March 29, 1955

E. M. MAY

2,704,945

CAM APPARATUS

Original Filed June 7, 1951

3 Sheets-Sheet 1

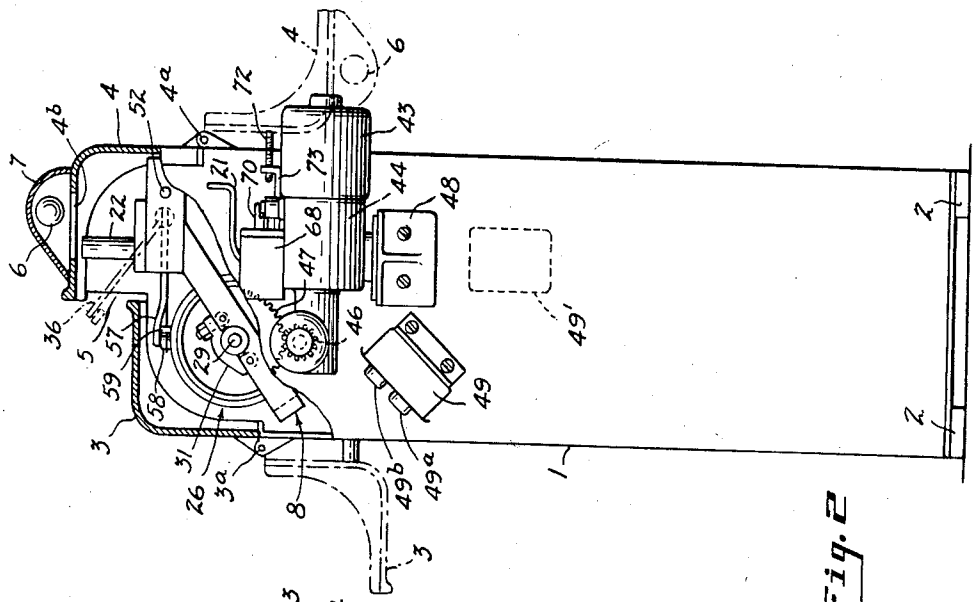


Fig. 2

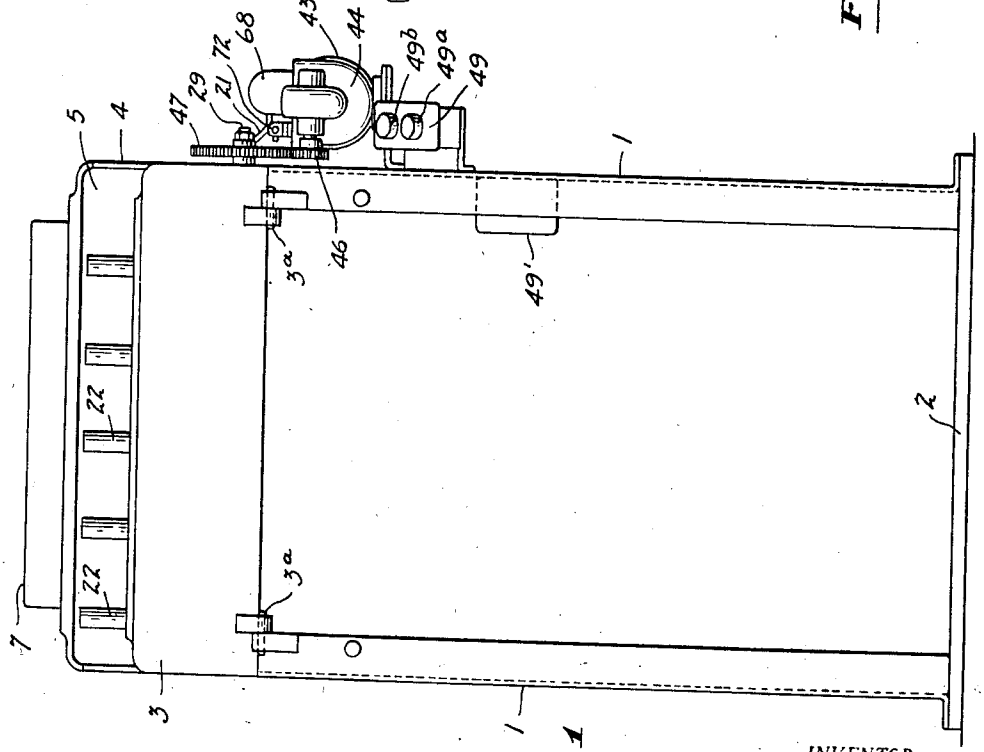


Fig. 1

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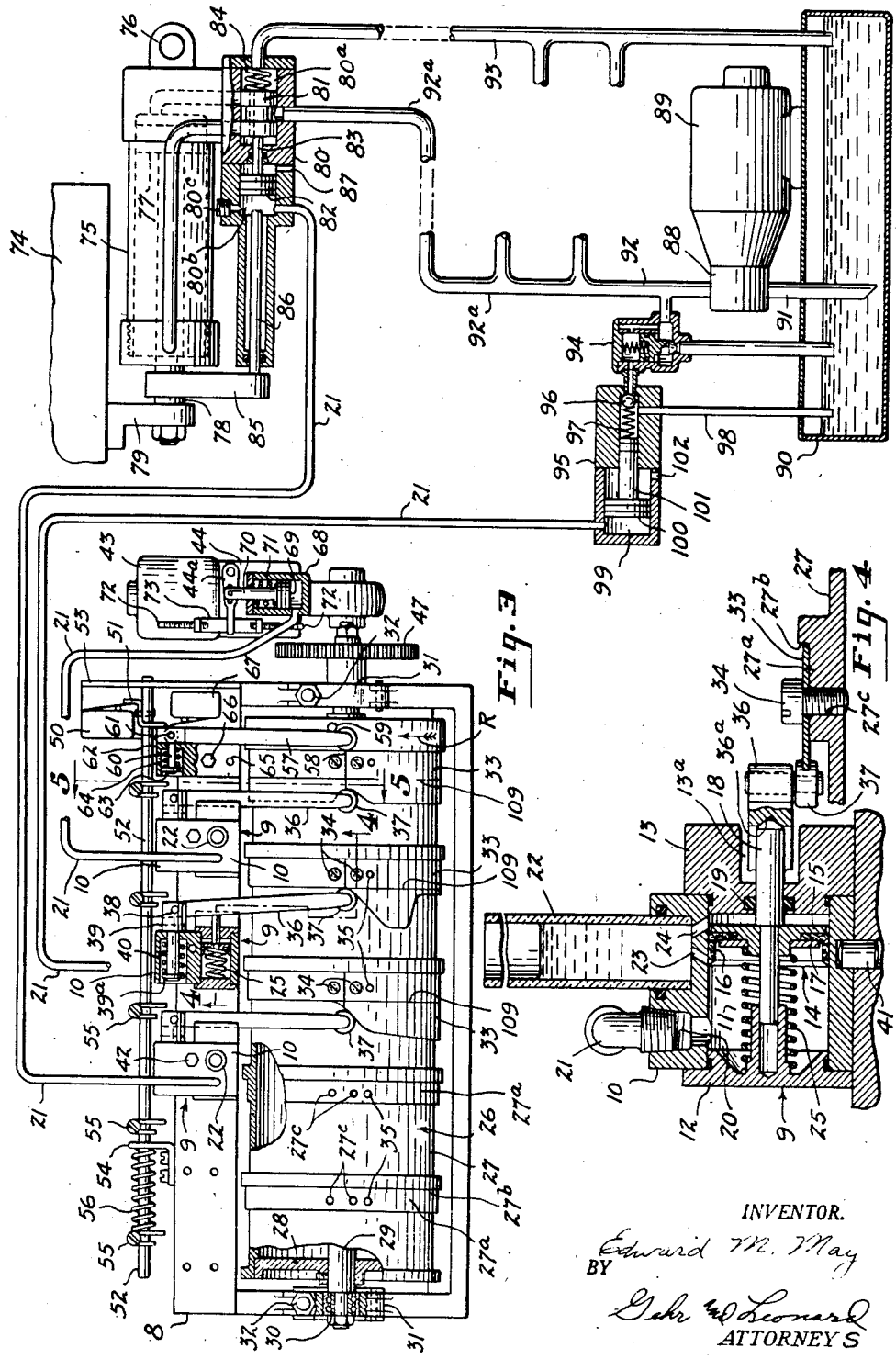


Fig. 3

Fig. 4

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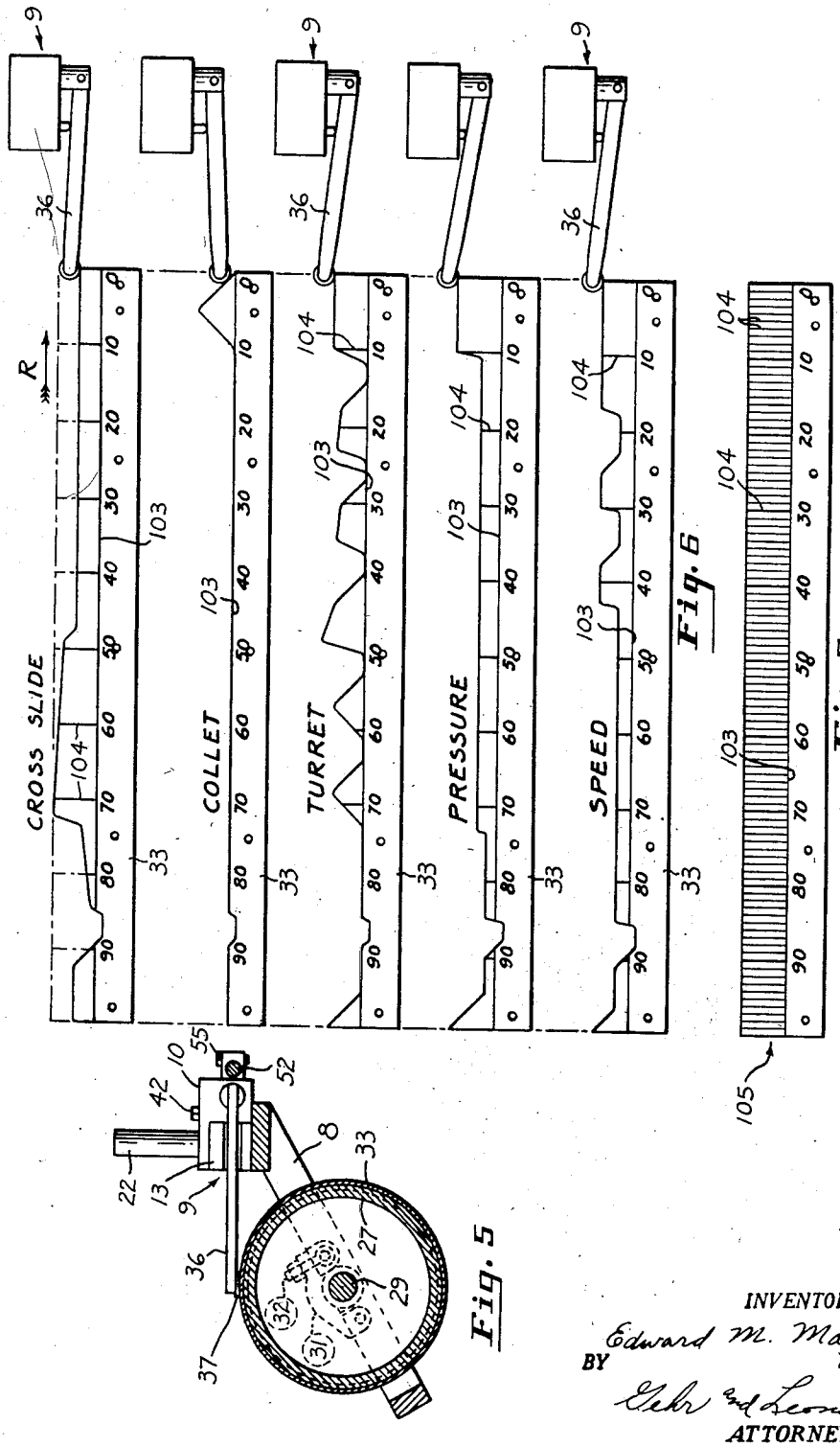


Fig. 6

Fig. 7

Fig. 5

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United States Patent Office 2,704,945
Patented Mar. 29, 1955

2,704,945

CAM APPARATUS

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Original application December 30, 1946, Serial No. 719,305, now Patent No. 2,607,196, dated August 19, 1952. Divided and this application June 7, 1951, Serial No. 230,375

4 Claims. (Cl. 74—567)

The invention relates to cam apparatus, the present application for patent being a division of my copending application Serial No. 719,305, filed December 30, 1946, now Patent No. 2,607,196, for Apparatus for Controlling the Operation of Power Driven Machines.

It is an object of the present invention to provide cam apparatus for controlling or driving other devices, which apparatus is simply constructed, based upon simple and easily understood design principles and susceptible of precision manufacture at relatively low cost.

Another object of the invention is to provide cam apparatus comprising a rotary carrier and one or more cams detachably mounted thereon and in which the individual cam or cams can be mounted for operation easily, rapidly and with a high degree of accuracy in relation to the carrier and devices which are to cooperate with the cams.

A further object of the invention is to provide cam apparatus such as last referred to above having demountable cam elements which can be compactly arranged for storage when not in use.

Still another object of the invention is to provide cam apparatus comprising a rotary carrier, cams removably mounted thereon, power drive means for rotating the carrier and means for supporting the carrier and drive means constructed to permit quick and easy demounting of the carrier from the support.

A further object of the invention is to provide cam apparatus comprising a rotatable cam carrier, variable-speed power driving means for the carrier and means comprising a cam on the carrier for cyclically varying the speed of the driving means.

Another object of the invention is to provide an improved method of making drum-type cams.

For the attainment of the above-stated objects and other objects more or less incidental or ancillary to those stated, the invention consists in the forms, combinations and arrangements of parts defined in the appended claims and explained in the following description of an exemplary apparatus shown in the accompanying drawings.

In the drawings,

Fig. 1 is a front elevation of hydraulic control apparatus presenting an application of the improved cam apparatus for actuation of hydraulic transmitter pistons.

Fig. 2 is a right side elevation of the apparatus shown in Fig. 1 with a portion of the casing structure broken away to show interior parts and with hinged cover portions of the casing structure shown in closed position by full lines and in open position by dashed lines.

Fig. 3 is a view, partially diagrammatic, showing the cam and hydraulic transmitter apparatus in plan view on a larger scale than in Figs. 1 and 2 with some parts omitted and others shown in section, and also showing one of the hydraulically actuated elements of a machine to be controlled and motor-driven pump means for supplying power liquid for the hydraulic motor of the machine.

Fig. 4 is an enlarged sectional view on the broken line 4—4 of Fig. 3 with some parts of the structure broken away.

Fig. 5 is a section on the line 5—5 of Fig. 3.

Fig. 6 is a diagrammatic view of a series of cams, in developed (flat) form, and hydraulic transmitters to be actuated by the cams, the form of the cams being appropriate for control of a turret lathe.

Fig. 7 is a face view of a cam blank useful in design and fabrication of cams for the control apparatus.

Referring now in detail to the structures illustrated in the drawings, numeral 1 designates as an entirety (Figs. 1 and 2) a cabinet designed to rest upon the floor and house cam apparatus in accordance with the invention and hydraulic transmitters driven thereby. The cabinet is preferably built up of sheet steel and is fitted with a pair of bottom skids 2, 2 adapted to slide upon the floor when the apparatus is moved. The front of the cabinet may be left open as shown but the top is partially closed by cover sections 3 and 4 which are hinged on the body of the cabinet at 3*a* and 4*a*, respectively, so that they can be swung downward to the positions shown in dotted lines to give free access to the apparatus within the cabinet and at the same time serve as shelves for tools and parts when changes and adjustments of the apparatus are being made. The rear cover 4 is disposed at a higher level than the front cover 3 so that an inspection opening or window is provided at 5 for a purpose which will presently appear. The cover 4 is formed in its top portion with an opening 4*b* over which are arranged an electric light bulb 6, preferably of the elongated tubular type, and a reflector 7, the purpose of the light being to illuminate parts of the enclosed apparatus as viewed through opening 5.

Within the upper part of the cabinet 1 is a rectangular frame 8 secured to the walls of the cabinet by bolts or screws (not shown), the said frame being inclined downwardly from the rear to the front of the cabinet as shown in Fig. 2. As best shown in Fig. 3, the rear side of frame 8 carries a series of hydraulic transmitters 9, 9 two of which have been omitted to facilitate disclosure of other parts. Each transmitter comprises a block 10 formed at its front end with a transverse cylinder chamber 11 (Fig. 4). This chamber is closed at its respective ends by heads 12 and 13. Within chamber 11 is a piston structure 14 comprising a disc 15, hydraulic packing 16 and retaining ring 17. The piston is fast on a rod 18 which is guided at one end in a boss carried by the head 12 and at its other end extends through an aperture in the head 13 fitted with a suitable hydraulic packing 19. The cylinder block 10 is formed on its top side with a threaded aperture 20 to which is connected a conduit 21 designed to connect chamber 11 with receiver apparatus which will later be described.

The cylinder block 10 of each transmitter is also formed with a top recess to receive an upright, open-topped tubular reservoir 22 of transparent material such as plastic or glass. The reservoir is designed to hold oil or other working liquid for the transmitter and has its joint with block 10 packed to prevent leakage. Passages 23 and 24 lead from the bottom of the reservoir 22 into the cylinder chamber 11, the passage 24 communicating with chamber 11 adjacent the closure head 13 while passage 23 communicates with chamber 11 at a point intermediate passage 24 and passage 20. With this arrangement the packing 16 of the piston structure serves to close the passage 23 as the piston moves forward on its working stroke. A coil spring 25 is interposed between the piston 14 and the head 12 and is adapted to retract the piston following its working stroke.

To effect the working stroke of the piston 14 cam devices are provided in accordance with the present invention comprising a horizontal cylinder 26 having a cylindrical shell 27 and end discs 28, 28 which are centrally apertured and secured by set screws or the like on a supporting shaft 29. Shaft 29 in turn is supported by antifriction bearings 30 in the respective ends of frame 8. To permit easy removal of the cylinder structure as a unit the end sections of frame 8 are fitted with swinging bearing caps 31 which are hinged at their front ends to the frame and are disengageably secured at their rear ends by swinding bolts 32.

The cylinder 26 is formed peripherally to receive a series of circumferentially extending cams 33, 33, one for each of the transmitters 9, 9. That is to say, the cylinder has a series of circumferentially extending cam seats 27*a* extending radially somewhat beyond the main surface of the shell 27, and adjacent each seat surface 27*a* the shell is formed with a circumferentially extending shoulder 27*b* to engage and locate one of the cams, each of which has a straight longitudinal edge affording a reference surface

to cooperate with the locating shoulder 27*b*. Each cam 33 is preferably formed from an elongated relatively thin strip of metal or other material susceptible of being manually bent from the flat state to circular form and preferably also possessing sufficient elasticity to return substantially to the flat state when released. Aluminum alloy sheet material of suitable temper is a satisfactory material for the purpose.

Each of the cams 33 is provided adjacent its two ends with apertures to receive securing screws 34, 34 which engage threaded holes 27*c*, 27*c* of the cylinder drum 27, and is also provided adjacent one end with a dowel hole to engage a dowel pin 35 attached to drum shell 27. Each cam may if desired be provided with additional securing screws spaced around the periphery of the cam drum. As will be apparent from Fig. 3, each of the cams 33 has one longitudinal edge formed with various lobes or active cam sections to effect desired movements of its hydraulic transmitter through the cam follower provided for that purpose. Such follower is in the form of a lever arm 36 fitted at its free end with a roller 37 to engage the cam and pivotally supported at its other end in position to engage the projecting end of the piston rod 18. The pivotal support for the arm 36 is afforded by pin 38 carried by the head of a bolt 39 having a swiveling support in the rear part of cylinder block 10. With this construction the follower arm 36 can be raised when desired as indicated by dotted lines in Fig. 2 to permit removal of the cam cylinder 26 from frame 8. The swiveling bolt 39 is fitted with a washer 39*a* and a coil spring 40 which engages the bolt washer and yieldingly presses the head of the bolt against the adjacent face of block 10 (Fig. 3). To support the roller 37 in operative engagement with the edge of the cam 33 the side of follower arm 36 where it engages the piston rod 18 is formed with an angular groove or depression 36*a* as shown in Fig. 4. The engagement between the arm and the end of the rod is normally maintained by the tension of the spring 25. As is shown in Fig. 4 the follower arm 36 during normal operation lies within a slot 13*a* of the cylinder head 13. The purpose of this is to facilitate manual actuation of the cam follower for certain purposes which will be referred to later in the description. The slot allows sufficient lifting of arm 36 to disengage its roller 37 from the cam but maintains the arm in operative engagement with piston rod 18.

For reasons later explained it is desirable to be able to adjust the transmitter blocks 10 in relation to the supporting frame 8 and to this end each block is secured to the frame by a pivot pin 41 (Fig. 4) and a clamping screw 42 which passes through a hole in the block 10 somewhat larger than the shank of the screw so that the block can be adjusted around the axis of pin 41.

Rotation of the cam drum is effected by an electric motor 43 which is connected to drive a variable speed mechanism 44 which in turn is connected through worm and wheel gears to drive a pinion 46 meshing with a spur gear 47 fast on shaft 29 of the cam drum. Preferably the motor, variable speed mechanism and worm and wheel gears constitute a unitary device which is supported on the end of cabinet 1 by a suitable bracket 48. With the described gear connection between the motor and the cam drum the removal of the latter from its supporting frame involves merely the disengagement of the bearing caps 31 and separation of spur gear 47 from the driving pinion 46. For control of motor 43 it is connected in circuit with switch and relay devices 49 and 49', respectively, of well known construction, the switch having a starting button 49*a* and a stop button 49*b*. Further reference will be made to these manual control devices later in the description.

The apparatus is further provided with safety devices comprising an emergency switch 50 which is connected in circuit with motor 43. Switch 50 is normally held in its closed position by means of a double-ended dog 51 fixedly secured to a rod 52 which is slidably mounted in bracket 53 and 54 attached to the frame 8 (Fig. 3). Dogs 55, 55 are adjustably clamped on rod 52, each a little to the right of the head of one of the pivot bolts 39. A coil spring 56 which is interposed between one of the dogs 55 and bracket 54 urges rod 52 toward the left. Rotation of the rod 52 is prevented by the disposition of the arms of dog 51 adjacent the horizontal surface of the bracket 53. With this arrangement if the discharge of any one of the transmitters should be blockaded or movement of the cam follower be in any way obstructed the spring 40 of the pivot bolt will yield and permit the follower arm 36 to swing about the end of piston rod 18 as a pivot with resultant movement of the sliding rod 52 toward the right and the opening of emergency switch 50.

With the hydraulic transmitters actuated by the circular or endless form of cams it is apparent that a cycle of transmitter movements is effected for each rotation of the cam drum 26. For the control of some types of machines and operations it may be desirable for the control mechanism, when started manually by switch button 49*a*, to run continuously for the performance of a considerable number of control cycles and then be stopped by manual switch button 49*b*. In other cases, however, it may be desirable to stop the control mechanism at the end of each cycle and have the apparatus started again manually. To this latter end means are provided to open emergency switch 50 at the end of each rotation of the drum 26. Said means comprise a lever arm 57 fitted at its front end with an antifriction roller 58 arranged to be engaged by a radial pin 59 carried by cylinder 26. At its rear end the arm 57 is slotted to receive the end of eye bolt 60 to which the arm is pivotally connected by pin 61. Bolt 60 has a swiveling support in block 62 carried by frame 8 and is fitted at one end with a washer 63 which is engaged by spring 64 to hold the arm 57 yieldingly against the side surface of block 62. The rear end of arm 57 is engaged by the front end of dog 51 on the sliding rod 52 and normally serves as a positive stop limiting movement of rod 52 by spring 56. With this construction when the control apparatus is started by actuation of the starting switch 49*a* the cam drum 26 rotates, in the direction of arrow R, until pin 59 engages roller 58 to swing the arm 57 around the right front corner of block 62 as a pivot with resultant movement of the rear end of arm 57 to the right. This movement carries dog 51 to the right and opens emergency switch 50 to stop the drive motor 43.

In order to insure the proper positioning of roller 58 in relation to the pin or dog 59, block 62 is adjustably secured to frame 8 by means of pin 65 and clamping screw 66, the clamping screw having a sufficiently loose fit in the block to permit the relatively small range of needed adjustment. When multiple cycle operation without manual control is desired it is only necessary to block up arm 57 to remove roller 58 from the path of dog 59, such positioning of arm 57 being permitted by the swivel mounting of bolt 60.

An additional motor control switch 67 is mounted on bracket 53 with its actuating arm disposed adjacent the rear end of arm 57. The switch, which is normally open, is closed by the above described swinging movement of arm 57. The purpose of switch 67 will appear at a later point in the description.

It is desirable that the stopping of the cam mechanism be effected without any considerable overrun when the control switch is actuated. To this end the motor 43 is preferably equipped with a magnetic brake so that it will stop promptly when deenergized. Alternatively (and at less cost) use may be made of well known switch and relay circuit means adapted to give the desired quick stopping.

The invention contemplates automatic control of the variable speed mechanism 44 through which motor 43 is connected to drive the cam drum 26. To this end gearing 44 is provided with a crank arm 44*a* connected to actuate the speed varying means of the mechanism. As has been stated any suitable form of speed varying mechanism can be employed but that manufactured by Graham Transmissions Inc. of Milwaukee, Wisconsin, and shown in U. S. Patent No. 2,405,957, has been found satisfactory for use. Crank arm 44*a* is actuated by a hydraulic receiver comprising cylinder 68 and piston 69 having a rod 70 with a pin and slot connection to arm 44*a*. One end of cylinder 68 is connected by a conduit 21 with one of the hydraulic transmitters 9. Thus the hydraulic impulse of the transmitter serves to move the piston 69 against the tension of a retracting spring 71 interposed between the piston and one end of cylinder 68. The speed change mechanism and the connections between it and arm 44*a* are such that the piston movement opposed to spring 71 increases the speed transmitted through pinion 46 and gear 47 to the cam drum. Movement of piston 69 in the reverse direction by spring 71 correspondingly reduces the speed transmitted to the cam cylinder. To determine the maximum and minimum speeds which may be thus automatically provided by the

hydraulic mechanism adjustable screws **72, 72** are mounted on bracket **73** carried by the casing of mechanism **44** and serve to limit the swinging movement of lever **44***a*.

By means of the described hydraulic devices for determining the speed of rotation of the cam drum **26** it is possible by the provision of a suitably shaped cam for actuating the transmitter connected to cylinder **68** to vary the speed of cam movement at will throughout the cycle of rotation of the cam drum.

In Fig. 3 of the drawings is shown more or less diagrammatically a machine element, hydraulic motor devices and pressure fluid supply means for the motor devices connected in a typical manner to the hydraulic transmitter control mechanism already described. The machine element **74** may be taken as a portion of the turret slide of a turret lathe. Associated with the slide is a hydraulic motor comprising a cylinder **75** anchored at **76** and having a piston **77** with rod **78** connected by arm **79** to the slide element **74**. This hydraulic motor is fitted with a hydraulically actuated control valve of the follow type. The valve comprises a casing **80** providing a chamber **80***a* for a spool valve **81** and a chamber **80***b* for an actuating piston **82** having its rod **83** extending into chamber **80***a* to urge the valve **81** toward the right against the tension of spring **84**. The chamber **80***b* is connected on the left side of piston **82** with one of the conduits **21** leading to one of the hydraulic transmitters **9**. Piston rod **78** of the main rotor carries an arm **85** to which is attached a follow rod **86** extending into chamber **80***b*. The latter chamber, on the right side of piston **82**, is open to the atmosphere through vent **87** so that no working fluid for the main motor can leak past the packing of rod **83** and affect the control piston.

A pump **88** of constant delivery type is directly driven by motor **89** mounted upon the top of a sump chamber **90**. The pump has its intake connected by a suction pipe **91** with the interior of sump **90** and has a discharge pipe **92** with various branches to supply a plurality of hydraulic motors. One such branch **92***a* is shown connected to the inlet port of valve casing **80**. The right end of the control valve chamber **80***a* discharges to a return pipe **93** delivering into sump **90**. Pipe **93** may also have branch return lines leading into it as indicated in Fig. 3.

To control the pressure of the working fluid delivered to the hydraulic motor or motors served by it discharge pipe **92** is fitted with a by-pass valve **94** of well known construction. For automatically varying the pressure of the working liquid supplied to the controlled motors valve **94** is equipped with relief valve devices comprising casing **95**, ball valve **96** and coil spring **97** which yieldingly urges the valve against the inlet port of casing **95**, the outlet port being connected by conduit **98** to sump **90**. To automatically vary the tension of spring **97** casing **95** is provided with a chamber **99** for hydraulic piston **100** having a rod **101** engaging the end of spring **97**. With chamber **99** connected as shown through a conduit **21** with one of the hydraulic transmitters **9** the impulse of the transmitter, determined by its actuating cam, serves to vary the tension of spring **97** and hence the pressure at which the valve **96** opens to control the opening of by-pass valve **94**. Casing structure **95** is provided with a relief port **102** on the right side of piston **100**.

By way of further explanation of the invention there is shown in Fig. 6 of the drawing an exemplary set of actuating cams suitable for controlling the operation of a turret lathe. For clarity the cams are shown in their flat form detached from the supporting cam cylinder. From the top to bottom of the figure the cams are designated "cross slide," "collet" (for feed of work piece), "turret," "pressure" and "speed," corresponding to the several control stations of a conventional turret lathe. Fig. 6 also indicates in connection with each cam the follower arm **36** and transmitter **9** driven by it.

It is observed first that each of the cams **33** is marked with a longitudinally extending base line **103** which is spaced exactly at a standard distance from the reference edge of the cam and the surface of the cam at one side of this line is marked with transverse lines **104** dividing the length of the cam into 100 equal subdivisions (Fig. 7), every tenth subdivision being numbered from the starting end of the cam upward. The cams move in direction of arrow R. To facilitate the design and fabrication of the cams, blanks **105** are provided as shown in Fig. 7. The width of the subdivided zone of the blank at one side of the base line is such as to provide for the maximum rise of the cam corresponding to the maximum working stroke of the transmitters **9** of the apparatus. Since the length of the cam measured along the base line represents time in the rotation of the cam cylinder and transverse distances measured from the base line represent movement of the transmitter mechanism (and therefore of the receiver mechanism actuated by the transmitter) it will be seen that a cam having a straight line slope represents a substantially uniform rate of transmitter displacement for any given speed of cam rotation. The laying out of the cam, therefore, involves merely simple rectangular coordinate measurements to establish critical points representing change of slope, intermediate points being established by straight lines between the critical points.

With a cam blank such as described a particular cam, because of the straight line characteristic, is readily laid out and scribed directly on the blank, the only departure from the straight line outline being at points of intersection of the straight line slopes, where the outline may be rounded somewhat to avoid the shock of too abrupt change. Thus a cam in accordance with the present invention has a cam surface made up essentially of a connected series of planar surfaces that can readily be formed with a high degree of accuracy.

Assuming that the apparatus has been adjusted and readied for operation, the cam cylinder **26** may be lifted from its bearing supports for the mounting thereon of cams suitable for the particular motor-driven machine or operation to be controlled. For the control of a conventional turret lathe it may be assumed that the set of cams shown in Fig. 6 is employed and mounted on the cylinder **26**. If the machine is to be stopped automatically at the end of each cycle the control arm **57** will be lowered into operative position to be engaged by dog **59** of the cam cylinder. The operator or attendant starts the operation by pressing button **49***a* of switch **49**. The cam cylinder thereupon is rotated in the direction of arrow R (Fig. 3) to carry out the cycle of operations determined by the forms of the five cams.

As illustrative both of the kinds of considerations involved in the design of the cams and of the advantages attained with the present invention some of the characteristics of the cams of Fig. 6 are here noted. In the case of the turret cam there is a level-topped lobe between **0** and **10**. This causes the turret stop rod of the lathe to be presented to the bar stock coming through the spindle. Correspondingly the collet cam has a rise and fall between **0** and **10**, which causes the collet mechanism first to open and retract and then advance bar stock through the lathe spindle and close. This requires heavy hydraulic pressure which is provided for by making the pressure cam with a high lobe between **0** and **10** so that the pump **88** will provide its maximum pressure. It is desirable to operate the collet rapidly but the cam slope that can be used is limited to about 45° to prevent undue tangential stress. Consequently it is desirable to turn the cam drum rapidly and the speed cam is made high to provide the high speed. Meanwhile the cross slide cam is level at only half the maximum height to hold the cross slide in central or inoperative position.

At point **10** the turret cam drops (rapidly at first but more slowly at the end where the cam slope is curved) to retract the turret and index it to its number **2** position whereupon it is again returned to the work. As will be noted, the form of the cam for this return motion is first fast and then slower at feed rate as the tool engages the work, the flatter cam slope at **20** being for the feed motion. This operation takes some time and if the drum should continue to turn at high speed an undue portion of the drum circumference would be exhausted. Accordingly the speed cam is made low beginning at about **17**.

Next there follows a fall and rise of the turret cam between **24** and **30** which indexes the turret to its number **3** position. Such indexing calls for a long rapid stroke so a corresponding rise between **24** and **30** is provided on the speed cam. Similarly the next two turret tools are fed through to **50** on the turret cam and then follows two indexes for empty turret stations to point **73** on the cam. Just as the last turret tool is retreating at **48** (turret cam), the cross slide advances to present the front forming tool. This is a long feed movement but there is plenty of cam length available to finish the operation so the moderate rotational speed is maintained as shown by the level sec-

tion of the speed cam from 44 to 85. After the front forming cut is finished by the cross slide, its cam reverses at 74, and, between 75 and 85, presents a cut-off tool to cut off the work piece.

Between 80 and 90 all of the cams fall below the base line 103 for a purpose related to the hydraulic system controlled by the cams and with which the present invention is not concerned. The feature is, however, explained in Patent No. 2,607,196.

Between points 90 and 100 all the cams return to their original heights to match the zero ends thereof, thus providing circular continuity of the active surfaces of the mounted cams.

The cams are seen to be simple right angle coordinate graphs of the operations to be performed and can be laid out by any intelligent mechanic having a knowledge of the machine operations to be controlled. Furthermore the cams are light in weight and when dismounted from the drums take substantially their original flat form which facilitates their compact storage for use at a future date. They form and preserve a record of timing and feed rates that in other types of apparatus would have to be worked out anew with each repeated setup. This is unnecessary with the improved cam apparatus because of the manner in which the cams are laid out and positioned on the rotary carrier, the active cam surfaces being laid down in relation to the straight reference surface of the individual cam and the latter surface being positioned by the locating flange of the carrier so that it is disposed at right angles to the axis of rotation. Thus a disassembled set of cams can be quickly and easily reassembled on the carrier with assurance that the assembly will accurately reproduce its prior performance.

The dismounting of a set of cams from the carrier or their reassembly thereon is facilitated by the ease with which the carrier can be lifted from its bearing supports and moved to similar supports at a work bench. This also has the advantage that any mechanism of which the cam apparatus is a part is not tied up while the cam setup is being changed.

The possibility of laying out and machining the straight line cam surfaces on flat strip material enormously simplifies and facilitates the fabrication, in comparison with prior practice. Thus the flat cam strip can be gripped in a fixture for grinding on a surface grinder and a required planar cam surface produced with a high degree of accuracy in a very short time; and with all of the cam surfaces of a cam strip laid out and ground with reference to the common reference edge of the strip a cam can be completed in a much shorter time and at a much lower cost than is feasible by other known methods of cam fabrication of comparable accuracy.

Without further comment it will be apparent that the apparatus which has been described attains the various objects of the invention noted at the beginning of the description.

It should be understood that while the construction of the apparatus shown and described is such as is preferred, other equivalent forms of construction can be employed within the bounds of the following claims.

What is claimed is:

1. In cam apparatus, the combination of a frame, a drum mounted on the frame for rotation about the drum axis; cam means on the periphery of the drum having a cam surface disposed transversely of the drum axis to move a follower substantially parallel to the axis of the drum when the drum is turned; a follower arm arranged to cooperate with the cam; and a carrier for the follower arm supported by the frame for rotation about an axis substantially parallel to the drum axis, the follower arm being pivotally supported on the carrier for movement by the cam about an axis in a plane substantially perpendicular to the drum axis and being free to partake of the rotational movement of the carrier, whereby the follower arm can be manually swung about the carrier axis for disengagement from the cam and movement about its pivotal support on the carrier.

2. In cam apparatus, the combination of a frame; a drum mounted on the frame for rotation about the drum axis; cam means on the periphery of the drum having a cam surface disposed transversely of the drum axis to move a follower substantially parallel to the axis of the drum when the drum is turned; a follower arm arranged to cooperate with the cam; a carrier for the follower arm supported on the frame for rotation about an axis substantially parallel to the drum axis and for axial movement; and resilient means for yieldingly resisting the axial movement of the carrier, the follower arm being pivotally mounted on the carrier for movement by the cam about an axis in a plane substantially perpendicular to the drum axis and being free to partake of the rotational movement of the carrier, whereby the follower arm can be manually swung about the carrier axis for disengagement from the cam and movement about its pivotal support on the carrier.

3. A method of making rotatable cams comprising provision of a rotatable cam carrier and an elongated, rectangular, transversely flexible strip of sheet material; cutting a longitudinal edge of the flat strip from end to end thereof to form connected planar cam surfaces; machining the planar surfaces of the flat strip accurately flat; and bending the strip around the periphery of the carrier and securing it thereto with its ends mutually abutting and its planar surfaces disposed transversely to the carrier axis of rotation and forming a continuous cam surface around the periphery of the carrier.

4. A method of making rotatable cams comprising provision of a rotatable cam carrier and an elongated, rectangular, transversely flexible strip of sheet material; marking on a face of the flat strip a rectangular coordinate design comprising a straight line extending parallel to one longitudinal edge of the strip from end to end of the strip and parallel straight lines extending from the longitudinal straight line to the other longitudinal edge of the strip and dividing the area between the longitudinal straight line and the said other longitudinal edge of the strip into a longitudinally extending series of narrow rectangles; marking on the rectangle design a cam profile extending from end to end of the strip and consisting of a connected series of straight lines; cutting the flat strip along the profile marking to form a series of connected planar edge surfaces; machining the said planar surfaces of the flat strip accurately flat; and bending the strip around the periphery of the carrier and securing it thereto with its ends mutually abutting and its planar surfaces disposed transversely to the carrier axis of rotation and forming a continuous cam surface around the periphery of the carrier.

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