June 18, 1963 W. H. VAN DEBERG 3,093,971

MEANS FOR VARYING WORK CYCLES

Filed March 29, 1961 2 Sheets-Sheet 1

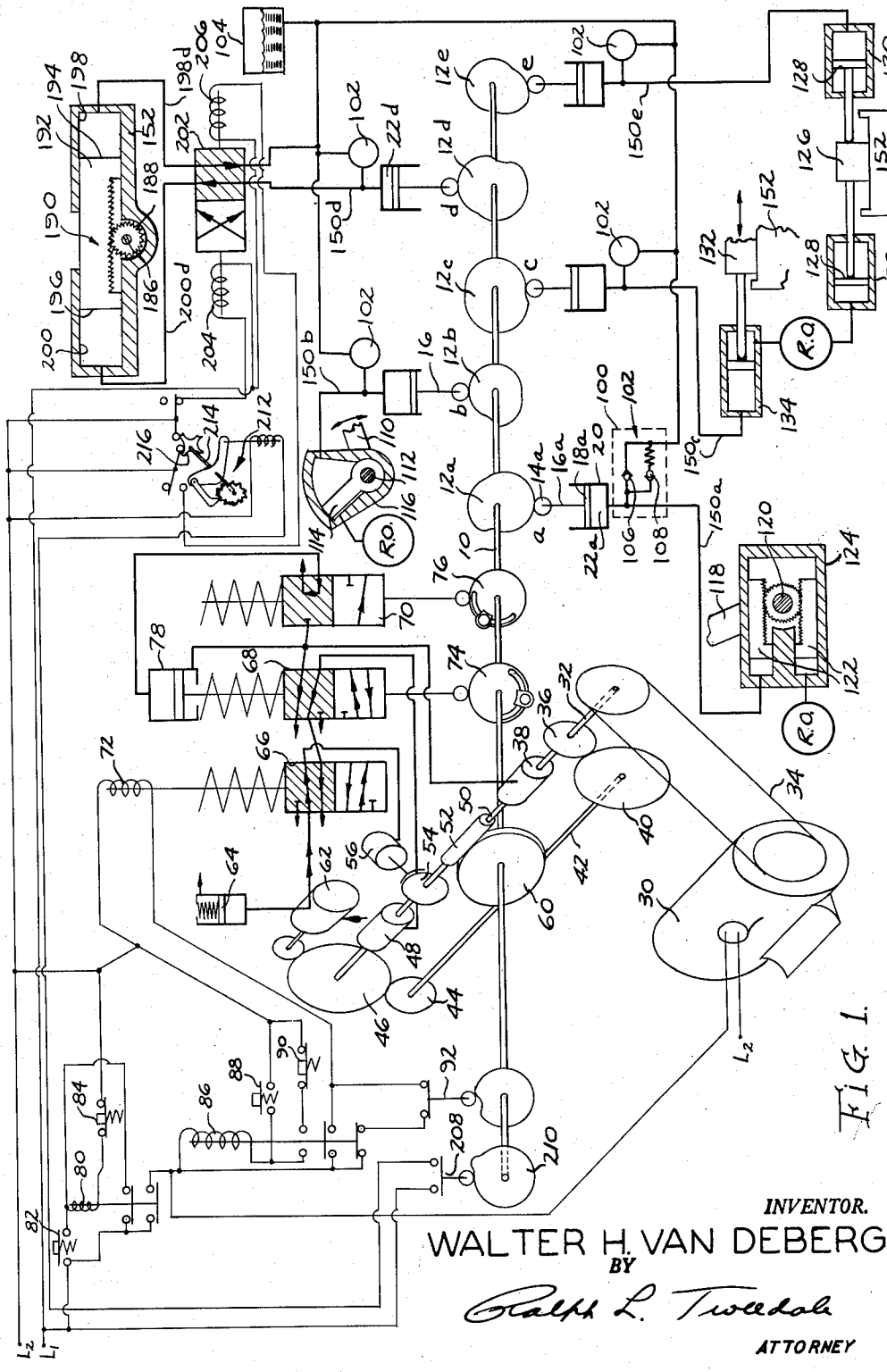


FIG. 1.

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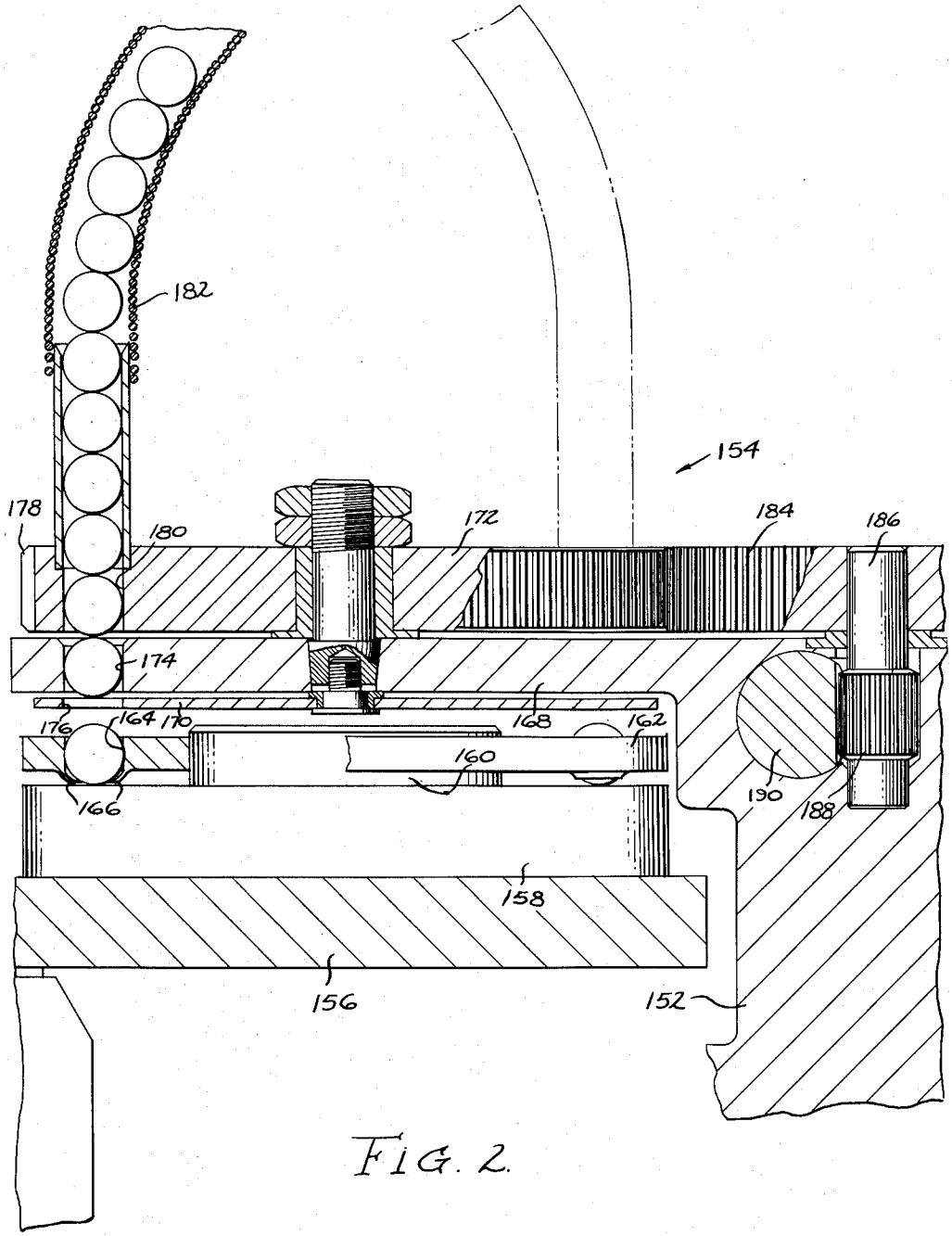


FIG. 2.

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MEANS FOR VARYING WORK CYCLES

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5 Claims. (Cl. 60—97)

This invention relates to an arrangement for modifying the output results of a mechanico-hydraulic motivator, and more particularly to apparatus for altering the output cycle frequency as compared to the input cycle frequency of a liquid column motion transfer system.

A mechanico-hydraulic motivator may be used to power and control automatic machinery of any type which includes one or more work members or load devices which must be moved to and fro. One type of mechanico-hydraulic motivator which is readily adaptable to such machinery is the type deriving its basic motion from rotary cams. A plurality of cams rotated in unison each actuate an expansible chamber type transmitter, such as a single acting pulsator piston reciprocated in a fixed cylinder by a cam follower. An expansible chamber type receiver, such as a double acting pulse responsive piston reciprocated in a cylinder, may be connected to a driven element or load device on the machine which is to be shifted to and fro during each revolution of the cam. A liquid column interconnecting the transmitter and the receiver to conduct motions therebetween may be confined in a rigid or a flexible conduit to provide utmost adaptability for modern complex production machinery. A combined replenishing and relief valve arrangement may connect each liquid column with a liquid reservoir to balance the volume of liquid in each closed motion transfer section of the motivator.

Ordinarily, each load device is returned to its rest position by an air, weight, spring or otherwise pressurized source of fluid connected to opposite the single acting cam motion transferred to the fluid motor receiver by the liquid column. When the driving cam presents its rising contour to the transmitter, the load device is shifted in one direction away from its rest position against the return bias of the pressurized source; and, when the cam presents its falling contour to the transmitter, the return fluid causes the entire closed motion transfer section to follow the cam and thus causes the driven element to be moved in the other direction back to its rest position with a desired motion accurately determined by the falling portion of the cam contour.

One problem, however, heretofore encountered in such mechanico-hydraulic motivator systems is the lack of freedom in varying the frequency of the cycles of the working parts. Each load device is necessarily moved both to-and-fro through one complete cycle with every complete cam revolution. There are devices now available for effecting limited changes in output result such as permanently advancing or retarding the timing of given sections of a multi-section motivator unit to compensate for changing conditions on the machine; similarly, mechanism is known for periodically automatically limiting or omitting entirely a given section of a multi-section motivator in response to some random variable factor. But prior to this invention a load device could not regularly be moved through a complete cycle in a total elapsed time that would vary from the total time required for the motivating cam to complete one revolution.

Accordingly, it is an object of the present invention to provide means for varying work cycles in a motion transfer system so that a load device may be operated through a time cycle which is a multiple of its driving cam's rotational cycle.

Another object of this invention is to provide in a liquid column motion transfer system cycle varying means for shifting a load device with a cycle differing from the cam cycle which eliminates the biasing effect of a pressurized return fluid and provides positive cam power and control in both directions of shifting.

A further object of this invention is to provide in a rotary cam powered and controlled liquid column type motion transfer system an arrangement for diverting the liquid column so that it is effective against a given piston face only during given revolutions of the driving cam.

A further object is to provide in a rotary cam powered and controlled liquid column type motion transfer system an arrangement for selectively directing a liquid column to alternate piston faces during successive cam revolutions to produce load device cycles which vary from the cam cycle.

Further objects and advantages of the present invention will be apparent from the following detailed description, with reference to the accompanying drawings in which like reference characters refer to the same parts throughout the several views, and in which:

FIGURE 1 is a view in schematic fashion of a known mechanico-hydraulic power and control unit showing combined therewith the means for varying or altering work cycles according to this invention; and

FIGURE 2 is a sectional view of a typical load device which is to be shifted to-and-fro on a machine with a cycle frequency that varies from the cycle frequency of the camshaft.

The basic elements of a rotary cam powered and controlled liquid column type motion transfer device are shown in FIGURE 1. Briefly, such a unit ordinarily comprises a main camshaft 10 having a plurality of rotary cams 12 keyed thereon, each cam having a contour composed of predetermined rise and fall ramps to produce a desired to-and-fro motion and impart it to a roller type cam follower 14 during each complete revolution or cycle of the cam. Each cam follower 14 is journalled in the end of the rod 16 of a pulsator piston 18 reciprocable within a fixed cylinder 20 so that motions imparted to the followers 14 by the cams 12 will move the pistons 18 to and fro in the cylinders 20 to vary the size of the cylinder chambers 22. The cam, cam follower, piston linked to the cam follower, cylinder, and variable volume chamber comprise a pulse transmitter of the expansible chamber type to which one end of a liquid column may be connected.

For turning the camshaft 10 a motor 30 drives an input shaft 32 of a two speed transmission through a belt drive 34. The input shaft 32 drives a pinion 36 and also the input member of a hydraulically-engaged, spring released clutch 38. Pinion 36 drives a gear 40 secured to a countershaft 42 which carries a pinion 44 at its opposite end. Pinion 44 drives a gear 46 and therewith constitutes a set of change speed gears. Gear 46 drives the input member of a second hydraulically engaged, spring released clutch 48. The driven members of clutches 38 and 48 are secured to the opposite ends of a shaft 50 having a worm 52 thereon and a brake drum 54. The latter has a spring-biased hydraulic motor 56 for engaging the brake. Worm

52 drives a worm wheel 60 secured to the main camshaft 10.

For the purpose of automatically controlling the starting, stopping and speed of the transmission, there is provided a hydraulic control pump 62 driven from the gear 46 which may circulate a body of oil contained in the housing surrounding the transmission. The pump 62 may deliver to a combined accumulator and relief valve comprising a spring loaded piston 64 and also supplies oil to a bank of control valves 66, 68 and 70. In the diagram each valve is shown as a two-position valve, spring biased to the position illustrated in which the connections shown in the cross-hatched rectangles are established. Single headed arrows are used to indicate flow at reservoir pressure and double headed arrows to indicate flow at pump delivery pressure. Each of the valves, when shifted, establishes the connections shown in the unhatched rectangles immediately below the hatched rectangles.

Valve 66 is arranged to be shifted by a solenoid 72. Valves 68 and 70 are arranged to be shifted by adjustable cams 74 and 76, respectively, which are positioned on camshaft 10. In addition, the valve 68 has a hydraulic holding cylinder 78 which holds the valve 68 in its shifted position until it is released by the shifting of valve 70. Valve 66 in the position shown delivers pressure fluid to engage the brake 56 and also exhausts fluid to release the low speed clutch 48. When shifted, valve 66 exhausts fluid to release brake 56 and supplies pressure fluid to engage the low speed clutch 48, subject, however, to a conjoint control by the valve 68.

The latter valve, in the position illustrated, exhausts fluid to release the high speed clutch 38 and places the low speed clutch 48 under the control of valve 66. In its shifted position valve 68, provided valve 66 has been shifted, delivers pressure fluid to engage high speed clutch 38 and exhausts fluid to release low speed clutch 48. As previously explained, the valve 70 is merely a reset valve for by-passing the holding cylinder 78 to permit valve 68 to return to its spring biased position shown in the drawings.

Thus, energization of solenoid 72 will start the camshaft 10 rotating at low speed. Thereafter, the cam 74 will shift the transmission to drive the camshaft at high speed, and still later the cam 76 will again shift the transmission to slow speed. So long as the solenoid 72 remains energized, the camshaft 10 will continue to rotate, first at a slow speed and then at a high speed during each revolution, controlling its own speed changes by operation of the cams 74 and 76.

For the purpose of controlling the drive motor 30 and solenoid 72, there is provided an electric control circuit connected between a pair of electric supply lines designated L1 and L2. The circuit may include a master relay 80 of the holding type having a manual master start switch 82 and a manual master stop switch 84. Relay 80 controls the motor 30 and also a cycle control relay 86 of the holding type having a cycle start switch 88 and a manual cycle stop switch 90. The normally open contacts of relay 80, which are of the make-before-break-type, control energization of cycle solenoid 72 directly. The normally closed contacts of relay 80 also control solenoid 72, but are in series with a cam switch 92 on the end of the camshaft 10 and arranged to be opened once during each revolution thereof. The arangement is such that when the cycle stop switch 90 is operated at any point in the rotation of camshaft 10, relay 80 will be deenergized, but solenoid 72 will remain energized until cam switch 92 opens at the predetermined stopping point. Operation of the master stop switch 84, however, will de-energize solenoid 72 immediately, regardless of the point in the cycle and will also de-energize motor 30.

The camshaft 10, as previously mentioned, drives a number of cam operated hydraulic pulsator sections designated *a* through *e*, inclusive. Each section may comprise units duplicating the typical single acting pulsator unit

above described in connection with FIGURE 1 and may be identified by corresponding reference numerals with the appropriate ones of the reference letters *a* through *e* appended thereto. The head 100 of the cylinder of each unit contains a balancing valve assembly 102 communicating between the pulsator moved liquid column and a liquid reservoir 104, which may be integral with the cam casing.

The balancing valve assembly 102 may comprise a suitable inlet replenishing check valve 106 and a high pressure relief valve 108, both of which communicate with the low pressure oil reservoir 104. When pressure in the cylinder exceeds a certain predetermined value, liquid will be diverted through the relief valve 108 to the reservoir 104; and, when the pressure drops below a given value, liquid will be recharged to the cylinder 20 by means of the replenishing check valve 106.

In order to insure proper synchronization of the driving and driven elements of each motion transfer section, it is desirable to provide a slightly more liquid displacement in the driving or transmitting elements than is present in the respective fluid motors (see below) at the opposite end of the liquid column line. The stroke, and consequently the displacement, of the fluid motors may be limited by suitable limit stops built into the motors or associated with the load devices. Thus, at the end of each advancing stroke of the transmitter piston 18, a small amount of liquid will be discharged to the reservoir 104 through the relief valve 108. The amount plus any amount lost by leakage will be replenished to the liquid column at the end of the return stroke by the operation of the replenishing valve 106.

In the right hand portion of FIGURE 1 are several typical load devices to be moved to and fro through a cycle which corresponds with the timing of the camshaft cycle, and which represent typical parts of a machine which are operated through a repeated sequence of motion. One such load device may comprise an arm 110 oscillatable about a pivot point 112 on the machine by the oscillating piston 114 of a shiftable piston fluid motor means 116. Another load device may comprise a swinging arm 118 pivoted at 120 on the machine and shifted by pinion interconnected pistons 122 oppositely reciprocable in parallel cylinder sections of a fluid motor means 124. Another such load device 126 is shifted to and fro on a machine bed between suitable limit stops by a pair of pistons 128 integral therewith and shiftable to and fro in the cylinder portions of fluid motor means 130. Other familiar types of load devices represented by the block 132 may be moved to-and-fro on the guideways of a machine by the single shiftable piston type fluid motor means 134. All of the fluid motors 116, 124, 130, and 134 with double acting shiftable piston means represent expansible chamber type receivers.

Interconnecting the expansible chamber type receivers with the expansible chamber type transmitters, for the purpose of transferring motion from the cams to the load devices are the previously mentioned liquid columns 150. The liquid columns may comprise any suitable generally non-compressible hydraulic fluid confined by either rigid conduits or flexible piping to conduct a column or liquid link for to and fro motion between a transmitter and a receiver.

In FIGURE 1 there are shown several circles marked RO connected to the end of the motive receiving cylinders opposite the liquid column connections. These symbols designate the return oil connections by means of which a pulsator system may be hydraulically biased so as to maintain the follower in close contact with the cam as the falling portion of the cam contour recedes from the follower. The showing of separate return oil connections is indicative of any suitable type of comparatively high biasing pressure source, whether it be a single accumulator or multiplicity thereof.

The pulsator section *a* of the motivator is connected

by its closed liquid column 150*a* with the fluid motor 124 for oscillating the arm 118 to and fro. The pulsator section *b* connects by means of its liquid column 150*b* with the fluid motor 116. The pulsator section *c* connects by means of its liquid column 150*c* with the fluid motor 134 to shift the load device 132 to and fro. Pulsator section *e* connects by means of its liquid column 150*e* with the fluid motor means 130 for shifting the load device 126 to and fro.

Upon each complete revolution of the cams 12 on the camshaft 10, each of the load devices 110, 118, 126 and 132 will be shifted to and fro through a complete cycle in response to its respective driving cam. A load device cycle may include both motion portions and rest portions depending upon the nature of the machine. However, whether a load device is in motion for only a small fraction of the time required for the camshaft to make one revolution, or is in motion through the majority of the revolution time, the complete cycle time of each load device will correspond directly with the cycle time of the camshaft.

In certain modern high production machine environments, it may be desirable to shift a load device to and fro with a cycle frequency which varies from that of the camshaft. For instance, it may be desirable for a load device to operate with exactly one-half the frequency of the camshaft cycle. Such a device is illustrated generally in FIGURE 2, and will be described as an example of the environmental setting with which the basic concepts of this invention may be utilized.

The FIGURE 2 drawing represents a loading station of a multiple operation transfer machine. The fixed bed or base of the machine 152 supports a station 154 for loading ball bearings into the circularly spaced openings of a retainer for a thrust bearing assembly. A transfer member 156, which may be a rotary index type table, or a straight line conveyor, moves beneath the station 154 at the beginning of each machine cycle and then waits for the balance of the cycle. Secured on the indexing member is one race 158 of a thrust bearing assembly which may include a central upstanding boss 160 upon which is centered a retaining ring 162 having a plurality of ball openings 164 spaced in a circle about the periphery of the ring, the lower corners of the openings already having been clinched as at 166. The index member 156 moves the member 158 of the thrust assembly with its carefully oriented retainer 162 beneath an overhanging portion 168 of the base at the loading station 154.

Depending from the overhanging portion 168 is an annular retainer plate 170 and supported thereon is a shiftable dispensing member 172. Located in the overhanging portion 168 are a plurality of ball positioning sockets 174 located one above each of the openings 164 in the thrust bearing retainer 162. A plurality of similar openings 176 in the check or retainer plate 170 are adapted to be aligned with the holes 174 to permit the passage of a ball under the influence of gravity when the plate 170 is rotated to the proper position; when the plate 170 is indexed through a small degree of angular motion, however, the balls will be retained in the positioning openings 174 of the overhanging portion of the base. Suitable means, not shown, connected between the plate 170 and the base 152 index the plate through its desired short amount of angular motion once on each cycle of the machine to allow the balls in the socket 174 to drop to the socket 164 of the retainer.

The dispensing member 172 comprises a large gear having teeth 178 around its periphery, and a ball socket 180 near its edge. The socket 180 is supplied with balls by means of a flexible conduit 182 which may comprise a long coil spring extending from a suitable supply source (not shown). As the gear member 172 is rotated in one direction through 360 degrees of angular motion, a ball will be deposited in each of the plurality of positioning sockets 174 extending around a circle in the overhanging portion 168. Because of the acceleration limit of the balls under the influence of gravity, the member 172 must be indexed through its working stroke at a comparatively slow rate compared to many of the load devices on a modern high volume mass production machine tool, a rate which requires most of the machine's cycle time to turn the member completely around.

For turning the orienting gear member 172, a second gear 184 is provided on the base 152 in mesh with the teeth 178 on the shiftable member 172. The gear 184 may be press fitted upon a shaft 186 which includes pinion teeth 188 meshing with a rack 190. As can be understood, to and fro reciprocatory motion of the rack will rotate the shiftable member 172 through this chain of gears.

To prevent damage to the flexible conduit 182, it will be obvious that the gear dispensing member 172 must be rotated back in the reverse direction through 360 degrees of angular motion on its next cycle to deposit balls in the sockets 174, one stroke in one direction of the rack 190 being sufficient to fill all the sockets 174 around the circle. If the rack were returned during the same cycle of the machine, balls would be falling again into the sockets 174 to replace balls which were falling from the sockets as a result of alignment of the holes 176 in the retainer plate with the sockets 174. Thus, it is desirable to have the shiftable member 172 oscillate only in one direction on each cycle of the machine, since a new bearing assembly 158 is presented at the loading station 154 on each cycle of the machine. Thus, on one cycle the balls are deposited by the dispensing shiftable member into the sockets 174 in a clockwise direction, and on the following cycle are deposited in the sockets 174 in a counterclockwise direction.

The rack 190 for shifting the dispensing member to and fro on the machine may be operatively connected with double acting shiftable piston means 192 in a fluid motor. As can be seen in the upper right hand portion of FIGURE 1, such an arrangement may comprise a pair of piston faces 194, 196 at either end of the rack reciprocable in aligned, opposed cylinder sections 198, 200, respectively. Connected with each cylinder section 198, 200 is a liquid column conduit 198*d*, 200*d*. These liquid columns are adapted to be connected alternately with the liquid column 150*d* of the mechanico-hydraulic motivator section *d*. The liquid column from the fluid motor which is not connected with the pulsator section *d* is automatically connected with the reservoir 104. Thus, when the liquid column 200*d* is connected with the column 150*d*, the rising ramp on the cam 12*d* will pulse liquid through the column and against the piston face 196 to shift the rack to the right. Oil in the chamber 198 will be diverted back to the reservoir 104. When the liquid column 198*d* is connected with the liquid column 150*d*, the rising ramp on the cam 12*d* will shift the piston rack 190 back to the left, and liquid in the cylinder 200 will be diverted to the reservoir. During the falling portion of the contour of the cam 12*d*, liquid will be replenished to the pulsator cylinder chamber 22*d* from the reservoir by means of the replenishing portion 106 of the balancing valve 102 which will allow the rack 190 to remain in its shifted position until acted upon again by a rising portion of the cam 12*d*.

Means are provided by this invention for automatically connecting the liquid columns 200*d*, 198*d* alternately with the pulsator section *d* on successive, revolutions of the camshaft 10, whereby the rack 190 will be shifted to and fro but in only one direction during each revolution of the cam. Such a means may comprise a four-way, two position, double solenoid flow control valve 202. One solenoid 204 is provided for shifting and holding the valve in one of its two positions, and the second solenoid 206 is provided for shifting and holding the valve in its other position. The valve 202, in the position shown, establishes the connections shown in the cross-hatched rec-

tangle, and in the alternate position establishes the connections shown in the other rectangle.

Suitable electric circuitry is provided by this invention for shifting the valve at the completion of each revolution of the camshaft **10**. Such a circuit may comprise a cam switch **208** of the momentary makes variety which is adapted to be closed once on every revolution of the camshaft by a single lobe cam **210** on the camshaft **10**. Every time the contacts **208** are closed by the cam, a standard solenoid actuated ratchet mechanism **212** may index a control shaft **214** through a small amount of angular motion. A scalloped switch actuating cam **216** on the shaft **214** closes the circuit from the supply line L_2 to the solenoid **206** and opens the circuit from the supply line to the solenoid **204** in one of its stop positions; and, conversely, opens the circuit from the supply line L_2 to the solenoid **206**, and closes the circuit from the supply line to the solenoid **204** on the other of its stop positions. Thus, on one revolution of the camshaft **10** the solenoid **206** is actuated to shift the valve, and on the next successive revolution of the camshaft **10** the solenoid **204** is actuated to shift the valve.

In operation, the camshaft **10** rotates continuously, each revolution constituting a complete cycle of the machine. Upon each cycle of the machine, the indexing table **156** presents a new bearing race **158** to be loaded with balls at the loading stations **154**. Mechanism for operating the index table may be powered and controlled by suitable liquid column pulsator sections (not shown) on the camshaft **10**, Other fluid motor means for operating the other work performing stations on the machine (not shown) may also be powered and controlled by the main mechanico-hydraulic motivator. Each shiftable member on the machine will be moved to and fro through its working stroke by the rise and fall pattern on its associated powering cam for each complete revolution of the camshaft.

The dispensing load device **172**, however, will, by the mechanism of this invention, be shifted to and fro but at a cycle frequency which varies from the cycle frequency of the camshaft, the load device being shifted to and fro but in only one direction during each revolution of the cam. When the scalloped cam wheel **216** actuates solenoid **206** so that the connections shown in the cross-hatched rectangle of the valve **202** are established, the rising portion of the cam **12***d* will shift the rack **190** to the right (FIGURE 1) and the remaining, falling portion of the cam contour will allow liquid to be replenished to the liquid column through the balancing valve **102** from the reservoir **104**. Upon completion of a revolution, the cam **210** at the end of the camshaft will operate the switch **208** to rotate the scalloped cam wheel **216** whereby the solenoid **204** will be energized so that the valve **202** establishes the connections shown in the other (non cross-hatched) rectangle. With the valve in the position, the rising portion of the cam contour will shift the rack **190** block to the left and the falling portion of the contour will again allow liquid to be replenished to the system from the reservoir **104**.

Thus, as the camshaft continues to rotate, through successive revolutions, the liquid column **150***d* at the pulsator section *d* is directed during one revolution against the piston face **196** to shift the rack **190** to the right and during the next successive revolution it is directed against the other piston face **194** to shift the rack **190** back to the left, thus effectively varying the work cycle of the rack **190** as compared to the input cycle frequency of the liquid column motion transfer system.

Consequently, a means for varying the work cycle of the output piston of a mechanico-hydraulic motivator has been provided which may readily be adapted to numerous machine motivation problems to increase freedom of design when working with the fixed limitations of a cyclical acting machine tool.

While the above described embodiment constitutes a preferred mode of carrying out this invention, many other forms may be adopted within the scope of the actual invention, which is variously claimed as:

1. A mechanico-hydraulic motion transfer arrangement for cyclically shifting a load device to and fro on a machine comprising in combination shiftable piston type fluid motor means connected to shift the load device to and fro on the machine, a rotary cam and an expansible chamber type pulse transmitter connected to be operated thereby, a motion transferring liquid column connected at one end with the transmitter, and alternating means connecting the other end of the liquid column with the fluid motor means on one side of the shiftable piston during one revolution of the cam and on the other side of the shiftable piston during the next revolution of the cam whereby the load device is shifted to and fro but in only one direction during each revolution of the cam.

2. A mechanico-hydraulic motion transfer arrangement for cyclically shifting a load device on a machine comprising in combination a fluid motor including a shiftable piston having at least one working face and connected to shift the load device, a rotary cam and an expansible chamber type pulse transmitter connected to be operated thereby through a working stroke on every revolution of the cam, a motion transferring liquid column connected at one end with the transmitter, and alternating means for connecting the other end of the liquid column with the fluid motor to transfer cam motion to the one piston working face during given revolutions of the cam and alternately with a different piston face to effect a different result with the cam motion during other revolutions of the cam whereby cam motion is transferred to the one piston face with a frequency less than once for every revolution of the cam.

3. A mechanico-hydraulic motion transfer arrangement for cyclically shifting a load device to and fro on a machine comprising in combination double acting shiftable piston type fluid motor means connected to shift the load device to and fro on the machine, a rotary cam including a rising working ramp and a falling idle ramp, an expansible chamber type pulse transmitter connected to be operated by the rotary cam, a reservoir for liquid, a pair of liquid columns connected to the fluid motor means one on each side of the shiftable piston, and means for connecting one liquid column with the transmitter and the other liquid column with the reservoir during one revolution of the cam to shift the load device in one direction and for reversing the liquid column connections with the transmitter and the reservoir during the next revolution of the cam to shift the load device in the other direction whereby the load device is shifted to and fro but in only one direction during each revolution of the cam and with a motion determined by the rising ramp of the cam.

4. A mechanico-hydraulic motion transfer arrangement for cyclically shifting a load device to and fro on a machine comprising in combination double acting shiftable piston type fluid motor means connected to shift the load device to and fro on the machine, a rotary cam and an expansible chamber type pulse transmitter connected to be operated thereby, a reservoir for liquid, relief and replenishing valves connected to exchange liquid between the transmitter and the reservoir, a pair of liquid columns connected to the fluid motor means one on each side of the shiftable piston, a two-position valve for connecting one liquid column with the transmitter and the other liquid column with the reservoir in the first of its positions and for connecting the other liquid column with the transmitter and the one liquid column with the reservoir in the second of its positions, and control means responsive to cam cycling connected to operate the valve from one position to the other at the completion of each revolution of the cam whereby the load device is shifted to and fro but in only one direction during each revolution of the cam.

5. A mechanico-hydraulic motion transfer arrangement for shifting a load device to and fro on a machine comprising in combination a plurality of load devices to be shifted, a plurality of shiftable piston type fluid motors connected to shift the load devices, a plurality of cams rotated in unison by common camshaft means, a plurality of expansible chamber type pulse transmitters one connected to be operated by each cam, a plurality of liquid columns each connected at one end with a transmitter, means connecting all but one of the liquid columns at their other ends with all but one of the fluid motors to shift them through cam determined cycles every rotation of the camshaft means, and means connecting the one liquid column at its other end with the one fluid motor only during given rotations of the camshaft means whereby the load device shifted by the one fluid motor operates less frequently than the other load devices on the machine.

No references cited.