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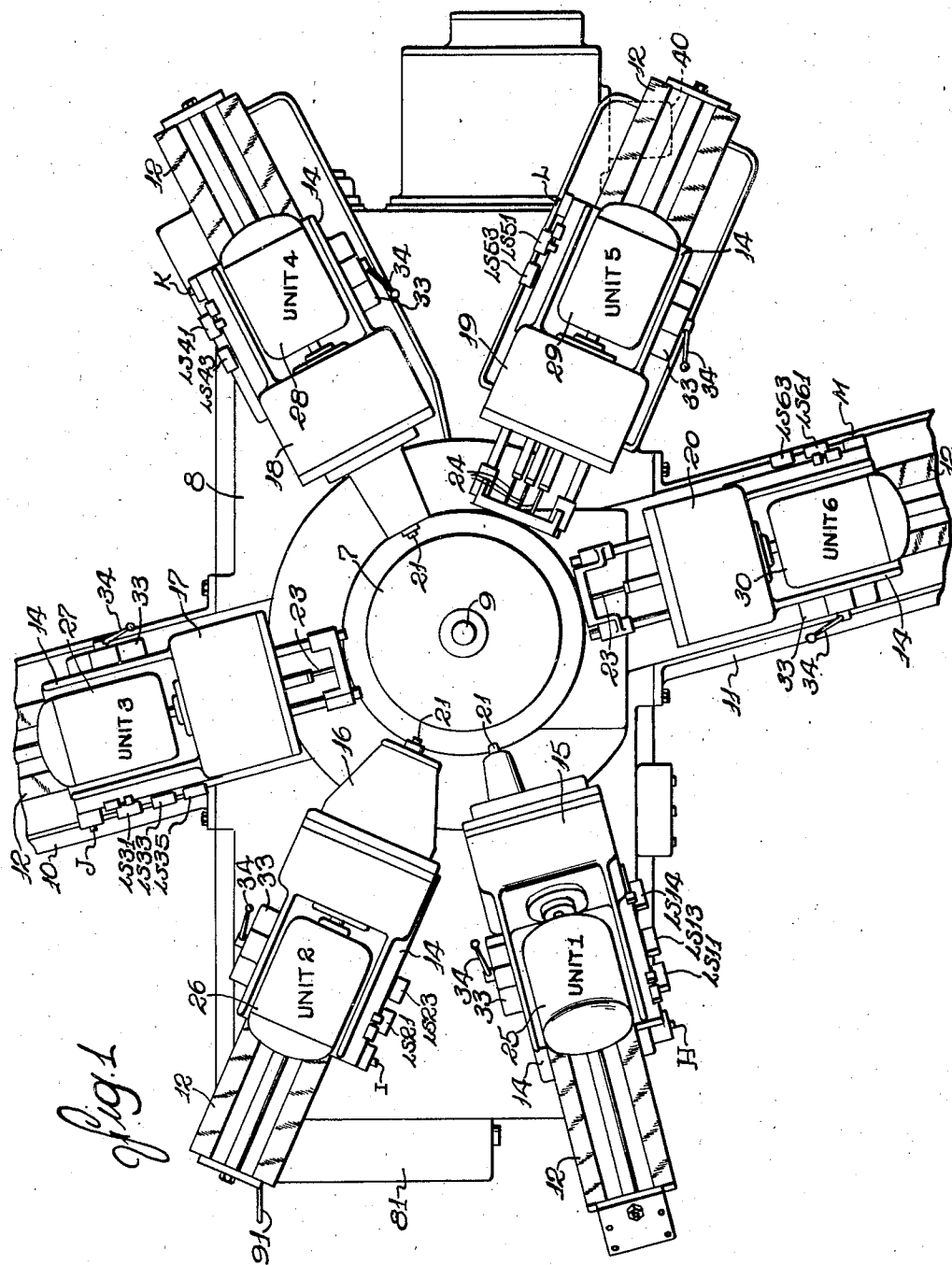
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2,429,938

MULTIPLE UNIT MACHINE TOOL

Filed Oct. 4, 1941

7 Sheets-Sheet 1



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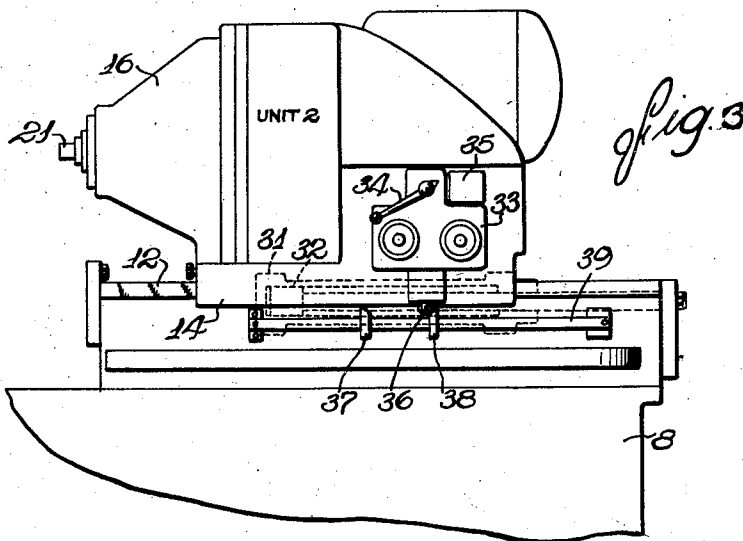
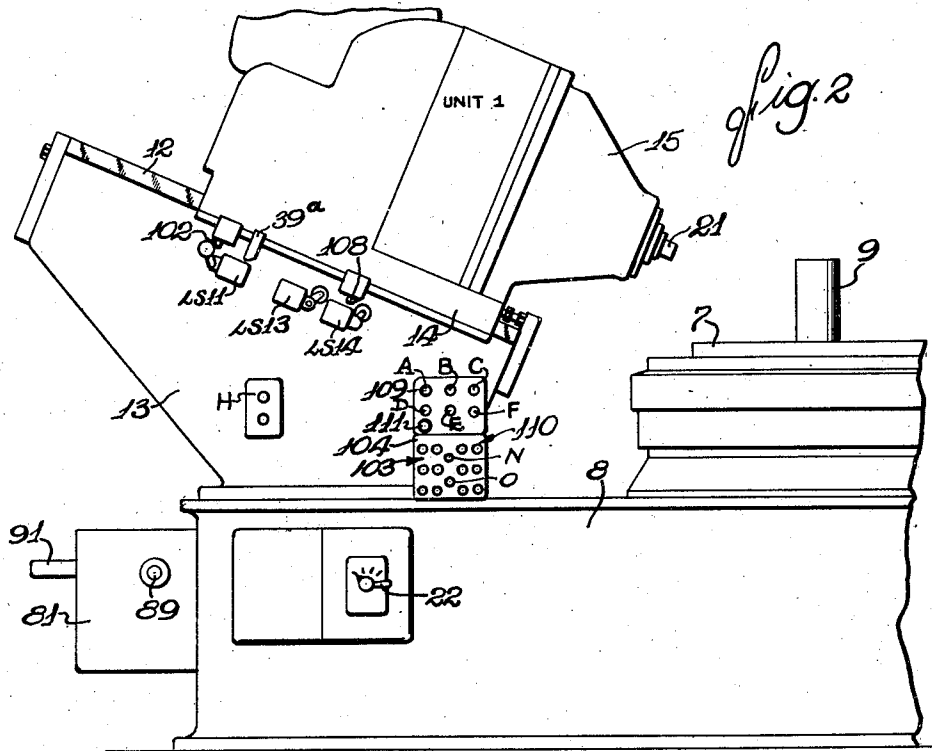
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MULTIPLE UNIT MACHINE TOOL

Filed Oct. 4, 1941

7 Sheets-Sheet 2



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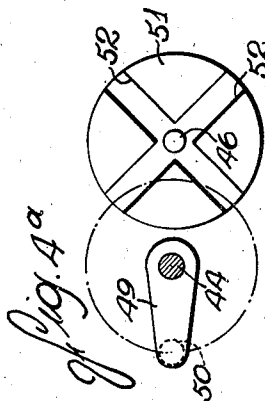
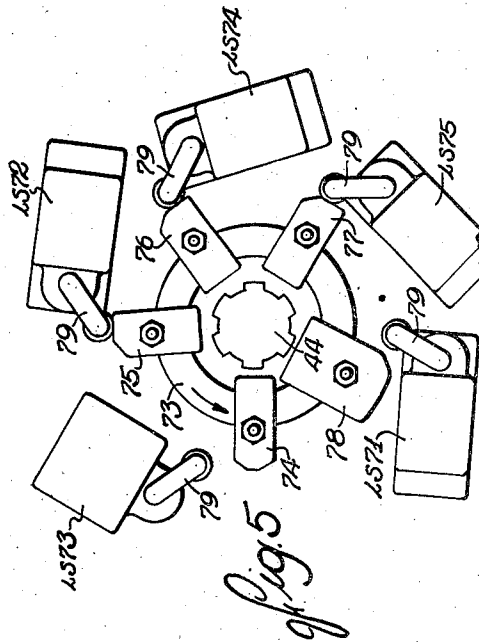
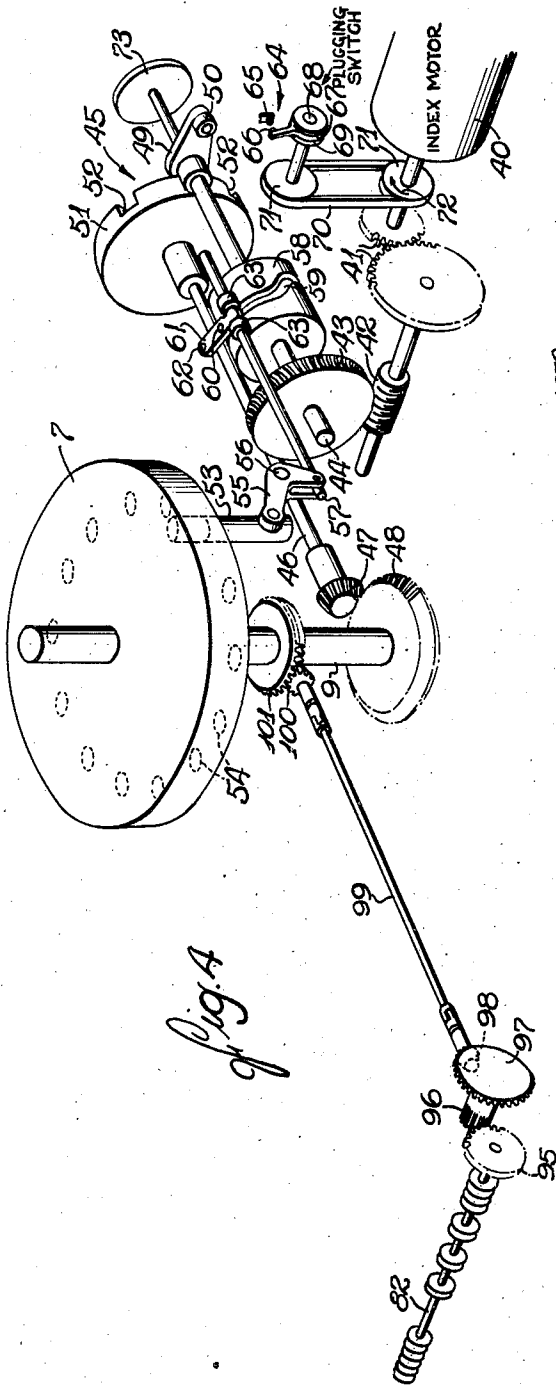
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MULTIPLE UNIT MACHINE TOOL

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7 Sheets-Sheet 3



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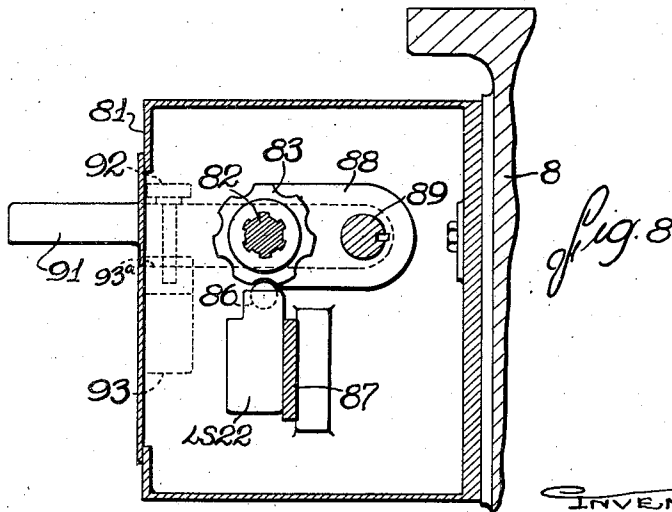
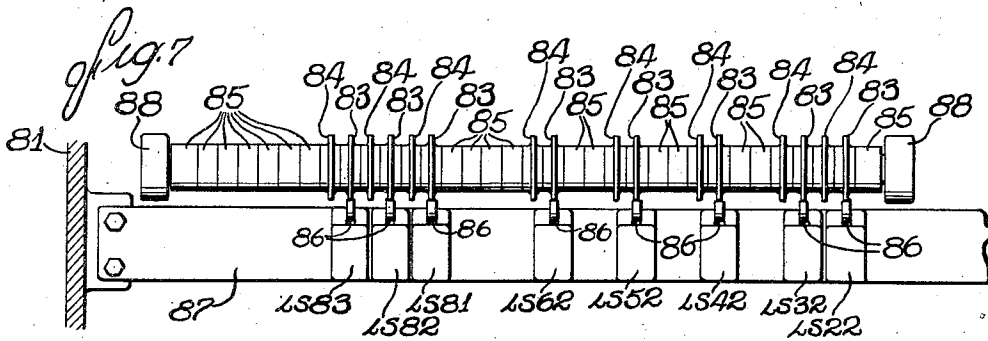
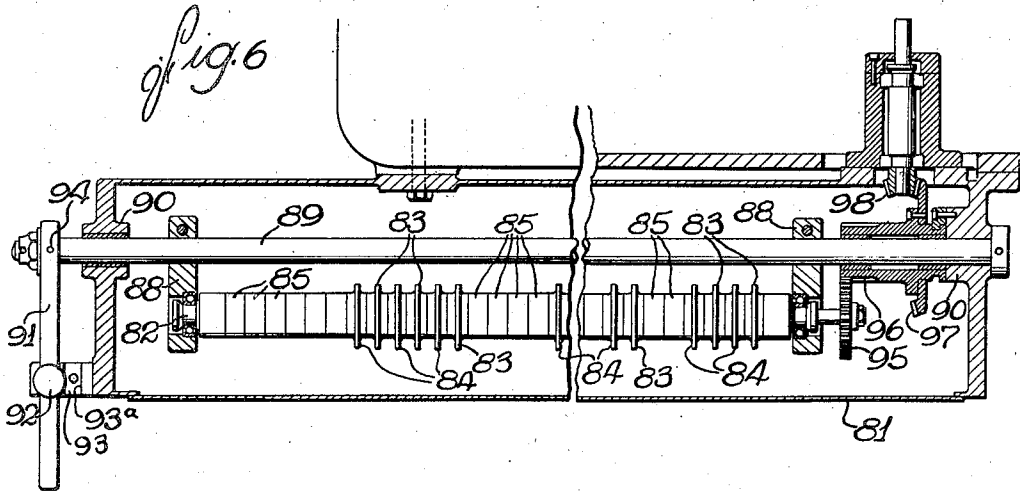
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MULTIPLE UNIT MACHINE TOOL

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7 Sheets-Sheet 4



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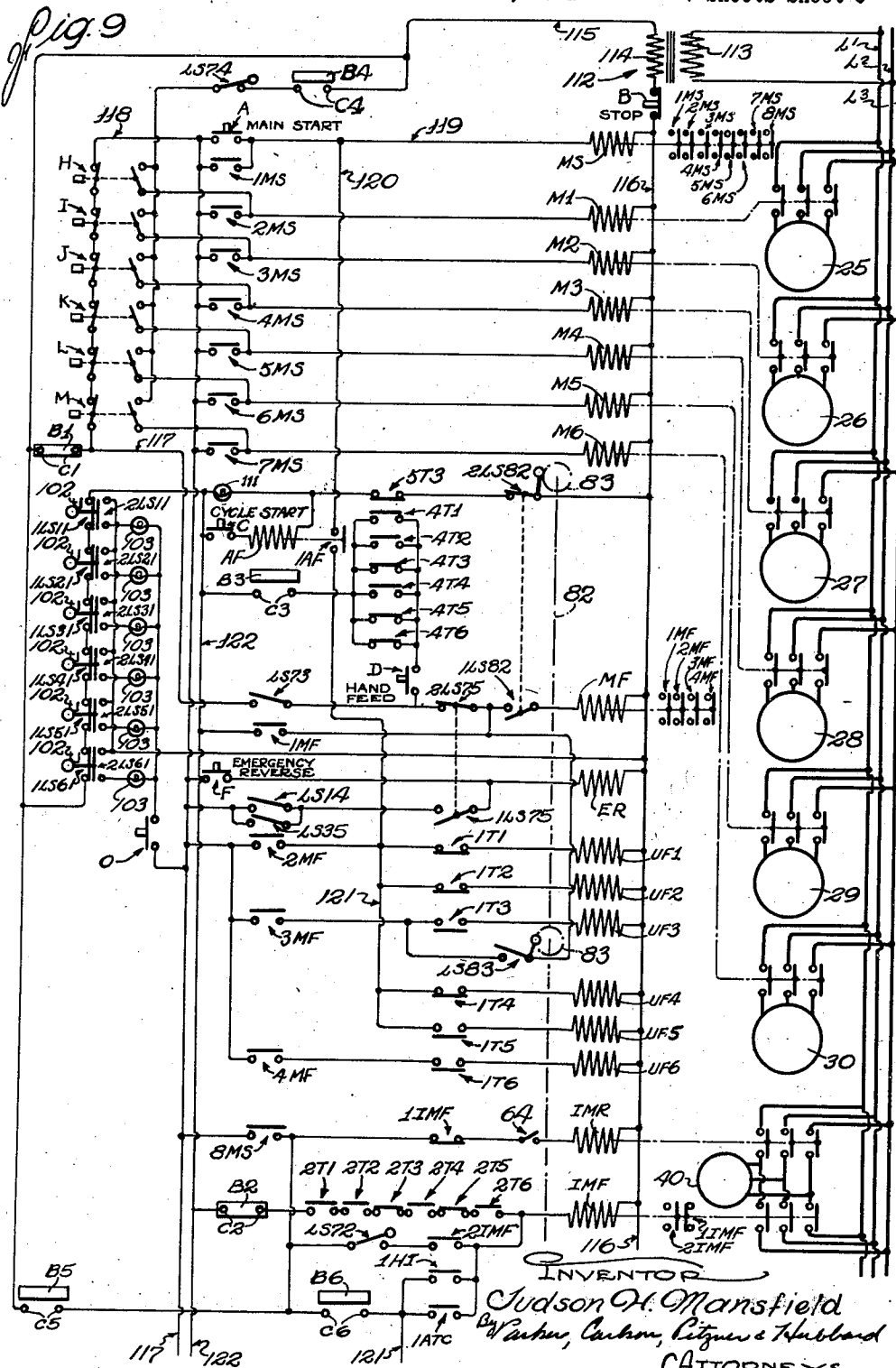
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MULTIPLE UNIT MACHINE TOOL

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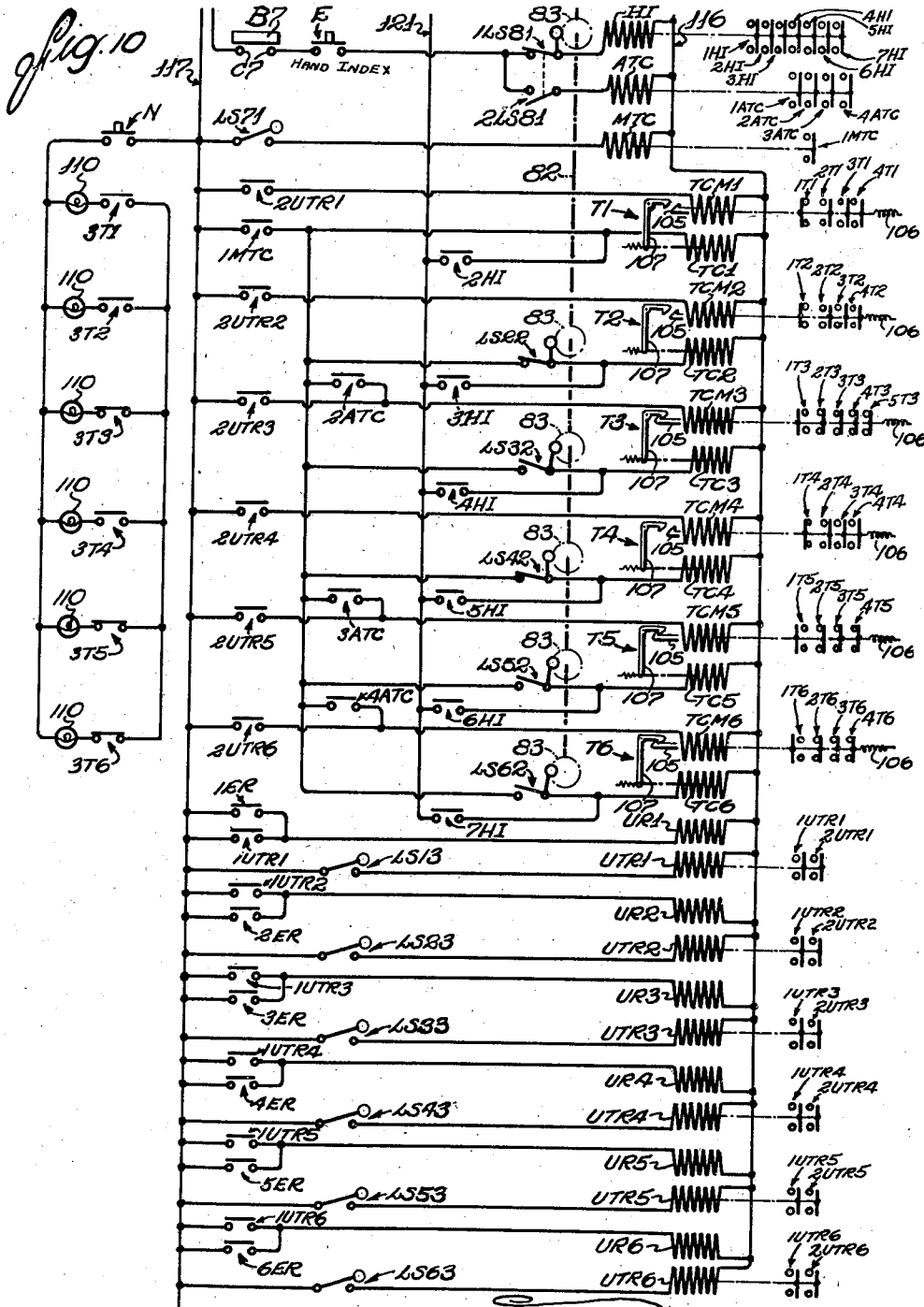
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MULTIPLE UNIT MACHINE TOOL

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7 Sheets-Sheet 6



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MULTIPLE UNIT MACHINE TOOL

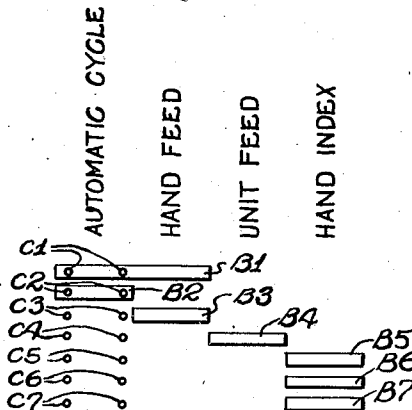
Filed Oct. 4, 1941

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INDEX	OP	UNIT 2		UNIT 3		UNIT 4		UNIT 5		UNIT 6		UNIT 7		UNIT 8		UNIT 9		UNIT 10	
		1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND
14	1																		
1	2																		
2	3																		
3	4																		
4	5																		
5	6																		
6	7																		
7	8																		
8	9																		
9	10																		
10	11																		
11	12																		
12	13																		
13	14																		
14	15																		

Fig. 11

Fig. 12



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UNITED STATES PATENT OFFICE

2,429,938

MULTIPLE UNIT MACHINE TOOL

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Application October 4, 1941, Serial No. 413,633

26 Claims. (Cl. 29—38)

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The present invention pertains primarily to a novel multiple unit type of machine tool, that is to say, to a machine tool in which there are a plurality of separately movable units or tool heads, each of which has its own individual tool-drive and feed mechanism for traversing the unit. In machines of this type, various tools may be provided on different ones of the units, for example, drills on some, taps on others, facing tools on still others, etc.

One object of the invention is to provide a machine tool of the type indicated, embodying a novel and improved arrangement for effecting a predetermined programed and coordinated feeding of the various units into and out of the operative relation with a work piece.

More specifically, it is an object to provide a machine of the type indicated which embodies a novel control arrangement for effecting a programed operation of the units in which different selected ones of the units participate in successive cycles of operation of the machine.

Another object is to provide a machine tool of the type set forth which can, simply by the manipulation of a control device as distinguished from a disassembly of the controls and new setup of the same, be conditioned at will to execute any selected one of a plurality of programs of cyclic operation.

Another object is to provide a multiple unit type of machine in which the units are advanced, by individual feed mechanisms, into operative relation with the work and retracted upon completion of a predetermined machine operation, a novel interlock arrangement of such character that a succeeding feed cycle for the units can only be instituted after the units have each completed a predetermined advance and retraction cycle movement. In other words, the interlock is such that the units must not only all be in their proper starting positions before a new cycle can be initiated, but must also have fully executed their previous cycle.

Still another object of the invention is to provide a machine embodying an interlock arrangement of the character indicated in the immediately preceding statement of object, and which is additionally adapted for a type of programing in which only a portion of the total available units are utilized in certain ones of the successive cycles. More specifically, provision is made for accommodating a condition in which less than all the units participate in a particular cycle so that the fact that there are such non-participating units, and which therefore remain at rest,

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will not interfere with the interlocking which compels all of the participating or selected units to completely execute their cycle of movement before the next cycle can be instituted.

Further objects and advantages of the invention will become apparent as the following description proceeds, taken in connection with the accompanying drawings, in which:

Figure 1 is a plan view of a machine tool embodying the invention.

Fig. 2 is a fragmentary front elevation of the lefthand portion of the machine as viewed in Fig. 1, showing particularly unit 1 of the machine.

Fig. 3 is a fragmentary rear elevation of the lefthand portion of the machine shown in Fig. 1, showing particularly unit 2 of the machine.

Fig. 4 is a generally schematic perspective layout of the table indexing mechanism and parts driven in unison therewith.

Fig. 4^a is a detail end elevation of the intermittent gearing included in the mechanism of Fig. 4.

Fig. 5 is an end elevation of a rotary switch actuating mechanism, and series of switches associated therewith, driven in timed relation with the table indexing mechanism.

Fig. 6 is a plan view, partially in horizontal section, of the program switch mechanism for the machine control, housed in a casing at the left end of the machine bed, as viewed in Fig. 1.

Figs. 7 and 8 are, respectively, a front elevation and end elevation, partially in section, of the program switch mechanism of Fig. 6.

Figs. 9 and 10 are wiring diagrams of the electrical control system for the machine tool, these two figures being adapted to be placed end to end with Fig. 10 below Fig. 9, to show the complete circuit.

Fig. 11 is a cycle chart for the control system, showing the open or closed condition of various switches during successive cycles in the program of operation for the machine.

Fig. 12 is a development of the movable contacts in the master controller for the control system.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

General organization of the machine

In the particular machine (Fig. 1) selected for exemplification of the invention, there are six individually movable tool supports shown as units or tool heads, 1 to 6 inclusive, each having a metal removing tool or tools thereon and all arranged to operate on a single work piece (not shown). These units are distributed generally circularly about a centrally located movable work support, shown in the form of a rotatably indexible table 7. Each of the six units is of what is commonly known as the "self-contained" type and is adapted to execute, independently, a cycle of movement in which it advances toward the work and then returns to its starting position. In the present instance each unit advances at a rapid approach rate, then at a slower feed rate while its tool is operating on the work, and is then retracted at a rapid return rate. For this purpose each of the units has its own individual tool drive and unit propulsion mechanism, as is common practice in such multiple unit machines, so that the operation of each unit is sufficiently independent of the others that it can be readily suited to the length of cutting advance and speed requirements of the particular operation which its tool or tools perform. The number, angle of approach and particular location of the units relative to the work piece are so chosen as to accommodate the requirements of a particular piece of work. In the present instance, the unit 1 is mounted to slide angularly downward toward the work (see also Fig. 2) while the other units slide horizontally.

All of the units 1 to 6 are supported from a massive bed structure, this structure comprising a rectangular main bed 8, in the center of which is mounted the table 7 on a revoluble upright table drive spindle 9, suitably journaled in the bed. The units 1, 2, 4 and 5 are disposed at the four corners of the top surface of the main bed 8 (Fig. 1), while the other two units 3 and 6 are supported on bed wings 10 and 11 bolted to the opposite sides of the main bed 8. Each of the units 1 to 6 is traversable along an individual guideway 12 thereof, fixed to the corresponding part of the bed structure. In the case of the unit 1, a wedge-shaped support 13 (Fig. 2) is interposed between the main bed 8 and the unit's guideway 12 so that the latter will be inclined for the desired angle of approach of the unit toward the work on the table 7. Of course, such supplemental mounting blocks or the like may be used for the guideways of the other units to provide any angle of approach for the same, relative to the work, required for a particular work piece.

In brief, the controls for the machine are such that the units are caused to move automatically in accordance with a predetermined program. In each main division of the program of unit operation, predetermined ones of the units are caused to execute their individual cycles of movement, that is, rapid approach toward the work, a slower or feed speed advance while their tools are operating on the work, and rapid return back to their initial position upon completion of the machining operation. Intermediate each such main division of the program of unit operation, the table 7 is indexed through a predetermined increment of rotation to present spaced portions of the work piece on it to the various units successively. Furthermore, the control system is such that the units, as well as the table 7, can

be operated individually rather than in the course of a program of automatic operation. Before proceeding further with a description of the control system, the exemplary construction of the units and table will be examined with particular reference, however, only to the control devices of the actuators therefor which are associated directly with the main control system.

Construction of the individual units

The details of the individual units 1 to 6, included in the machine illustrated, form per se no part of the present invention, and since units of this general self-contained type are well-known in the art, simply a brief description will suffice. All of these six units are essentially similar in construction. Thus, each includes a slide or carriage 14 traversable along its corresponding guideway 12. On the forward ends of the slides 14 are casing structures 15 and 20 for the respective units 1 to 6. The forms of the individual ones of these tool head casings are such as to adapt them to accommodate the particular tools assigned to the corresponding units. Thus, in the present instance the units 1, 2 and 4 have spindles 21 adapted to receive rotatable rough boring and facing tools, the units 3 and 6 having rotatable drill spindles 23, while the unit 5 has three such rotatable drill spindles 24. It will be appreciated by those skilled in the art that, of course, a wide variety of different forms and numbers of rotatable tools may be provided on the various tool heads.

Any one of a number of well-known forms of drive and propulsion mechanisms of either the electric or hydraulic types may be utilized for the several units. For present purposes the primary requirement is simply that they be capable of control, as to starting and preferably stopping, from a remote point as, for example, through the use of electromagnetically operated switches or valves. In the present instance electric motors, started and stopped by remotely controlled relays or contactors, are used for driving the tool spindles; and hydraulic propulsion systems, started and reversed by remotely controlled valve-operating solenoids, are used to traverse the units. Thus individual electric drive motors 25 to 30 are provided for the respective units 1 to 6 (Fig. 1). These motors are mounted on the unit slides 14 and are connected through suitable gear connections (not shown) in the casings 15 to 20 to drive the tool spindles of their respective units. Additionally, these motors serve to drive fluid supply pumps (not shown) for hydraulic type feed or propulsion mechanisms of their respective units. These hydraulic feed mechanisms have not been detailed, since they may be of any one of a variety of forms available on the market today and which, per se, form no part of the present invention. It is sufficient to note that the feed mechanism of unit 2, shown in Fig. 3, and which is typical of those for the whole series of units, comprises a hydraulic actuator in the form of a cylinder 31 rigid with the slide 14 and having slidable in it a piston 32 fixed to the bed 8. Thus as pressure fluid is supplied to the left end of the cylinder 31 (as viewed in Fig. 3) and exhausted from the righthand end, the slide 14 is traversed to the left, i. e., advanced toward the work; and similarly, as fluid is supplied to the righthand end of the cylinder 31 and exhausted from the lefthand end, the slide 14 is retracted to the right.

Pressure fluid for this purpose is, as noted above, supplied from a suitable pump driven by the unit's motor 26.

Control of the pressure fluid is effected by a suitable valve mechanism housed within a casing 33 fixed on the slide 14. Since hydraulic control valve mechanisms of the general type here contemplated are commonly available on the market and their construction well known (for a publication giving details of the same see "Hydraulic Controls on Machine Tools" published in 1940 by General Motors Institute, and particularly the Vickers System in Sec. C.—Unit 4, page 7) only the general program of operation need be detailed here, together with the actuating devices therefor which form a part of the general control system that enters into the present invention.

In brief, the valve mechanism housed in the casing 33 has four positions, viz: a neutral or stopped position in which supply of fluid to the cylinder 31 is cut off, a rapid approach position in which fluid is supplied at a high volumetric rate for advance of the slide 14, a slow feed position in which fluid is supplied to the cylinder 31 at a lower volumetric rate for a slower or feed advance of the slide, and finally a rapid return position in which fluid is supplied to the cylinder for a rapid retraction of the slide 14. The valve mechanism can be shifted to any of such four positions by a hand lever 34 swingably mounted on the side of the casing 33, or by automatic-operation instrumentalities including a pair of solenoids hereinafter detailed, in a casing 35 and a plunger 36 operated by dogs 37 and 38 adjustably fixed to a rail 39 on the side of the bed 8.

At the start of a cycle of unit movement, momentary energization of the starting solenoid shifts the valve mechanism to its rapid approach position; then as the slide 14 moves forward, elevation of the plunger 36 by the dog 37 shifts the valve mechanism from its rapid approach position to its feed position. At the end of the forward stroke of the unit a limit switch is closed to energize the reversing solenoid momentarily so that it shifts the valve mechanism to its rapid return position, whereupon the slide 14 is caused to retract. Finally, when the slide 14 reaches its initial position, the valve mechanism is shifted back to its neutral position by engagement of the dog 38 with the plunger 36 to stop the unit.

The solenoid and other electrical connections in the master control system are shown in the wiring diagram, Figs. 9 and 10, and are hereinafter detailed, though it may be convenient to note at this point that the starting or "unit forward" solenoids are identified as UF1, UF2, UF3, UF4, UF5 and UF6, and the "unit reverse" solenoids as UR1, UR2, UR3, UR4, UR5 and UR6 for the units 1 to 6, respectively. In Fig. 2 is shown the reversing limit switch LS13 for the unit 1 and which is typical of the location of the similar switches, mentioned generally above, for all of the units. This switch LS13 is mounted stationarily adjacent the unit 1 and is a normally open switch. It is closed at the extremity of forward motion of the unit by a dog 39^a adjustably mounted on the side of the latter opposite the valve mechanism. Incidentally, it may be noted here that the similarly located reversing limit switches for the units 2 to 6 are identified in the wiring diagram (Fig. 10) as LS23, LS33, LS43, LS53 and LS63, respectively.

Table indexing mechanism

A reversible electric motor 40 (Fig. 4) is provided for indexing the table 7. This motor is connected through a speed reduction gearing 41, and a worm and worm wheel 42, 43 to a rotatable shaft 44. The latter shaft is connected through an intermittent gearing, designated generally at 45, with a shaft 46, which is in turn connected through bevel gears 47, 48 to the table spindle 9. The intermittent gearing 45 may be of any suitable well-known form and is shown as including a driver arm 49 fixed on the shaft 44 and having a roller 50 journaled on its outer end. The driven element 51 of the intermittent device comprises a disk fixed on the shaft 46 and having four radial slots 52 in its outer face, merged at their inner ends (see Fig. 4^a for a face view of the member 51). Upon each revolution of the shaft 44 the roller 50 enters the outer end of one of the grooves 52, passes down the same and then outward, thus revolving the disk 51 through a quarter-turn. Consequently, each revolution of the shaft 44 advances the shaft 46, and thereby the table 7, through one step of the movement. The ratio of the gears 47, 48 is so chosen, in the present machine, that the table 7 will be moved through one-fourteenth of a complete revolution during each step of its advance.

To locate the table 7 accurately in its various index positions, any suitable locating or locking means may be utilized, and of which a number are well-known in the art. In the present instance, such a mechanism has been shown generally schematically in the form of a locating pin 53 which is projectable vertically into registering ones of a series of fourteen holes 54 corresponding to the various index positions of the table. The pin 53 is pivotally mounted on the outer end of a bell crank lever 55, which is carried by a stationarily mounted pivot pin 56. The arms of the bell crank 55 are bifurcated, and the lower one is pivotally connected to an endwise-movable shifter rod 57.

The rod 57 is shifted endwise in timed relation with the indexing of the table (to raise and lower the pin 53) by means of a barrel cam 58 fixed on the shaft 44. This cam 58 has a peripheral groove 59 in which is received a cam follower roller on a pin 60 journaled in a swinging arm 61. The latter is carried by a pivot 62. The outer end of the arm 61 is received between a pair of collars 63 fixed on the rod 57. The cam groove 59 is contoured so that as the shaft 44 begins to revolve from the position shown in Fig. 4, the arm 61 will swing to the right, thereby freeing the pin 53 from the table 7. As the rotation of the shaft 44 continues, the intermittent gearing mechanism's driver roller 50 engages the driven member 51 just before the pin is freed from the table. The cam groove 59 is contoured so that the pin is retained out of engagement with the table until the step of indexing motion of the latter is almost completed and just before the roller 50 leaves contact with the driven member 51, and thereafter the cam groove 59 is contoured to swing the arm 61 back to the left, and thereby re-engage the pin with the corresponding hole 54 during the completion of the revolution of the shaft 44.

Various means may be provided for insuring accurate location of the table in the precise angular position required. In the present instance the control system is arranged, through switching mechanism hereinafter detailed, to open-circuit

the indexing motor 40 at the completion of the indexing movement of the table and then to "plug" it to insure immediate stoppage. In other words, the motor is, upon stopping, energized for reverse rotation and remains so energized until the instant at which such reverse rotation actually starts and at which time a plugging switch 64 (Fig. 4) opens to de-energize the motor. Plugging switches for the general purpose noted are well known in the art, and the switch 64 has been generally schematically illustrated in Fig. 4. As there shown, it comprises a stationary contact 65 coacting with a movable contact 66 on an arm having a hub 67 loosely journaled on a shaft 68. Frictionally engaging the face of the hub 67 is a disk 69 fixed to the shaft 68. The latter shaft is driven by a belt 70 and pulleys 71 from the motor 40.

As the shaft of the motor 40 revolves in the direction of the arrow 72 in Fig. 4, which is the direction of motor rotation utilized for advancing the table, the movable switch contact 66 is urged into closed position with relation to the stationary contact 65 by the frictional engagement of the disk 69 with the hub 67. When it is desired to stop the motor it is energized for rotation in a reverse direction through a circuit including the plugging switch. Then as soon as the motor begins to revolve in the opposite direction the plugging switch opens and the motor is thus stopped.

A group of five control switches (see Fig. 5) is arranged to be actuated in timed relation with the rotation of the table indexing 40 and, accordingly, the construction of their actuator may conveniently be described at this point since it is driven by the table's indexing mechanism. The actuator comprises a disk 73 (see also Fig. 4) fixed to the outboard end of the motor-driven shaft 44. Fixed at suitable points on this disk, and projecting radially from it are five dogs 74, 75, 76, 77 and 78 which are adapted to actuate respective ones of an adjacent series of switches LS73, LS72, LS74, LS75 and LS71. The dogs are all displaced from each other in a direction axially of the shaft 44 a sufficient amount that the associated switches can be mounted so that only the corresponding dog will engage the actuator of the same as the series of dogs revolves.

As indicated in Fig. 5, the series of switches mentioned just above are all of the form commonly used for limit switches and each embodies swingable actuator arm 79 having a roller on its outer end adapted to be engaged by the corresponding dog, the arms being spring-urged toward the dogs. Of these five switches, all except the switch LS75 have a single set of contacts, and those of all except LS72 are normally open and are closed when the associated dog moves the switch's actuator arm 79. The switch LS72 has normally closed contacts, opened by its dog and the switch LS75, has a pair of alternatively closable contacts 1LS75 and 2LS75 (see Fig. 9). The contacts of the switch LS75 are normally urged to a position in which the contact 1LS75 is closed and the contact 2LS75 opened. The dog 77 engages the actuator arm of the switch LS75 when the shaft 44 is in such angular position that the locating pin 53 is projected upward in engagement with the table 7. Accordingly, the contact 1LS75 is closed at all times when the pin 53 is not in engagement with the table and is open when the pin is properly engaged with the table. As will hereinafter appear, the switch LS75 is used as an interlock to prevent operation of the

units 1 to 6, except when the locating pin 53 is in engagement with the table 7, thus showing that the table is in a properly indexed position. It should be observed that the switch LS75 is actuated by its dog 77 somewhat in advance of the time that the shaft 44 reaches the position shown in Fig. 5 and remains actuated by its dog until the shaft does reach such position. On the other hand, the switch LS73 is closed momentarily by its dog 74 just before the shaft 44 reaches the position shown, but is freed to reopen when the shaft stops in such position. The timing is such as to give an overlap of the operation of switches LS75 and LS73 so that the switch LS73 will be closed coincidentally with contacts 2LS75, and then reopened.

The functions of the other four switches LS71 to LS74 described just above will be more fully developed in connection with the description of the operation of the control system as a whole. It is sufficient for present purposes to note that the switch LS71 is closed by its dog 78 during each indexing movement of the table and serves to pre-set certain interlock contactors for the units. Opening of the switch LS72 by its dog 75 stops the table indexing motor 40. The momentary closure of LS73 by its dog 74 initiates the forward movement of the units, but is connected in series (see Fig. 9) with the contacts 2LS75 of the switch LS75 so that it will only be effective to initiate movement of the units when the locating pin 53 is properly engaged with the table 7. The switch LS74, like the switch LS75, is shifted to closed position by its cooperating dog when the table-locating pin 53 is properly engaged with the table, or in other words, when the table is properly set in one of its indexed positions. The switch LS74 is, however, connected in a different portion of the control circuit (see Fig. 9) from that which includes the switch LS75 and serves, in general, as an interlock which permits movement of the units only when the table is properly positioned, during operation of the units individually, as distinguished from their operation in the course of a program of automatic operation.

Master controller for selection of general type of operation

Provision has been made for conditioning the machine as a whole for various types of operation. In the instant machine, four general types of operation are optionally available to the user, and these are:

- (1) "Automatic cycle" operation.
- (2) "Hand-feed" operation.
- (3) "Unit-feed" operation.
- (4) "Hand index" operation.

A master controller is provided for the machine and has four positions or settings corresponding to the four types of operation noted above. The master controller is housed within the bed 8 and is operable by a four-position hand lever 22 on the front of the machine (see Fig. 2). The controller itself is of conventional construction for such devices and its contacts are shown in development in Fig. 12. As indicated in the latter figure, there are seven bridging contacts B1 to B7, movable as a group, and seven pairs of stationary contact points C1 to C7, said bridging contacts being movable endwise of the set of stationary contacts to the four positions indicated by the legends in Fig. 12 and which correspond to the four types of operation listed for the machine

above. Thus, in the "automatic cycle" position, only the contacts C1 and C2 are closed; in the "hand-feed" position only the contacts C1 and C3 are closed; in the "unit-feed" position only the contacts C4 are closed; and in the "hand index" position only the contacts C5, C6 and C7 are closed. The circuits connected to the contacts C1 to C7 are shown in Figs. 9 and 10 and more fully described hereinafter.

In brief, when the master controller is set in its "automatic cycle" position the machine is conditioned for operation in accordance with a predetermined program which is executed from beginning to end completely automatically by the machine. In the course of this program the table 7 is rotatably indexed through fourteen steps to complete one full revolution, and in each of the fourteen positions thereof certain predetermined ones of the units 1 to 6 are caused to execute their cycles of movement heretofore described, so that their tools operate upon the corresponding portions of the work piece on the table presented to such units. The "hand feed" setting is used when it is desired to have the units repeat their cycles for only some one particular step in the over-all program mentioned just above. In the third, or "unit-feed" type of operation, the drive motors for desired individual ones of the units may be set in operation by corresponding push buttons H to M, inclusive (see Fig. 9), and the units traversed by manipulation of their control levers 34 for the valve mechanisms heretofore noted. In the fourth or "hand index" type of operation the table 7 can be indexed step-by-step through any distance desired without setting in operation any of the units. The last three types of operation are used primarily in setting up the machine for a new work piece. The controls and their operation for effecting all four of these types of operation will appear in detail hereinafter.

Program control for automatic operation

As noted above, when the master controller is in its "automatic cycle" position the machine is adapted to operate throughout a complete program of automatic operation. Also of particular importance in the present invention is the provision of means by which the machine can be readily conditioned to execute any desired one of several such programs of automatic operation. In the exemplary machine, provision is made for two alternately available programs. This makes it possible to arrange one program for carrying out a series of operations on one work piece, and a second program for carrying out either a second series of operations on the same work piece or a second series of operations on a different form of work piece. In this way, wastage of time for "set-up" of the machine is avoided, since with the present arrangement a shift from one program to another entails no more than simply shifting a hand lever, as hereinafter described. It will be appreciated by those skilled in the art that "set-up" time represents not only the cost of highly skilled labor in reconditioning the machine for a different operation, but also loss of output from a very expensive machine tool during the time that it is idle.

In brief, the programing in the present machine is accomplished by means of a cam mechanism driven in timed relation with the indexing of the table 7. For each index step of the table the cam mechanism sets up the controls automatically in such manner that predetermined ones of the units are conditioned for operation.

To make possible more than one program, a corresponding plurality of sets for the cams are provided.

In the exemplary construction, the cam mechanism, and the control switches which it operates, are housed in a casing 81 at the left end of the machine bed 8 (Figs. 1 and 2). The cam mechanism itself (see Figs. 6, 7 and 8) comprises a cam shaft 82 extending longitudinally of the casing and having keyed on it two sets of peripheral cams 83 and 84, respectively, and various groups of these cams from the two sets are separated by suitable spacer collars 85. These two sets of cams are positioned to be used selectively to actuate an associated set of electric control switches comprising switches LS22, LS32, LS42, LS52 and LS62, corresponding to units 2 to 6, respectively, and a group of three additional control switches LS81, LS82 and LS83. No such switch need be provided for unit 1 since the exemplary machine happens to be set up in such a way that this unit participates in each step of both of the available programs, except in the final step of the second program, and in this last step the unit 3 operates alone through the use of a special circuit controlled by the switch LS83, rather than under the control of its usual unit switch LS32, all of the unit switches being cut out of service at such time.

The switches LS22, LS32, LS42, LS52 and LS62 are all normally open switches and have cam followers 86 on their upper ends (see Figs. 7 and 8) which, when thrust downward by the associated cam, close the corresponding switch. Of the other three switches, the switch LS83 is of the same single-contact, normally open type, but the switches LS81 and LS82 are of the double-contact type. Thus, the switch LS81 (see Fig. 10) has two mechanically interconnected alternately closable contacts, 1LS81 and 2LS81, while the switch LS82 also has two alternatively closable contacts 1LS82 and 2LS82 (see Fig. 9). The switches LS81, LS82 and LS83 also have actuators 86, operated by the associated cams. All of the eight switches noted are mounted on a bracket bar 87 (Figs. 6 and 7) within the housing 81. The connections to the various switches, hereinafter detailed, are shown in Figs. 9 and 10 where the cam mechanism associated therewith is also indicated diagrammatically.

Longitudinal shifting of the cam shaft 82, together with a short rocking motion of it, is utilized to condition one or the other of the sets of cams 83 or 84 to operate the associated series of switches. For this purpose, the cam shaft 82 is journaled in a pair of swingable bracket arms 88 fixed on a shifter rod 89, which is mounted for longitudinal as well as rocking movement in bearings 90 in the end walls of the housing 81 (Fig. 6). A hand lever 91, pinned to the rod 89 at 94, is utilized in shifting the rod endwise to one or the other of its two alternative positions. These two alternative positions are defined by a pair of slots 93^a in a bracket 93 (Fig. 6). When the lever 91 is seated in the outermost one of the slots 93^a as shown in Fig. 6, the cams 83 are in operative relation with the switches, and when the lever is pushed to the right, carrying the rod 89 with it, and seated in the other or innermost slot 93^a, the other set of cams 84 is positioned for operation. A locking screw 92 passing through the lever and threaded in a tapped hole in the root of the slot in which the lever is located holds the hand lever releasably in one or the other of the slots 93^a. In

shifting the lever 91 from one slot to the other the screw 92 is released and the lever is pulled upward to free it from the slot, the rod 89 being thereby rocked, thus raising the cams to clear the switch actuators 86 (Fig. 8).

The cam shaft 82 is driven in timed relation with the table 7, and like it, is indexed to fourteen successive rotary positions in making a full revolution. For this purpose, the cam shaft 82 has a gear 95 fixed on one end thereof (Figs. 4 and 6) and meshed with a pinion 96 loosely journaled on the shifter rod 89. This pinion 96 is, in turn, driven from a bevel gear 97 fixed to it and meshed with a bevel gear 98. The latter gear is driven through a jointed shafting 99 (Fig. 4) from a bevel gear 100 meshing with a bevel gear 101 fixed on the table spindle 9.

The cams 83 and 84 are peripherally notched (see Fig. 8) and when a notch thereon is shifted into registry with the actuator roller 86 on the corresponding switch, the latter is permitted to move upward under the urging of its spring bias. On the other hand, when a lobe or projection on the cam contacts the actuator roller, the latter is thrust downward and the switch contacts closed. Each of the sets of cams 83 and 84 is so contoured that for each of their fourteen successive positions certain desired ones of the unit-control switches LS22, LS32, LS42, LS52 and LS62 will be closed. Through the use of control connections hereinafter set forth, the closure of such switches is utilized to condition the corresponding units for operation. The functions of the other three switches LS81, LS82 and LS83 appear hereinafter in connection with the description of operation of the general control system.

Interlocking system

A fairly large number of interlocks are provided at various points throughout the machine to insure its safety of operation. The principal ones of these are outlined in the present section.

First to be noted is the means for insuring full retraction of each of the units or heads 1 to 6 prior to the institution of each indexing step of the table 7. It will be appreciated that since the units have individual propulsion mechanisms, and may be set up to operate at different speeds and through different ranges of travel, that they will ordinarily not be returned to their idle stations coincidentally. Accordingly, it is necessary to interconnect their controls so that all of them must be fully retracted before the table 7 can be indexed. For this purpose a plurality of limit switches LS11, LS21, LS31, LS41, LS51 and LS61 are provided for respective ones of the units 1 to 6 (see Fig. 9). The mounting of the switch LS11 for the unit 1 is typical for all and is shown in Fig. 2. As indicated in the latter figure, the switch is stationarily mounted adjacent the unit and is disposed to be closed by a dog 102 adjustably mounted on the side of the unit's slide 14. Each of these switches embodies, respectively, normally open main contact 1LS11, 1LS21, 1LS31, 1LS41, 1LS51 and 1LS61, as well as a normally closed auxiliary contact 2LS11, 2LS21, 2LS31, 2LS41, 2LS51 and 2LS61 (Fig. 9). Engagement of the dogs 102 with the actuator arms of the respective switches causes the main contacts to close and the auxiliary contacts to open. In Fig. 9 the dogs 102 are indicated as so engaged, which is the condition which prevails when all of the units 1 to 6 are fully retracted and ready to start a cycle. The main contacts are all connected in series with each other so

that all of them must be closed before a circuit can be completed through them for initiating operation of the table's indexing motor 40.

The auxiliary contacts 2LS11, etc., noted above, serve to control corresponding ones of a set of pilot lamps 103 (Fig. 9). These lamps are mounted on a panel 104 (Fig. 2) on the front of the machine. Closure of a push button switch O (Fig. 9) sets up a supply circuit for the lamps and if any one of the auxiliary contacts is closed its corresponding pilot lamp will light, thereby indicating that its unit is not fully retracted. The operator can thereby readily inform himself of the particular unit or units which are not fully retracted at any time and which are therefore holding up indexing of the table.

The second and much important feature of the interlocking system to be noted is the means for insuring that the units programmed for operation in any particular step of the program of automatic operation have, in fact, actually executed their cycles of movement before the table 7 can be indexed to its next position. In other words, the arrangement is such that if, say, units 1 and 4 are programmed for operation at a particular point in a program they must not only be retracted before the table can be advanced a further step, but must have also been fully projected forward prior to their arrival in such retracted position. Moreover, the interlocking for this purpose is such as to accommodate the programming of only selected ones of the whole series of units for participation in particular steps of the program. Upon reflection it will be seen that the latter factor introduces a prime difficulty. In particular, the system cannot be merely such that the units complete an interlocking circuit by closing corresponding series connected limit switches when fully advanced, for, in that case, there would be no way to distinguish between a switch which was unactuated because of failure of a unit to advance, by reason of mechanical difficulty, from one which was unactuated because of failure of the unit to advance by reason of its non-selection for that particular part of the program. These antithetical requirements have been reconciled in the present novel control system, as will more fully appear below.

With the foregoing in view, the control system comprises in addition to the limit switches LS11, LS21, etc., responsive to the movement of the units into their retracted positions, another series of control devices dependent for their operation upon the movement into their advanced positions of the units preselected in the immediately preceding operation of the programming device. In the present instance these additional control devices (see Fig. 10) are in the form of six interlock or timing contactors, T1, T2, T3, T4, T5, T6, provided for the respective units 1 to 6. These contactors have respective main energizing windings TCM1, TCM2, TCM3, TCM4, TCM5 and TCM6, as well as respective auxiliary release windings TC1, TC2, TC3, TC4, TC5 and TC6. Each of the contactors has an endwise-movable armature 105, carrying a plurality of movable contacts in the usual manner for contactors, the armature being normally urged to the right (as view in Fig. 10) by a biasing spring 106. Momentary energization of the contactor's main winding pulls the armature to the left, where it is held in position by a spring-urged mechanical latch 107. Energization of the auxiliary or release winding of the contactor releases the latch, thereby permitting the ar-

mature to snap back to the right, under the urging of its biasing spring 106; to its initial position.

In brief, the control system is such that during each indexing advance of the table 7, the programming mechanism energizes the release windings for the interlock contactors of the particular units preselected for participation in the next step of the program, thus unlatching their interlocking contactors so as to render further operation of the indexing mechanism subject to a relatching operation in response to the movement of the units into their advanced positions. It is, incidentally, the closure of switch LS71 during the indexing of the table by the actuator mechanism therefor heretofore described which sets up the circuits to permit such energization of the release windings at the proper time, the circuits therefor being hereinafter detailed. When the units corresponding to the unlatched interlock contactors reach their points of full advance, the resultant closure of their reversing limit switches (LS13, LS23, LS33, LS43, LS53 and LS63 heretofore described) causes the main windings of the unlatched contactors to be energized, thereby relatching such contactors. In this way the interlock contactors of the selected units for each step in the program are unlatched and then relatched when the corresponding units have been properly advanced. By virtue of this arrangement all of the contactors will be latched in at the end of the step of the program and the control system is so arranged that such a latched-in condition for all of the interlock contactors is a condition precedent to institution of the next succeeding indexing step for the table.

The third feature of the interlocking system to be particularly noted is the means for effecting an emergency retraction of the units in the event that any of them start forward when the table is not properly located in one of its fourteen index positions. For this purpose switches LS14 and LS35 are mounted alongside the units 1 and 3 (Figs. 1 and 2). These are normally open switches and are closed by dogs 108 on the units during the initial portion of the advance movement of the latter. By circuits hereinafter set forth, closure of either of these switches effects an emergency retraction of all of the units if it happens that the contacts 1LS75 of switch LS75 are also closed at the same time. It will be recalled that these contacts 1LS75 are closed whenever the locating pin 53 is not engaged with the table 7. Only two interlock switches LS14 and LS35 are included since one or the other of the units 1 and 3 are utilized in every step of the two programs for which the exemplary machine happens to be set up. Of course, with other program arrangements, additional switches of the same character could be provided on other ones of the units.

Electric control system

The various automatic switches heretofore described are included in an integrated control system. The control system is, in a primary sense, set up for various types of operation by the use of the master controller heretofore noted, and the execution of these various types of operation is in turn instituted or arrested by suitable ones of a set of manually operated push button switches on a panel 109 at the front of the machine (Fig. 2). These push button switches include the following:

A. Master "start" switch.—Momentary actua-

tion of this switch starts the various drive motors 25 to 30 for the several units.

B. Master "stop" switch.—Momentary actuation of this switch stops the entire machine.

C. Automatic "cycle start" switch.—Momentary closure of this switch initiates the automatic cycle of operation for a complete program.

D. "Hand feed" switch.—Momentary closure of this switch institutes the operation of the units for the particular step in the program corresponding to the position of the table so that the machine is caused to execute that one step of the program and then come to rest. This control is used in repeating a particular step in the program, for example, in setting up the machine. The table must have been positioned through the use of the automatic cycle control rather than the hand index control so that the units and table will be in step with each other.

E. "Hand index" switch.—Closure of this hold-down switch causes a step of indexing motion for the table 7 without affecting the units 1 to 6.

F. "Emergency reverse" switch.—Momentary closure of this switch causes all of the units 1 to 6 to be emergency retracted back to their initial or idle positions.

Upon reference to Fig. 2 it will be observed that the control switch panel 109 is located adjacent the signal or pilot lamp panel 104. On this latter panel are not only the set of pilot lamps 103 heretofore noted for indicating the lack of full retraction in particular ones of the units, but also a set of six pilot lamps 110. These latter lamps (see Fig. 10) correspond to the respective units 1 to 6 and are controlled, respectively, by contacts 3T1, 3T2, 3T3, 3T4, 3T5 and 3T6 of the interlock contactors T1 to T6. The contacts noted are open when the corresponding interlock contactors are released, and closed when they are latched in. Consequently, closure of a push button switch N, in the supply circuit for the bank of pilot lamps 110, will cause those lamps to light whose corresponding interlock contactors are latched in, thereby indicating that those units whose lamps do not light have not yet fully executed their forward movements. The push button switches O and N for the sets of pilot lamps 103 and 110 are also mounted on the panel 104 (Fig. 2). A further pilot lamp 114 is mounted on the switch panel 109, and is connected in a portion of the control circuit shown in Fig. 9, in a particular manner which will hereinafter appear, so that it will be lighted whenever the circuits are properly conditioned for institution of an automatic cycle of operation by closure of the "cycle start" push button C.

In the control system of Figs. 9 and 10 current is supplied for all of the motors as well as for the control circuits per se from a common source of current. As there indicated, the drive motors 25 to 30 for the respective units are uni-directional three-phase motors fed from supply lines L1, L2, and L3, while the index motor 40 is shown as a reversible three-phase motor. Current for the control circuits is supplied at a suitable low voltage through a step-down transformer 112 having a primary winding 113 (connected across supply lines L1 and L2) and a secondary winding 114. One terminal of this secondary winding is connected to a low voltage supply line 115 and the other to a line 116 through the "stop" switch B. The line 116 is in turn connected to a supplemental supply line 117 through contact B1 of the master controller. The lines 117 and 118 are continued onto Fig. 10 and the devices shown in the

latter figure are energized by connecting them across these lines.

Suitable relays and contactors are provided in the control system for controlling various portions thereof. Thus, each of the drive motors 25 to 30 (see Fig. 9) is controlled by a corresponding one of a set of motor contactors M1, M2, M3, M4, M5 and M6. The reversible indexing motor 40, on the other hand, has two contactors IMF and IMR associated therewith and which, respectively, connect it for forward and reverse rotation. The "unit forward" solenoids UF1 to UF3, heretofore noted, are included directly in the control circuit (Fig. 9), but the "unit reverse" solenoids UR1 to UR6 (Fig. 10) are energized indirectly through the medium of respective unit reversing relays UTR1 to UTR6. Moreover, the control circuit includes six intermediate relays or contactors, namely, a "master start" relay MS, an "automatic feed" relay AF, a "master feed" relay MF (all shown in Fig. 9), a "hand index" relay HI, an "automatic timing" or interlock contactor ATC, and a "master timing" or interlock contactor MTC (all shown in Fig. 10). In the case of the various motor contactors all of which are shown in Fig. 9, the contacts thereof have been shown as mechanically connected (indicated by broken lines) with the actuating windings therefor. In the case of the other contactors and relays the reference characters for the same have been applied to their actuating windings and their contacts have been shown immediately adjacent the actuating windings. These immediately adjacent contacts are not, however, shown at such point as connected in the circuits but are repeated in the proper points in the circuit. The individual contacts of the various relays and contactors are identified with the reference character for the particular contactor or relay preceded by a digit for the particular set of contacts. Thus, for example, the master start relay MS has contacts 1MS, 2MS, etc., which are shown in the upper right-hand portion of Fig. 9 immediately adjacent the actuating winding of the relay and repeated at their proper points in the circuit.

Résumé of programed automatic operation

As a preliminary to programed automatic operation of the machine, the following initial settings of the machine elements and controls must be made:

(a) The master controller lever 22 (Fig. 2) is shifted to its "automatic cycle" position (Fig. 12), thereby closing controller contacts C1 and C2, while leaving C3 to C7 open. In the wiring diagrams of Figs. 9 and 10 these various contacts of the main controller have been shown in such condition.

(b) The program selector lever 91 (Fig. 6) is moved, to condition for operation, a selected one of the alternatively available sets of cams 83, 84. It will be assumed in the succeeding description of the machine that the set of cams 83 is the one first conditioned for operation. The program chart constituting Fig. 11 designates the various ones of the cam-operated switches which are closed in successive steps of the first and second programs, corresponding respectively to the two sets of cams 83 and 84. As appears in the first column of the chart of Fig. 11, the table 7 has fourteen index positions and is finally returned to the fourteenth position as its final rest position. In each of the resultant fifteen rest positions of the table in making a complete revolution (the first and last of which are the same),

fifteen different "operations" are performed (see second column in the chart) by the various designated units. A black square in the chart indicates that the corresponding switch is closed and a white square that it is open.

(c) The units 1 to 6 must all be returned to their fully retracted positions, in which event the main contacts of the switches LS11, LS21, LS31, LS41, LS51, LS61 are all closed.

(d) The table 7 must be positioned in its proper starting position, that is, the location corresponding to position No. 14 in the chart of Fig. 11. In such case, the switch LS71 (Fig. 10) will have been closed momentarily in advancing the table to such position and, assuming current to be available in the supply lines, the master timing contactor MTC will also have been momentarily energized (being connected across lines 116, 117 through switch LS71) and will have momentarily closed its contacts 1MTC. Closure of these contacts will have momentarily completed energizing circuits for the release coils of timing contactors T1, T2 and T4. Thus, release winding TC1 will have been connected across lines 116, 117 through contacts 1MTC; release winding TC2 will have been connected across these lines through contacts 1MTC and switch LS22; and release winding TC4 will have been connected across the lines noted through contacts 1MTC and switch LS42. Consequently, the interlock contactors T1, T2 and T4 are unlatched preparatory to the first step of cycle in the program.

Having preliminarily conditioned the machine for automatic operation through its first program as noted above, the operator starts the various unit drive motors 25 to 30 by momentarily closing the "start" push button switch A (Fig. 9). Such momentary closure of this push button switch energizes the main starting relay MS (through a circuit 115-B1-M-L-K-J-I-H-118-A-119-MS-116-B) so that this relay closes all of its eight normally open sets of contacts. Of these 1MS closes in shunt with the push button switch A so that the relay is sealed in, contacts 2MS to 7MS connect the actuating windings of the respective motor contactors M1 to M6 across the lines 116, 117 so that these latter contactors are all pulled in and set their respective motors 25 to 30 running, and contacts 8MS close to preliminarily set up a portion of the energizing circuit for the indexing motor's contactors, though such circuits are not completed at this time. With the unit drive motors thus running, and the machine preliminarily conditioned as described, the pilot lamp 111 will be lighted, apprising the operator of the fact that the machine is ready for institution of its programed automatic operation.

To initiate the automatic operation of the machine, the operator momentarily closes the "cycle start" push button switch C, thereby energizing the automatic feed relay AF by connecting it across lines 115, 116 (through 115-LS61-LS51-LS41-LS31-LS21-LS11-C-AF-5T3-2LS82-116). Thereupon, this relay momentarily closes its contacts 1AF, whereby the "unit forward" solenoids UF1, UF2 and UF4 for units 1, 2 and 4 are correspondingly momentarily energized. Thus, closure of these contacts 1AF connects a supply line 120 (which is connected to 119 and thence back through 1MS, 118, H to M, and B1 to line 115) to a line 121. The "unit forward" solenoids UF1, UF2, UF4 and UF5 are connected between this line 121 and line 116 through their respective interlock contactor contacts 1T1,

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1T2, 1T4 and 1T5. Of these latter contacts 1T1, 1T2 and 1T4 are closed, in the present instance, due to the energization of their respective release coils as heretofore noted, so that momentary closure of contacts 1AF effects a resultant energization of solenoids UF1, UF2 and UF4.

As was heretofore pointed out, the momentary energization of the "unit forward" solenoid of any of the units throws its associated valve mechanism into a position to effect a rapid advance of the unit. Accordingly, the energization of solenoids UF1, UF2 and UF4 causes the corresponding units 1, 2 and 4 to start a rapid approach movement. As this movement progresses, the dogs 37 therefor (see Fig. 3) actuate the corresponding plungers 36 so that their valve mechanisms are shifted to a "feed" position and the rate of advance of the units is diminished to a slow feed rate. During this slow feed advance of the units 1, 2 and 4, their tools operate upon the work piece. At the conclusion of the advancing or feed movements of the units 1, 2 and 4, the dogs 39 thereon trip their corresponding "reverse" limit switches LS13, LS23 and LS43 (Fig. 10), closing the same. Closure of these three switches serves respectively to connect the relays UTR1, UTR2, and UTR4 across the lines 116, 117, thereby picking up these relays. Each of these relays has two normally open contacts, the first of which serves to close an energizing circuit for the respective "unit reverse" solenoid, and the other of which serves to complete an energizing circuit for the main winding of the corresponding interlock contact to latch it in. Thus, for example, closure of contacts 1UTR1 connects the solenoid UR1 across lines 116, 117 to energize it, and closure of contacts 2UTR1 connects winding TCM1 across lines 116, 117 to energize the latter winding and thereby latch in the interlock contactor T1. In this way, the reversing solenoids UR1, UR2 and UR4 for the three operative units are actuated to shift the valve mechanism therefor to their rapid return positions and at the same time the interlock contactors T1, T2 and T4 therefor are relatched for the interlocking purpose heretofore described. It will be understood that as soon as the units actually reverse, they release their switches LS13, LS23 and LS43 so that the latter reopen and drop out the relays UTR1, UTR2 and UTR4. That is as it should be, however, since these relays have already done their work at that time and the circuits are thus conditioned for subsequent operation.

As each of the units 1, 2 and 4 finally reaches its initial or retracted position, it is stopped by engagement of its corresponding dog 38 with the valve plunger 36 which shifts the valve mechanism to its neutral or stop position. At the same time, the dogs 102 of the respective units close their corresponding unit interlock switches LS11, LS21 and LS41.

When all three of the units have been restored in this manner to their initial positions, the series of switches LS11, LS21, LS31, LS41, LS51 and LS61 will all have their main contacts closed (Fig. 9) and, furthermore, all of the interlock contactors T1 to T6 will be latched in. With the circuits in the latter condition, the index motor 40 for the table 7 is automatically started. In particular, its "forward" contactor IMF is connected across lines 115, 116 (through a circuit 115-LS61-LS51-LS41-LS31-LS21-LS11-122-B2-2T1-2T2-2T3-2T4-2T5-2T6-IMF-116). Observe that the series of

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contacts 2T1 to 2T6 in the latter circuit makes it imperative that all of the interlock contactors T1 to T6 be properly latched in, as heretofore noted, before the circuit can be completed to start the index motor, and that the inclusion of the unit switches makes it imperative that all units be fully retracted. Such energization of the "forward" contactor IMF for the index motor 40 picks up its main contacts, which connect the motor to the supply lines for forward rotation of the motor, and in addition opens the contactor's auxiliary contacts 1IMF and closes the auxiliary contacts 2IMF. The opening of the contacts 1IMF prevents energization of the "reverse" contactor IMR when the plugging switch 64 closes during the forward rotation of the index motor; the initial open condition of this plugging switch having prevented previous energization of the "reverse" contactor IMR.

As the table 7 indexes, the switch LS72 is freed by its dog 75 (see Fig. 5) and thereupon closes so that a circuit is completed through this switch and the contacts 2IMF in shunt with the series of contacts 2T1 to 2T6, with the result that the "forward" contactor IMF is retained energized through this shunt circuit even though some of the interlock contactors are unlatched, as they are, in anticipation of the next step in the program.

Upon completion of the indexing movement of the table 7, the switch LS72 is engaged by its dog 75 and opens. This deenergizes the "forward" contactor IMF, whereupon the contacts 1IMF close. Accordingly, the "reverse" contactor IMR is energized, being connected between lines 116 and 117 through SMS, 1IMF and the plugging switch 64. As soon as the index motor 40 starts to revolve in a reverse direction, however, the plugging switch 64 opens automatically in the manner heretofore described, whereupon the "reverse" contactor IMR drops out and the index motor is at a standstill.

In the course of the indexing of the table the circuits are preliminarily set up for the institution of unit movement in the next step of the program. Before detailing this operation it should be noted that the first step of the program was initiated as described before by energization of the relay AF. As will appear below, the subsequent steps in the program are initiated, not through this relay, but through the medium of the relay MF. This shift from one intermediate relay to the other is accomplished by the cam-operated switch LS82. As shown in the program chart of Fig. 11, the contacts 1LS82 of this switch are open during the first step of the program and closed during the subsequent steps, while its contacts 2LS82 are closed during the first step and open during the subsequent steps, being reclosed at completion of the program. The contacts 1LS82 connect in the relay MF and the alternatively closable contacts 2LS82 connect in the other relay AF. Such a switching arrangement, that is, the alternate use of these relays AF and MF in the manner noted, introduces a desirable safety feature in the system, in that an inadvertent or inadvised closure of the "cycle start" push button C during the automatic operation of the machine cannot cause it to recycle, since the circuit of the relay AF (in series with which the push button C is connected) is retained open by the contacts 2LS82. At the completion of the program, however, the opening of contacts 1LS82 drops out the relay MF and the closure of contacts 2LS82 restores

the relay AF to its initial condition in the system for the initiation of another program when desired.

As to the particulars of the switching operations which take place automatically during the indexing of the table, it will be recalled that the cam shaft 82 is indexed in unison with the table. Hence, the cam shaft is turned from its first to its second position during the first index of the table, whereupon cam-operated switches LS22 and LS42, which are closed during the first step of the program, are opened, as indicated in the program chart in Fig. 11. This is done since only unit 1 is scheduled to participate in the second step of the program. Furthermore, as the table indexes, the switch LS71 closes momentarily, being actuated by its dog 73 (see Fig. 5) as before. The closure of the switch LS71 momentarily energizes the master timing contactor MTC, but this time only the interlock contactor T1 will be released, since all of the cam-operated switches controlling the other interlock contactors are now open. In this way, the unit 1, which is the only one scheduled for the second step in the program, is conditioned for operation.

At the conclusion of the indexing of the table, the operation of unit 1 is instituted for the second step in the program. For this purpose the switch LS73 is closed momentarily by its dog 74 (see Fig. 5) after shaft 44 has turned far enough to index the table and just before it has completed a full revolution. At the same time, if the locating pin 53 has been properly engaged with the table, the contacts 2LS75 of the dog operated switch 2LS75 will also be closed. Thereupon, an energizing circuit for the master feed contactor MF (Fig. 9) is momentarily completed (through LS73, 2LS75 and 1LS82). When this relay is thus picked up, it closes its four sets of contacts 1MF, 2MF, 3MF and 4MF. Of these, 1MF are relay contacts in shunt with the switches LS73 and 2LS75 so that the relay MF will remain energized even though switch LS73 reopens before the index shaft 44 completes a full revolution; contacts 3MF and 4MF are associated with the starting circuits for units 3 and 6, and hence perform no useful function during the second step in the program in which these particular units are not included; and contacts 2MF complete an energizing circuit for the "unit forward" solenoid UFI for unit 1.

The operation of unit 1 having been instituted in this manner it proceeds to execute its cycle of movement in the same manner heretofore described. As soon as the unit starts forward it releases its switch LS11 so that contacts 1LS11 of the latter open and drop out the relay MF. When unit 1 reaches its forward limit of movement, its interlock contactor T1 is relatched in the same manner heretofore described in the first step of the program, and at the completion of the cycle of unit movement the unit is stopped by dog-operation of its valve mechanism and its unit switch LS11 is reclosed, whereby to complete a starting circuit for the indexing motor 40. Then this latter motor indexes the table 7 through its next step of movement and it is automatically stopped in the manner previously described; and during this indexing motion the switching system is conditioned for the next succeeding step in the program.

The machine proceeds automatically to execute the subsequent steps in the program in substantially the same manner with an indexing

advance of the table between each step. The program chart in Fig. 11 indicates the units, in addition to the unit 1, which participate in each particular step, the unit 1 being omitted from the chart since it is included in all steps in the first program. In particular, the units 1 and 2 participate in the third step of the program, the unit 1 alone in the fourth step, the units 1 and 2 in the fifth step, the unit 1 alone in the sixth step, the units 1 and 2 in the seventh step, the unit 1 alone in the eighth step, the units 1 and 2 in the ninth step, the unit 1 alone in the tenth step, the units 1 and 2 in the eleventh step, the unit 1 alone in the twelfth step, the units 1 and 2 in the thirteenth step, and the unit 1 alone in the fourteenth step.

At the conclusion of the fourteenth step, the unit 1 is, of course, retracted to its initial position and the table 7 automatically indexed to its first or initial position to complete a full revolution. During this last index step of the table, the cam-operated switch LS82 is thrown so that its contacts 1LS82 are opened and its contacts 2LS82 closed (see chart in Fig. 11). Consequently, the relay MF is dropped out, thereby preventing inadvertent recycling of the machine, and the closing of the contacts 2LS82 lights the pilot lamp 111 and conditions the circuit of the relay AF for subsequent completion by closure of the push button switch C to institute another complete program when desired. It will thus be seen that the machine comes to rest with all of its control devices in their initial condition.

The same program described above can be repeated on another work piece in the same manner described, if desired, or the machine can be run through its second program to operate on the same or a different work piece.

To condition the machine for the second program, the operator has only to shift the lever 91 (Fig. 6) to the right so as to bring into play the alternative set of switch operating cams 84. Having thus conditioned the machine for operation through its second program, the automatic operation is instituted as before simply by a momentary closure of the "cycle start" push button switch C (Fig. 9). Thereupon, the machine will proceed to operate through the second program, outlined in the chart constituting Fig. 11, in substantially the same manner as for the first program, except for the last step. In particular, during the second program the units 1, 2 and 4 participate in the first step, the unit 1 alone in the second step, the units 1, 2, 3 and 5 in the third step, the unit 1 alone in the fourth step, the units 1, 2 and 3 in the fifth step, unit 1 alone in the sixth step, the units 1, 2 and 3 in the seventh step, the unit 1 alone in the eighth step, the units 1, 2 and 3 in the ninth step, the unit 1 alone in the tenth step, the units 1, 2, 3 and 6 in the eleventh step, the unit 1 alone in the twelfth step, the units 1, 2, 3 and 6 in the thirteenth step and the unit 1 alone in the fourteenth step.

After the operation of unit 1 is completed in the fourteenth step of the second program, as noted above, the table 7 is indexed automatically to its initial or starting position. As in the case of the first program, the switch LS81 is actuated so that the relay MF is dropped out and the relay AF conditioned to start a new program. In the case of the second program, however, it is desired to have the unit 3 operate on the work piece after the table has thus been returned to its initial or starting position. Such operation poses a diffi-

culty, since the relay MF, which normally effects operation of the units in the steps after the first step in a program, has been dropped out and must be dropped out to prevent inadvertent recycling. It is to overcome this difficulty, and make possible the operation of a unit after the table has been indexed a full revolution, that the cam-operated switch LS83 is utilized. Upon reference to the program chart Fig. 11, it will be seen that this latter switch is closed only during the second program and then only when the table is in its starting or No. 14 position.

Closure of the switch LS83 (Fig. 9) sets up an energizing circuit for the "unit forward" solenoid UF3 for the unit 3, which is independent of the contacts of the relay MF. In particular, the solenoid UF3 is connected from the supply line 116, through the interlock contactor contacts 1T3 (this contactor having been unlatched during the preceding indexing step of the table) and thence through switch LS83, switch contacts 2LS75 and switch LS73 to the line 117. It will be recalled that the switch contacts 2LS75 are closed only when the locating pin 53 is properly engaged with the table, thereby indicating that the table is properly positioned and that switch LS73 is momentarily closed by the table indexing or drive mechanism's shaft 44 to normally institute operation of a selected unit or units. At the completion of the forward movement of the unit which results from the energization of its "unit forward" solenoid UF3, the interlock contactor T3 is unlatched, in the manner heretofore described, so that its contactors 1T3 open and de-energize the solenoid UF3, in addition to energizing the reversing relay UTR3 (Fig. 10) in the manner heretofore described. At the completion of the retraction movement for unit 3, the dog operation of its valve mechanism stops the same and the machine is thus at rest in its initial condition.

Attention should be given at this point to the arrangement by means of which it is possible to cause the unit 3 to operate, as described just above, when the table returns to its final or initial position, and yet participation of unit 3 in the first step of the second program is prevented. In other words, the second program presents this dilemma: Only units 1, 2 and 4 are to participate in the first step of this program, when the table is in its initial position, and yet during the second time that the table is again in this initial position (i. e., at the end of the program) only the unit 3 is operated. It was pointed out above that the relay MF is dropped out and the switch LS83 used to condition for operation the unit or units (in the present instance only the unit 3) which are to operate when the table is in its initial position for the second time. Upon the institution of the second program of operation, the unit 3 is excluded from participation by virtue of the fact that this first step of the program is initiated through the medium of the relay AF, and the contacts 1AF of this relay do not set up a circuit for the "unit forward" solenoid UF3 for unit 3 (Fig. 9).

It will be observed upon reference to Fig. 9 that the interlock contactor T3 for unit 3 has an extra pair of contacts 5T3 in series with the lamp 111 and "cycle start" switch C. These contacts are open when the contactor T3 is unlatched and, hence, disable the machine against institution of a new cycle, by closure of the switch C while unit 3 is moving forwardly during its special operation at the end of the second program.

The machine can be stopped at will during either of the foregoing programs of automatic operation simply by momentarily opening the "stop" push button switch B (Fig. 9). This switch is normally closed and is interposed in the control supply line 116. Since all of the contactors, relays and solenoids are supplied through this line 116, opening of it will drop all of them out, thereby stopping all of the motors 25 to 30 and 40. The propulsion mechanisms for the various units will stop, irrespective of the positions of their control valves, since the motors 25 to 30 supply pressure fluid for them.

In the foregoing description of automatic operation, it was assumed that the various units properly executed their corresponding cycles so that the interlock mechanisms were not compelled to interrupt the operation. It will be appreciated, however, that if any of the units had failed to move forward fully, their interlock contactors T1 to T6 would have failed to be latched in, and consequently one of the series of contacts 2T1 to 2T6 would have been open, thereby preventing the next indexing step of the table. Upon such a failure of the table to index, the operator should close the push button switch N (Fig. 10) and the pilot lamps 113 would thereupon indicate which one of the units was at fault. Similarly, if any of the units fail fully to retract, the main contacts of the corresponding one of the series of switches LS11, LS21, LS31, LS41, LS51, LS61 would be open so that, again, the table would not index. In such event, the operator should close the push button switch O (Fig. 9) whereupon the pilot lamps 113 will indicate which one of the units is at fault.

Finally, if any of the units should start forward before the table 7 is properly positioned, the closure of one or the other of the switches LS14 or LS35 would cause an emergency retraction of all of the units. It will be recalled that these latter switches are closed, respectively, by the corresponding dogs on units 1 and 3 and that one or the other of these units participates in each step of both programs. These switches (Fig. 9) are connected in series with the switch contacts 1LS75 which, it will be recalled, are closed whenever the table is not positioned by its locating pin 53 in one of its proper index positions. Accordingly, if switch LS14 or LS35 is closed coincidentally with contacts 1LS75, the "emergency retract" relay ER will be connected across lines 116, 117 and energized. This relay has contacts 1ER, 2ER, 3ER, 4ER, 5ER, 6ER (Fig. 10) connected in series with respective ones of the "unit reverse" solenoids UR1 to UR6. Consequently, energization of the relay ER causes all of these reversing solenoids to be energized, whereupon the units are each set for reverse operation as heretofore noted. The provision of this safety interlock for retracting the units under the conditions noted is especially desirable here, since to speed up machine operation the switch LS73 for instituting unit forward motion is, as heretofore noted, closed momentarily after the table has indexed but before the index mechanism has actually stopped. Hence, no danger can arise even if the index drive mechanism should inadvertently overrun and shift the table after the units had started, for the latter would be retracted by the action of switches LS14 and LS35, just described. In this connection it will be observed that only about one hundred and twenty degrees of the rotation of the index shaft 44 is used in indexing the table and the remaining two

hundred and forty degrees of each revolution of this shaft used to operate switches. Though this is convenient, especially with a large number of switches, it does make desirable an interlock of the type just noted.

The "emergency retract" relay ER can also be energized at will by manual closure of the push button switch F (Fig. 9). Such energization of this relay always causes emergency retraction of all of the units in the manner just described above in connection with their automatic retraction under the control of switches LS14 and LS35.

Hand feed operation of machine

The "hand feed" operation of the machine is of a type which may be termed semi-automatic in character, and is used to effect a repetition of the operation of the units in a desired step of the program. Such a control is, of course, especially useful in the "set-up" of the machine for a new type of work piece. In using this so-called "hand feed" the table must have been indexed to the desired position by the "automatic cycle" operation of the machine and then stopped by switch B (rather than having been positioned by use of the "hand index" control) so that the unit-selection portion of the circuit will be properly set up for the selected table position. With the master controller lever 22 (Fig. 2) thrown to its "hand feed" position, the machine is conditioned so that a momentary closure of the "hand feed" push button D will cause those units to execute their automatic cycles of operation which are programmed for operation in the particular position in which the table 7 has been located by interrupting an automatic cycle of operation at a desired point. Thus, if the table has been shifted as noted into its No. 3 position (chart Fig. 11) for the first program, units 1 and 2 will be conditioned to execute their cycles of movement upon closing the "hand feed" switch D, but at the completion of the same no indexing of the table will take place, as contrasted with the operation heretofore described during automatic programming. This "hand feed" style of control can be used for any position of the table except its first or initial position, the circuits being such as to exclude operation of the units by the switch D when the table is in that position.

When the master controller is thrown to "hand feed" position its contacts C1 remain closed just as in the "automatic cycle" position, but its contacts C2 are opened and its contacts C3 closed (Fig. 12). The contacts C1 are retained closed so that closure of the "main start" switch A will start all of the unit motors 25 to 30 just as before (Fig. 9). The controller contacts C2 are opened to cut the index motor 40 out of service; and the controller contacts C3 are closed to put the "hand feed" switch in service.

Upon reference to Fig. 9 it will be observed that the switch D is connected in a branch circuit between the master feed relay MF and line 115, which branch circuit includes a group of interlock contactor contacts 4T1 to 4T6 (all in parallel with each other) the master controller contacts C3 and the series of unit limit switches LS11, LS21, etc. This branch circuit is, in effect, in shunt with the switch LS73 that was used in the "automatic cycle" operation to energize the relay MF to institute unit movement in all steps of the automatic program except the first. Accordingly, momentary closure of the push button switch D, during the "hand feed" operation is used, instead

of LS73, to pick up the relay MF. It will thus be clear that whenever the switch D is momentarily closed the relay MF will pick up, seal itself in, and cause energization of the "unit forward" solenoids for the units (preselected by the unlatching of their contactors T1 to T6 as the table shifted into the position which it happens to occupy). Thereafter these units automatically execute their individual cycles just as before. Recycling is prevented since the relay MF drops out as soon as one of the units starts forward and opens its corresponding one of the series of switches LS11, LS21, etc. The index motor has been cut out of service by opening of the controller contacts C2 as heretofore noted, so when the units come back to their initial position they remain there and nothing further happens until the operator again presses the switch D, whereupon the same units will again repeat their same cycles of movement. This can be done over and over again in adjusting them for some particular step in the program.

Individual unit feed operation

When the master controller is shifted to its third or "unit feed" position, the various units can be operated individually with manual control thereof. In this position of the controller only its contacts C4 are closed (Figs. 9 and 12). These contacts connect line 115, through the interlock switch LS74, to a group of push button switches H to M corresponding, respectively, to the several units 1 to 6. Accordingly, closing any one of these switches picks up its corresponding motor contactor M1 to M6 and starts the one of the motors 25 to 30 for the associated unit. The motor can, of course, be stopped at any time by reopening the corresponding one of the push button switches H to M.

When the motor of a desired one of the units has been started as described above, the hydraulic propulsion mechanism of the unit can be controlled by the hand lever 34 (Fig. 3) on its valve mechanism to move the unit to and fro as desired. Since, as heretofore noted, the switch LS74 is only closed when the table 7 is properly positioned in one of its several index positions, such manually controlled operation of the units can only be utilized when the table is safely and properly positioned.

Hand index

The "hand index" operation of the present machine is arranged to make possible indexing of the table 7 without operating any of the units 1 to 6. Preferably, the arrangement is such that the institution of hand indexing serves automatically, as below described, to cut out of service the programming controls for the various units, and in the present instance, this is accomplished by automatically unlatching all of the interlock contactors T1 to T6. This disabling of the program controls during the "hand index" operation makes it possible to use the "unit feed" control freely in various positions of the table to which it is hand indexed, and as the units are moved by "unit feed," any resultant operation of the limit switches, etc., will not disorganize the set-up for later "automatic cycle" operation. One result of the unlatching of the interlock contactors T1 to T6 by the "hand index" operation is, however, that all of their contacts 4T1 to 4T6, in series with the "hand feed" switch D are opened (Fig. 9) so that the latter switch is disabled. It is for this reason, as heretofore noted, that for a "hand feed"

operation the table must be moved to a desired position by the use of the "automatic cycle" controls and not by the use of the "hand index" controls.

Although the "hand index" operation of the machine does result in unlatching all of the interlock contactors T1 to T6, thereby disabling the program system, provision is made for restoring the program controls to their proper condition for institution of a program of automatic operation when the table 7 is indexed into what is its initial position for such a program. In particular, the automatic timing contactor or relay ATC (Fig. 10) is arranged in a manner detailed below to be cut into service during hand indexing, when the table is indexed from its next to last position to its initial position, and this contactor ATC serves to latch in the ones of the interlock contactors T1 to T6 which correspond to the non-participating units for the first step of the program. Consequently, the machine comes to rest after the hand indexing with the table in its initial position and with the interlock contactors for only the units which are to participate in the first step of the program unlatched.

Turning now to the details of the circuits utilized during "hand indexing" operation (Figs. 9 and 10), the master controller is shifted to its "hand indexing" position, thereby closing contacts C5, C6 and C7 and opening contacts C1 to C4 (see Fig. 12). Upon reference to Fig. 9 it will be seen that the contacts C5 and C6 are interposed in the circuit of the "forward" contactor IMF of the index motor 40, and upon reference to Fig. 10 that the controller contacts C7 are included in the circuit of the hand index relay HI. Upon closure of the "hand index" push button switch E (Fig. 10), the relay HI is energized through contacts 1LS81 of the switch LS81. When the relay HI thus picks up, it closes its contacts 1HI (Fig. 9) to energize the index motor contactor IMF and also closes its contacts 2HI to 7HI (Fig. 10) to energize the release windings TC1 to TC6 of the interlock contactors T1 to T6, the latter being connected between line 116 and a line 121. The interlock contactors are thus all released to disable the program controls, and the index motor 40 is energized for rotation in a forward direction. The index motor is retained energized in this manner so long as the switch E is held closed, so that the table is rotatably indexed step by step. Finally, when the table reaches its position No. 13 (chart Fig. 11) the switch LS81 is shifted so that its contacts 1LS81 open and its contacts 2LS81 close. Such shifting of the switch LS81 drops out the relay HI and picks up the contactor or relay ATC. Energization of this latter contactor causes it to close its contacts 1ATC (Fig. 9) in shunt with the contacts 1HI to retain the index motor 40 energized and to close its contacts 2ATC, 3ATC and 4ATC for energizing, respectively, the main windings TCM3, TCM5 and TCM6 of the interlock contactors TC3, TC5 and TC6 to latch the latter in. Consequently, when the table 7 reaches its No. 14, or initial, position, the interlock contactors T1 to T6 will be set up as they should be for subsequent institution of an automatic cycle. In other words, only the contactors for the units 1, 2 and 4, which are scheduled to participate in the first step of the program, are unlatched.

From the foregoing it will be clear that the table can be revolved as many times as desired with the use of the "hand index" control, but that whenever it is located in what is its initial position for the automatic cycle, the program control

portion of the circuits will be properly conditioned for institution of the latter type of operation.

I claim as my invention:

1. In a multiple station machine of the character set forth, the combination with indexible work positioning means, a plurality of tool units reciprocable toward and from the work, and a control system including a programming mechanism governing the operation of said units selectively in successive operating cycles in timed relation to the advance of the work by said positioning means, said positioning means including an actuator, and said control system further including a pair of control devices for each of said units, one operative to detect the advance of the unit into engagement with the work and the other to detect its retraction from the work, the control devices of the several units coacting with said programming mechanism to prevent operation of said actuator in the event of failure of performance of any of the units preselected for operation by the programming mechanism in the preceding cycle.

2. A machine tool comprising, in combination, a work support and a tool support, first power actuated means for indexing one of said supports and a second power actuated means for effecting a cyclic relative movement between said supports including advance and retraction of said supports relative to each other, first and second switches, means for closing said first switch in response to completion of a predetermined relative advance of said supports by said second power actuated means, means for closing said second switch in response to completion of a predetermined relative retraction of said supports by said second power actuated means, a control circuit including both of said switches, and means for automatically instituting indexing of said one support by said first power actuated means in response to completion of said control circuit by closure of both of said switches.

3. A machine tool comprising, in combination, a work support and a tool support; a first power actuated means for indexing one of said supports and a second power actuated means for effecting a cyclic relative movement between said supports including advance and retraction of said supports relative to each other; an interlock contactor having a main winding, an armature shiftable in response to energization of said main winding, means for mechanically latching said armature in the position to which it is shifted in response to energization of said main winding, a release winding operable upon energization thereof to release said latch, and means for normally urging said armature out of latched position; control means for initially energizing said release winding to unlatch said armature; means responsive to the completion of a predetermined relative advance of said supports toward each other for momentarily energizing said main winding to relatch said armature; means operable in response to completion of a predetermined relative retracting movement of said supports to initiate operation of said first power actuated means to index said one support; and means for preventing operation of the last-mentioned means except when said armature is in its latched position.

4. A machine tool comprising, in combination, a work support and a tool support; a first power actuated means for indexing one of said supports and a second power actuated means for effecting a cyclic relative movement between said supports including advance and retraction of said supports with relation to each other; an interlock contactor

having a main winding, an armature shiftable in response to energization of said main winding, means for mechanically latching said armature in the position to which it is shifted in response to energization of said main winding, a release winding operable upon energization thereto to release said latch, and means for normally urging said armature out of latched position; control means for initially energizing said release winding to unlatch said armature; means responsive to the completion of a predetermined relative advance of said supports toward each other for momentarily energizing said main winding to relatch said armature; a control switch and means for closing the same in response to completion of a predetermined relative retracting movement of said supports; and means operable to initiate operation of said first power actuated means only when the said switch is closed and said armature in latched position.

5. A machine tool comprising, in combination, a work support, a first power actuated work indexing means, a plurality of tool supports, a second power actuated means for moving said tool supports individually in cycles of movement therefor from retracted initial positions toward the work support and back to such initial positions, a manually operable starting device, program control means for causing said first power actuated means to index said work step-by-step through a predetermined series of steps with a dwell between successive steps and for causing said second power actuated means to move predetermined ones of said tool supports through their individual cycles of movement during each dwell of the work, all in response to a single initial actuation of said starting device, an electrical control circuit for said first power actuated means, said first power actuated means being operable only upon a completion of said control circuit, a plurality of normally open switches interposed in said control circuit, one for each tool support, means for closing said switches when the corresponding tool supports are in their initial positions, a second series of switches interposed in said control circuit, one for each tool support, means operable automatically during each indexing step of said work for opening only those ones of said second series of switches which correspond to the tool supports that are scheduled to participate in the next succeeding operation, and means operable automatically in response to completion of the advancing movement of the participating tool supports for closing their corresponding ones of said second series of switches.

6. A machine tool comprising, in combination, a work support, a first power actuated work indexing means, a plurality of tool supports, second power actuated means for moving said tool supports individually in cycles of movement therefor from retracted initial positions toward the work support and back to such initial positions, a manually operable starting device, program control means for causing said first power actuated means to index said work step-by-step through a predetermined series of steps with a dwell between successive steps and for causing said second power actuated means to move predetermined ones of said tool supports through their individual cycles of movement during each dwell of the work, all in response to a single actuation of said starting device, an electrical control circuit for said first power actuated means, said first power actuated means being operable upon the completion of said control circuit, a plurality of

interlock contactors, one for each tool support, each of said contactors including a main winding, an armature shiftable in response to energization of said main winding, means for mechanically latching said armature in the position to which it is shifted in response to energization of said main winding, a release winding operable upon energization thereof to release said latch, means for momentarily urging said armature out of its latched position, means operable automatically during each index of said work for momentarily energizing the release windings of the interlock contactors of only those tool supports scheduled for operation during the next succeeding dwell of said work, means responsive to the completion of predetermined advancing movements of said tool supports for relatching the armatures of their respective interlock contactors, and means for preventing institution of the next step of indexing of said work until all of said contactor armatures have been latched.

7. A machine tool comprising, in combination, a work support, a first power actuated work indexing means, a plurality of tool supports, second power actuated means for moving said tool supports individually in cycles of movement from retracted initial positions therefor toward the work support and back to such initial positions, a manually operable starting device, program control means for causing said first power actuated means to index said work step-by-step through a predetermined series of steps with a dwell between successive steps and for causing said second power actuated means to move predetermined ones of said tool supports through their individual cycles of movement during each dwell of the work, all in response to a single actuation of said starting device, an electrical control circuit for said first power actuated means, said first power actuated means being operable only upon completion of said control circuit, a plurality of interlock contactors, one for each tool support, each of said contactors including a main winding, an armature shiftable in response to energization of said main winding, means for mechanically latching said armature in the position to which it is shifted in response to energization of said main winding, a release winding operable upon energization thereof to release said latch, and means for normally urging said armature out of latched position, means operable automatically during each index of said work for momentarily energizing the release windings of the interlock contactors of only those tool supports scheduled for operation during the next succeeding dwell, means responsive to the completion of predetermined advancing movements of said tool supports for relatching the armatures of their respective interlock contactors, a series of control switches associated with respective ones of said tool supports and arranged to be closed by them only when the tool supports are in their initial positions, and means for initiating the next succeeding step of indexing of said work in response to closure of all of said switches plus latching of all of said contactor armatures.

8. In a machine tool, the combination of a work support and a tool support, means for indexing the work relative to the tool support, power actuated means for effecting a cycle of relative advancing and retracting movement between said supports, and means for causing said power actuated means to interrupt said cycle and effect automatically an emergency relative retraction movement between said supports upon the in-

stitution of a relative advance movement thereof when the work is not precisely located in one of its index positions.

9. In a machine tool, the combination of a work support and a tool support, means for indexing the work with a step-by-step motion into a succession of predetermined index positions, a locating device movable into and out of a predetermined position and movable into such position only when the work is located precisely in one of its index positions, power actuated means for effecting a cycle of relative advancing and retracting movement between said supports, and means for causing said power actuated means to interrupt said cycle and effect an emergency relative retraction movement between said supports upon the institution of a relative advancing movement when said locating device is not in said predetermined position therefor.

10. In a machine tool, the combination of a work support and a tool support, means for indexing the work relative to said tool support, power actuated means for effecting a cycle or relative advancing and retracting movement between said supports, a first switch and means for closing the same only when the work is not in one of its index positions, a second switch and means for closing the same momentarily in the initial portion of each relative advance of said supports by said power actuated means, and means operable in response to a simultaneous closure of said first and second switches for interrupting said cycle and causing said power actuated means to effect automatically an emergency relative retraction movement of said supports.

11. In a machine tool, the combination of an indexible work positioning mechanism and a tool supporting mechanism, power actuated means for effecting a cycle of relative advancing and retracting movement between said tool supporting mechanism and the work positioned by said work positioning mechanism, and means for causing said power actuated means to interrupt said cycle and effect automatically an emergency relative retraction between said tool supporting mechanism and the work upon the institution of a relative advance movement thereof when the work is not properly located by said work positioning mechanism.

12. A machine tool comprising, in combination, a plurality of individually movable machine tool elements, a corresponding plurality of individual power actuating mechanisms therefor, manual controls for said mechanisms, a unified control system inter-connecting said mechanisms for effecting a cyclic operation of said elements in predetermined timed relation to each other, a plurality of selectors, one for each power actuating mechanism, and operable to condition the associated mechanism alternatively for operation either by manual control thereof or under the control of said unified control system, and means operable in response to the shifting of any one of said selectors to its manual control position for interrupting the cyclic operation of all of the mechanisms by said unified control system.

13. A machine tool comprising, in combination, relatively movable work and tool supports, power actuated means for effecting an alternative advancing and retracting movement between said supports, a manually operable starting device, first and second relays, means operable in response to actuation of said starting device for momentarily energizing said first relay, means operable in response to energization of said first relay for in-

stituting operation of said power actuated means, means operable in response to the initiation of operation of said power actuated means for disabling said first relay and for rendering said second relay operative, means operable in timed relation with the relative movements of said supports for periodically energizing said second relay, means responsive to energization of said second relay for initiating operation of said power actuated means, and means responsive to the completion of a predetermined series of operations of said power actuated means for disabling said second relay and for rendering said first relay operative again, whereby inadvertent recycling of the machine is prevented as well as inadvertent restarting during the course of a cycle.

14. A machine tool comprising, in combination, relatively movable work and tool supports, power actuated means for effecting a relative advancing and retracting movement between said supports, a manually operable starting device, first and second relays, means including a two-position switch for alternatively rendering one of said relays operative and the other inoperative in the respective first and second positions of said switch, said switch being momentarily disposed in the first position thereof and in which said first relay is operative and said second relay inoperative, means operable in response to actuation of said starting device for normally energizing said second relay, means operable in response to energization of said first relay for instituting operation of said power actuated means, means operable in response to the initiation of operation of said power actuated means for shifting said switch from its first to its second position, whereby to disable said first relay and render said second relay operative, means operable in timed relation with the relative movements of said supports for periodically energizing said second relay under the control of said switch, means responsive to energization of said second relay for initiating operation of said power actuated means, and means operable upon the completion of a predetermined series of operations of said power actuated means for shifting said switch from its second to its first position, whereby to again disable said second relay and restore said first relay to operative condition.

15. A machine tool comprising, in combination, an indexible work positioning mechanism and a plurality of tool supports reciprocable toward and away from the work positioned by said mechanism, power actuated means for indexing said work positioning mechanism with a step-by-step motion and with a dwell after each step, propulsion mechanisms for causing said tool supports to execute individual cycles of reciprocation from respective retracted initial positions therefor toward the work and back to said initial positions, individual controls corresponding to the several work supports for causing respective ones thereof to execute their respective cycles of movement, means including a plurality of optionally available program cams driven in timed relation with the indexing of said work positioning mechanism for actuating the controls of preselected various ones of said tool supports to effect operation thereof during successive dwells of said work positioning mechanism, whereby to effect operation of said tool supports in accordance with a program correlated with the indexing of said work positioning mechanism, each of said cams being adapted to effect a different program, and selector means for

rendering a desired one of said cams operative to actuate said controls.

16. A machine tool comprising, in combination, an indexible work positioning mechanism and a plurality of tool supports reciprocable toward and away from the work positioned by said mechanism, power actuated means for indexing said work positioning mechanism with a step-by-step motion and with a dwell after each step, means including a manually operable starting device for initiating operation of said power actuated means, means for automatically stopping said power actuated means at the end of a predetermined series of indexing steps for the work positioning mechanism, propulsion mechanisms for causing said tool supports to execute individual cycles of reciprocation from retracted initial positions therefor toward the work and back to said initial positions, individual controls corresponding to the several work supports for causing respective ones thereof to execute said cycles of movement, means including a plurality of optionally available program cams driven in timed relation with the indexing of said work positioning mechanism for actuating the controls of preselected various ones of said tool supports to effect the operation thereof during successive dwells of said work supports, whereby to effect the operation of said tool supports in accordance with a program correlated with the indexing of said work positioning mechanism, each of said cams being adapted to effect a different program, and selector means for rendering a desired one of said cams operative to actuate said controls.

17. A machine tool comprising, in combination, an indexible work positioning mechanism and a plurality of tool supports reciprocating toward and away from the work, power actuated means for indexing said work positioning mechanism with a step-by-step motion and with a dwell after each step, propulsion mechanisms for causing said supports to execute individual cycles of reciprocation therefor from respective initial retracted positions toward the work and back to said initial positions, means including a plurality of switches, one for each tool support, for conditioning the propulsion mechanisms of the corresponding tool supports for operation upon the actuation of such switches, means including a plurality of optionally available program cams driven in timed relation with the indexing of said work positioning mechanism for actuating said switches, and selector means for rendering a desired one of said cams operative to actuate said switches.

18. A machine tool comprising, in combination, a plurality of relatively movable machine tool elements, a corresponding plurality of power actuated means for moving respective ones of said elements, a movable actuator driven in timed relation with the movement of one of said elements, a plurality of control means, one for each of the remainder of said elements, operable when actuated to cause the power actuated means of the corresponding element to move such element through a predetermined cycle of movement, means including a plurality of optionally available program cams driven by said actuator for actuating said controls to effect the operation of said remaining elements in timed relation with said one element in a program of operation determined by the particular cam utilized, and selector means for rendering a desired one of said cams operative to actuate said controls.

19. A machine tool comprising, in combination, a plurality of relatively movable machine tool elements, a corresponding plurality of power actuated means for moving respective ones of said elements, a plurality of selectively available program cams, selector means for conditioning a desired one of said cams for operation, means for moving at least the cam rendered operative by said selector means in timed relation with the movement of one of said elements, and control means actuated by the one of said cams rendered operative by said selector means for initiating the operation of the various power actuated means for the remainder of said elements in accordance with a predetermined program.

20. A machine tool comprising, in combination, a plurality of relatively movable machine tool elements, a corresponding plurality of power actuated means for moving said elements through individual cycles of movement therefor, control means for conditioning said power actuated means to cause their respective elements to execute said cycles thereof, said control means including a plurality of switches, one for each of a plurality of said elements, and said switches being operable upon actuation thereof to condition the control means for initiation of the operation of the corresponding element's propulsion mechanism, a revoluble cam support driven in timed relation with another one of said elements, a plurality of sets of cam elements removably mounted on said cam support, each of said sets including a separate cam element for each of said switches, and means for adjustably supporting said sets of cam elements and switches for adjusting movement relative to each other to bring a desired one of said sets of cam elements into operative relation with said switches for actuating the latter.

21. A machine tool comprising, in combination, a plurality of relatively movable machine tool elements, a corresponding plurality of power actuated means for moving said elements through individual cycles of movement therefor, control means for conditioning said power actuated means to cause their respective elements to execute said cycles of movement, said control means including a plurality of switches, one for each of a plurality of said elements, and said switches being operable upon actuation thereof to condition the control means for initiation of the operation of the corresponding element's propulsion mechanism, a revoluble shaft driven in timed relation with another of said elements, said switches being disposed in a row along said shaft, a plurality of sets of disk-shaped, peripheral cam elements telescoped on said shaft and fixed thereto, there being one of said cam elements in each of said sets for each of said switches, and means supporting said shaft and said switches for adjusting movement in a direction axially of the shaft to bring a desired one of said plurality of sets of cam elements into operative engagement with said switches for actuating the latter.

22. A machine tool comprising, in combination, an indexible work positioning mechanism and a plurality of tool supports reciprocal toward and away from the work, power actuated means for indexing said work positioning mechanism, propulsion mechanisms for reciprocating individual ones of said tool supports, program control means operable to cause the propulsion mechanisms of predetermined ones of said tool supports to advance and retract their associated tool supports

in accordance with a predetermined program of operation in which preselected tool supports participate in each of a plurality of steps of the program, means including a manually operable starting device for initiating the operation of said program control means, said program control means also including means for initiating a step of indexing of said work positioning mechanism by said power actuated means upon completion of each step of said program by the ones of said tool supports scheduled for participation in that particular step and for causing said power actuated means to restore said work positioning mechanism to its initial position at the conclusion of the last step in said program, and additional control means for automatically causing the propulsion mechanisms of a predetermined one or more of said tool supports to effect an additional cycle of movement therefor at the conclusion of said program and after said work positioning mechanism has returned to said initial position.

23. A machine tool comprising, in combination, an indexible work support and a plurality of tool supports reciprocal toward and away from said work support, power actuated means for indexing said work support, propulsion mechanisms for reciprocating individual ones of said tool supports, program control means operable to cause the propulsion mechanisms of predetermined ones of said tool supports to advance and retract their associated tool supports in accordance with a predetermined program of operation in which preselected tool supports participate in each of a plurality of steps of the program, means including a manually operable starting device for initiating the operation of said program control means, said program control means also including means for initiating a step of indexing of said work support by said back actuated means upon completion of each step of said program by the ones of said tool supports scheduled for participation in that particular step and for causing said power actuated means to restore said work support to its initial position at the conclusion of the last step in said program, additional control means for automatically causing the propulsion mechanisms of a predetermined one or more of said tool supports to effect an additional cycle of movement therefor at the conclusion of said program and after said work support has returned to said initial position, and means including a switch mechanism operated in timed relation with the indexing of said work support for conditioning said additional control means for operation upon restoration of said work support to said initial position and for automatically conditioning said program control means for restarting of the same by said starting device upon the completion of the operation of said additional control means.

24. A machine tool comprising in combination, an indexible work positioning mechanism, a plurality of tool supports reciprocatory toward and away from the work, power actuated means for indexing said work positioning mechanism, individual propulsion mechanisms for advancing and retracting said tool supports, a manually operable starting device, first control means operable in response to an actuation of said starting device to cause said power actuated means to index said work positioning mechanism step by step through a series of steps with a dwell after each step and finally to restore said work positioning mechanism to its initial position and to cause the pro-

pulsion mechanisms of predetermined ones of said tool supports to advance and retract the latter during successive ones of said dwells in accordance with a predetermined program, means for stopping the operation of said machine at will during said program, a second control means for effecting the repetition by said tool supports of any step in said program corresponding to the position of said work positioning mechanism to which the latter has been previously indexed under the control of said first control means, and selector means for conditioning one or the other of said control means for operation.

25. A machine tool comprising, in combination, a plurality of relatively movable machine tool elements, a corresponding plurality of power actuating means for moving respective ones of said elements, a first control means for causing said power actuated means to move the respective machine tool elements in accordance with a predetermined program in which various preselected ones of said elements are moved cyclically in successive steps of the program, a second control means for causing said power actuated means to effect the cyclical movement of their corresponding machine tool elements in accordance with any particular single step in said program, and selector means for rendering one or the other of said first or second control means operative and the other inoperative.

26. A machine tool comprising, in combination, an indexible work support and a plurality of tool supports reciprocatory toward and away from said work support, power actuated means for indexing said work support with step-by-step motion through a series of steps and back to an initial or starting position therefor, propulsion mechanisms for each of said tool supports for advancing and retracting the same, program control means operable in timed relation with the indexing of said work support for automatically conditioning for operation the propulsion mechanisms of predetermined ones of said tool supports for successive index positions of said work support, and alternatively available first and second indexing control means, said first indexing control means being operable upon actuation thereof to cause said power actuated means to index said work support through said series of steps and back to said starting position and to render said program control means operative during such indexing of the work support, said second indexing control means being operable upon actuation thereof to disable said program control means and to index said work support through any desired number of steps and also automatically to restore said program control means to operative condition upon a return of said tool support to its initial position.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,975,005	Kingsbury et al.	Sept. 25, 1934
1,975,007	Kingsbury	Sept. 25, 1934
2,118,024	Potter et al.	May 17, 1938
2,118,025	Curtis	May 17, 1938
2,029,335	Oberhoffen et al.	Feb. 4, 1936
2,255,739	Curtis	Sept. 9, 1941
2,053,400	Kingsbury	Sept. 8, 1936