

Miscellaneous Types

All of the major classifications of intermittent motion mechanisms and systems have now been considered: gears, ratchets, cams, Genevas, stepping motors, escapements, etc., but the subject is not yet complete. Since intermittent motion devices are used in many different ways, special or unusual features are often required. The various common solutions will not solve all of the problems nor will they fit all possible applications. Designers have, therefore, evolved many other devices and systems for producing intermittent motion. Some of these are ancient and yet have never found mass application. Others are more recent and may some day become as popular as Genevas, ratchets, and the more common mechanisms. In this chapter we will consider a few of these, as yet, uncommon devices.

Star Wheels

Figure 15-1 shows two common intermittent motion mechanisms we have considered previously: a pair of gears, one of which has been mutilated, and a five-slot Geneva. Both are simple and popular devices and each has advantages and disadvantages. The Geneva mechanism, for example, has a relatively attractive acceleration and deceleration pattern; at least when compared to mutilated gears which produce severe impact. Mutilated gears, on the other hand, are capable of producing a long motion cycle interrupted by a relatively short dwell period. They can also produce one, two, or three dwells per revolution of the output. The Geneva, of course, produces a fairly short motion period fol-

lowed by a long dwell period and can usually produce no fewer than four dwell periods per revolution of the output. (Genevas with only three dwells have been made, but are awkward; while one- and two-dwell Genevas are impossible.)

Good ideas always appear to be simple and inevitable once some clever designer has thought of them. In this next case, someone decided to combine the better features of a Geneva and a mutilated gear. The result is called a star wheel, and an early example is shown in Fig. 15-2. A drive member similar to a Geneva driver, but containing five drive pins instead of one, indexes an output wheel. This wheel has "starting slots" that are similar to the drive slots of a Geneva wheel, although they are curved rather than straight. The first pin on the driver engages one of these slots and starts the output wheel in motion. The other pins on the driver then engage the gear teeth and continue the drive motion until the output member is brought to rest by Geneva-like locking surfaces on input and output members.

In the earliest star wheels the starting slots were epicyclic curves. Figure 15-3 shows a modern star wheel in which the slots are circular arcs and involute gear teeth have replaced the drive pins for the constant velocity portion of the motion cycle. Using circular arcs instead of epicyclic curves makes the star wheel a lot easier to manufacture. The use of involute teeth instead of pins also helps and it is felt that these improvements make the star wheel a practical device for the first time.

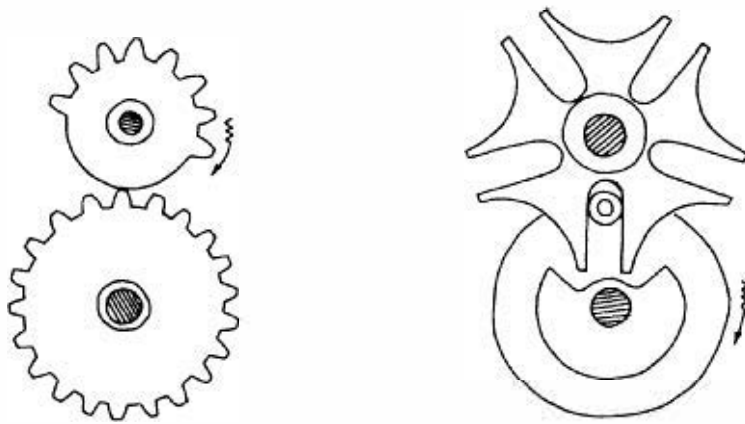
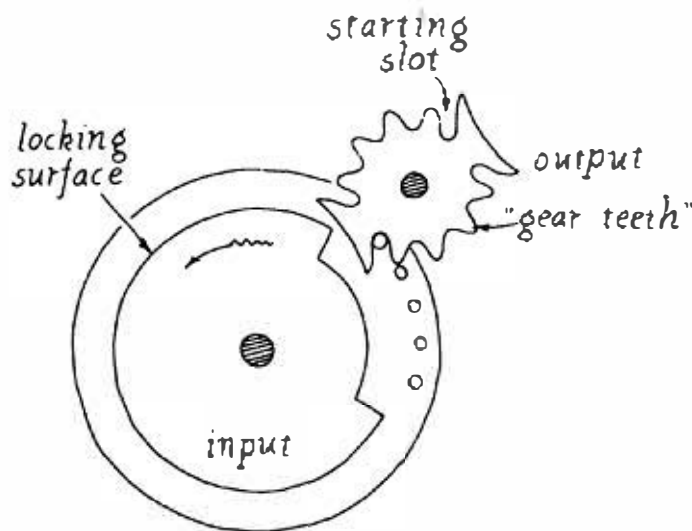


Fig. 15-1. Two common intermittent motion mechanisms; a mutilated gear and a four-slot external Geneva. The star wheel combines some of the good and bad features of both types.

Other versions of the external star wheel, producing between one and six stops per revolution of the output member can be seen in Fig. 15-4. Note that gear segments are not included on the star wheels with more than two stops per revolution, but that the curved "starting slots" are still present. A star wheel with four stops, therefore, is more comparable to a Geneva than are the one- and two-stop versions. The advantage of the four-slot wheel over a Geneva lies in the acceleration pattern. The dwell motion ratio of the input of these star wheels can also be varied somewhat, as with a Geneva.

Acceleration curves for one quarter cycle of revolution of a four-slot external Geneva and a four-stop star wheel are compared in Fig. 15-5. The star wheel has a smaller peak acceleration than the Geneva, but has a larger instantaneous change in acceleration at the beginning and end of motion.



Drawing courtesy MACHINE DESIGN Magazine; Dec. 23, 1965; p. 121 ff

Fig. 15-2. Early star wheel. This is called a two stop wheel since it will dwell twice for each output revolution.

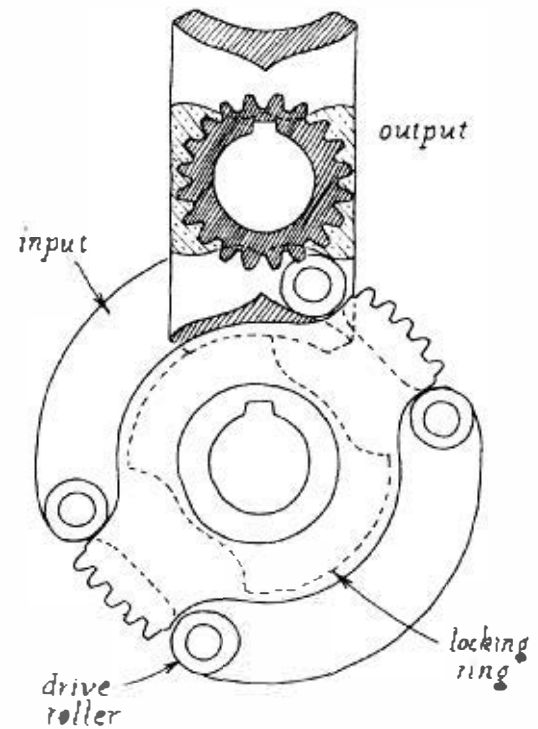
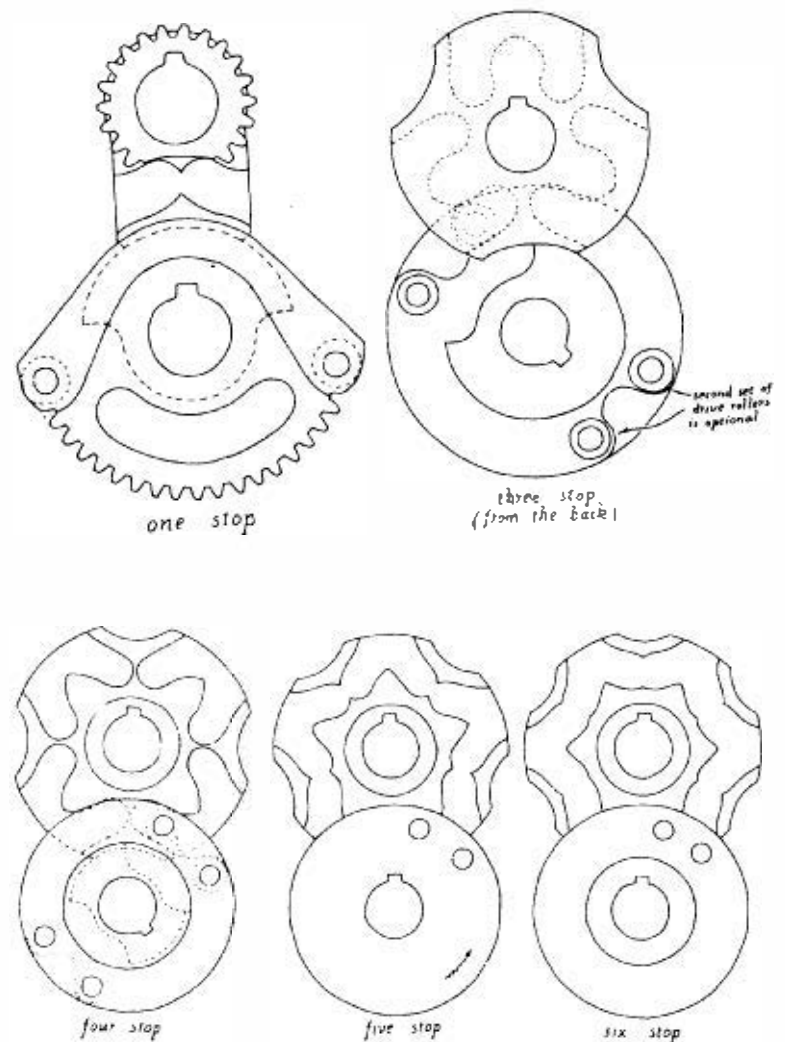


Fig. 15-3. Contemporary two-stop star wheel. (U.S. Patent 3,443,455; M. J. Zugel.)



Drawings courtesy of the Cyclo Index Corporation

Fig. 15-4. One- to six-step external star wheels. Note that the dwell-motion ratio of the input can also be varied somewhat by providing additional drive rollers as with a Geneva.

Theoretically, any instantaneous change in acceleration will produce infinite jerk. In practice, however, a greater instantaneous change (or a more rapid rate-of-change) in acceleration will produce more jerk; this is considered a disadvantage of the star wheel by some machine tool designers. The lower maximum acceleration, however, attracts other designers, since torque is proportional to acceleration, not to jerk; and a lower peak acceleration means lower maximum drive torque. A given diameter drive pin, therefore, will see less stress and/or wear less rapidly in a star wheel system than in a Geneva system.

The acceleration curve of a star wheel is altered significantly by changes in the radius of curvature of the starting slots; the curve in Fig 15-5 being an optimum curve obtained with the optimum slot shape. As with a Geneva, the acceleration curve is also dependent upon the number of dwells per revolution of the output member, with the peak acceleration tending to decrease as the number of dwells is increased (again, similar to a Geneva).

In Fig. 15-6 several types of internal star wheels are shown. In each case the output member rotates in the same direction as the input (counterclockwise), with the lead roller starting the action (accelerating the output) and the second roller stopping it. As indicated in the first part of Fig. 15-6A, 240 degrees of input motion produces 360 degrees of motion in the output. The output then dwells during the next 120 degrees of motion of the input. In the other design shown, 180 degrees input motion produces 360 degrees of output motion. During the next 180 degrees of input motion there is 180 degrees of output dwell. The action is reversible. The other designs, shown in part B of the illustration, produce different amounts

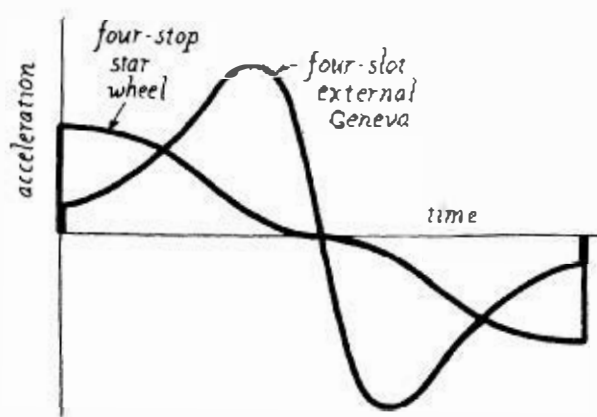
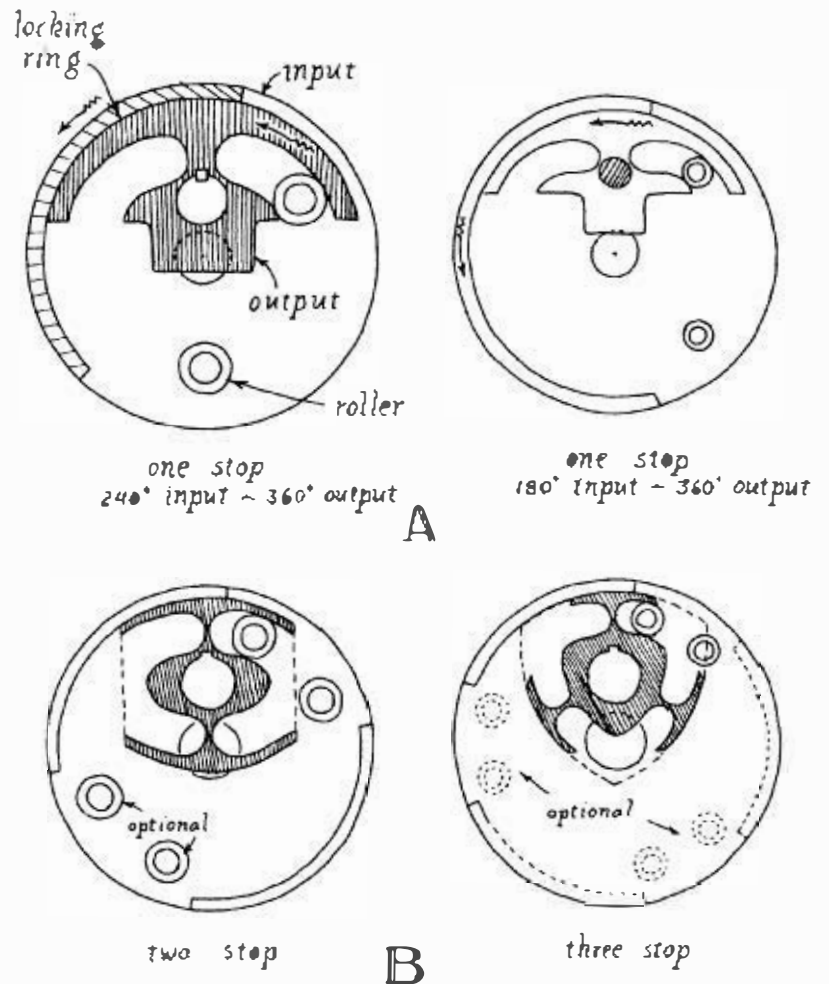


Fig. 15-5. Acceleration curves for a four-stop external Geneva and a four-stop star wheel. Note the initial and peak accelerations produced by each mechanism.



Drawings courtesy of the Cyclo Index Corporation

Fig. 15-6. One-, two-, and three-stop internal star wheels.

of output motion for varying inputs. Gear segments cannot be included in an internal star wheel (eliminating one of its advantages over the Geneva), but one, two, and three dwells per revolution of the output are still possible, while with an internal Geneva, this is either difficult or impossible.

The units of commercially available star wheels shown in the upper photograph in Fig. 15-7, are miniature devices with one-inch center distances between input and output members. The large, five-stop external start wheel (Left, below) is twelve inches in diameter (9½-inch center distance), while the two-stop internal unit (shown at right) has produced over 100 million trouble free (and maintenance free) operations in one application, and is still going strong.

Roll Cam Drives

Electrical typewriters, computer printers and other business machines and peripheral equipment operate at very high indexing speeds—pushing ratchets, escapements, Genevas, and other simple indexing



Photographs courtesy of The Curtis Center Corporation

Fig. 12-2. Eccentrically mounted star which rolls on teeth by 2.5-inch center distance.

devices to their limits. Designers of this type of equipment, therefore, have looked for alternate systems which would produce high indexing rates with little or no impact. Some of the approaches taken were seen in Chapter 10, on Gearing. Another approach, shown schematically in Fig. 12-8, is called a roll cam drive system; a very popular system in contemporary business machinery. The input consists of a high-speed, continuously rotating drum which has a friction surface (rubber or elastomeric coating). The output members do not normally engage this roller. When an output is desired, an electrical signal energizes the small control solenoid. This actuates a trigger which, in turn, releases an

eccentric cam. As shown in a, on the cam rotates in clockwise motion the cam engages the input roll. The roll now rotates the cam further. All rotation of the cam is transmitted through a pin-and-groove to the output shaft which also acts as a fulcrum for the lever (b) on which the friction roller is mounted. A spring *c* allows the action of the eccentric cam mounted in the bar, *b*, to move up and down as the action occurs. When it is desired to stop the output motion the control solenoid is de-energized, releasing the trigger which moves to interfere with the pin on the eccentric cam, catching and stopping the cam. The input drum continues to rotate with the output held out of contact with it by the latch. This mechanism will produce 300 degrees of motion in the output gear for each momentary actuation of the trigger.

The eccentric cam can be shaped to take the acceleration pattern produced in the output shaft. The ease with which the designer can alter this acceleration pattern, in fact, is one of the attractions of this system. Output acceleration patterns can be sinusoidal, cycloidal, or modified trapezoidal, as with other cam systems.

Furthermore, just as an exemplar, the roll cam system is a good torque or energy amplifier. Input energy can be quite substantial and is produced by a continuously rotating drive motor. Only a small control signal in the control solenoid is needed to initiate action. With suitable spring and lever systems to engage the eccentric cam and the drive roller, output torque can be astonishingly high.

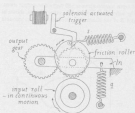


Fig. 12-8. Schematic of a roll cam drive system. This mechanism will produce 300 degrees of motion in the output gear for each momentary actuation of the trigger.

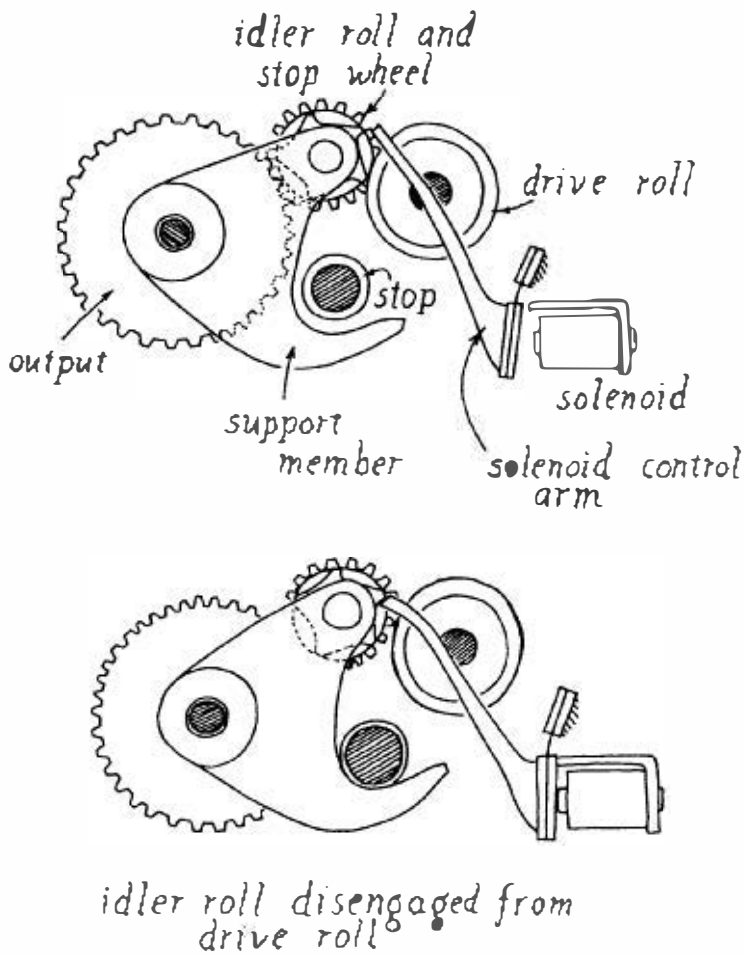


Fig. 15-9. Another type of roll cam drive system in which the output can be stopped in any one of ten different positions (U.S. Patent 2,759,872; C. S. Simonds, et al.)

There is probably little or no slip between drive cam and input roller, but even if there is, the length of the output step is not affected since this is determined by the trigger system and by the sequencing of the control solenoid (slip would, of course, increase the wear rate of the system).

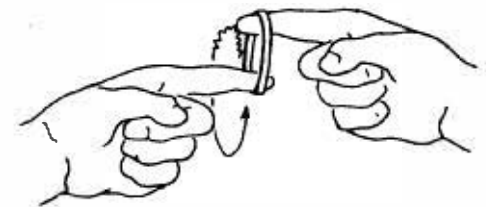
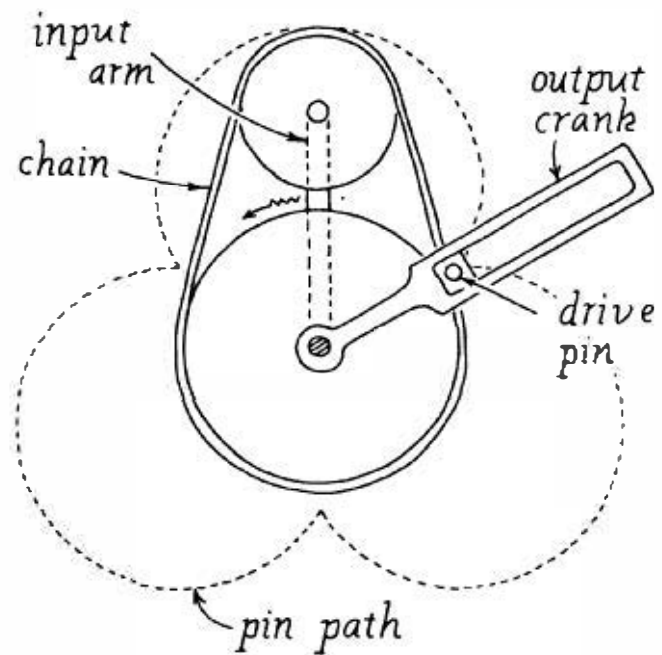
Figure 15-9 shows another roll cam system. This is similar to the first, but the friction roller is cylindrical rather than eccentric, and the output can be stopped in any one of ten positions rather than in just one. Kinetic energy in the stopping driven member rocks the support member to disengage input and output rolls when the stop arm catches the stop wheel.

Chain and Belt Drive

All of the mechanisms discussed so far have used only rigid links (unless operating speeds were high enough to make them act as elastic members). Some systems will now be considered in which flexible links, such as chains and belts, are used. Since such members have some built-in elasticity, they often act to cushion shocks and impacts in a desirable

manner. It must be remembered, of course, that any impact damper which returns energy to the system must return it at the right time (between drive cycles rather than on top of the next drive cycle) if it is, indeed, to reduce and not intensify, impact and shock effects. As long as this possible trouble is kept in mind, belts—and to a lesser extent—chains, can be used to cushion sudden starts and stops.

One simple system incorporating a chain is shown in Fig. 15-10. This system bears a strong family resemblance to an epicycloidal gear arrangement (Fig. 10-16) but is different in performance. The input member is a rotating arm, the output member a slotted crank. This crank is driven by a drive pin as with an epicycloidal gear system. Instead of the drive pin being mounted on a planet gear, however, it is now mounted on a chain which connects the freely rotating “planet pulley” and the stationary “sun pulley.” The output crank in this system dwells for approximately 120 degrees of rotation of the input arm while the planet pulley is “walking along the belt.” This action can be demonstrated by walking an elastic band around one index finger with



Drawing courtesy of *PRODUCT ENGINEERING Magazine*; Oct. 26, 1964; pp. 109, 110

Fig. 15-10. Chain and slider indexing system. The chain is “walked around” the fixed sun pulley by the motion of the planet pulley, periodically indexing the chain mounted drive pin.

the other, as in the illustration. Mark one point on the rubber band with ink or a piece of tape so you can see how the drive pin is periodically lifted and moved over the surface of the large stationary center pulley.

Figure 15-11 shows another belt system; this one involving a four-bar linkage and two timing belts. The input crank rotates about the input shaft (16), carrying with it a shaft (20) and pulley (25), that

Dec. 22, 1970 T. WATKIN 3,548,669
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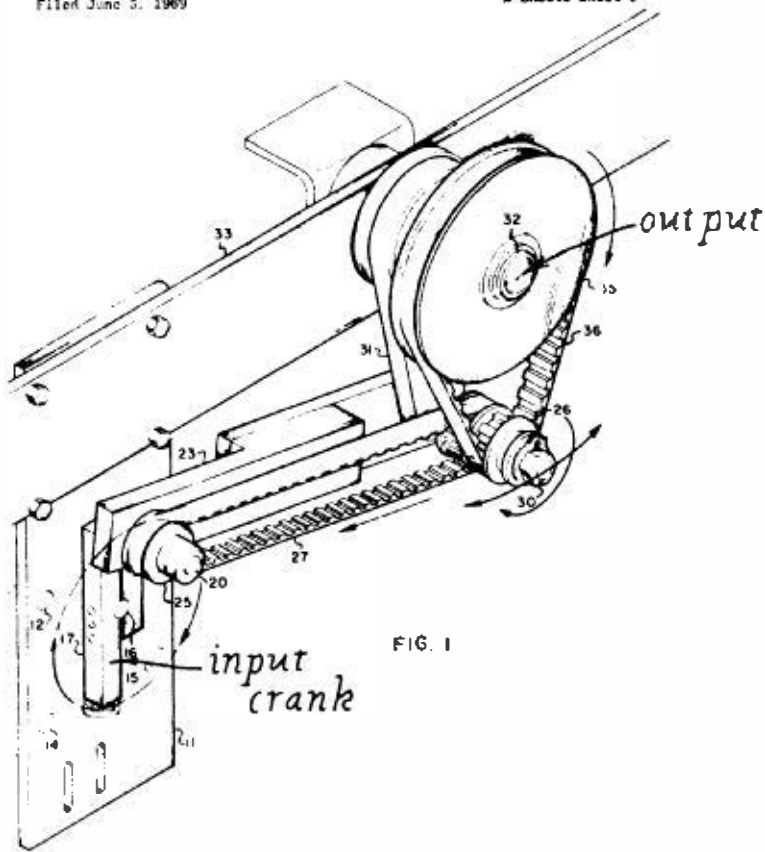
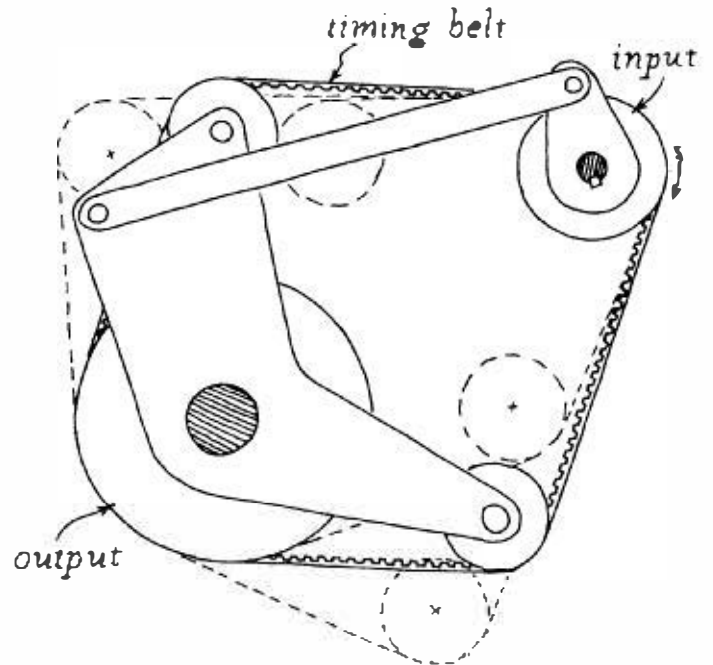


FIG. 1

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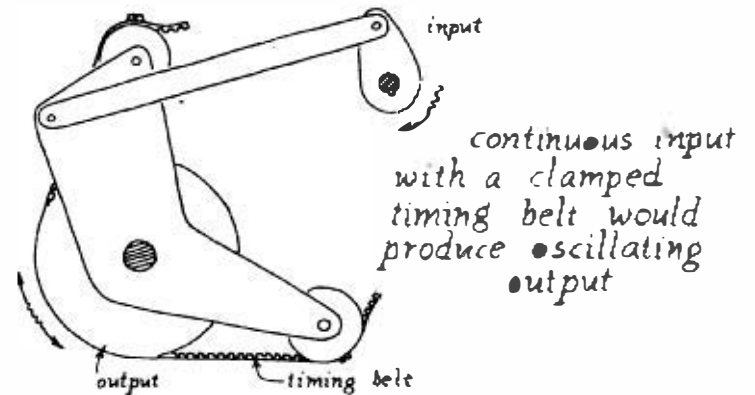
Fig. 15-11. Timing belt and four-bar linkage indexing mechanism. In this device, an oscillatory motion is added to a continuous motion to produce intermittent motion with instantaneous dwell. (U.S. Patent 3,548,669; T. Watkin.)

are not allowed to rotate with respect to the input crank. As the crank rotates, therefore, this "fixed" input pulley will tend to rotate the output pulleys. As the input crank rotates, however, it also oscillates the four-bar linkage (consisting of members 17, 28, 31, and the frame). This oscillation tends to produce an output motion which periodically adds to and subtracts from the rotational motion produced by the input timing belt. Dual pulley (26) sometimes merely "walks along" output timing belt (36), and

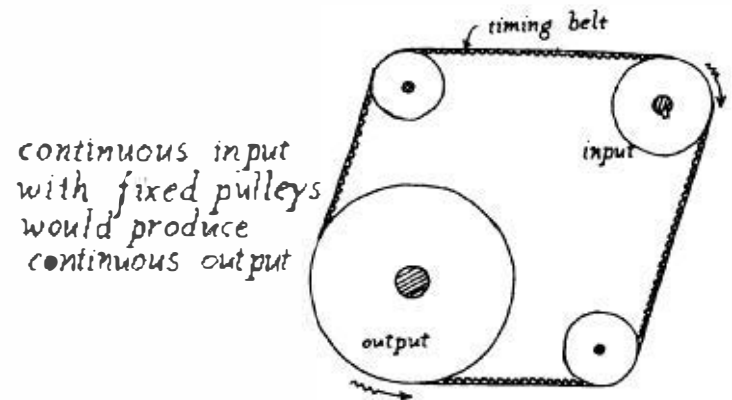


superimposed continuous and crank inputs produce intermittent output

Fig 15-12. Another timing belt and linkage system. (See Fig. 15-13 for an explanation of how it functions.) Again, an oscillatory motion is added to and subtracted from a rotational motion.



continuous input with a clamped timing belt would produce oscillating output



continuous input with fixed pulleys would produce continuous output

Fig. 15-13. Showing how the mechanism of Fig. 15-12 combines oscillatory motion with rotating motion to produce intermittent motion.

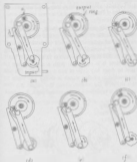
in $\frac{1}{2}$ times θ gives it. The result is intermittent motion in shaft (22).

A similar gear and crank arrangement is shown in Figs. 10-12 and 13-13. Again, the oscillatory motion of a linkage is added to and subtracted from a continuous rotational motion that is best shown in Fig. 13-13. A similar addition of θ rotational and a reciprocal motion was shown in Fig. 10-9.

A system of the type shown in Fig. 13-21 theoretically produces only instantaneous dwell periods with a more or less sinusoidal output motion in-between. Some designers, therefore, have modified such systems with clutches and brakes to extend dwell periods. The clutch-brake unit is used to turn the input to the ball cam on and off at certain dwell periods, minimizing starting and stopping accelerations. The length of the dwell period will then be under the control of the operator of a manual external computing device.

Linkage Drives

The versatile four-bar linkage can also be used in other ways to produce intermittent rotary motion.



Operating sequence of the Jackson-Walker Profile Drive, *Journal of Mechanical Engineering*

Fig. 15-14. Linkage drive mechanism for intermittent motion. Drum (1) is a spring-loaded drive cam. Arm 2, pivoted to the input cam, periodically locks and releases the output ring to which the shaft is fastened.



Photograph showing the Jackson-Walker Profile Drive, *Journal of Mechanical Engineering*

Fig. 15-15. Locking table with the drive mechanism in Fig. 15-14.

Figure 15-14 shows the sequence of operation of a mechanism used in a machine tool indexing table. An input cam drives a linkage arm which, in turn, rotates a drum with the indexing table. An output ring, connected to the working surface of the indexing table, surrounds this drum but is kept from moving by a locking lever, A, which is controlled by the input cam. A spring-loaded tooth, a, on the drum also engages this output ring.

When the cam releases the locking lever, A, the spring-loaded tooth, a, can carry the output ring along with the drum as shown in (b) and (c) in the illustration. At the end of the drum stroke, the locking lever depresses the spring-loaded tooth, as shown in (d), so that the drive drum and tooth can return to the starting position (e) and (f). The output ring dwells during the portion of the cycle. Eventually, the drive tooth picks up the ring again and another index motion occurs. The complete indexing table is shown in Fig. 15-15.

Figures 15-16 and 15-17 show another linkage system. The system, in most of the ball-and-gear drives considered earlier, are designed to produce intermittent motion with instantaneous dwell periods. In fact, this linkage system is a close cousin of the gear system shown in Fig. 10-28 which is illustrated at some detail in the accompanying text.

Intermittent

The remaining illustrations in this chapter show other ways to produce intermittent motion. Some were designed independently and may never find application again, but have been included, never-

theless, to make this book as complete as possible. Perhaps one of these unusual solutions will be the only possible solution for some future reader.

Other devices in this collection are included here

July 1, 1969

J. M. STEINKE

3,452,613

INTERMITTENT ROTARY MOTION TRANSMISSION

Filed Jan. 2, 1968

Sheet 2 of 3

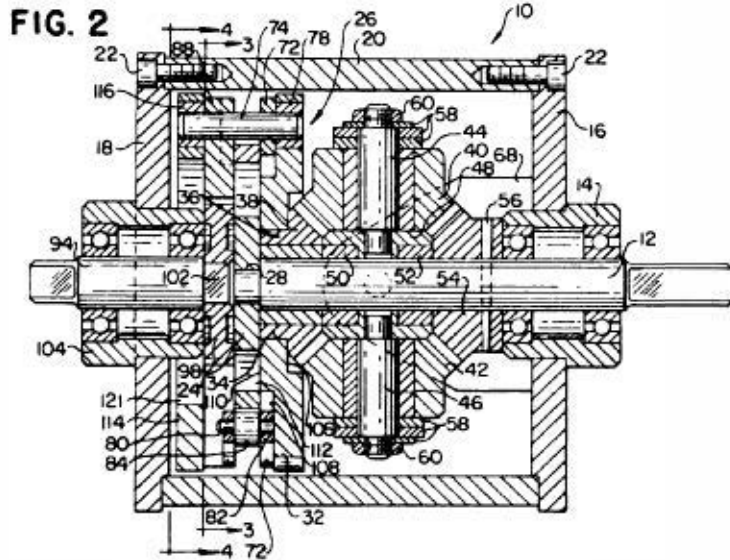
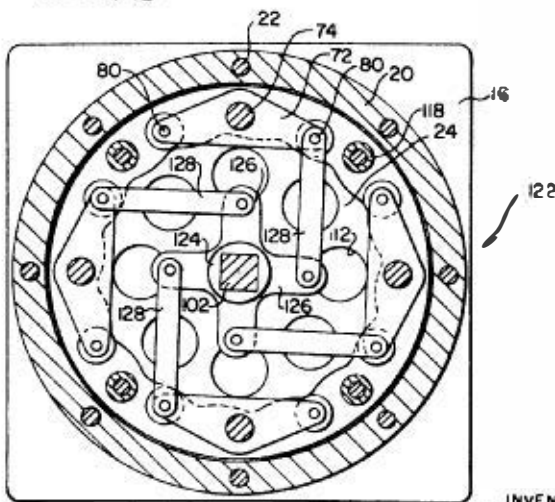


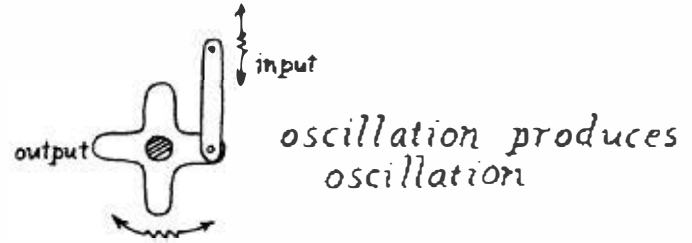
FIG. 5



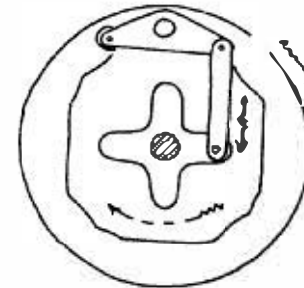
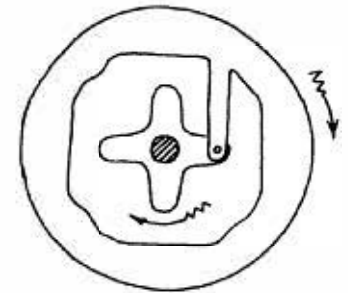
INVENTOR
JAMES M. STEINKE
BY *Roma A. Kline*
Albert S. Siskind
Spencer A. Sego
HIS ATTORNEYS

Fig. 15-16. Cam and linkage indexing system. See Fig. 15-17 for description of operation. See also Fig. 10-28. (U.S. Patent 3,452,613; J. M. Steinke.)

simply because they cannot be classified with any of the devices which have gone before. It is quite possible that they may find widespread application in the future, and, indeed, are used rather broadly at the present time. The fact that they are presented last should not in any way indicate that they are least effective.



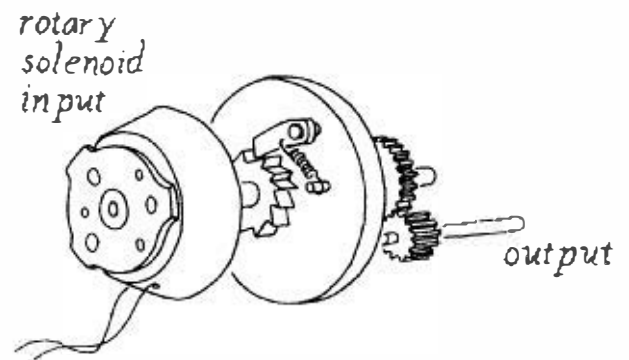
rotation produces rotation.



oscillation plus rotation produces rotation and dwell

Fig. 15-17. Demonstration of oscillatory motion combined with rotational motion to produce intermittent motion in the mechanism of Fig. 15-16.

The first illustration, Fig. 15-18, shows an old friend (a ratchet) combined with a type of driver (a rotary solenoid) that has not yet been discussed. The rotary solenoid typically produces something less than 360 degrees of rotation in an output shaft every time it is energized. Such a solenoid can be used to drive any type of one-way clutch. (In the illustration, a ratchet clutch is used.) The input to this clutch is the ratchet wheel; the output is a disc on which is mounted a spring-loaded pawl. A no-back



Drawing courtesy of MACHINE DESIGN Magazine, Nov. 21, 1968

Fig. 15-18. Rotary solenoid and ratchet clutch. The rotary solenoid typically produces something less than 360 degrees of rotation in an output shaft every time it is energized.



Reamed end view of the Cone Pneumatic

Fig. 15-18. Pneumatic vane type actuator with cone reamed. This actuator produces 90 degrees of rotation in an output shaft whenever high-pressure air is introduced on the proper side of the vane.

part (not shown) would also be required. The following illustration Fig. 15-19, shows a pneumatic driver that can do the same job as the rotary solenoid but with higher torque. This vane type actuator produces 90 degrees of rotation in an output shaft whenever high-pressure air is introduced on the proper side of the vane. The device, then, can serve as a pneumatic "rotary solenoid" in conjunction with one-way clutches to provide the pneumatic equivalent of the system shown in Fig. 15-18. Both these drivers are worth knowing about.

Figure 15-20 is an entirely different type of mechanism in which two basically linear devices (pneumatic or hydraulic cylinders) are used to produce intermittent rotary motion. A considerable amount of torque could be developed by this type of system, although positioning accuracy would prob-

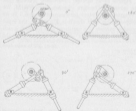
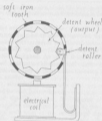


Fig. 15-20. Two pneumatic or hydraulic cylinders are operated in sequence to provide four-step output motion. (U.S. Patent 3,558,477; R. Kinisutt, Jr.)

ably not be very great. Linear actuators of any kind could be used in a similar fashion. The output dwells whenever both drivers are at rest (extended or retracted).

The device shown in Fig. 15-21 bears some relationship to an inverse escapement and some to a vibrating motor, but not enough to either one to warrant its inclusion in those chapters. It is one of the ~~mechanical~~ devices that have been invented to solve some special intermittent rest and run problem. The output wheel has ten soft-iron teeth and a ten-toothed, star-shaped detent wheel. When the electrical coil (the only input here) is energized, it will

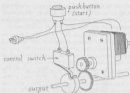


Drawing courtesy of MACKYER DESIGN, Pasadena, Dec. 22, 1961; p. 102 P

Fig. 15-21. Electro-mechanical stopping motor. The output wheel has ten soft-iron teeth and a ten-toothed star-shaped detent wheel.

attract the nearest soft-iron tooth. When the coil is de-energized, the detent roller will move the output wheel a few degrees further. Periodic excitations of the electrical coil, therefore, will step the output wheel.

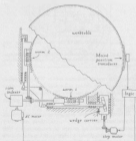
Although discussion has been concentrated on intermittent motion components, there are many systems (cooperating groups of components which alone could not produce intermittent motion) that could be mentioned. Figure 15-22 illustrates a very simple one, the switched electrical motor system. A push button is depressed momentarily to start the electrical motor. The first few degrees of rotation of the output shaft closes the control switch which is in parallel with the push button. This keeps the motor



Drawing courtesy of MACHINE DESIGN Magazine, Dec. 21, 1961

Fig. 13-23. Switched electrical motor. The push button is depressed momentarily to start the electrical motor.

running (after the push button has been released) until the cam reaches the initial position, opening the control switch and stopping the motor. The motor, of course, must be braked by friction and/or the load, before it coasts far enough to re-close the control switch. This is usually no problem, however, with a braked motor such as that shown in Fig. 13-23.



Drawing courtesy of The Glenn Loran

Fig. 13-25. Curvic coupling system. An AC motor operating through a cam indexing mechanism drives a pair of worm gears to position a work table near a desired position. A stopping motor operates a wedge cam system to improve the accuracy of the final position.



Drawing and photograph courtesy of Information Inc.

Fig. 13-24. (Left) External view of a hydraulic-pneumatic stepper. (Right) Schematic of the interior mechanism.

Figure 13-23 shows the Curvic coupling system, a very sophisticated system that is used for high-performance machine tools. An AC motor operating through a cam indexing mechanism drives a pair of worm gears to position a work table near a desired position. A stopping motor operates a wedge cam system to improve the accuracy of the final position. A Moiré transducer (see Chapt. 16) measures table motion very precisely. Logic circuits determine the desired and actual table positions and control the two drive motors to produce the missing motion.

The hydraulic-pneumatic stepper is an interesting device using a one-way clutch to produce intermittent motion; it is shown in Fig. 13-24. A hydraulic or pneumatic cylinder drives a rack which displaces. A one-way roller clutch connects the piston to the output shaft. The shaft, (hereafter, is indexed as the piston moved back and forth. The degree of output motion is the stroke of the piston rack assembly.

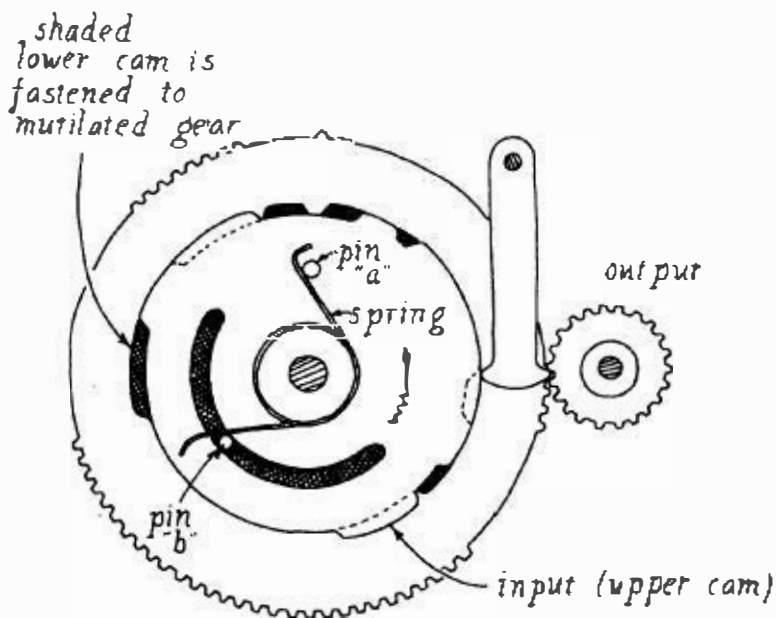
PRIM

Figures 13-25 through 13-27 show a device that its inventor, Theodore Simpson, calls PRIM, for "Programmed Rotary Intermittent Motion." In its simplest form, that shown in Fig. 13-25, the input mechanism consists of a modified gear to which a cam is pinned. The former drives an output gear, the



Fig. 13-25. Basic configuration for the PRIM mechanism: (A) PRIM mechanism with the input in motion and the output at rest. (B) Output gear in motion. (U.S. Patent 3,442,146; T. Simpson.)

latter controls a locking lever (Fig. 15-25A) which releases the output gear (Fig. 15-25B) just prior to each drive cycle (and locks it again just after each motion cycle). In its basic form, the device bears a family resemblance to the detented mutilated gear system shown in Fig. 10-11, although the output is under better control in Mr. Simpson's design. The detent lever is spring loaded against the input cam, or is driven out of engagement with the output gear by the motion of that gear whenever the input cam allows this. Furthermore, additional refinements have been evolved. In Fig. 15-26 input is provided by one control cam which is spring loaded to the original cam (still fastened to a mutilated gear). The locking lever engages both cams and the output gear is always locked—no output will occur—until the two cams are aligned, i.e., a slot on each so that the locking lever can swing to the left. Pin, *a*, on the input cam loads a drive spring to drive the mutilated gear and lower cam through pin *b*, which operates in a slot in the input cam. The result is to combine



Drawings made from information supplied by T. Simpson

Fig. 15-26. Load-and-fire snap-action version of the PRIM mechanism of Fig. 15-25.

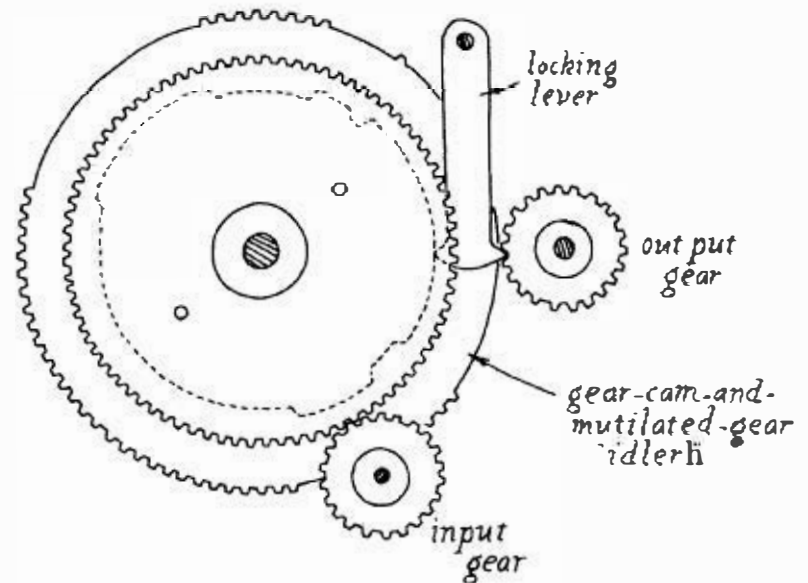


Fig. 15-27. In this version of the PRIM mechanism the input gear rotates three times for each revolution of the mutilated gear.

the features of a load-and-fire escapement (see Fig. 12-11) with the features of a mutilated gear.

The inventor also has pointed out (Fig. 15-27), that if either of these devices is driven through a step-down gear ratio the amount of output motion (or dwell) can vary from one full revolution of the input to another (with, of course, a cyclic repeating pattern), since different amounts of output can be produced for each interaction between the mutilated gear and the output gear. This degree of programming over the output is difficult or impossible to obtain with most of the mechanisms discussed previously. The various gears can be sized, of course, so that only two shafts are involved, making a very compact mechanism. Three shafts have been shown in Fig. 15-27 merely to clarify the operation of the design. As a result of this and other refinements, Mr. Simpson's device truly deserves the name programmed rotary intermittent motion. It would have the normal disadvantages of intermittent gearing at high speeds or heavy loads, but properly applied it should be quite a versatile and useful mechanism.