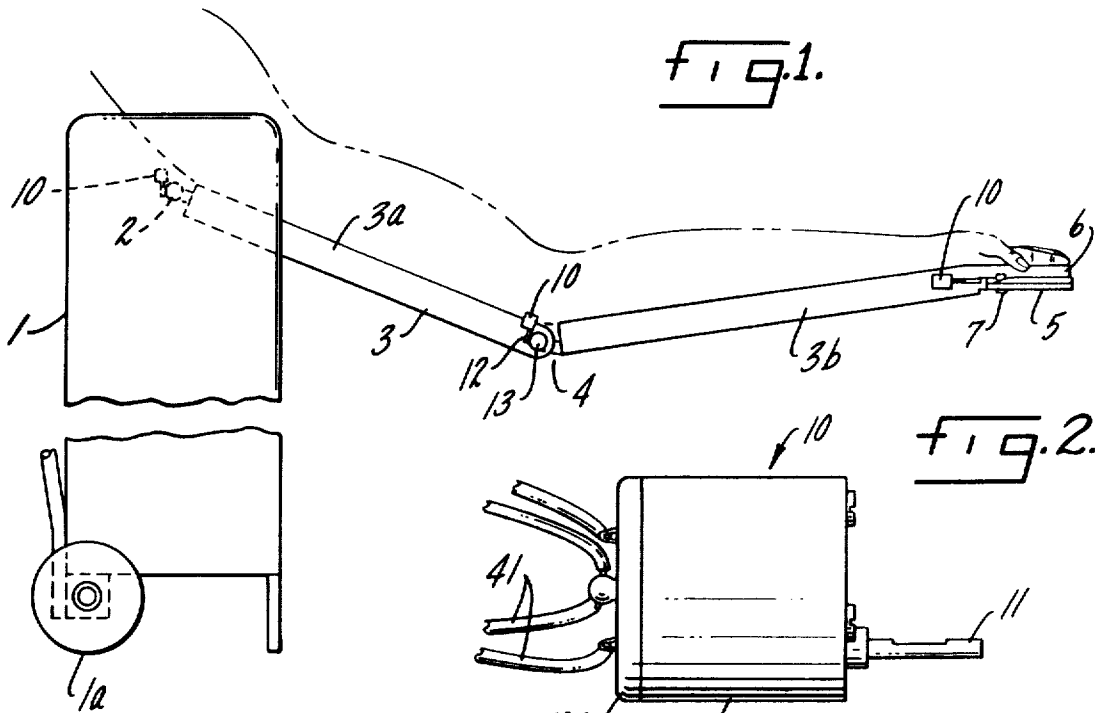
Attorney—Parker, Carter & Markey

[57] ABSTRACT

An electric motor-controlled device having elements corresponding to human appendages, the elements being manually movable to perform a function recorded on tape, the elements thereafter repeating the function in response to repeated playbacks of the tape.

22 Claims, 22 Drawing Figures





INVENTORS.
KENNETH B. HARPER
HUBERT J. TREMBLAY
BY Parker, Carter & Markey
Attorneys.

fig. 6.

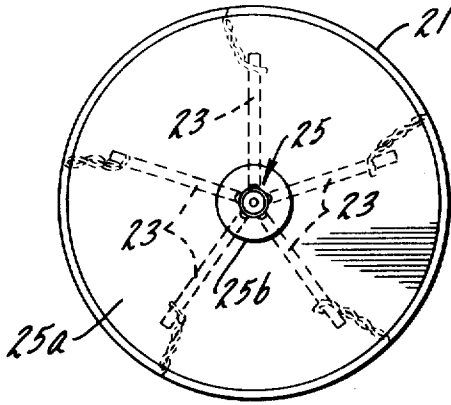


fig. 7.

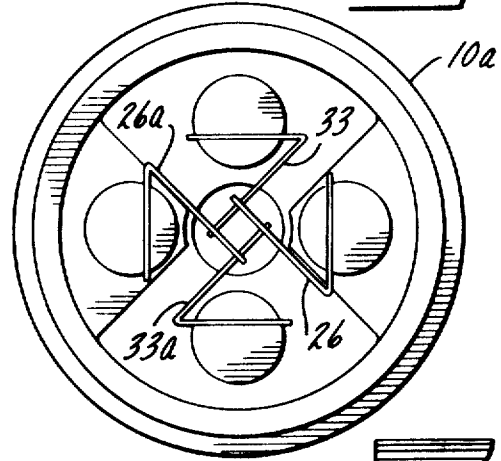


fig. 9.

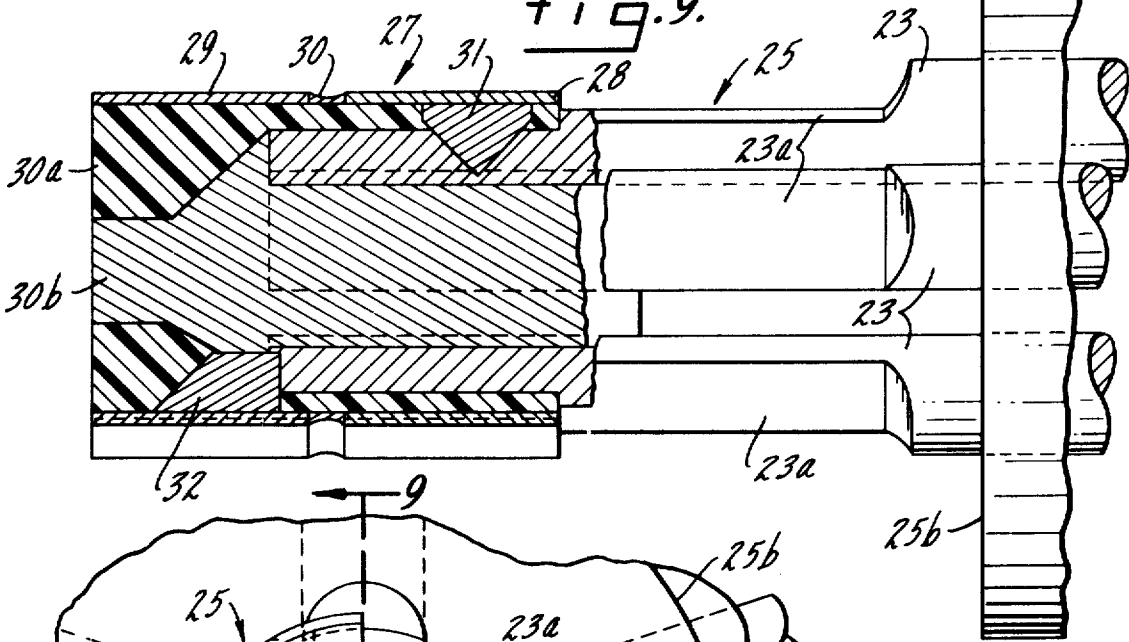
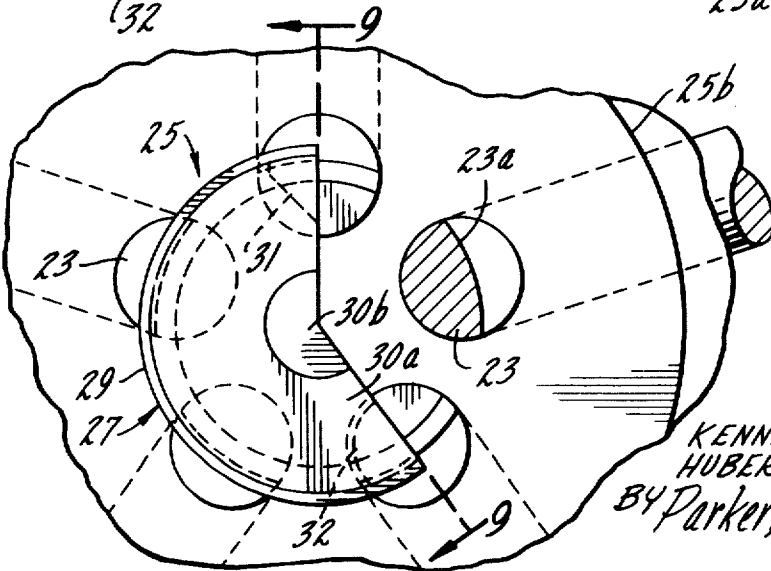
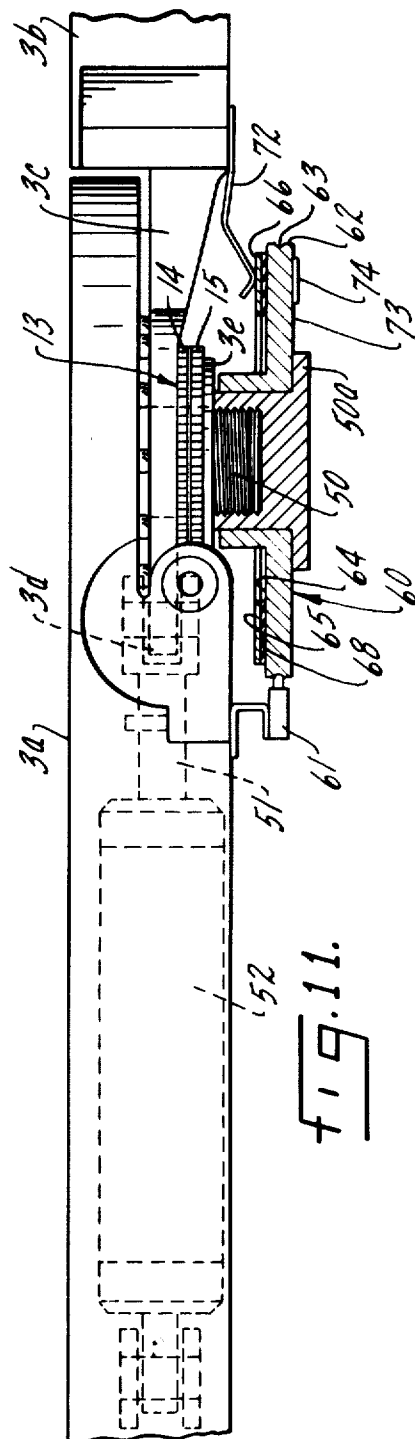
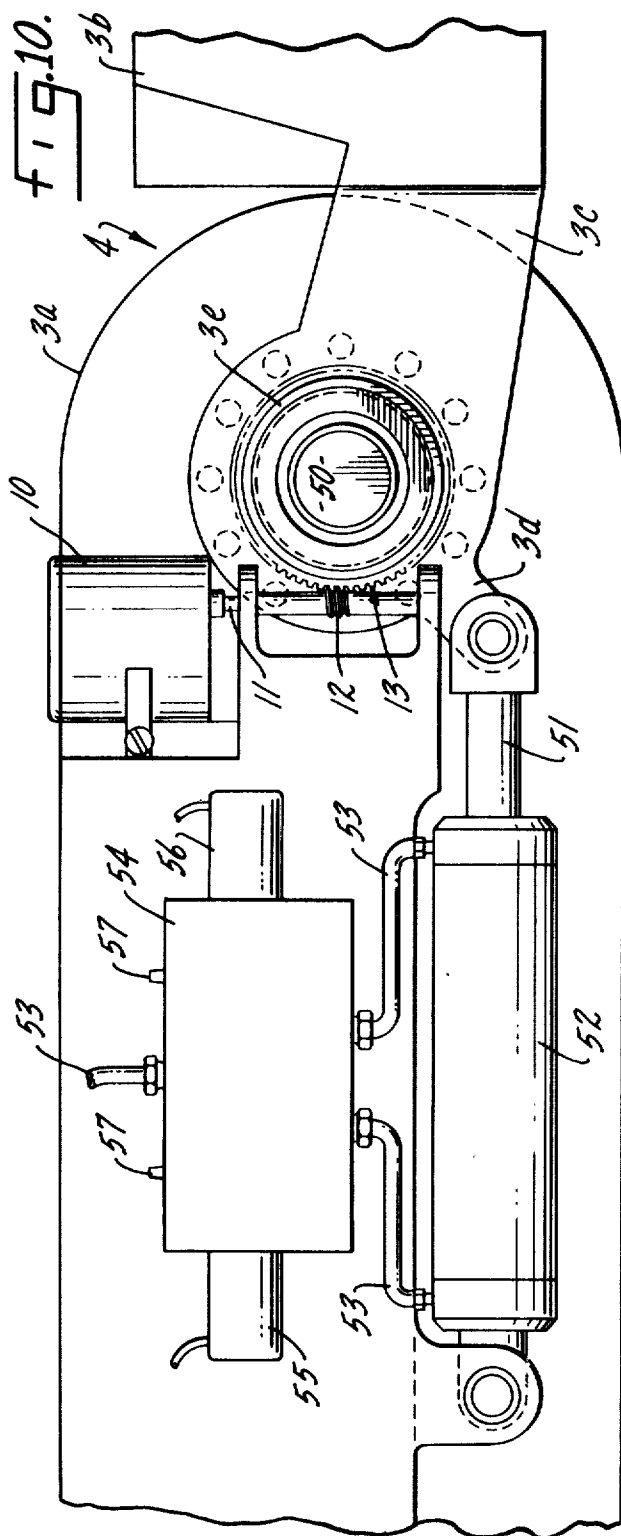


fig. 8.



INVENTORS.
KENNETH B. HARPER
HUBERT J. TREMBLAY
BY Parker, Carter & Markey
Attorneys.



INVENTORS.
KENNETH B. HARPER
HUBERT J. TREMBLAY
BY Parker, Carter & Markey
Attorneys.

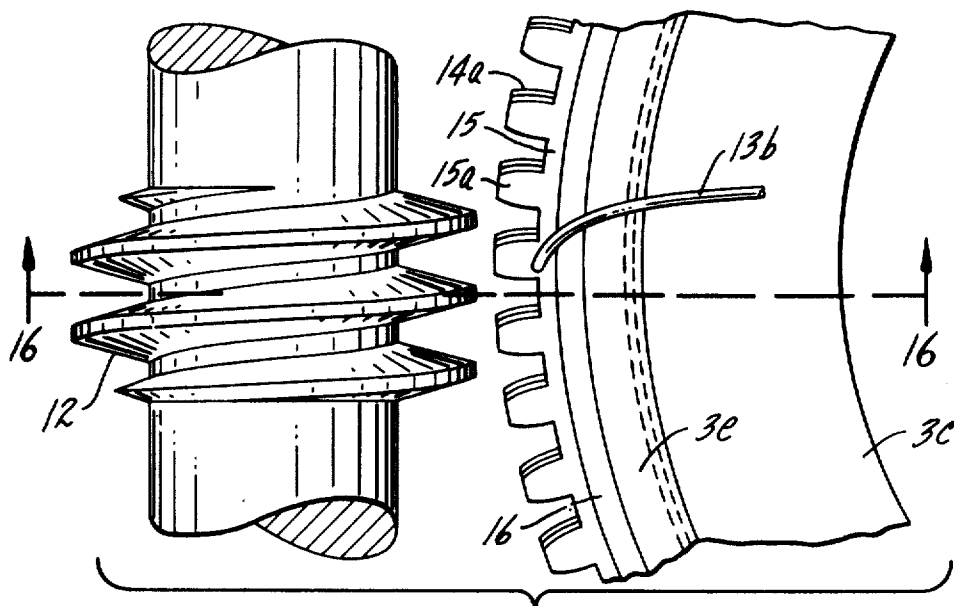


fig. 12.

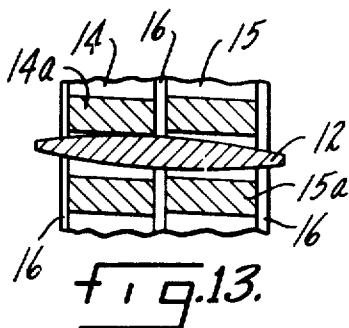


fig. 13.

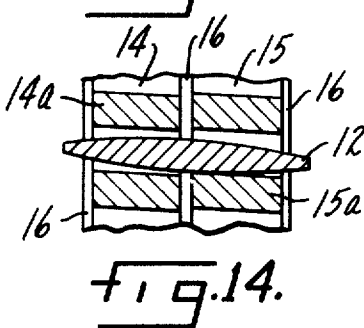


fig. 14.

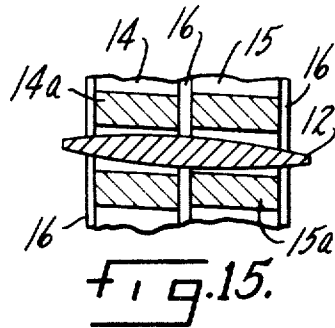


fig. 15.

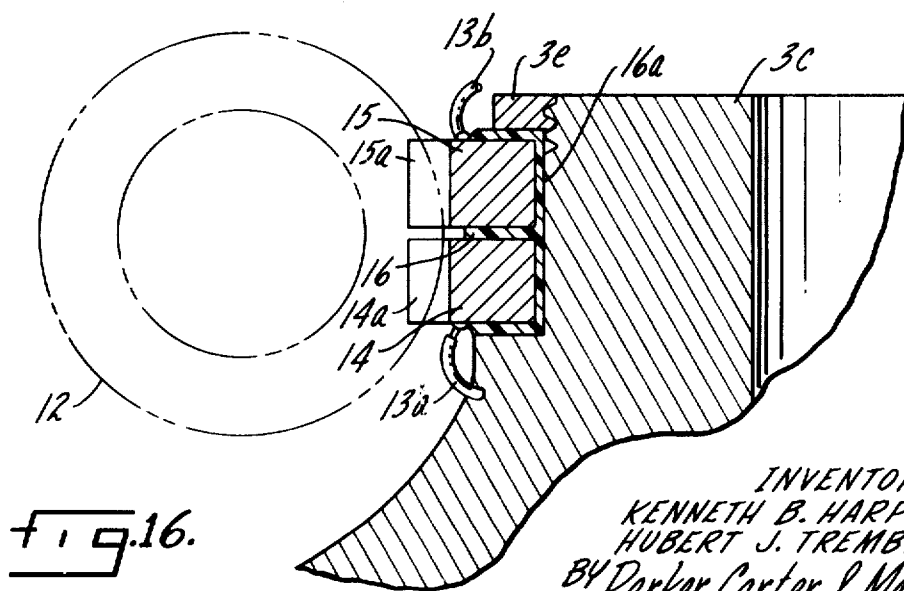
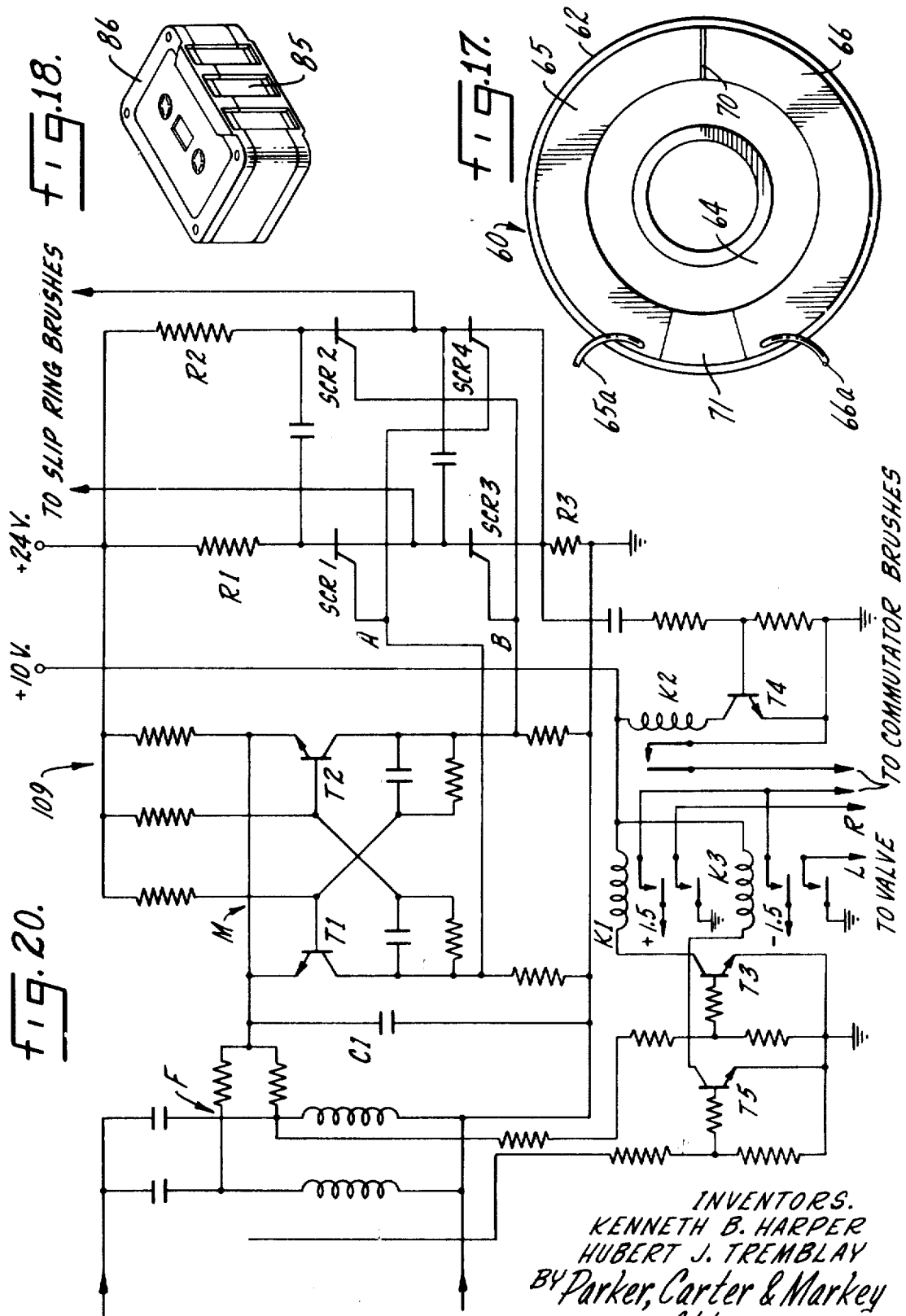
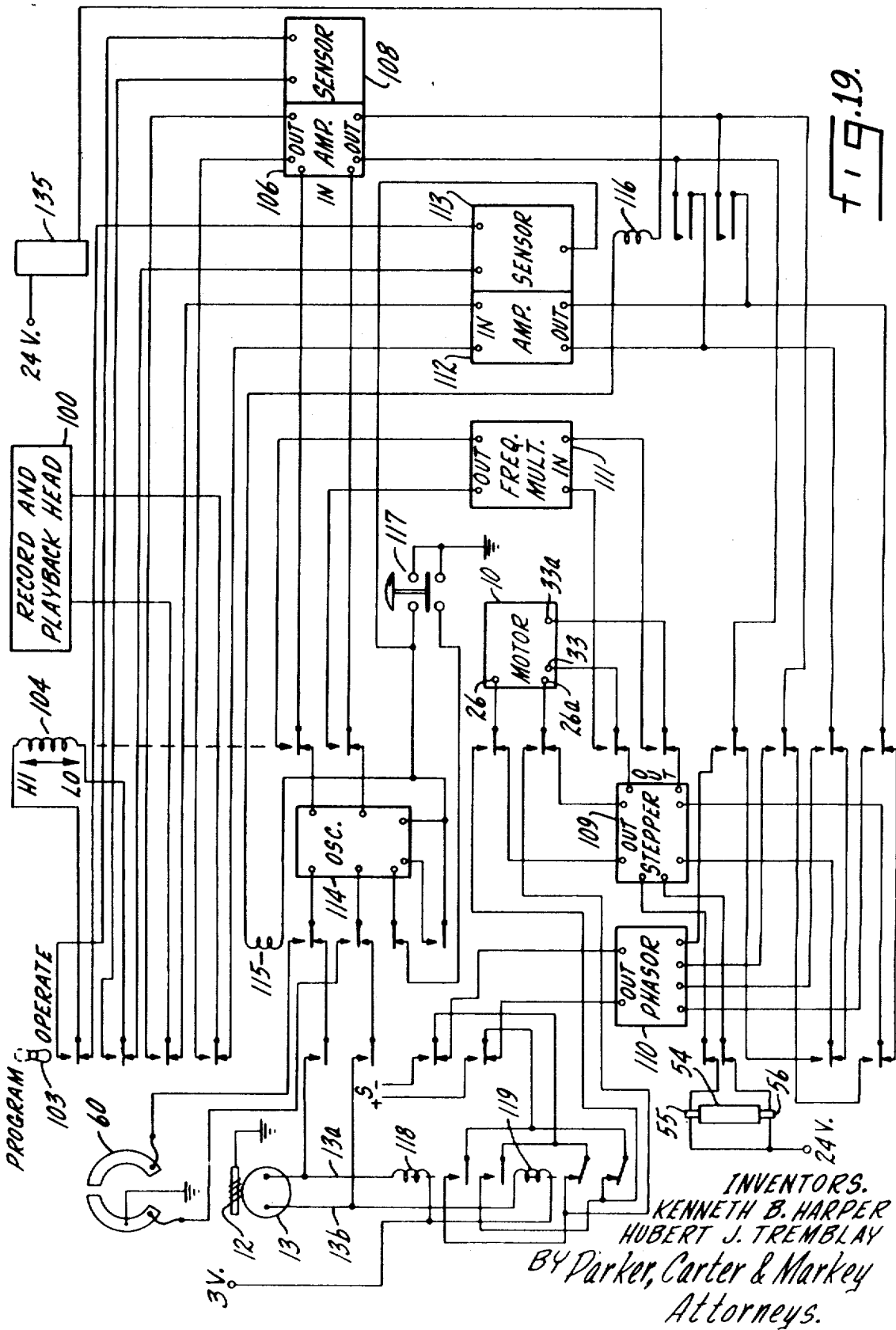
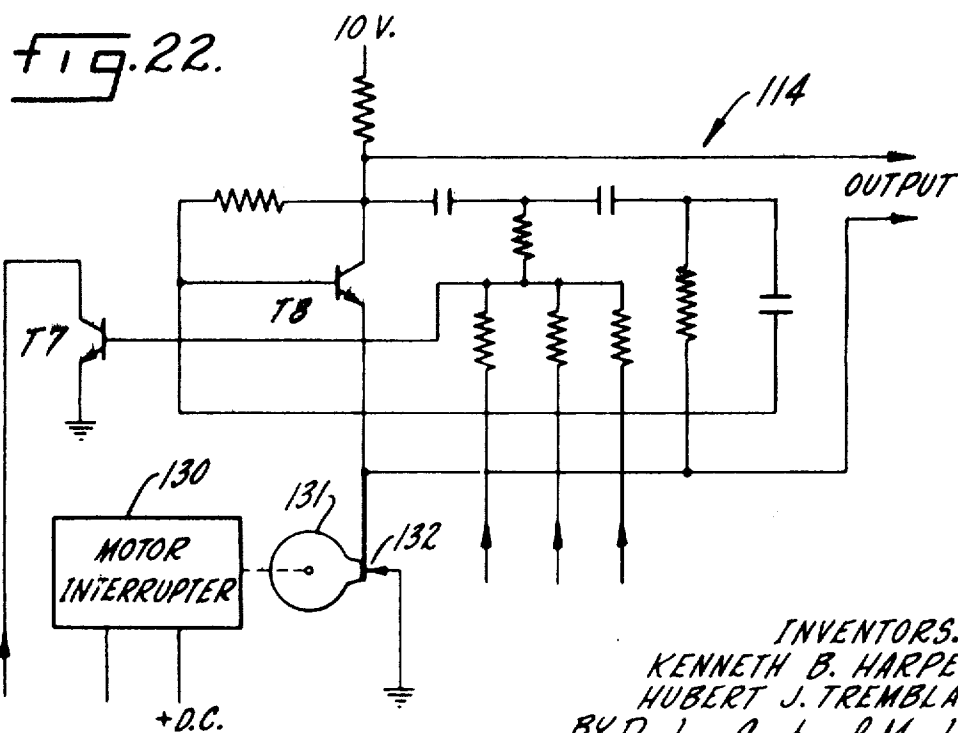
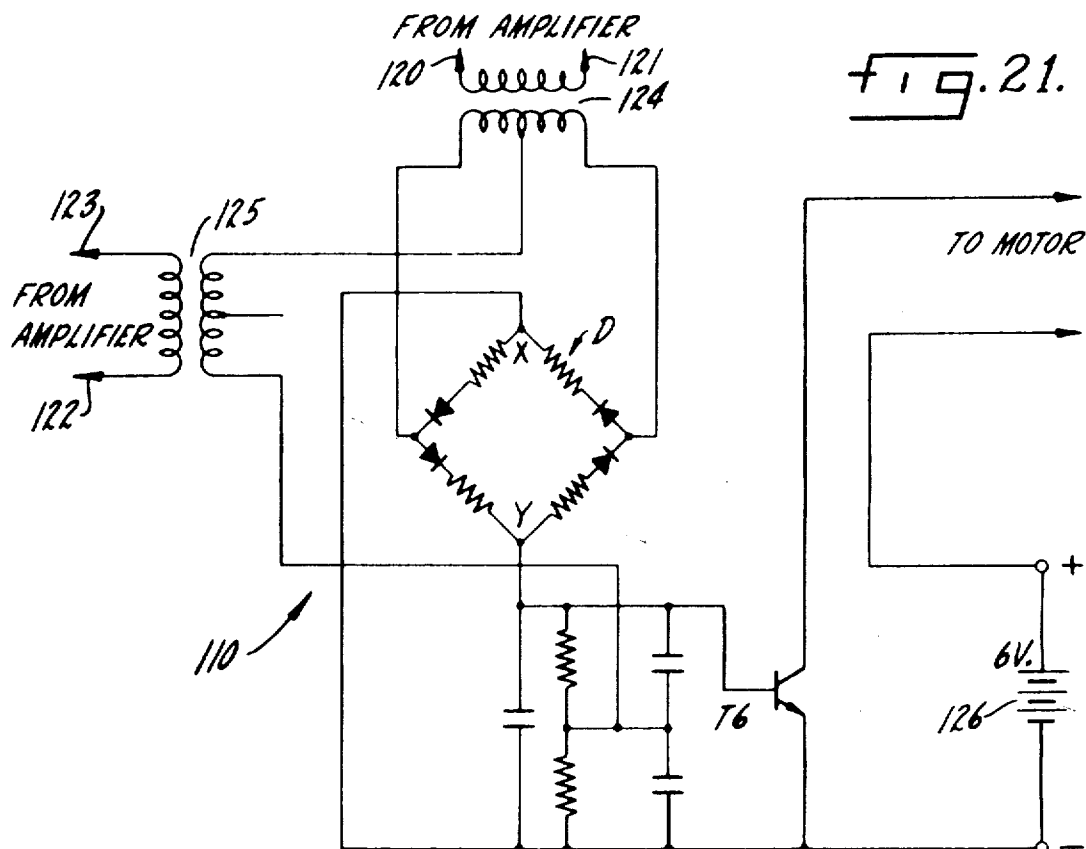


fig. 16.

INVENTORS.
KENNETH B. HARPER
HUBERT J. TREMBLAY
BY Parker, Carter & Markey
Attorneys.







INVENTORS.
KENNETH B. HARPER
HUBERT J. TREMBLAY
BY Parker, Carter & Markey
Attorneys.

AUTOMATIC WORK-REPEATING MECHANISM

SUMMARY OF THE INVENTION

The invention includes a support having electric motor-controlled elements thereon. The elements correspond to human appendages such as arms and fingers. A recording tape and electrical circuitry records the actions of the electric motors when the elements are manually moved to perform a piece of work or function. In response to playback of the tape, the elements will repeat the movements. A gear switch assembly and circuit enables motor operation to assist during manual element manipulation. An adjustable bezel ring and circuit ensures return of the elements to a home base position. A low-speed control stepper operates the motor at low speed in half-revolutions and directs a biasing signal to insure motor direction. A phase detector ensures accurate matching of motor speed to tape signals. An oscillator and rewind circuit provide homing and rewind signals and low-speed program recording. Fluid power means assist element movement. The motor of the invention is a small DC motor of particular construction and having a commutator shaft and slipring structure.

This invention relates to automatic work-repeating mechanisms and has as one of its purposes the provision of such a mechanism of maximum simplicity and minimum cost.

Another purpose is to provide an automatic mechanism which may be taught or programmed to perform a wide variety of functions.

Another purpose is to provide an automatic mechanism which may be taught by manual manipulation.

Another purpose is to provide an automatic work mechanism which may be retaught to perform a changed function without modification of the mechanism itself.

Another purpose is to provide a teachable mechanism having electrical means for assisting in the teaching operation.

Another purpose is to provide an electrical motor of minimum complexity, size and weight.

Another purpose is to provide such a motor energized by DC current and generating AC current.

Another purpose is to provide an actuating assembly in which a fluid power means rotates a gear and an electric motor rotates a worm to permit said gear rotation.

Another purpose is to provide an electrical circuit capable of recording motor-generated signals on tape.

Another purpose is to provide a circuit capable of high and low speed motor operation, recording signals on tape and operating said motor in response to such signals.

Another purpose is to provide an electrical phase detector circuit.

Another purpose is to provide a control circuit having automatically alternating high and low speed characteristics.

Another purpose is to provide an electrical motor and circuit effective to change the direction of movement of the motor.

Another purpose is to provide a tape-controlled assembly having automatic rewind capability.

Another purpose is to provide a method of operating a motor.

Another purpose is to provide a driving gear connection having electrical transmission characteristics.

Another purpose is to provide a method of recording and reproducing movement of a mechanism.

Another purpose is to provide an electrical motor and circuit and means biasing the motor.

Another purpose is to provide bezel and circuit means insuring return of elements to a predetermined position.

Another purpose is to provide an electrical motor having commutator and slipring elements, each with associated brushes.

Other purposes will appear from time to time during the course of the specification and claims.

BRIEF DESCRIPTION OF THE DISCLOSURE

The invention is illustrated more or less diagrammatically in the accompanying drawings wherein:

FIG. 1 is a side elevation;

FIG. 2 is a side elevation of a motor of the invention;

FIG. 3 is a view similar to that of FIG. 2 with parts removed and parts broken away;

FIG. 4 is a detail view showing a gear train for the motor of FIGS. 2 and 3;

FIG. 5 is an end view of the motor of FIG. 2;

FIG. 6 is a detail view on an enlarged scale of an armature disc of the motor of FIG. 2;

FIG. 7 is a detail view on an enlarged scale of a brush-holding closure for the motor of FIG. 2;

FIG. 8 is a detail end view on an enlarged scale, with parts in cross section of a commutator shaft for the motor of FIG. 2;

FIG. 9 is a view taken on the line 9—9 of FIG. 8;

FIG. 10 is a side view on an enlarged scale of an articulation area of the structure of FIG. 1;

FIG. 11 is a top plan view of the structure of FIG. 10;

FIG. 12 is a partial exploded view of a drive connection of the structure of FIG. 1;

FIGS. 13, 14 and 15 are detail views illustrating elements of FIG. 12 in various positional relationships;

FIG. 16 is a view taken on the line 16—16 of FIG. 12;

FIG. 17 is a detail view of a bezel element shown in FIG. 11;

FIG. 18 is a perspective view of a cassette useful with the invention;

FIG. 19 is a schematic view of a circuit of the invention;

FIG. 20 is a schematic view of a stepper circuit of the invention;

FIG. 21 is a schematic view of a phasor circuit; and

FIG. 22 is a schematic view of an oscillator circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and particularly to FIG. 1, the numeral 1 generally designates a support or base. The base 1 may suitably take the form of a rectilinear box or cabinet rendered portable by handle and wheel arrangement 1a, for example.

Mounted as at 2, externally of the base 1 and for movement thereon, is an arm element 3. The arm 3 is preferably formed of segments 3a, 3b articulated as at 4. At the distal end of arm portion 3b a finger element 5 is articulated for movement toward and away from distal arm segment 6, as indicated at 7.

A thumb-size electric motor 10 is positioned adjacent each of the articulation points 2, 4 and 7, the motor at point 2 being mounted on base 1 for movement control of arm segment 3a, the motor at point 4 being mounted on segment 3a for movement control of segment 3b and the motor at point 7 being mounted on segment 3b for movement control of finger 5.

While the single arm 3, formed of the portions 3a, 3b, and a single finger 5 workable toward and away from the distal end segment 6 of arm segment 3b are shown, it will be understood that more than one of the assemblies indicated at 2-10 may be suitably carried on base 1. Similarly, while a single finger element 5 is shown in the drawings, it will be realized that a suitable number of similar finger elements could be carried at the distal portion of each of the arms thus mounted on the base 1. For simplicity and clarity, a single assembly 2-10 is illustrated and described herein, it being understood that similar assemblies could be increased in number without departing from the nature and scope of the invention.

It will be understood that the articulation-driving assembly is repeated as often as necessary at the points 2, 4 and 7, for example. As illustrated, the arm segment 3a is intended for rotation about the point 2 in a single plane. Hence a single motor 10 and its driving-control connection are shown. The same is true at points 4 and 7. Should it be desired to move the arm portions 3a, 3b and finger or fingers 5 in more than one plane, it will be understood that additional motors 10 and associated driving-control connections and articulation joints

would be supplied at points 2, 4 and 7 for movement of the associated element in the desired planes. Further, in such event, a wrist-simulating universal-type connection with associated motors 10 and driving connections could be supplied between the end of arm portion 3b and the finger elements.

As best seen in FIGS. 10-16, motor 10 drives a shaft 11 carrying a worm drive configuration 12. Secured to the element to be moved, such as the arm portion 3b, is a gear member 13 having spaced, parallel, peripherally toothed annuli 14, 15 having spaced teeth 14a, 15a, respectively offset for alternate engagement by worm gear configuration 12. The annuli 14, 15 are separated by and supported in a ceramic or insulation block 16 axially bored as at 16a. Rotation of the worm gear 12 in opposite directions thus enables corresponding rotation of gear 13 and vertical motion of the arm portion 3b in relation to arm portion 3a, for example.

The motor 10 is illustrated in FIGS. 2-9 and includes a motor housing 20 serving as a magnetic flux retainer. Rotatable within the housing 20 is a crisscross wound barrel armature winding 21. The winding 21 surrounds a disc magnet 22, the magnet being suitably centered about the axis of winding 21 and fixedly secured to an insulating housing divider wall 22a as by an adhesive for example. Inwardly, radially directed wires 23, preferably five in number, are suitably connected to and extend from the winding 21, having their inner ends extending axially in circumferentially spaced, parallel relationship to form the commutator shaft 25. A lightweight, plastic disc 25a with axial collar 25b supports wires 23 and shaft 25 rotatably with winding 21.

A pair of brushes 26, 26a are provided for transmittal of DC current and are hereafter referred to as commutator brushes. The brushes 26, 26a are spring urged against the shaft 25 on opposite sides thereof for sequential contact with the machined, reduced curvature surfaces 23a of wires 23 as the shaft 25 formed thereof rotates.

A shaft extension or slipping collar 27 is secured to the distal end of the shaft 25 formed of wires 23. The collar or extension 27 includes a first ring 28 and a second ring 29 with an insulated area 30 positioned therebetween. The area 30 may, for example, be filled with an appropriate varnish. The area within collar 27 and between wires 23 therein is filled with an insulation material such as plastic 30a and glue 30b. The ring 28 is suitably secured to one of the wires 23, as indicated at 31, a silver compound being suitable for the connection 31. The ring 29 is suitably secured to a second wire 23 by a second supply of silver compound, as indicated at 32.

A brush 33 is yieldingly urged against the ring 28 of collar 27 and a brush 33a is yieldingly urged against the ring 29 of collar 27, the brushes 33, 33a being hereinafter referred to as the slipping brushes. The brushes 26, 26a and 33, 33a are carried by closure plate 10a.

The motor shaft 11 is suitably geared, as indicated generally at 40, to the center shaft 25d which is secured by boss 25c to plate 25a for rotation therewith in response to delivery of electrical energy to the motor 10, shaft 25d extending through magnet 22 and wall 22a. A ratio of 59 to 1 has been found effective between armature shaft 25d and output shaft 11. Appropriate electrical conductors, such as the wires 41, are connected through suitable terminals to the commutator and slipping brushes.

A DC current across the commutator brushes will cause a corresponding rotation of the armature 21, the speed of rotation being substantially proportional to the voltage applied, the motor shown being capable of an armature speed, for example, of up to 40,000 r.p.m. In response to any rotation of the armature 21 and commutator shaft 25 a sinusoidal wave form is produced across the slipping brushes 33, 33a, generating a low-level AC signal of up to 0.5 volts.

A DC current pulse across brushes 33, 33a orients the armature winding 21 to a predetermined point at which the polarity of the winding 21 is opposite that of permanent magnet 22, i.e. north on winding 21 overlies south on magnet 22 and south on the winding overlies north on the magnet, a continued applica-

tion of that current holding the armature in orientation. A reverse DC current across brushes 33, 33a displaces the winding polarity, reversing south to north and vice versa, reorienting the armature with the magnet and "stepping" the armature half a revolution.

The base 1 is conveniently of sufficient size to contain the circuitry and recording and playback mechanism described hereinbelow. Hence it will be understood that conductors such as those indicated at 41 in FIG. 2 conveniently extend within the arm segments 3a, 3b, from each of the individual motors 10 to the base 1.

Referring now to FIGS. 10 and 11, it will be observed that articulation point 4 is illustrated. The arm portion 3a carries the motor 10 and a fixed shaft 50 on which arm portion 3b is pivoted. The arm portion 3b may include an end section 3c, for example, from which the ear 3d may extend for pivotal connection with the rod 51 of a suitable air or hydraulic piston and cylinder booster means 52.

Since the specific internal details of the booster means 52 form no specific part of the present invention, a conventional such means may be employed and the details are not shown or discussed. It will be understood, however, that a suitable source of air or hydraulic pressure (not shown) may be positioned within the base or console 1. From such source suitable conduits 53 are provided for conveyance of pressure to opposite sides of a piston (not shown) within the means 52, the direction of such pressure being controlled by conventional solenoid valve 54, the details of which form no part of the present invention. As discussed below, appropriate electrical signals are delivered to the solenoids 55, 56 of valve 54. The rod 51 has an excursion greater than the intended extent of rotation of gear 13 in either direction and suitable exhaust means 57 are provided for the boost system 51-56.

Carried on section 3c for rotation about shaft 50 therewith and retained by nut 3e is the gear member 13, above described. It will be observed in FIG. 16 that the gear member 13 is insulated from the arm segment 3b and nut 3e by insulation 16. As indicated below, the gear structure 13 serves the additional function of an electrical switch means and is provided with a flexible, elongated conductor 13a secured to annulus 14 and a flexible, elongated conductor 13b secured to annulus 15.

It has been found effective to provide a substantial ratio between the worm 12 and gear 13. Preferably, for example, a gear 13 having an outside diameter of 1.025 inches and a diametrical pitch of 72, having 72 teeth in each annulus, provides a ratio of 72 to 1 with a worm 12 of corresponding tooth size and approximately one-fourth inch in diameter. The resultant total gearing between armature shaft 25d and the gear 13 is 4,248 to 1.

As indicated above, the two metal-toothed annuli 14, 15 of gear structure 13 are insulated from all structures other than the worm 12, as well as from each other. The worm 12 is permanently grounded. The teeth of annulus 14 are slightly offset or axially misaligned from those of annulus 15 and are separated by the thickness of the insulation 16 therebetween. Worm 12 and annuli 14, 15 are positioned to provide for a clearance of the worm out of contact with the teeth of either annulus. Hence worm 12 is in contact with a tooth 14a or with a tooth 15a or with neither. Thus in FIG. 13 worm 12 is seen in contact with a tooth 14a. In FIG. 14 worm 12 contacts a tooth 15a and in FIG. 15 worm 12 is centered between and entirely out of contact with either set of teeth.

A start-return point or "home base" device is illustrated in FIGS. 11 and 17. The device takes the form of a ring or bezel 60. The ring 60 is rotatably mounted about shaft 50 and retainer 50a and yieldingly held in selected rotational position by a suitable means, such as the ball or pin retainer 61 carried by arm segment 3a, for example. Retainer 61 is yieldingly urged toward the circumference 62 of ring 60 in which suitably circumferentially spaced pockets 63 are formed for locking reception of element 61.

An annular surface 64 of bezel ring 60 carries spaced electrical energy transmitting crescent surfaces 65,66. Elongated, flexible conductors or leads 65a,66a are connected, respectively, to surfaces 65,66. As best seen in FIG. 11, the crescents 65,66 are suitably insulated from the ring 60 as by the insulation layer 68. Opposed ends of surfaces 65,66 are spaced to form the nonconducting, null or void area 70. A similar spacing exists diametrically therefrom on the ring 60 as indicated at 71. Carried by and for rotation with the arm segment 3b, for example, is a wiper 72. The wiper 72 rides on the wiper surface 65 or 66. Since the intended positioning of ring 60 and the intended movement of arm segment 3b are known, the placement of leads 65a,66a adjacent the area 71 provides more than sufficient wiping surfaces for the wiper 72.

An outer surface 73 of the bezel 60 is exposed to view of the operator. An appropriate indicia, such as the arrow 74, is formed on the surface 73 in alignment with the nonconducting or null point 70. Thus electrical contact is provided between wiper 72 and either of the crescent surfaces 65,66, except when the wiper is aligned with the area 70 which is the start-return or "home base" point selected by the operator in rotating and positioning the bezel 60. The wiper 72 being continuously grounded, contact thereof with surface 65 will ground lead 65a and contact with surface 66 will ground lead 66a. As discussed below, the resulting circuits are effective to drive motor 10 in one or the other direction to produce movement of arm segment 3b until the wiper 72 reaches the prepositioned nonconducting area 70.

As shown in FIG. 18, a conventional magnetic tape 85 may be of substantial width to provide for recording thereon of a track for each articulation point in the assembly of the invention and may be carried in a conventional cassette structure 86 thickened to receive the tape 85.

Referring now to FIG. 19, there is illustrated a circuit and associated components effective to achieve the goals of the present invention. A recording and playback head 100 may be of conventional, well-known construction. A "program-operate" switch 103 is shown in its full line "operate" position. Accordingly, a series of switches aligned on the drawing with the manually operable switch 103 are shown in their "operate" positions. Similarly, a high-low relay 104 is supplied with energy of the order of 24 volts and controls a series of switches aligned therewith in FIG. 19, said switches being shown in their "low" position.

A program or recording amplifier 106 has associated therewith the sensor 108. Indicated at 109 is a low speed control or stepper component. A phase detector comparator or phasor component is indicated at 110. A frequency multiplier is shown at 111. An operate or playback amplifier 112 has sensor 113 associated therewith. An oscillator 114 is shown adjacent a rewind relay 115 which, it will be understood, controls the four switches shown as aligned therewith in the drawing. A second rewind relay is shown at 116, controlling the switches shown therebeneath. A homing and rewind double switch button is indicated at 117. Gear switch leads 13a,13b are connectable, respectively, to the two upper terminals of oscillator 114 and are connected to relays 118,119 for respective control of the switches shown adjacent, aligned with and beneath each of said relays.

Referring now to FIG. 20, the slow-speed control or stepper 109 is illustrated. The input terminals at the left of the drawing have the filter F thereacross. Beyond the filter F the multivibrator M, formed of transistors T1,T2 and associated components, delivers voltage to points A or B and thence respectively to a dual silicon-controlled rectifier formed of SCR1, SCR4, SCR2, SCR3 and associated components. A transistor T3 is fed one signal from the input for activation of a relay K1 and a transistor T4 controls a relay K2. Transistor T5 is fed a signal from the input and controls a relay K3 which, in conjunction with relay K1, will deliver energy through their respective switches to solenoid 55 or 56. At the lower center right of FIG. 20 the arrows indicate outputs to the commutator brushes 26,26a. The arrows at the upper right-hand por-

tion of FIG. 20 indicate outputs to the slipping brushes 33,33a. Those at the lower left center indicate outputs to solenoid valves 55,56.

Referring now to FIG. 21 in which the phaser 110 is illustrated, the input from a first amplifier is indicated at the terminals 120,121 and their transformer 124. The input from a second amplifier is indicated at terminals 122,123 and their transformer 125. The transformers are connected to a diode ring D having its diametrically opposed points X and Y. Voltage at ring D controls a transistor T6 and associated components which in turn can vary the output of the phaser 110, as indicated by the arrows in the right-hand portion of FIG. 21.

An effective oscillator component 114 is illustrated in FIG. 22. The three input terminals shown in the center bottom of FIGURE 22 appear in the left-hand side of oscillator 114 in FIG. 19. In the left-hand portion of FIG. 22 the two terminals appearing at the bottom of oscillator 114 in FIG. 19 appear, the left bottom terminal being connected to a transistor T7. The adjacent bottom terminal is connected to a motor interrupter 130 which in turn drives a cam 131 for operation of cam switch 132, the oscillator 114 including transistor T8 and associated components, the output of oscillator 114 being indicated by the arrows at the right-hand portion of FIG. 22 and corresponding to those shown in the right-hand portion of the oscillator 114 in FIG. 19. Since amplifiers 106,112 and their associated sensors 108,113 are of standard construction and well know in the art, the same are not internally illustrated herein.

The use and operation of the invention are as follows:

As shown in FIG. 1, the operator places his own arm and fingers over the arm 3, segment 6 and finger 5. Where necessary, the arm portion 3b may be suitably strapped or otherwise secured to the forearm of the operator, the arm portion 3a may be suitably secured to the upper arm of the operator and the finger parts 5,6 may be secured to the thumb and index finger of the operator. The operator then manipulates or moves the arm portions 3a and 3b and finger 5 to perform the function normally performed by the operator in his daily work routine.

For purposes of simplification and clarity, a pair of elements 5,6 may be considered as substituted for the thumb and index finger, respectively, of the operator. The normal work routine of the operator may be considered as the grasping of a workpiece or part at a first level, the raising of the part to a higher level and the release of the part at said higher level, all in one vertical plane.

It will be understood, as set forth above, that movement of the part in a horizontal plane, rotation of the part about a horizontal, inclined or vertical axis, joinder of the part to a second part (grasped and held by another arm 3a,3b and fingers 5,6), etc., may all be accomplished through the provision of additional elements corresponding to those described herein. Thus virtually any work routine presently accomplished manually by manual production workers seated, for example, before a machine, a conveyor belt or the like, may be accurately and continuously accomplished by the teachable, programmable, work-repeating mechanism of the invention.

Considering the simplified work routine illustrated herein, for example, the operator presses finger element 5 toward the finger portion 6 to grasp the workpiece therebetween. As this is done, the gear 13 at the pivot point 7 is rotated in response to movement of the finger 5. The operator then raises finger elements 5,6, with the piece grasped therebetween, raising, at the same time, the arm segments 3a,3b. At the normal point the operator then opens the finger elements 5,6 to release the piece and returns to grasp a second piece. As the arm segments 3a,3b were raised and lowered, the gears 13 at points 4 and 2 were rotated. If the piece part be heavy, and in view of the length of arm 3, fluid power booster means, such as the air cylinders and associated controls 51-57 may be employed, particularly at points 2 and 4.

In view of the gearing involved, provision has been made for electrical assistance permitting movement of the gears 13, worms 12 and motors 10 in response to manual movement of the arm 3 and finger elements 5,6.

In the programming stage, manual movement of arm segment 3b, for example, would cause rotation of gear 13, yet mechanical transmittal of motion from gear 13 to worm 12 is not feasible. Rotation of gear 13, however, produces contact of the teeth of one of the annuli with the worm, thus grounding that annuli through its lead 13a or 13b and producing a circuit therethrough, the resulting circuit, as described below, being effective to drive the motor 10 in one or the other direction corresponding to the direction of movement imparted to the arm by the operator. Thus the grounding of worm 12 through one or the other of annuli 14,15 functions as a single-pole, double-throw switch and the motor 10 is employed to drive the worm in correspondence with motion imparted to the gear 13 by the operator in moving the arm segment 3b, for example. As the operator continues motion of the segment 3b, the motor 10 is continuously stepped in response to energy delivered as a result of worm and gear contact.

The direction and extent of rotation of gears 13 at slower speeds is recorded in the form of a suitable tone or signal on tape 85 for later delivery to motors 10.

As the motors 10 are actuated in response to faster, continuous manual manipulation of the arm 3 and fingers 5,6, the direction, speed, and duration of each rotation of each motor is recorded on the tape 85 in the form of a suitable tone or signal.

The operator then removes his arm and hand from the arm 3 and fingers 5,6. The tape 85 is rewound to its original position.

Thereafter the tape 85 is traversed across the head 100 and the signals on the tape are played back through head 100 and amplifier 112 to the motors 10 to cause the arm 3 and fingers 5,6 to repeat precisely the functions accomplished when the arm 3 and fingers 5,6 were secured to the arm and fingers of the operator.

In the programming step or phase of operation, the switch 103 is placed in its dotted line or "program" position. Thereupon all of the switches shown in alignment with the switch 103 in FIG. 19 are placed in their upward position.

It will be understood that the bezel 60 may be set with or without the supply of electrical energy to the assembly of the invention. If each of the arm and finger segments are positioned in alignment with the arrows 74 and thus with the non-conducting areas 70 of their associated bezels, the operator will manually engage elements 3,5,6, turn "on" a suitable power supply switch (not shown), turn switch 103 to "program" and perform his normal work routine.

If the bezels 60 are set at the desired start-return points or "home bases" and any of the arm or finger segments are not aligned with the associated arrows 74, a bezel circuit such as that shown in FIG. 19 may be activated, upon positioning of switch 103 at "program" to cause such arm and finger segments to move into alignment with their associated bezel arrows. In such bezel control mode, the arm and finger segments are responsive solely to the information received from the bezel, designating the dislocation from the home base point and the direction of run to arrive thereat. The rate of startup, run to home base and stop is fixed or constant in the bezel control circuit.

For simplicity the movement of arm segment 3b in relation to arm segment 3a is considered, it being understood that the description thereof applies equally to the simultaneous or sequential movements of all of the other arm and finger segments. In the simplified showing of FIG. 1, for example, each of the motors 10 has its discrete track on tape 85 and its circuit such as that illustrated in FIGURE 19.

Accordingly, as arm segment 3b is rotated about pivot shaft 50 motion is imparted to gear structure 13. Upon contact of either of the teeth 14a or 15a with worm 12 a circuit is created. With switch 103 in "program" position, the control system is set to accept program information from the gear 13

and to provide electrical assistance permitting and abetting manual manipulation of the structure.

The gear-switch structure 12,13 is thus connected to the oscillator 114 for production of the selected "low" signals of 4,000 or 6,000 cycle per second signal frequencies, depending upon the direction of rotation, clockwise or counterclockwise, of gear structure 13.

A high-low relay 104 is supplied with energy of the order of 24 volts and controls the switches shown in alignment therewith in FIG. 19. As shown, the full line position of said switches corresponds to the low speed position of relay 104. The output of oscillator 114 is connected to amplifier 106 with relay 104 in low speed configuration and the output of amplifier 106 is connected to sensor 108, recording head 100 and stepper 109.

Either the 4,000 or the 6,000 cycle input signal to oscillator 114 will thus be grounded as gear 13 is rotated in one or the other direction, resulting in transmittal of that frequency from the oscillator 114 to amplifier 106. The sensor 108, detecting the signal to be one of the preselected low speed indicators, energizes the relay 104 to position the switches controlled thereby in their "low" position shown.

The output of oscillator 114 is thus amplified and recorded by amplifier 106 on the tape 85 through head 100. At the same time the same signal is fed from amplifier 106 to stepper 109, producing continuous application of a reversing DC voltage to the slipping brushes 33,33a of motor 10 and a momentary DC pulse to the commutator brushes 26,26a providing both operating energy and direction information to the motor in the low speed mode, the stepper 109 distinguishing between the 4,000 OR 6,000 cycle signal to produce direction information. Activation of motor 10 thus frees gear 13 to rotate.

As the operator manipulates the elements 3,5 at a higher speed, sensor 108, sensing the higher frequency output of amplifier 106, cause relay 104 to switch into its "high" mode, placing all of its switches in their upper positions. As elements 3,5 are manually manipulated in this mode, motor 10 is operating and worm 12 and teeth 14a,15a are continuously making and breaking contact, producing momentary closures of the switches of relays 118 and 119 or neither to feed from source S either a positive or negative or no voltage to commutator brushes 26,26a, giving the motor 10 accelerating or decelerating pulses, the combination of which will control the speed of the motor so that worm 12 maintains, in effect, a centered position between teeth 14a,15a throughout any displacement of gear 13 and gear 13 is thus freed to rotate in either direction.

With the switches controlled by relay 104 in their high position, the output of the slipping brushes 33,33a of motor 10 is connected to frequency multiplier 111 from whence a greatly multiplied signal is delivered to amplifier 106 for recording by head 100 on the tape 85.

Since amplifier 106 remains continuously connected to recording head 100 while the switch 103 is in its "program" position, the proper frequency signals are continuously applied to head 100 and a continuous record of the actions of gear 13 and motor 10, their speed and direction of rotation as well as any periods of inactivity, is formed on the tape 85.

When the operator completes his work function, the arms and finger segments of the invention are preferably returned to the proximity of their "home base" or start-return points, resulting in alignment of said segments with the arrows 74 on their associated bezels 60. Normally the workpiece or pieces will have been disengaged prior to such return. When desired, the programming may be completed upon disengagement of the workpiece or pieces and the arm and finger segments be left at the position of such disengagement, the bezel control circuit being relied upon to establish the arm and finger segments at their home base position.

In any event, upon the disengagement of the workpiece or pieces, and the consequent completion of the work program, a suitable rewind signal of a discrete frequency, such as 8,000 cycles, for example, is supplied to and deposited on tape 85 by

operation of a suitable button switch 117. Said signal will be later sensed by sensor 113 to activate a rewind mechanism in tape transport 135. Various types of tape-transport and winding means may be employed without departing from the spirit of the invention.

Depression of momentary rewind/homing button 117 sequentially closes two separate switch paths. Since elements 3,5 are stopped, the switches controlled by relay 104 will be in their "low" positions shown. The first closed path connects ground to the lower left side input of oscillator 114 causing the oscillator to generate the discrete, e.g., 8,000 cycle, tone which is fed through amplifier 106 and recorded on tape 85 through record head 100.

As button 117 is depressed further, the second path is closed which applies ground to the rewind relays 115,116, causing the relays to operate their associated switches. The rewind signal input to the oscillator is thus disengaged and the 4,000 and 6,000 cycle directional signal inputs from the bezel 60 are connected to oscillator 114. Relay 115 also closes a path to the left-hand bottom terminal of the oscillator causing transistor T7 to place that terminal at ground potential to energize the motor interrupter 130 and also to hold the rewind relay 115 operated.

With the interrupter 130 energized, the operate path of the oscillator circuit is interrupted by cam 131 and switch 132 at a predetermined rate of approximately 30 pulses per second to produce a predetermined speed at which elements 3,5 return to their home base positions. Thus a stream of pulses of either 4,000 or 6,000 cycle frequency, depending on the direction of run required to home base, is generated by the oscillator 114 so long as ground is received from bezel 60. When the home position 70 is reached and ground is removed, the signal is removed from the base of transistor T7 thereby releasing the motor interrupter 130 and the homing relays 115,116 simultaneously and causing the oscillator to cease functioning.

When the operator desires to operate the mechanism of the invention, the foregoing programming phase having been completed, the switch 103 is placed in its "operate" position positioning all of its aligned switches in their "operate" position as shown in FIG. 19. At the same time, as in the programming stage, the tape transport 135 will be activated by a suitable connection (not shown) with switch 103 and tape 85 will be moved across head 100 for playback of the tape.

The signals on tape 85 are amplified in amplifier 112 and sensed by sensor 113. At the outset, one of the predetermined low speed signals, of 4,000 or 6,000 cycles per second, for example, will be sensed, causing sensor 113 to activate relay 104's "low" side and thus to position its controlled switches in their "low" position as shown in FIG. 19.

The low speed signals are conveyed to stepper 109, which converts the burst or pulses of 4,000 or 6,000 cycle signals to DC reversals which are held in alternate polarity across slipring brushes 33,33a of motor 10, each reversal producing a 180° rotation of the motor. The stepper 109, as described below, detects whether the signal is 4,000 or 6,000 cycles, thus indicating clockwise or counterclockwise direction, respectively, and the bias element of the stepper will accordingly supply a momentary DC pulse, positive or negative depending on direction, to the commutator brushes 26,26a of motor 10.

As the frequency received from tape 85 and head 100 changes from the 4,000 or 6,000 cycle per second format to the high mode frequency range, the sensor 113 energizes the high-low relay 104 to its high position, throwing the switches aligned therewith in FIG. 19 to their upper position. Accordingly, the output of amplifier 112 will be directed into the phasor 110; the output of amplifier 106 will also be directed into phasor 110; the output of phasor 110 will be connected to the commutator brushes 26,26a of motor 10 through the switches controlled by relay 118 or relay 119.

The inputs from amplifiers 112,106 to phasor 110 are compared in its phase-detector circuit. Depending upon the relationship of said inputs, a controlled higher or lower DC volt-

age is applied by phasor 110 to commutator brushes 26,26a to regulate the speed of motor 10 and to ensure its identity with that recorded on tape 85 in the programming step described above.

Referring now to FIG. 20, the output of amplifier 112 or 106 is delivered to the low speed control or stepper 109 in the form of pulse bursts of either 4,000 or 6,000 cycles per second frequencies, producing in either case a voltage peak at the appropriate midpoint of the two circuits shown across the inputs and applying a positive potential to the trigger input of a multivibrator formed of transistors T1,T2 and associated components. Capacitor C1 filters out the 4,000 or 6,000 cycle frequency which makes up the pulse leaving only the pulse envelope as the triggering signal at the emitters of the two transistors T1,T2, the transistors T1,T2 operating alternatively on successive pulses. Thus a positive DC triggering pulse is produced alternatively at points A and B. The pulse delivered at A appears also on the gates of dual silicone-controlled rectifiers SCR2 and SCR3 causing them to conduct and to produce a current from the positive 24-volt supply shown through resistor R2, through SCR2 to slipring brush 33a, through the armature winding to brush 33, through SCR3 and R3 to ground. The alternating pulses appearing at point B appear also on the gates of rectifiers SCR1 and SCR4, producing a current flow through R1, through SCR1 to slipring brush 33, through the armature winding to brush 33a, and through SCR4 and R3 to ground. Thus the stepper circuit delivers a DC current continuously to the slipring brushes 33, 33a but the stepper reverses the direction of that current in response to each 4,000 or 6,000 cycle per second pulse received, each such reversal resulting in a 180° rotation of motor 10.

Signal inputs from the 4,000 -cycle filter across the input from amplifiers 112 or 106 are fed to transistor T3 causing it to conduct and to operate relay K1, the relay K1 being supplied as shown with a low power supply of the order of ten volts. Activation of relay K1 delivers a positive 1.5 volts from the source indicated to commutator brush 26 for a short pulse at the start of any 4,000-cycle pulse burst. Signal inputs from the 6,000 cycle per second filter are fed to transistor T5 causing it to conduct and to operate relay K3 and thus delivering a negative 1.5 volts to commutator brush 26. Transistor T4 is caused to conduct in response to conduction in the multivibrator formed of the SCRs and associated components, the period of conduction of T4 controlled by its input circuit. With T4 conducting, current flows through the winding of relay K2 and a ground pulse is applied to DC brush 26a.

Thus the output of the slow-speed control illustrated in FIG. 20 is shown as delivered directly to the slipring brushes 33,33a and thus to the sliprings 28,29 of motor 10 to apply DC reversals at a rate controlled by the input to the slow-speed control unit 109 and to provide driving force for the motor 10. At the same time, the circuit of stepper or slow-speed control provides a biasing potential to the DC brushes of the motor through relay K1 or K3 and K2 to ensure the correct, clockwise or counterclockwise, direction in the rotation of the motor produced in response to the power reversals supplied to brushes 33, 33a.

The phasor circuit, schematically illustrated in FIG. 21, is designed to provide close control of the motor within the range of phasor operation, i.e., in the high-speed mode. There is substantial overlap in motor r.p.m. between low and high mode operation, the staccato or stepping operation in low mode being distinguishable in such respect from the continuous, steady operation in high mode.

With relay 104 and its switches in the "high" or upper positions, terminals 120, 121 are connected through amplifier 106 and frequency multiplier 111 to the slipring brushes 33, 33a of the motor 10. The signal at terminals 120, 121 is therefore a reading directly from the motor of its speed of rotation. The form of the signal is a sign wave multiplied by a preferred factor of eight through frequency multiplier 111 and amplified in amplifier 106 to a level suitable for detection. The signal received at phasor terminals 122, 123 is from amplifier 112

and is the same signal previously recorded on tape during the programming operation of the invention.

The signals thus received at terminals 120, 121 and 122, 123 are fed through their respective transformers 124, 125 to the diode ring D. When the input signals are of identical frequency and phase, the voltage across points X and Y of ring D will be zero and phasor 110 will deliver its normal or reference output. As either phase or frequency deviates, a voltage will appear across the points X-Y, such voltage being positive when the input from one transformer exceeds that from the other and negative when the reverse condition exists. Through the appropriate circuitry illustrated the voltage across X-Y controls or biases transistor T6 which in turn controls the phasor DC output current employed to drive the motor 10 through its commutator brushes 26, 26a. A 6-volt power supply is indicated at 126.

Thus, as motor 10 begins to increase in speed the frequency input at transformer 124 leads the prerecorded signal at input transformer 125, producing a negative voltage across points X-Y and reducing the current through transistor T6 and thus to the motor, resulting in a slowing of the motor speed. Similarly, as input frequency at transformer 125 exceeds that at transformer 124 a positive voltage is built up across points X-Y, causing transistor T6 to conduct more heavily and increasing the current to the motor and increasing its speed correspondingly. The circuit control is such that the virtually instantaneous modulation or change in motor speed, synchronizing it under virtually absolute control with the prerecorded signal frequency on tape 85 ensures that the motor response called for by the taped signal can be accurately and minutely repeated, virtually without variation in indeterminate and substantially unlimited number of times. Thus, so long as the desired work function remains unchanged, the mechanism of the invention will continue to perform said work function without interruption and without reprogramming.

When the programmed operational cycle is completed, the 8,000-cycle tone recorded onto tape 85 at the end of the programming cycle, as described above, is sensed by sensor 113 and translated into a ground at the output shown at the bottom of the sensor 113 in FIG. 19. This ground bypasses button 117 and is applied to the rewind/homing relays 115, 116, causing them to operate. From that point on the rewind/homing cycle is identical to that which occurs in the program mode as described above. The arm and finger elements 3,5 will be returned to their preset home base positions and the tape will be rewound by means 135 for automatic repetition of the work function.

Thus it may be considered that the operation of the invention generally encompasses seven conditions or modes in which the circuitry and various components illustrated in FIG. 19 are variously operative.

In the program-low mode, contact of worm 12 with gear 13 grounds lead 13a or 13b depending on direction of gear rotation. The appropriate upper left-hand terminal of oscillator 114 is grounded, delivering a corresponding signal to amplifier 106 from which it is recorded on tape 85 through head 100. The same signal is delivered through the stepper 109, stepping the motor in the correct direction in response to each signal from gear 13 and delivering motive power to motor 10 through its slipping brushes and biasing or directionally urging motor 10 through its commutator brushes to permit rotation of gear 13.

In the program-high mode motor 10 is driven directly by plus or minus pulses from source S. Grounding of leads 13a or 13b activates relay 118 or 119, respectively, determining whether a plus or minus pulse is delivered to the commutator brushes. The AC output across the slipping brushes is delivered through multiplier 111 to amplifier 106 for recording on tape 85 through lead 100.

The end program-signal mode is employed but once in establishing a given program. The system is always in program-low mode at the end of the program. The first contact on

depression of button 117 grounds the lower left-hand terminal of oscillator 114 to produce a discrete signal recorded on tape 85 through amplifier 106 head 100.

The end program-rewind/homing mode occurs upon full depression of button 117 activating rewind relays 115, 116. The lowermost switch controlled by relay 115 holds the relay in operation after button 117 is no longer depressed. Since, as indicated, the system is in the program-low mode, the output of oscillator 114 is triggered by bezel 60 and delivered through amplifier 106 and the switches controlled by relay 116 to the stepper 109. Thus, if the elements 3,5 are not in home base position, the bezel 60 will drive the motor 10 through oscillator 114, amplifier 106 and stepper 109 to return the elements 3,5 to their home base positions. At the same time, the relay circuit will direct the tape transport 135 to rewind tape 85.

In the operate-low mode the signals or tones from tape 85 are played through the playback portion of head 100 through playback amplifier 112 to stepper 109 which drives motor 10 as above described, delivering DC reversals to the slipping brushes of motor 10 to step it in 180° revolutions and delivering DC pulses to the commutator brushes to provide direction information for each such half-revolution. Stepper 109 also energizes the appropriate solenoid 55 or 56 to operate valve 54 and boost 52.

In the operate-high mode sensor 113 detects the frequency signal for high-mode operation and shifts the circuit. The varying frequency signal from tape 85 through head 100 is delivered to playback amplifier 112 and then to the two left-hand bottom terminals of phasor 110. The AC output signal of motor 10 is delivered through frequency multiplier 111 and amplifier 106 to the two right-hand bottom terminals of phasor 110. Relay 118 or 119 is held continuously grounded by the continuous grounding of gear 13 through its continuous contact with worm 12, under urging of cylinder 52, in the high-speed mode. Plus or minus output voltages are thus delivered to the commutator brushes of motor 10. When booster 52 is employed it remains in full boosting status as it was in the low mode, any change in direction requiring a passing back through low mode and a redirecting of booster 52 prior to a further high mode operation.

The bezel control-rewind/homing mode occurs at the end of the operate cycle. Since the motion of elements 3,5 is ceasing, the circuit will be in operate-low condition or mode. Sensor 113 will detect the discrete end of program or rewind signal on tape 85 as it is delivered by head 100 to amplifier 112. The bottom terminal of sensor 113 will then activate rewind relays 115, 116, bringing bezel 60 into connection with oscillator 114, grounding one of the upper left terminals thereof and producing the appropriate signal to amplifier 106. Activation of relay 116 closes its switches, bringing amplifier 106 into connection with stepper 109 to drive the motor in the appropriate direction for return of the elements 3,5 to their home base positions. At the same time tape transport 135 rewinds and thereafter replays the tape, the work function of elements 3,5 being thus automatically repeated as often and for as long as desired.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A work-repeating mechanism including a base, a work-performing arm movably mounted on said base, an electrical motor having a driving control connection with said arm, means for generating signals in response to manual movement of said arm, recording means for recording said signals and playback means for transmitting said signals from said recording means to said motor to cause movement of said arm corresponding to said manual movement.

2. The structure of claim 1 characterized by and including electrical means for activating said motor in response to the manual movement of said arm.

3. The structure of claim 2 wherein said electrical means comprises a gear on said arm, a permanently grounded gear on said motor, a circuit including said arm gear and said motor, said circuit being activated in response to contact of said gears, said gears forming said driving connection.

4. The structure of claim 3 wherein said arm gear has a dual set of teeth offset from each other and said motor gear has conformations formed and adapted for engagement with one or the other of said sets of teeth or with neither.

5. The structure of claim 1 wherein said arm includes an upper arm segment, a forearm segment, and at least one finger segment and characterized by and including an electrical motor and driving connection for each of said segments.

6. The structure of claim 1 characterized by and including a homing member adjustably carried on said base, a conducting surface on said member, a nonconducting surface on said member and a wiper positioned on said arm and in contact with one of said member surfaces at all positions of said member.

7. The structure of claim 6 characterized by and including an electrical circuit including said member and said motor, said circuit being activated in response to contact of said wiper with said conducting surface, said circuit being deactivated in response to contact of said wiper with said nonconducting surface.

8. The structure of claim 1 wherein said motor has a dual set of brushes and said playback means includes a playback head, an amplifier receiving said signals from said head, a stepper receiving said signals from said amplifier and thereupon delivering first signal pulses to one set of brushes in said motor to drive it, said stepper substantially simultaneously delivering second signal pulses to another set of brushes in said motor to control the direction of rotation thereof.

9. The structure of claim 1 wherein said motor has a first and second set of brushes and said playback means includes a playback head, a first amplifier receiving said signals from said head, a phase detector receiving said signals from said first amplifier, a frequency multiplier receiving signals from said first set of motor brushes, a second amplifier receiving said last-named signals from said frequency multiplier, said phase detector receiving said last-named signals from said second amplifier, said phase detector determining the relationship of said signals and delivering its output to said second set of motor brushes to drive said motor.

10. The structure of claim 1 wherein said motor has a first and second set of brushes, said driving connection includes a gear driven by said motor and a second gear mounted on said arm and said recording means includes means for recording the direction speed and duration of motion of said motor in response to manual manipulation of said arm, said recording means including a circuit including said second gear and said motor, a source of positive and negative voltage, a set of relays in contact with said second gear for alternate activation in response to rotation of said arm gear in clockwise or counter-clockwise direction, said relays placing said voltage source in circuit with said first brushes to drive said motor, a frequency multiplier in said circuit and receiving an output signal from said second brushes, an amplifier receiving said signal from said frequency multiplier and delivering said last-named signal to a recording head for recording the same.

11. The structure of claim 1 wherein said driving connection includes a first gear driven by said motor and a second gear mounted on said arm for driving engagement with said first gear and said recording means includes means for recording the motion of said second gear, said last-named means including a circuit including said second gear, an oscillator, an amplifier and a recording head, said first gear being permanently grounded, said second gear having a first set of teeth engaging said first gear when said arm is moved in one direction and a second set of teeth engaging said first gear when said arm is moved in a second direction, contact of said teeth with said motor gear being effective to activate said circuit.

12. The structure of claim 1 characterized by and including fluid power means engaging said arm and an electrically operable valve means directing operation of said fluid power means to urge said arm in the direction imparted to said arm by said motor, said playback means including means delivering electrical energy to said valve means.

13. The structure of claim 5 wherein said recording means includes a cassette cartridge and a tape record therein, said tape record having a width sufficient for recording thereon of an individual track for each of said motors and driving connections.

14. A mechanism including a base, a manually movable arm on said base, an electric motor, a driving connection between said motor and said arm, a record and an electrical circuit for recording signals on said record in response to movement of said driving connection and motor and for delivering said signals to said motor to operate it in response to playback of said record, said circuit including an oscillator, a first amplifier, a first sensor sensing the input to said first amplifier, said motor, a second amplifier, a second sensor sensing the signal input to said second amplifier, a slow-speed motor control circuit, a phase comparator, a source of voltage, relays operable in response to grounding of said driving connection and operable to connect said voltage source to said motor, said oscillator being responsive to grounding of said driving connection to deliver signals to said first amplifier, said first amplifier delivering said last-named signals to said record, said second amplifier receiving signals from said record and delivering said last-named signals to said comparator, and a multiplier receiving signals from said motor and delivering said last named signals through said first amplifier to said comparator, said comparator delivering its output to said motor to operate it.

15. The structure of claim 14 wherein said circuit includes a high-low relay and a series of switches controlled thereby, said relay being responsive to said sensors.

16. The structure of claim 14 characterized by and including a rewind relay, said relay being operable in response to a signal received from said tape to rewind the same.

17. The structure of claim 14 characterized by and including a homing circuit including at least two conducting surfaces adjustable on said base, a nonconducting surface adjacent said conducting surfaces and adjustable therewith, a wiper on said arm and engageable with said surfaces, said surfaces being connectable with said oscillator in response to activation of said rewind relay, said oscillator in response to contact of said wiper with one of said conducting surfaces delivering a signal to said first amplifier, said first amplifier delivering said last-named signal through said slow-speed control to said motor to operate it and to move said arm and wiper toward said nonconducting surface.

18. The structure of claim 14 wherein said motor has a first set and a second set of brushes and said slow-speed control is connected to said brushes for delivery of pulse signals simultaneously to said first and second set of brushes.

19. The method of recording on a record the manual movement of a movable member which includes the steps of providing an electric motor and a driving control connection between said motor and said member, said connection having a grounded part and a part movable into contact with said grounded part in response to movement of said member which includes the steps of manually moving said member to bring said last-named part into contact with said grounded part to cause grounding of said driving connection and production of a signal in an oscillator, amplifying said signal, transmitting said signal to a recording head and transferring said signal from said recording head to said record.

20. The method of claim 19 characterized by and including the steps of continuing to manually move said member, electrically activating said motor in response to said continued manual movement of said member to produce a signal from said motor, amplifying said signal, transmitting said signal to a recording head and transferring said signal from said recording head to said motor.

21. A work-repeating mechanism including a support, an arm movably mounted on said support, an electric motor, a worm driven by said electric motor, a gear carried on and movable with said arm, said gear having teeth interpenetrating with said worm, said worm being permanently grounded, an electrical circuit including said electric motor, said gear and a

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recording means, said gear being movable into contact with said worm in response to manual movement of said arm to ground said circuit and to activate said electric motor for rotation of said worm and to permit further movement of said gear, said circuit and recording means being effective to 5 record the movement of said motor in response to said activation.

22. The structure of claim 21 characterized by and includ-

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ing motor means connected to said arm, a playback circuit including said electrical motor and said motor means, said motor means being activated by said circuit to continuously urge said arm in one of two directions, said electric motor being activated by said circuit to rotate said worm to permit said movement of said arm by said motor means.

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