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INTERMITTENT DRIVE APPARATUS

Filed July 17, 1956

2 Sheets-Sheet 1

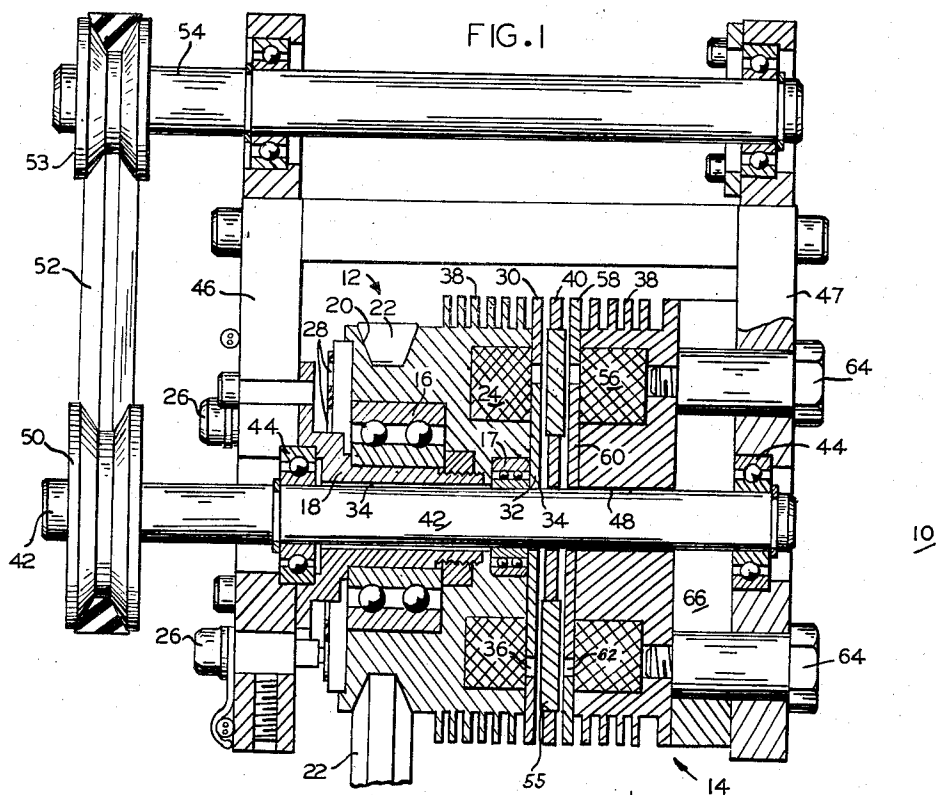


FIG. 2

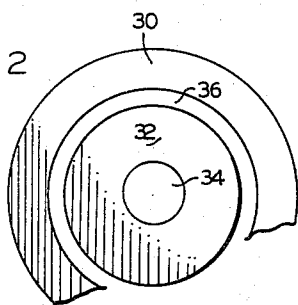


FIG. 3

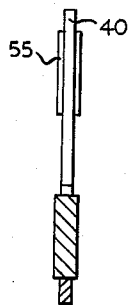
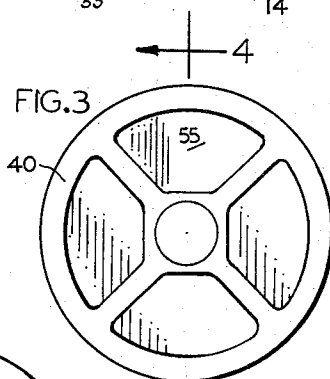
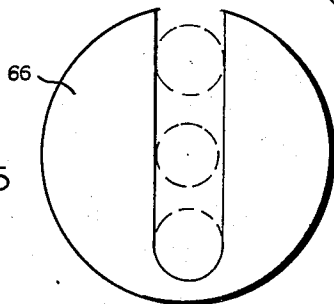


FIG. 4

FIG. 5



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2 Sheets-Sheet 2

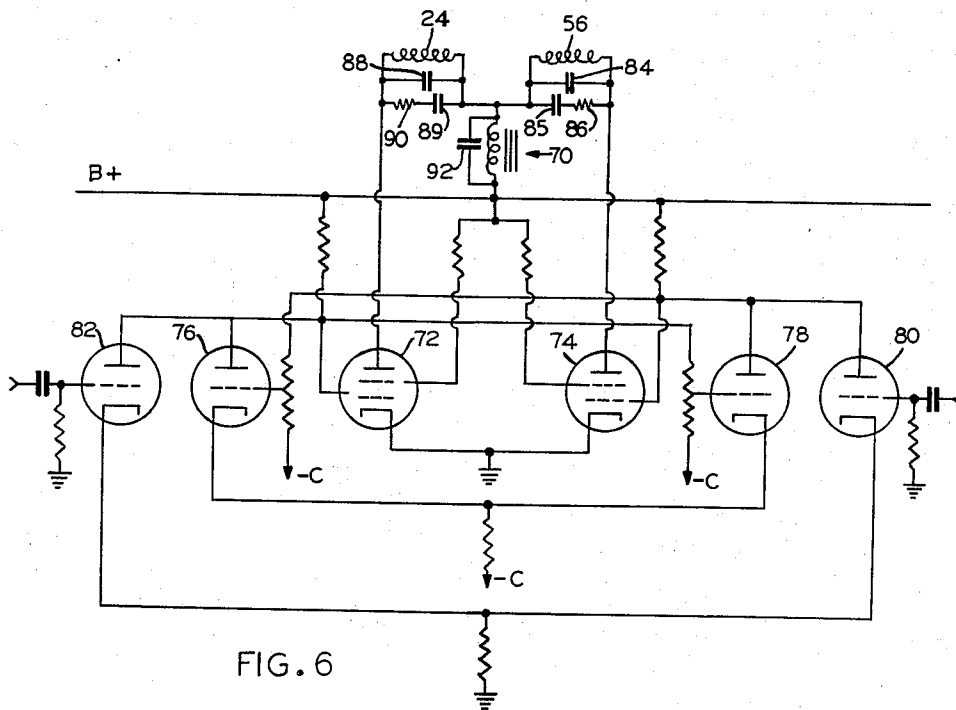


FIG. 6

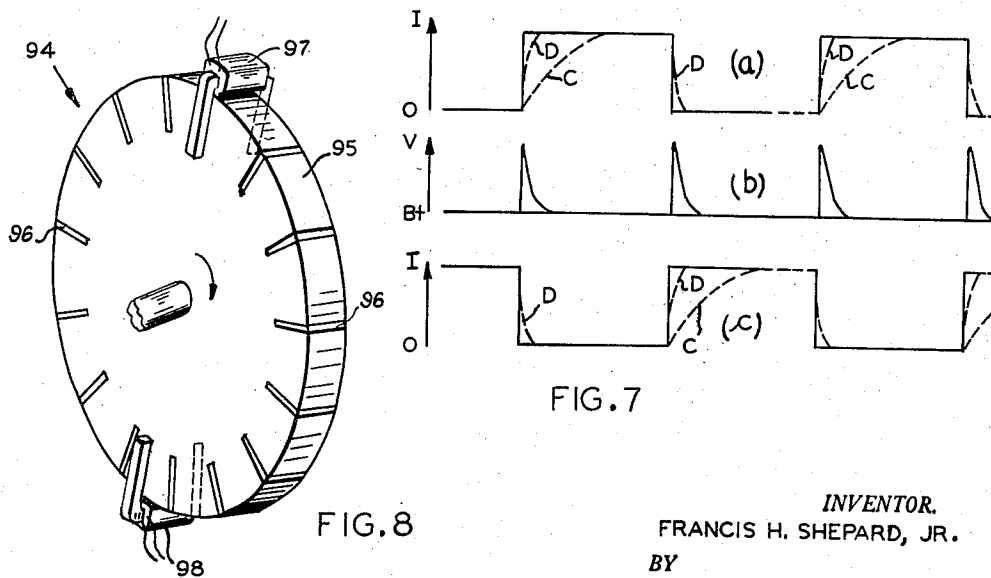


FIG. 7

FIG. 8

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INTERMITTENT DRIVE APPARATUS

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13 Claims. (Cl. 192—18)

This invention relates to a mechanical clutch and brake and to the electrical control circuit therefor.

An object of this invention is to provide an arrangement for suddenly starting and suddenly stopping a drive mechanism many millions of times with great reliability and with very accurately controlled and very quick movements.

A more specific object is to provide a mechanism for advancing a sheet of material, such as a long strip of paper feeding into a high-speed typewriter, a step at a time in exactly measured amounts many times a second over long periods of time.

Additional objects are to provide such mechanism at low cost and of a kind which is extremely easy to maintain at peak efficiency.

High-speed electronic computers are able to solve problems in mathematics and science with lightning-like speed and of such complexity that they stagger the imagination. The speed of these computers is so great that it is difficult if not impossible for their human operators to keep up with them. This is particularly true when it comes to taking down the answers being given by one of these computers.

To ease the burden of taking down these answers, there have been developed high-speed electro-mechanical typewriters which are designed to accept information and to type it out many times faster than even the best secretary can type. Even so, many if not most of these special typewriters are still not fast enough to keep up with a really speedy computer.

One of the big problems affecting the speed of these electro-mechanical typewriters is how to advance a sheet of paper fast enough one step at a time on command through the typewriter mechanism. The paper in these machines is usually advanced along its length a line at a time, much as in an ordinary office typewriter, but unlike the latter is advanced at much greater speed and very many lines per minute. However, the mechanical stresses due to inertia, the large amount of power required to overcome this inertia and the wear and tear on the parts of the drive mechanisms previously devised have in the past limited the top speed at which the paper could be driven. Moreover, even though these drive mechanisms were operated at what is now only a moderate speed, their service life was short. The present invention provides a drive apparatus which overcomes these difficulties and which furthermore can be operated at appreciably higher speeds than most if not all previous drives.

In accordance with one aspect of the present invention there is provided a combined clutch-brake unit for mechanically starting and stopping on command a drive shaft abruptly and in quickly repeated though aperiodic cycles many millions of times. The inertia of the moving parts of this unit has by a unique arrangement been kept to a minimum so that these parts can be started and stopped very quickly and only a relatively small amount of power is required to control this starting and stopping.

The control power for this unit is in the form of an electric current which energizes either one or the other of two electromagnets. The energization of one electromagnet couples the output drive shaft of the unit to a continuously rotating motor-driven input shaft. The energization of the other electromagnet couples the output shaft to a fixed brake and causes the shaft to stand still. The output shaft clutch-element in this unit, through which this shaft is alternately coupled to the input shaft and the brake, is subdivided into a plurality of very light-weight and hence low inertia plates which can be attracted to and engaged by one or the other of the two electromagnets with great force and practically instantaneously. These plates can be engaged by one or the other of the two electromagnets at a given time, but cannot be engaged by both electromagnets at the same time. Thus there is no possibility of mechanical locking between clutch and brake.

In accordance with another aspect of the invention, the output drive shaft of the clutch-brake is connected in low-speed relation with the rotatable load shaft of another unit, for example, the paper shift drive of a typewriter. By so connecting and operating the clutch-brake unit, substantially more efficient starting and stopping is obtained than if the output drive shaft were driven at appreciably higher speed for a given load shaft speed. A reason for this is that the effective inertia of the system is greatly reduced by driving the output shaft at the lowest practical speed consistent with torque requirements. By this arrangement, contrary to what might be supposed, the ability of the unit to start and stop almost instantaneously is substantially enhanced and the slippage and wear between friction surfaces in the unit is greatly reduced.

So successful and so efficient is this arrangement that in one unit which has been built and tested, after being stopped and started under load something like fifteen times a second for several million cycles, a reference number stamped in ink on one of the friction faces of the unit remained completely legible and in fact showed no signs of wearing off. This indicates that there is practically no slippage between the friction faces of the unit and hence that the output drive shaft is brought to full speed from a stopped condition almost instantaneously and, conversely, stopped from full speed just as quickly.

Even though this brake-clutch unit is so free of wear, nonetheless provision has been made for replacing the parts in it which are most subject to wear with minimum effort and time lost. In fact, these parts can be replaced and the unit readied for operation in about a minute's time. This is made possible in part by the simple and unique clutch-element carried by the output drive shaft and by the way this element is carried.

In accordance with another aspect of the invention, an electric control circuit for supplying energizing currents alternatively to one or the other of the clutch-brake unit's two electromagnets is made able to build up these currents practically instantaneously in spite of the relatively large inductances of the electromagnets. This means that the full attractive force of one or the other of these electromagnets is applied to the clutch-element carried by the output drive shaft of the unit so fast and to such degree that this clutch element does not have a chance for appreciable slippage. This, with the low effective inertia of the moving parts of the unit as previously explained, minimizes wear and time lost in changing the speed of the output drive shaft.

In accordance with still another aspect of the invention there is provided a line-finder wheel which can be mechanically connected to the output drive shaft of the brake-clutch unit and electrically connected to the electric control circuit therefor to measure and to control very ac-

curately the amount of movement given the output shaft each time. This line-finder wheel consists of a non-magnetic disk having imbedded around its periphery at equally spaced intervals small pieces of magnetic material. These pieces are adapted to be rotated by the disk past one or more pickup coils and to induce therein pulses of voltage as each passes a coil. These pulses can then be fed into the electric control circuit in order to switch off the clutch electromagnet and switch on the brake to stop the output drive shaft of the unit at the proper time to place, for example, the next line of paper in a typewriter in proper position for typing. An advantage of this line-finder wheel is that no actual contact is made between wheel and pickup coil and hence dirt and the like cannot interfere with its operation. Another advantage is that the wheel is self-powered, i.e. it does not require a separate power supply to provide energy for the control pulses generated in the pickup coil. This wheel is therefore inexpensive to make and inexpensive to maintain. Since the clutch-brake unit is so fast acting and since the line-finder wheel is able to generate control pulses of relatively large amplitude occurring precisely when a magnetic piece on the wheel moves past a pickup coil, the resolution obtained with this arrangement is excellent. The material being advanced by the output drive shaft of the clutch-brake unit can therefore be advanced line by line quickly and with the same high accuracy many millions of times.

A better understanding of the invention together with a fuller appreciation of its many advantages will best be gained from the following description given in connection with the accompanying drawings in which:

Figure 1 is a side view partly in section of the clutch-brake unit embodying features of the invention;

Figure 2 is a face view of one of the electromagnets of the unit;

Figure 3 is a face view of the spider wheel which is fixed to the output drive shaft of the unit and which carries the individual plates of the clutch element;

Figure 4 is a partial section view along line 4—4 of the spider wheel shown in Figure 3;

Figure 5 is a side view of a removable part of the unit of Figure 1;

Figure 6 is a diagram of the control circuit embodying features of the invention;

Figures 7 (a), (b), and (c) illustrate various waveforms in connection with the circuit of Figure 6; and

Figure 8 is a perspective view of a line-finder wheel embodying features of the invention.

Referring now to Figure 1, there is shown here a brake-clutch unit 10 which includes a clutch electromagnet 12 and a brake electromagnet 14. Clutch 12 is rotatably mounted near its left end on a collar bearing 16 which is carried by the fixed support 18. The right end of clutch 12 is rotatably supported on the bearing 17 mounted between clutch and the shaft 42 to be described later. Near the left end of the clutch is a groove 20 which is engaged by a belt 22 which in turn runs to a drive motor (not shown) and by which the clutch is adapted to be continuously rotated. Clutch 12 has recessed below its right face an annular space into which a coil 24 is placed. When properly energized with current led in from the stationary brushes 26 through the slip rings 28 carried on the clutch, this coil will induce in the clutch a strong magnetic field. By making the body of the clutch of magnetic material, such as soft iron, the clutch will act as a very powerful electromagnet when energized. The pole faces for this magnet consist of the concentric annular flat rings 30 and 32 fastened in the same plane at the right end of the body of the clutch and concentric with the opening 34 which runs along the longitudinal axis thereof. This opening 34 is larger than shaft 42. Pole faces 30, 32, also shown in Figure 2, are of magnetic material and can be removably fastened to the clutch body by screws, for example, in order to facilitate replacement if

necessary. By making these rings 30 and 32 of hardened and polished steel their resistance to wear can be made very high. Since they contribute only a small amount of the magnetic circuit of the clutch they will not be able to support a significant amount of remanent magnetization. These rings are separated by the circular air gap 36 across which a strong magnetic field is developed by coil 24, this field falling effectively to zero when the current through coil 24 is switched off. Clutch 12 and brake 14 each have encircling them sets of cooling fins 38 which carry away any excess heat generated by the action of clutching and braking.

To the right of clutch 12 and closely spaced therefrom is the thin spider wheel 40. This wheel is rotatably mounted by means of the drive shaft 42 to which it is fixed and which in turn is supported at its two ends by the bearings 44. These last are held by fixed supports 46 and 47. Shaft 42 runs through opening 34 in clutch 12 and through a similar opening 48 in brake 14 and is thus free to rotate relative to these two members. Shaft 42 near its left end carries a sheave 50 which engages a belt 52 leading to a sheave 53. This last is carried by a rotatable load shaft 54 to be driven by unit 10. For a given rate of advance of shaft 54, shaft 42 is run at the lowest rate consistent with the required resolution in starting and stopping shaft 54, and within the torque limit on shaft 42 permitted by the clutch and brake unit. By running shaft 42 at this minimum rate, the inertia of the system is effectively reduced as previously mentioned.

Spider wheel 40, which is also shown in Figure 3, carries loosely fitted within corresponding cut-through portions in itself several segment shaped plates 55, four, for example, which are made of magnetic material. These plates will be drawn against rings 30 and 32 and held with great force across air gap 36 when coil 24 of clutch 12 is energized. When so held, spider wheel 40 is forced to turn in unison with clutch 12.

To the right of wheel 40 is positioned brake 14 which is stationary and which is very similar in structure to clutch 12. Brake 14 includes a coil 56 energized through leads not shown, and annular face rings 58 and 60 substantially the same as rings 30 and 32 and separated by the air gap 62. When clutch 12 is de-energized and brake 14 energized, the plates 55 carried by wheel 40 lock the wheel to the brake and keep the wheel from rotating.

The thickness of the plates 55 relative to that of wheel 40 can be just slightly larger than the thickness of the wheel as is indicated in Figure 4. Plates 55 can be made from soft iron covered on both faces with a suitable long wearing material such as Raybestos sintered bronze clutch facing. This facing introduces a small air gap between plates 55 and the faces of the brake or clutch unit and assures quick release of these plates.

Brake 14 is removably clamped to the stationary member 47 by the screws 64 and the insert or spacer 66. By simply loosening these screws and slipping out the insert (seen also in Figure 5) the brake can be moved to the right exposing spider wheel 40. Then plates 55 in the wheel can easily and quickly be replaced. The lateral distance between rings 30, 32 and rings 58, 60 is normally held fixed at a value slightly greater than the thickness of spider wheel 40 or of plates 55. Thus there is no possibility that wheel 40 can become locked to clutch 12 and to brake 14 at the same time.

By dividing the laterally moving clutch element of unit 10 into the segmental plates 55 instead of making this element an integral annulus or a disk, for example, by making wheel 40 a solid disk of magnetic material and allowing it to shift back and forth laterally on shaft 42, it is possible to clamp each plate 55 against the clutch or brake face almost instantaneously and without chatter or screeching. Any small vibratory motion which may develop in a plate 55 is quickly damped out by friction between it and spider wheel 40. If on the other hand instead of using these loose plates 55, wheel 40 were solid

5

and were used as the moving clutch element, an attempt to clamp it, while rotating, against the brake, for example, would result in a gyratory action of wheel 40 and it would take an appreciable interval before the wheel could be brought to rest against the brake. This gyratory effect is easily demonstrated by trying suddenly to clamp a spinning or gyrating fifty-cent piece against a flat table top.

Spider wheel 40 as seen in Figure 3 is made of a suitable non-magnetic material and preferably of a light-weight one such as aluminum. Thus, because of its small size and light weight, the inertia of the moving parts which are connected to output drive shaft 42 is further held to a minimum. The inertia of clutch 12 instead of hindering the operation of unit 10 in fact helps to bring shaft 42 up to full speed almost instantaneously.

The large inductance of coil 24 and of coil 56 would normally prevent currents from rapidly changing in them. This would be a serious limitation where, as here, the energizing currents for these coils must be brought up to strength almost instantaneously to provide the required fast clutch or brake action for unit 10. However, according to another aspect of the invention, the effect of the large inductances of coils 24 and 56 is minimized.

The control circuit for applying currents to coils 24 and 56 is shown diagrammatically in Figure 6. Coil 24 is connected to be supplied with current from the high voltage direct current supply line B+ through the inductor 70 connected in common with it and coil 56. Current through coil 24 is controlled by tube 72 and flows or not depending on whether this tube is conducting or not. Similarly current from the lead B+ via inductor 70 through coil 56 is controlled by the tube 74. Tubes 72 and 74 are biased so that one is fully conducting and the other is cut-off, this condition being reversible at will. The biases applied to these tubes are supplied by a bi-stable flip-flop arrangement including the tubes 76 and 78, one or the other of which is always conducting. This flip-flop arrangement is well known to the art and does not require detailed description of its operation. A positive pulse applied to the grid of the buffer amplifier tube 80 causes tube 78 to become conducting and tube 76 to cut off. Thereafter these tubes will remain in this condition until a positive pulse is applied to the grid of the buffer amplifier tube 82 whereupon tube 76 becomes conducting and tube 78 cuts off.

When tube 78 becomes conducting, its plate will pull the grid of tube 74 sufficiently negative to cut that latter tube off. At the same time, tube 76 cuts off allowing the grid of tube 72 to go sufficiently positive to make tube 72 conducting. Thus the current which had been flowing through coil 56 via inductor 70 is switched to coil 24. At this instant this happens, though there is no current flowing into coil 24, current rapidly builds up to full value because of the current flowing through inductor 70 which can not change quickly and which has no return path except through coil 24. To avoid a destructive voltage surge, a path for the current which is flowing in coil 56 when tube 74 cuts off is provided by the small capacitor 84 and the capacitor 85 and resistor 86 connected in shunt across the coil, a similar capacitor 88, and capacitor 89 and resistor 90 being connected across coil 24.

Figures 7(a), and 7(c) respectively show the qualitative effect of inductor 70 on the buildup of current through clutch coil 24 and alternatively, through brake coil 56. Without inductor 70, current through these coils would change relatively slowly to and from a maximum value I along the dotted lines C in Figure 7(a) and 7(c). With inductor 70 in circuit, however, the current through coil 24 or 56 rises much more rapidly as indicated by the dotted lines D which very closely approach the perfect square waves shown by the solid lines. The voltage surges across inductor 70 which adds to the supply voltage to cause the coil currents to follow lines D instead of lines C are indicated in Figure 7(b). These surges go

6

from +B to voltage V in a short instant and then drop to +B again at the respective times noted. The maximum value of V is limited by a small capacitor 92 in shunt across inductor 70.

The amount of rotation imparted to the rotatable shaft 54 in unit 10 for each cycle of operation is controlled by the time difference between a positive starting pulse applied to tube 80 in Figure 6 and the first positive stopping pulse thereafter applied to tube 82. A particularly efficient and advantageous means of obtaining stopping pulses timed in accordance with the rotation of shaft 54 includes the line-finder wheel shown in Figure 8 and which also embodies features of the invention.

Referring to Figure 8, line-finder wheel 94 includes the disk 95 which is non-magnetic and which is adapted to be rotatably mounted, for example, directly on the shaft 54. Disk 95 carries recessed around its periphery the magnetic pieces 96, which can be permanent magnets, these pieces being evenly spaced and being positioned transverse to the rim of the disk. Two pickup coils, coil 97 and coil 98, with disk 95 spaced therebetween, are placed opposite the rim of disk 95 so that when a piece 96 moves past one of the coils, it will induce a voltage in the coil winding. These coils, to detect non-magnetized but magnetic material, can be suitably energized by a small permanent magnet, for example, with a steady state flux. To detect pieces 96 when they are permanent magnets, no such auxiliary flux is required. The pulse of voltage obtained from either coil 97 or 98, after suitable shaping and clipping in circuits well known to the art, can then be applied in positive sense to the grid of tube 82 to switch unit 10 from clutch to brake condition.

As seen in Figure 8, coil 98 is spaced relative to coil 97 and disk 95 so that when a piece 96 passes the legs of coil 97, the legs of the coil 98 are half way between two other magnetic pieces 96. Thus disk 95 need rotate only half the distance between pieces 96 for one of them to induce a voltage in one of the coils 97, 98.

The above description is intended in illustration and not in limitation of the invention. Various changes in the arrangement described may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention as set forth.

I claim:

1. In an intermittent drive apparatus, a body having two concentric arms of magnetic material terminating in faces at least one of which faces is annular and both of which are located level with each other and are separated by a circular magnetic flux gap, a thin spider wheel co-axial with said arms and rotatably positioned in a parallel plane closely adjacent said faces, a plurality of clutch plates loosely recessed in said wheel, said plates being of magnetic material and being movable relative to said wheel substantially only toward and away from said flat faces whereby when a magnetic field is developed across said flux gap said plates will be tightly held thereacross and said wheel will be held from rotating relative to said arms, and means to generate a magnetic field across said gap a plurality of times for each revolution of said spider wheel.

2. The combination of elements as in claim 1 in which said concentric arms are shaped around an annular opening in said body and in further combination with a multi-turn coil positioned in said opening and adapted to conduct a magnetic-field-producing current.

3. The combination of elements as in claim 2 in which said body is of soft iron and in further combination with two thin flat concentric circular members of hardened steel fitted across the ends of said arms and forming said flat faces.

4. In an intermittent drive apparatus, a clutch or brake unit including an electromagnet having a generally plane face and a thin disk-like wheel rotatably positioned in front of said face and including a plurality of freely mov-

able magnetic elements adapted to be moved toward or away from said face thereby to hold or not hold said wheel with respect thereto, and a load shaft adapted to be started and stopped a number of times per revolution and connected in at least one-to-one drive relation with said wheel.

5. The combination of elements as in claim 4 in which said wheel is non-magnetic and has cut through it a plurality of openings in which said magnetic elements are loosely carried and in which said wheel is rotatably carried on a shaft extending through an opening along the common axis of said electromagnet.

6. In a clutch-brake unit wherein a load shaft is to be suddenly started and suddenly stopped a number of times per revolution, a brake electromagnet, a clutch electromagnet spaced therefrom, a spider wheel carried on a drive shaft and rotatably positioned between said electromagnets, said wheel loosely carrying at least one magnetic member movably only perpendicular relative to the wheel toward and away from said electromagnets, the thickness of said wheel being small and being only slightly less than the separation between said electromagnets, a load shaft for advancing the paper in a typewriter line by line, said load shaft being connected to said drive shaft in the lowest drive ratio permitted by the required resolution of starting and stopping, and means to energize said electromagnets to stop and start said load shaft a plurality of times per revolution.

7. The combination of elements as in claim 6 in which said spider wheel carries a plurality of magnetic members positioned in generally symmetrically arranged cutout portions in said wheel, and in which said electromagnets each have a circular or annular magnetic flux gap across which said magnetic members are adapted to be held.

8. An intermittent drive apparatus comprising a brake electromagnet and a clutch electromagnet each having relatively large inductance, and energizing means to supply said electromagnets alternatively with current which builds up to full value very quickly, said energizing means including a source of direct current, switch means to connect said source alternatively to one or the other of said electromagnets, and energy storage means associated with said switch means and in conjunction therewith for supplying energy to one or the other of said electromagnets at the instant it is connected to said source at a rate greater than energy can be supplied by said source alone, whereby current is built up to full value in said electromagnet in a very short time after it is connected to said source.

9. The combination of elements as in claim 8 wherein said energy storage means includes a large inductor connected in series with said source and adapted to be connected alternatively in series with each of said electromagnets.

10. A control circuit for suddenly switching current from a brake electromagnet to a clutch electromagnet to suddenly stop or suddenly start a drive shaft controlled by said electromagnets, said circuit including a first large-

inductance coil associated with the clutch electromagnet and a second large-inductance coil associated with the brake electromagnet, a source of direct voltage, a large inductor connected in series with said source, and an electric switch for suddenly connecting said first coil in series with said source and said inductor and alternatively for suddenly connecting said second coil in place of said first coil.

11. In an apparatus of the character described, a rotatably mounted load shaft adapted to advance the paper in a typewriter line by line a plurality of times for each revolution of said load shaft, a rotatably mounted drive shaft connected in at least one to one drive relation with said load shaft, a thin non-magnetic spider wheel carried by said drive shaft, a clutch electromagnet rotatably mounted around said drive shaft and rotatable relative thereto, a fixed brake electromagnet mounted around said drive shaft and rotatably clearing it, the faces of said electromagnets being spaced closely on opposite sides of said spider wheel and generally parallel thereto, each of said electromagnets having an annular air gap opposite said spider wheel, a plurality of laterally movable magnetic elements loosely carried in openings through said wheel and adapted to be clamped in turn to one then the other of said electromagnets across its respective air gap, a respective conductive coil in each of said electromagnets, and means for energizing said coils one after the other in turn including a source of direct current, an inductor connected in series with said source and each of said coils, and an electric switch for connecting one then the other of said coils with said inductor across said source.

12. The combination of elements as in claim 11 in further combination with means including a line finder wheel for operating said electric switch to start and to stop said load shaft a plurality of times per revolution.

13. The combination of elements as in claim 11 wherein said clutch electromagnet is rotatably mounted on a fixed frame and said brake electromagnet is fastened to said frame by screws and by a spacer, said spacer being removable by loosening said screws and when removed permitting said brake electromagnet to be moved laterally away from said spider wheel whereby said magnetic elements can quickly and easily be replaced.

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