

March 26, 1963

J. H. MacNEILL ET AL

3,082,925

VACUUM CAPSTANS

Filed Dec. 5, 1960

4 Sheets-Sheet 1

FIG. 1.

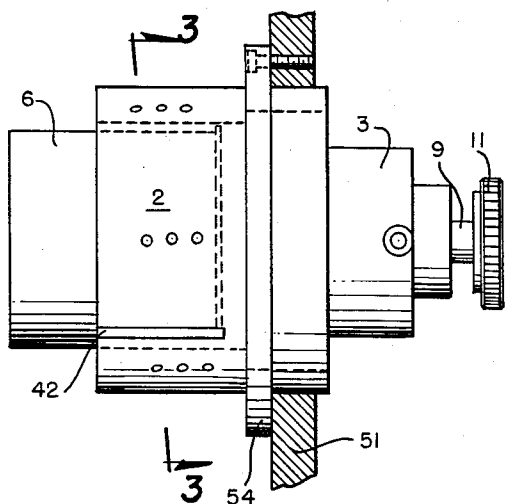


FIG. 2.

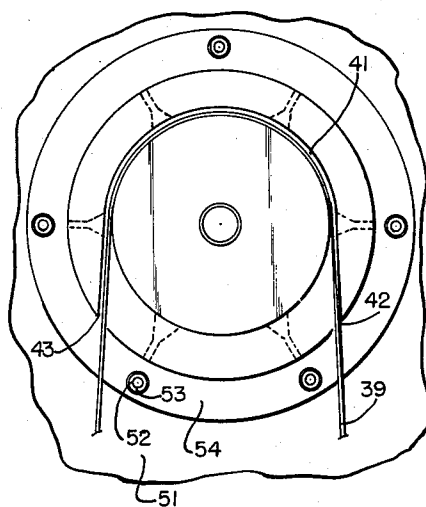


FIG. 3.

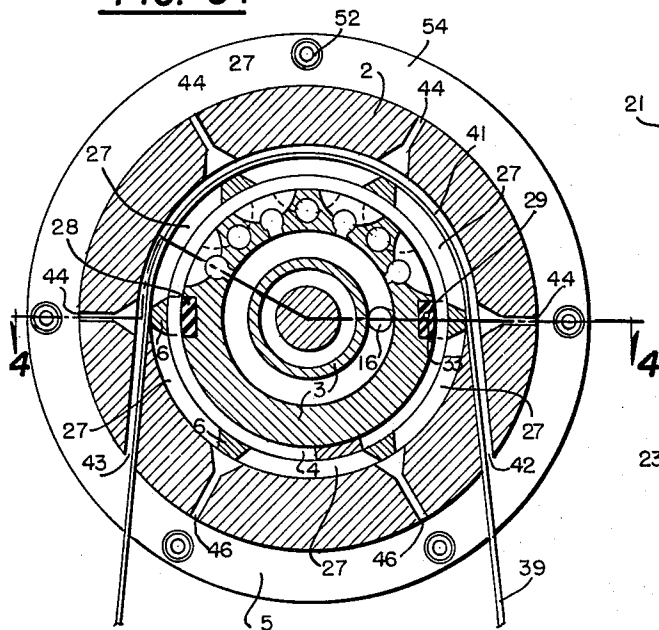


FIG. 9.

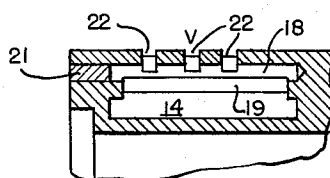
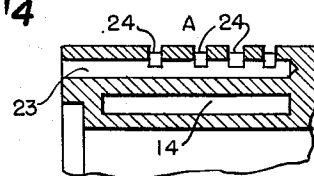


FIG. 8.



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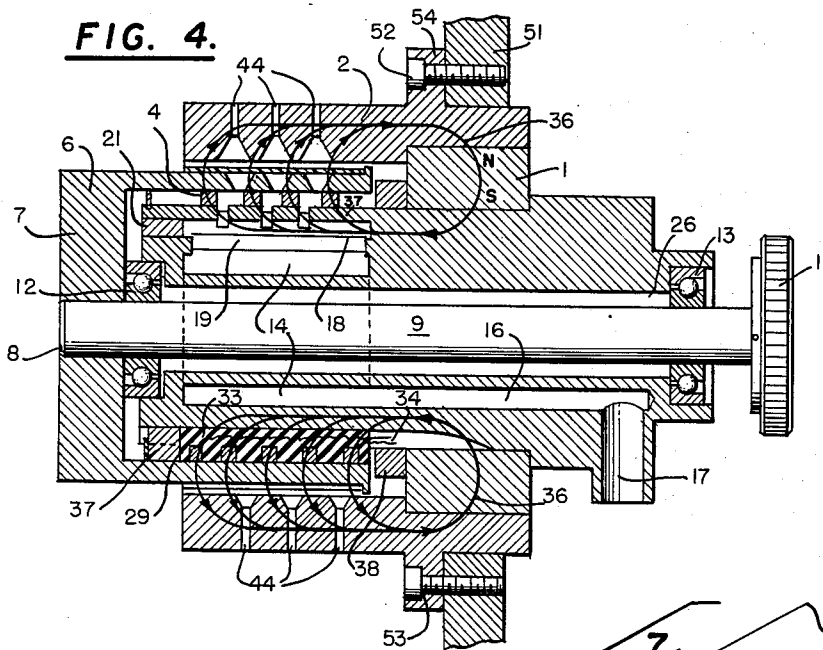
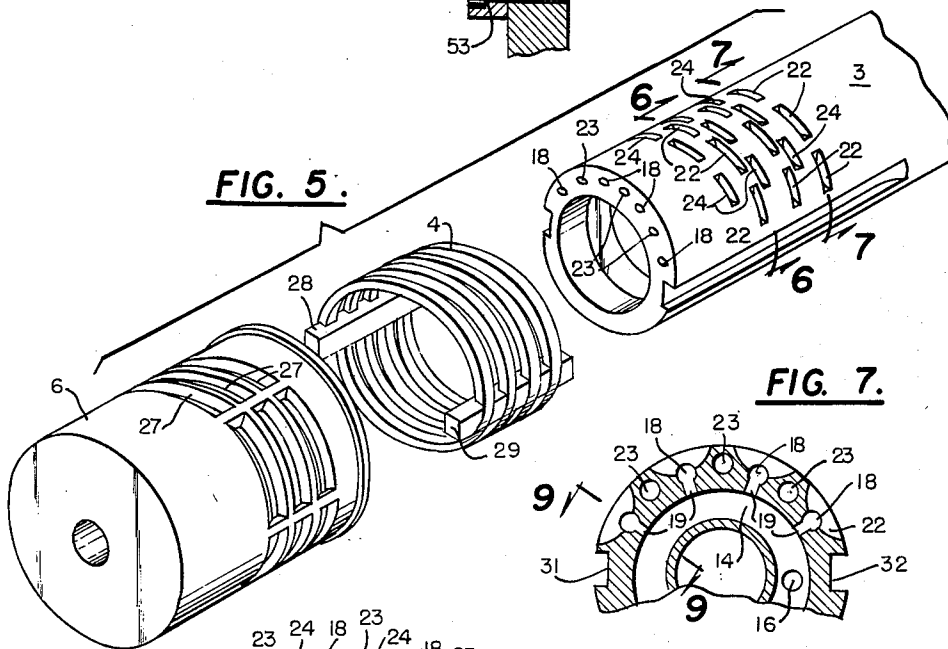
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FIG. 10.

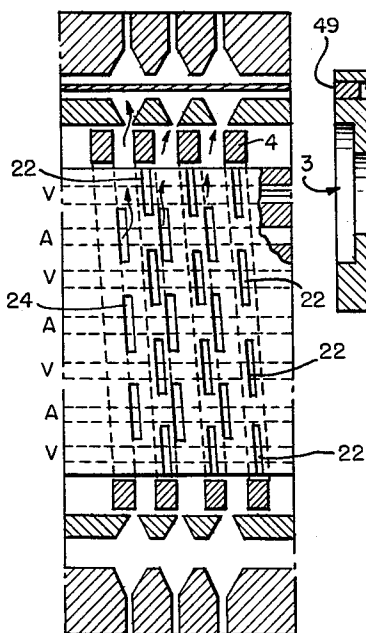


FIG. 12.

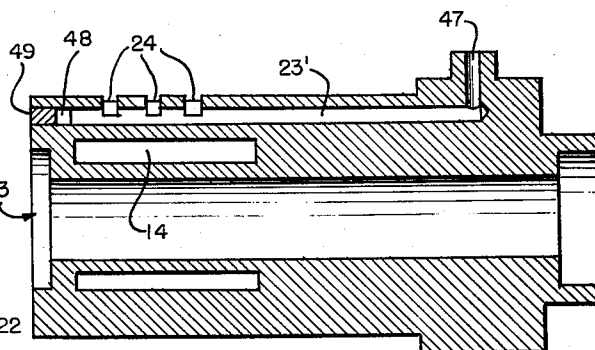


FIG. 11.

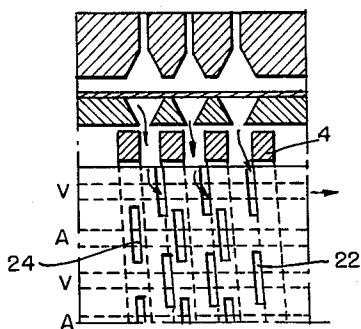
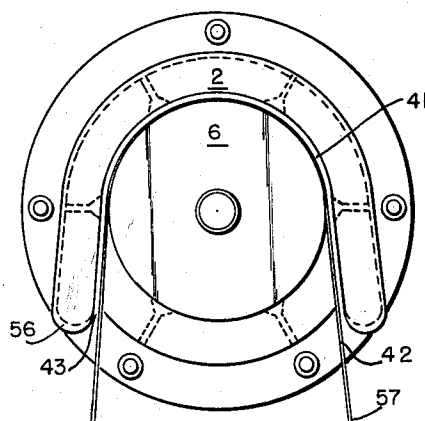


FIG. 13.



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Filed Dec. 5, 1960

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FIG. 14.

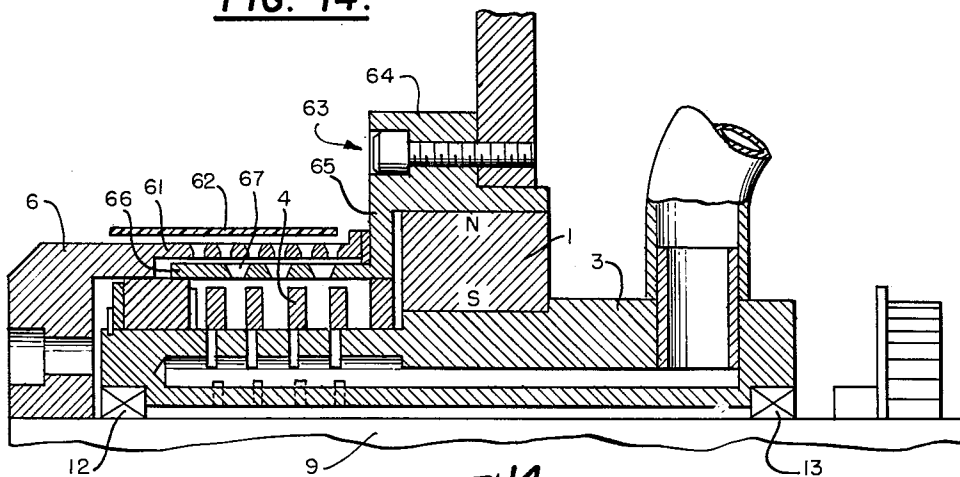
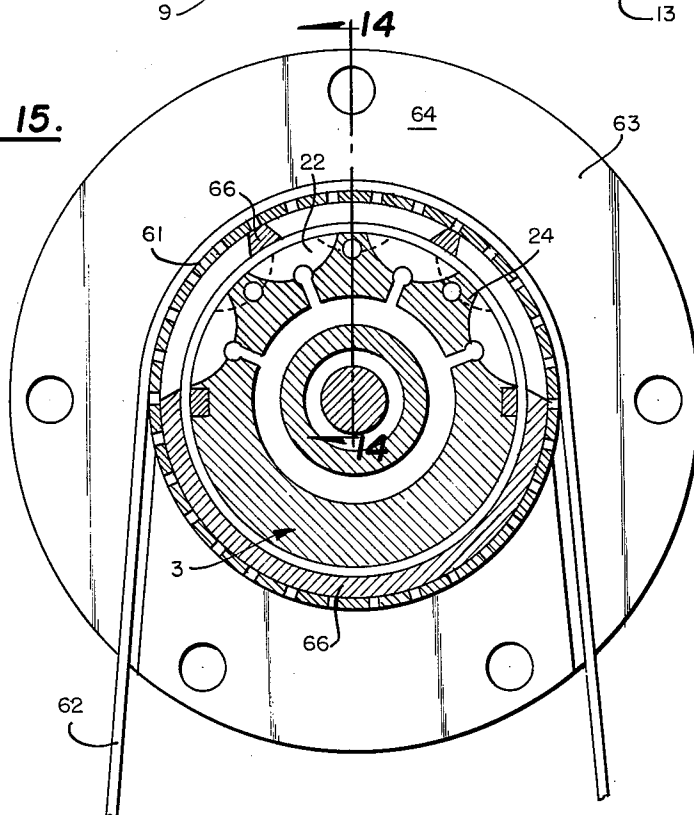


FIG. 15.



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VACUUM CAPSTANS

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Filed Dec. 5, 1960, Ser. No. 73,693

15 Claims. (Cl. 226-95)

The present invention relates to capstans for utilization in driving elongated tapes and more specifically to a vacuum capstan in which a partial vacuum is developed between a constantly rotating capstan and a flexible tape in order to clamp the tape to the rotating capstan so as to effect transport thereof.

Vacuum capstans which are employed to selectively transport a length of flexible tape have been known in the prior art for some time. Devices of this type operate by drawing a vacuum through apertures in a rotating capstan which vacuum causes the tape to be drawn against the surface of the capstan and to be transported thereby. When it is desired to terminate transportation of the tape, the vacuum is removed and the tape, due to friction, comes to a halt. The prior art vacuum capstans are relatively slow in response; that is, in picking up the tape and terminating transport thereof, as a result of the fact that the valves employed to control the vacuum system are relatively slow acting. Further, the valves are located remote from the capstan which introduces further delay due to velocity of sound and pressure drop in the lines. In the conventional systems, an electric signal is fed to a solenoid which is then used to control a valve, the speed of responses of such systems being quite low. Alternatively, pneumatic systems may be employed in which the control signal is a pneumatic signal. However, even in systems of this type, the speed of response is of the order of forty to sixty cycles per second.

It is, therefore, an object of the present invention to provide a vacuum capstan having a very rapid response to control signals.

It is another object of the present invention to provide a vacuum capstan which is relatively simple in construction, and has a rapid response to control signals.

In accordance with one embodiment of the present invention, a vacuum capstan comprises a constantly rotating capstan to which a tape may be selectively clamped or from which it may be selectively released. The capstan has an apertured surface through which the vacuum may be drawn and the drawing of the vacuum is under the control of a voice coil valve. The system comprises hollow, cylindrical, inner and outer magnetic poles and a permanent magnet for developing a flux field through the poles. The outer pole surrounds the capstan and is spaced therefrom by a distance necessary to permit passage of a tape at least over an arcuate portion of the capstan. The inner pole is disposed inwardly of the capstan. The inner pole is stationary as is the outer pole and is provided with a series of peripherially extending apertures divided into two groups. One of these two groups is coupled to a source of vacuum and the other of the two groups is coupled either to atmosphere pressure or to a source of pressurized gas. A voice coil comprising a helix or offset winding of rectangular aluminum wire is snugly disposed about the inner pole between the inner pole and the capstan. By applying currents of different polarity to the voice coil, which is disposed in the magnetic field established by the permanent magnet, the voice coil can be made to assume one of two extreme positions. In one position, the voice coil covers the apertures in the inner pole which are connected to the vacuum system and, in the other extreme position, covers the apertures in the surface of the inner pole which are coupled to atmosphere or a source of pressure. As a result, the voice coil op-

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erates as a valve to apply a pressure or develop a vacuum under the tape disposed between the outer pole and the capstan so as to provide selective decoupling of the tape from and coupling of the tape to the capstan.

The apparatus of the present invention is capable of rapidly accelerating and decelerating a flexible tape and further may be cycled between intervals of acceleration and deceleration at relatively high frequencies as a result of a combination of several features. Since the capstan is permanently rotating and therefore does not have to be accelerated and decelerated, it may be made quite heavy with respect to the effective weight of the tape as seen by the capstan. Consequently, coupling the load to the capstan does not reduce its speed and rapid acceleration of the tape is possible so long as a sufficient vacuum is developed by the system to hold the tape tightly against the capstan. Further, the spacing between the tape and capstan is quite small so that the tape is moved rapidly into contact with the capstan.

If it is desired to produce rapid deceleration of the tape, a source of pressurized air is provided which is coupled to the system so as to develop a pressure (above atmospheric) under the tape when the tape is to be stopped. The air pressure blows the tape off of the capstan and into contact with the stationary outer pole which therefore operates as a brake for the tape.

The ability of the apparatus to be cycled between intervals of acceleration and deceleration at relatively high frequencies is, to a degree, dependent upon the interval required to effect tape acceleration and deceleration. However, an equally important consideration is the interval required to change the conditions under the tape from a vacuum condition to a non-vacuum condition. This interval may be minimized by employing a capstan in which the cylindrical portion between the two poles is quite thin so that the volume of the region to be evacuated is small compared with the capacity of the pump and reservoir associated with the system. The rate at which the aforesaid region can be evacuated is determined by the transit time of the pressure front through the region since there is substantially no drop in pressure of the source due to load for the reason set forth immediately above. The pressure front travels at sonic velocities and since the valve is located immediately adjacent the region to be evacuated or pressurized, rapid changes in pressure are obtainable. In consequence, the speed of response of the pneumatic system is determined to a large extent by the speed of response of the voice coil valve. The valve may be fabricated from aluminum wire and therefore is physically quite light. A strong permanent magnet may be employed which, in conjunction with the application of relatively large control signals to the light-weight voice coil, provides extremely rapid operation of the valve. With respect to electrical delays in building up the current in the coil, such a coil has little inductance so that delays introduced by the electrical time constants are minor compared with those of the mechanical system. As a result of the above factors, response in the kilocycle per second region is obtainable with the capstan of the present invention.

It will be noted that in the embodiment of the apparatus described above, the magnetic poles are disposed on opposite sides of the flexible tape and, therefore, a magnetic field is established across the tape. Consequently, the apparatus of the first embodiment of the invention cannot be employed with magnetic tapes since the magnetic field would erase any information recorded thereon. In a second embodiment of the invention, the inner pole and the voice coil valve are substantially identical with the first embodiment of the invention but the outer pole is disposed between the voice coil valve and the drive capstan. The outer pole has a plurality of apertures therein

so that a vacuum or pressure may be transmitted there-through, to the inner periphery of the drive capstan, and through the capstan to the flexible tape disposed outwardly thereof. If a braking is required, an outer member of non-magnetic material, which conforms generally to the shape of the outer pole of the first embodiment of the invention, may be employed as a friction surface against which the tape may be pressed by appropriate pressure.

In this embodiment of the invention, the tape is disposed a greater distance from the vacuum source than in the first embodiment of the invention due to the fact that the outer pole is disposed between the tape and the source of vacuum. However, the additional distance is relatively small compared with the overall parameters of the system and the operation of the apparatus, although slower than the apparatus of the first embodiment of the invention, is still quite rapid and is operable in the kilocycle per second range.

It is another object of the present invention to provide a vacuum capstan having a light-weight voice coil valve for selectively coupling the apertures in a continuously rotating and relatively heavy capstan to a source of vacuum or pressure.

It is yet another object of the present invention to provide a vacuum capstan employing a voice coil pneumatic valve which capstan can be quickly cycled between tape transport and tape holding conditions as a result of rapid acceleration and deceleration of the tape and rapid switching between a vacuum source and a pressure source.

Yet another object of the present invention is to provide a vacuum capstan employing a voice coil valve shiftable between two extreme positions for alternatively causing a partial vacuum or a pressure to be developed between a flexible tape and a rotating capstan so as to draw the tape to the capstan or to press the tape against a stationary member disposed adjacent the capstan, respectively.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a side view in elevation of the apparatus of the present invention;

FIGURE 2 is an end view of the apparatus of the present invention;

FIGURE 3 is a cross sectional view in elevation taken along line 3—3 of FIGURE 1;

FIGURE 4 is a cross sectional view in elevation taken along line 4—4 of FIGURE 3;

FIGURE 5 of the accompanying drawings is an exploded view of the inner pole, voice coil valve, and the capstan;

FIGURE 6 is a sectional view taken along line 6—6 of FIGURE 5;

FIGURE 7 is a sectional view taken along line 7—7 of FIGURE 5;

FIGURE 8 is a partial sectional view taken along line 8—8 of FIGURE 6;

FIGURE 9 is a partial sectional view taken along line 9—9 of FIGURE 7;

FIGURES 10 and 11 are orthogonal projections illustrating the various positions of the voice coil valve to effect selectively coupling of the system to the atmosphere and to the source of vacuum;

FIGURE 12 is a cross section in elevation of the inner pole employed in a modification of the invention;

FIGURE 13 is an end view in elevation of a further modification of the present invention;

FIGURE 14 is a cross-sectional view of the apparatus of FIGURE 15 taken along section line 14—14; and

FIGURE 5 is a front elevational view partially in section of a third embodiment of the invention.

Referring now specifically to FIGURES 1 to 5 of the

accompanying drawings, the vacuum capstan of the present invention comprises five major elements; namely, a permanent magnet 1, an outer pole piece 2, an inner pole piece 3, a voice coil valve 4, and a rotating capstan 6. The capstan 6 includes a hollow, cylindrical member and an end wall 7 having a central aperture 8. The cylindrical portion of the capstan 6, although it is illustrated as having a substantially radial thickness in order to clarify the drawings, is actually quite thin in order to reduce the volume of the region to be evacuated.

A shaft 9 is disposed in the aperture 8 and is snugly received by the end wall 7 so that the capstan 6 rotates with the shaft. The shaft 9 is driven by a gear 11 secured to the end thereof remote from the end wall 7. The inner pole 3, which is essentially a thick-walled, hollow cylinder, supports the shaft 9 by means of bearings 12 and 13 and, in consequence, the shaft 9 is rotatable with respect to the pole 3. The inner pole 3 is provided with a hollow annulus 14 axially aligned with the region in which the voice coil valve 4 is generally disposed. The annulus 14 communicates via a bore 16 with a transverse bore 17 adapted to be connected to a vacuum source. In consequence, a vacuum may be selectively developed within the hollow annulus 14 and, in fact, is developed therein during all periods of operation of the apparatus.

Referring specifically to FIGURES 3, 4, 7 and 9, a plurality of equally spaced, axially extending bores 18, four in the illustrated embodiment of the invention, extend into the left end wall of the inner pole 3 and penetrate to a depth generally axially aligned with the right end of the hollow annulus 14. The bores 18 communicate via slots 19 with the annulus 14 and the left ends of the bores 18 are closed by means of plugs 21 so as to maintain the vacuum in the system. Each of the bores 18 communicates with three axially aligned, generally arcuate grooves 22 in the surface of the inner pole 3. The grooves 22 in the illustrated embodiment, which is intended to be exemplary only, each have an included angle of approximately 30°. Since each of the bores 18 is in communication with three circumferential grooves 22 and four such bores are provided in the illustrated embodiment, there are twelve grooves in the periphery of the pole 3 which are in communication with the vacuum system via the slots 19, hollow annulus 14, bore 16 and vacuum connection 17.

The individual bores 18 are displaced from one another by approximately 40° on center, in the example illustrated in the figures of the drawings, and a further set of bores 23 are interposed between the bores 18, these being three of the bores 23. The bores 23 are also drilled into the inner pole from the left face thereof and penetrate to the region of the right end of the annulus bore 14. The bores 23 communicate with arcuate grooves 24 formed in the surface of the inner pole 3, there being three axially aligned grooves communicating with each of the bores 23 and, since there are three such bores, there are a total of nine grooves 24. The left end of the bores 23 may be left open and communicate with the atmosphere via an annular region 26 between the inner pole 3 and the shaft 9. In the event that insufficient air is available through the region 26 due to grease on the bearings 12 and 13, the left end wall 7 of the capstan may be drilled or the bores 23 may extend almost to the right end of the pole 3 where they would communicate with the atmosphere via transverse holes drilled in the surface of the pole 3.

The capstan 6 is provided about its entire periphery with a plurality of grooves 27 which penetrate its walls and extend into its central hollow region. There are six sets of grooves 27 formed in the surface of the capstan 6, each groove subtending an arc of approximately 55° and each set of grooves 27 including three grooves disposed side by side axially of the capstan. The grooves 27 are axially arranged in alignment with the hollow annulus 14 of the inner pole and may be placed in com-

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munication with the annulus 14 via the grooves 22 or in communication with the atmosphere via the grooves 24.

Control of which of the sets of grooves 22 or 24 communicate with the grooves 27 is determined by the voice coil valve 4. The voice coil valve 4 constitutes a helix (or alternatively an offset winding) of rectangular aluminum wire which fits snugly about the outer surface of the inner pole 3. The turns of wire are rigidified by two insulating strips 28 and 29 in which diametrically opposed portions of the wire are embedded. The strips 28 and 29 extend short distance inwardly of the turns of wire forming the voice coil valve 4 and are received in rectangular recesses 31 and 32 respectively formed in opposite sides of the inner pole 3. The strips 28 and 29, therefore, serve to provide rigidity to the coil and further serve as guides to prevent rotation thereof. Wires 34 are embedded in the plastic strip 29 and communicate with opposite ends of the voice coil. Control currents are applied to these wires for purposes which will become apparent subsequently.

The apparatus is provided with an annular permanent magnet 1, as previously indicated, secured about the inner pole 3 while the outer pole 2 is disposed about the outer periphery of and in contact with the magnet 1. The outer pole 2 extends to the left approximately to the region in which it is radially aligned with the left-hand limits of the hollow annulus 14. The magnetic flux set up by the permanent magnet 1 extends as illustrated by the lines 36 through the magnetically permeable outer and inner poles 2 and 3, respectively, and cuts the turns of the voice coil magnet 4. In consequence, upon the application of current to the wires 33 and 34, the voice coil valve 4 shifts to the left or right as illustrated in FIGURE 4, depending upon the polarity of the current.

The spacing between the adjacent turns of the voice coil valve 4 is equal to the spacing between each pair of axially aligned grooves 22 or each pair of axially aligned grooves 24 formed in the surface of the inner pole 3. Further, the permissible axial translation of the voice coil valve 4 as determined by stops 37 and 38 is equal to the width of grooves 22 or adjacent grooves 24 plus a little extra for sealing at the edges. Further, the stops are adjusted so that in one position, the coils of the valve 4 cover all of the grooves 22 and, in the other position, cover all of the grooves 24. This is illustrated in FIGURES 10, 11 and 12 of the accompanying drawings. In FIGURE 10, the turns of the voice coil valve 4 cover the grooves 22 in the surface of the inner pole 3 whereas in FIGURE 11, the turns of the voice coil valve 4 cover the grooves 24. Consequently, in the position of the voice coil valve 4 illustrated in FIGURE 10, air proceeds from the atmosphere through the bores 23, the grooves 24, between the turns of wire of the voice coil valve 4 and to the grooves 27 formed in the surface of the capstan 6. In FIGURE 11, a vacuum is drawn via the transverse aperture 17, the bore 16, the annulus 14, the grooves 19, the bores 18, the grooves 22 and between the turns of the coil 4 to the grooves 27 formed in the surface of the capstan 6. It will be noted that since the voice coil valve 4 is fabricated from helical turns of wire, the various sets of grooves 22 and 24 in the surface of the inner pole 3 must be skewed so as to be aligned with the turns of the valve 4.

A tape to be transported, and generally designated by the reference numeral 39, is disposed in an arcuate space 41 between the capstan 6 and the outer pole 2. This annular space 41 has an extent of approximately 180° and, in general, extends from the region of the insulating strip 28 to the region of the insulating strip 29 of the voice coil valve 4. In consequence, this annulus extends above the region of the various sets of grooves 22 and 24 formed in the surface of the stationary inner pole 3. The annulus 41 communicates with slots 42 and 43 which extend tangentially from opposite ends of the annulus slot 41 through the outer pole 2. The tape 39

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enters the apparatus through a slot 42, extends through the annulus 41 and comes out of the apparatus through the slot 43.

Normally, that is, during non-driving conditions, the voice coil valve 4 is energized so that it assumes the position illustrated in FIGURE 10 and, in consequence, the slots 27 formed in the capstan 6 are in communication with atmospheric air. Normal forces acting on the tape 39 under these circumstances prevent the tape, which rides an air film, from moving with the capstan 6. When it is desired to drive the tape, opposite polarity current is applied to the voice coil valve 4 and it assumes a position as illustrated in FIGURE 11. Under these circumstances, the grooves 27 are in communication with the vacuum system and the tape is pulled down against the capstan and moves therewith.

In order to permit the tape to be pulled down rapidly against the capstan 6, a plurality of holes 44 are drilled through the outer pole 2 and into communication with the annulus 41. These holes permit ready access of air to the region above the tape 39 so as to prevent the generation of a partial vacuum on the upper side of the tape which would tend to counteract the effect of the vacuum developed under the tape. Additional holes 46 are drilled in the lower portion of the outer pole 2 and extend into communication with the capstan so as to expedite stripping of the tape from the capstan.

As was previously indicated, it is an important object of the present invention to provide an apparatus which is capable of rapidly picking up and transporting a tape and also rapidly terminating transport of the tape. The extremely light voice coil valve coupled with a strong permanent magnet 1 permits the voice coil to be translated at very high speeds between a vacuum and an atmospheric condition. Further, the proximity of the voice coil to the region to be evacuated and the small volume of this region, due to the thinness of the cylindrical portion of the capstan, permits the fabrication of a device which is capable of rapidly picking-up and accelerating the tape.

In order to permit rapid termination of transport a path is provided from the apertures 27 in the capstan to the atmosphere to permit rapid dissipation of the vacuum and thereby rapidly decouple the tape from the capstan.

If rapid braking of the tape is desired, the bores 23 may communicate with a source of pressure so that the tape is blown off of the capstan 6 and into contact with the inner surface of the outer pole 2. In this case, the outer pole 2 operates as a brake since a frictional force is developed between the tape and the pole as a result of air pressure applied to the tape. In this embodiment of the invention, and reference is now made to FIGURE 12 of the accompanying drawings, one of the bores in communication with the grooves 24, which bore is designated by the reference numeral 23, extends to a position to the right of the magnet 1 and communicates with a transverse aperture 47. The aperture 47 is adapted to be connected to a source of pressure and this pressure may be transmitted to the remaining bores 23 via a circular channel 48 formed in the left end wall of the inner pole 3 as viewed in FIGURE 12.

The passages 23, 23', etc. are sealed by a plug 49 which partly fills the channel 48. In consequence, a pressure is developed under the tape whenever the grooves 27 of the capstan are placed in communication with the grooves 24 in the pole 3.

The apparatus may be secured to a mounting panel 51 during actual utilization of the device by means of a plurality of bolts 52 extending through appropriate apertures 53 in a peripheral flange 54 of the outer pole 2 extending radially thereof.

The basic principles of the apparatus of the present invention are generally applicable to transport of all types of flexible tapes. However, as indicated previously, the permanent magnetic field established across the tape by the apparatus of FIGURE 1, prevents its use with magnetic tape. Further, the apparatus of the first embodiment

of the invention is not appropriate for utilization with punched paper tape since a vacuum cannot be readily developed under the tape in order to hold the tape against the capstan. The apparatus of the first embodiment is useful with other types of recording tapes such as tapes having information recorded thereon electrostatically or may be employed to transport any type of flexible, non-perforated material where rapid acceleration and deceleration is required.

The apparatus may be employed with perforated tapes if the capstan is designed with holes located so as to be aligned with the spaces between rows of perforations. The efficiency of such an apparatus may not be great and a more ready solution to this problem is provided by the apparatus illustrated in FIGURE 13 of the accompanying drawings.

The only modification required of the apparatus illustrated in FIGURES 1 through 12 to adapt it to handling perforated tapes is to remove the sharp points formed by the intersection of the upper portion of the outer pole. The sharp points are rounded and an endless unperforated member or tape 56 extends through the apertures 42, 41 and 43 and loops around the outer periphery of the upper portion of the outer pole 2. The perforated tape, which is designated by the reference numeral 57, is disposed in the slot 41, between the endless, unperforated tape 56 and the capstan 6. Thus, when a vacuum is developed under the tape, the tape 56 is drawn down against the capstan, thereby clamping the perforated tape 57 between the endless tape 56 and the capstan. The endless tape rotates with the capstan and, if desired, appropriate, non-friction mechanisms may be formed on the outer surface of the pole 2 so as to reduce the drag on the system. When it is desired to release the tape 57, atmospheric pressure or air under pressure may be applied to the capstan 6 which removes the clamping force acting to press the tape 57 against the capstan 6.

Referring now specifically to FIGURES 14 and 15 of the accompanying drawing, there is illustrated an embodiment of the invention which may be employed with magnetic tapes. Those elements of FIGURES 14 and 15 which are identical with the corresponding element in the prior figures bear the same reference numerals as in the former figures. The apparatus is provided with an inner pole piece 3 of generally hollow, cylindrical configuration, and an annular permanent magnet 1 disposed about one end of the inner pole piece 3. The shaft 9 extends along the horizontal axis of the cylindrical pole piece 3 and is supported therein by means of bearings 12 and 13 so that the shaft may rotate with respect to pole piece 3. The shaft 9 carries a capstan 6 which is identical with the capstan 6 of the prior figures except that it is provided with an undercut portion 61 which provides a region of larger diameter than the remainder of the cylindrical portion of the capstan in the region under which the magnetic tape 62 is disposed. A voice coil valve 4 is disposed about the inner pole member 3 and cooperates with various slots 22 and 24 formed in the pole piece 3 so as to alternately block and unblock these slots upon application of current of the proper polarity to the voice coil.

The apparatus is provided with an outer pole piece 63 having a portion or a region 64 disposed about and in contact with the permanent magnet 1. The outer pole piece is provided with a further region 66 connected to the region 64 by an inwardly directed radial member 65. The region or portion 66 constitutes a relatively thin hollow cylindrical member disposed between the undercut portion of the capstan 61 and the voice coil valve 4. A magnetic field is now established between the member 66 of the outer pole 63 and the inner pole piece 3 across the voice coil. However, this magnetic field does not intercept the outer portions of the capstan. The magnetic tape is disposed about the outer diameter of the cylindrical portion of the capstan 6, and is isolated

from the magnetic poles by the thickness of the region 61 of the capstan.

In this modification, the displacement between the source of vacuum or, alternatively, pressure and the magnetic tape is greater than in the two previous embodiments of the invention. However, the additional displacement is in part compensated for by reducing the thickness of the portion 61 of the capstan and thus the additional time delay is not great. The apparatus is still capable of operating in the kilocycle range.

It will be noted that the outer pole 66 is provided with a plurality of apertures 67 to permit the passage of fluid pressure therethrough. However, these apertures subsist only over an arc commensurate with the length of the arc over which the tape 62 is in contact with the capstan. The remainder of portion 66 of the outer pole is solid, this being clearly illustrated in FIGURE 15.

The above embodiments of the present invention are intended to be exemplary only and the invention is not limited to the specific structural details illustrated. For example, the voice coil valve 4 may employ an offset winding rather than helical turns of wire. Specifically, the coil may comprise circular turns interconnected by axially extending sections, which sections are embedded in the insulating supports. Further, the permanent magnet may be replaced by an electromagnet. The valving apparatus is not restricted to utilization with a capstan but may be employed in various valving situations where high speed operation is required.

The capstan 6 is illustrated as a slotted member but it is not intended to limit the invention to this construction since other forms of capstans may be employed. Specifically, a porous capstan may be utilized or, more particularly, a solid capstan may be provided with a porous region adjacent the annular bore 14.

In a further modification, the form of the voice coil valve may be altered. The valve may constitute a coil of the form employed in D'Arsonval galvanometers. In this case, the coil rotates about the axis of the inner pole and the turns are disposed axially of the pole rather than circumferentially. Finally, the slots in the inner pole are rotated 90° with respect to their present orientation.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What we claim is:

1. In combination, a first cylindrical member having a plurality of apertures in its periphery, said apertures adapted to be placed in communication with a source of pressure different from the ambient pressure, a second cylindrical member surrounding said first cylindrical member and spaced radially therefrom, a cylindrical valve disposed between said members, said valve comprising a plurality of spaced turns of conductive material, the axial spacing between said turns being approximately equal to the axial spacing between said apertures, said conductive material having a length parallel to the axis of said cylindrical members at least as long as the axial length of said apertures, means for establishing a magnetic field across said valve, means for establishing a first axial position of said valve in which said turns cover said apertures and means for establishing a second axial position in which said turns are remote from said apertures, and means for applying current to said valve to shift said valve axially from one of said positions to the other of said positions.

2. In combination, a first elongated member having a plurality of axially spaced apertures therein, means interconnecting said apertures, a valve comprising a plurality of spaced, electrically interconnected turns of conductive material, said turns of conductive material ex-

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tending about the periphery of said first member generally transverse to the elongated dimension thereof, the axial spacing between said turns being approximately equal to the axial spacing between said apertures, and the axial length of said conductive material being at least as long as the axial length of said apertures, means for establishing a magnetic field across at least a predetermined region of said valve, means for establishing a first axial position of said valve in which said turns cover said apertures, means for establishing a second axial position in which said turns are remote from said apertures, and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

3. In combination, an inner magnetic pole having a plurality of spaced, interconnected apertures therein, an outer magnetic pole encircling said inner pole and spaced therefrom, a valve disposed between said poles and snugly receiving said inner pole, said valve comprising a plurality of spaced, electrically connected turns of conductive material, the axial spacing between said turns being approximately equal to the axial spacing between said apertures, the axial length of said conductive material being approximately as long as the axial length of said apertures, means for establishing a magnetic field in said poles and across said valve, means for establishing a first axial position of said valve in which said turns cover said apertures, means for establishing a second axial position in which said turns are remote from said apertures, and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

4. In combination, an inner magnetic pole having a first plurality of spaced, interconnected apertures therein and a second plurality of spaced interconnected apertures therein, said pluralities of apertures being axially interleaved on a one-for-one basis, an outer magnetic pole spaced from and encircling said inner pole, a valve disposed between said poles and comprising a plurality of spaced, electrically connected turns of conductive material, the axial spacing between said turns being approximately equal to the axial spacing between apertures of the same plurality of apertures, the axial length of the cross section of said conductive material being approximately equal to the axial length of each of said apertures, means for establishing a magnetic field through said poles and across said valve, means for establishing a first axial position of said valve in which said turns cover said first plurality of apertures, means for establishing a second position of said valve in which said turns cover said second plurality of apertures and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

5. In combination, an inner magnetic pole, an outer magnetic pole encircling said inner pole, a rotatable capstan disposed between said poles and having a plurality of apertures therein, a coil valve comprising a plurality of spaced turns of conductive material disposed between said capstan and said inner pole, an arcuate air gap between a predetermined section of said capstan and said outer pole for receiving a flexible member, a plurality of apertures in said inner pole generally in alignment with said apertures in said capstan and in alignment with said predetermined section, said apertures in said inner pole being divided into two groups, one of said groups of apertures being adapted to be placed in communication with a source of pressure less than the ambient pressure and the other of said groups of apertures being adapted to be placed in communication with a source of pressure at least as great as the ambient pressure, means for establishing a magnetic field through said poles and across said coil valve, means for establishing a first axial position of said valve in which said turns cover said first plurality of apertures, means for establishing a second position of said valve in which said turns cover said second plurality of

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apertures and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

6. The combination according to claim 5 wherein said means for establishing magnetic flux comprises a magnet disposed between and in contact with said poles remote from said air gap.

7. In combination, a cylindrical inner pole, a cylindrical outer pole encircling said inner pole and spaced therefrom, a cylindrical rotatable capstan disposed between said poles, said capstan being spaced from said inner pole about its periphery and spaced from said outer pole over a predetermined arc to provide an arcuate air gap for receiving a flexible member to be transported, a cylindrical valve disposed in the annular space between said inner pole and said capstan, said inner pole having a first plurality and a second plurality of apertures extending over a region generally coextensive with said air gap, said apertures of each of said plurality being arranged in circumferentially extending rows and axially extending columns, the apertures of said pluralities of apertures being axially interleaved one-for-one, said capstan having a plurality of apertures extending about its periphery in a region generally coradial with said air gap and said apertures in said inner pole, said valve comprising axially spaced turns of conductive material relatively snugly enclosing said inner pole in the region of said apertures, said turns of said valve having an axial spacing approximately equal to the axial spacing between said apertures of each of said plurality of apertures of said inner pole, the axial length of the cross section of said conductive material being generally at least equal to the length of said apertures in said inner pole, a magnet disposed between and contacting said inner and outer poles, means for connecting said first plurality of apertures to a first source of pressure less than atmospheric pressure, means for connecting said second plurality of apertures to a second source of pressure at least as great as atmospheric pressure, means for establishing a first axial position of said valve in which said turns cover said first plurality of apertures, means for establishing a second position of said valve in which said turns cover said second plurality of apertures and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

8. The combination according to claim 7 wherein said second source of pressure is greater than atmospheric pressure.

9. In combination, an inner magnetic pole having a plurality of spaced, interconnected apertures therein, an outer magnetic pole encircling said inner pole and spaced therefrom, a valve disposed between said poles and comprising a plurality of spaced, electrically connected turns of conductive material, the spacing between said turns being approximately equal to the spacing between said apertures, the length of the cross section of said conductive material being approximately as long as the length of said apertures, means for establishing a magnetic field in said poles and across said valve, means for establishing a first position of said valve in which said turns cover said apertures and a second position in which said turns are remote from said apertures, and means for applying a current to said valve to move said valve from one of said positions to the other of said positions.

10. In combination, an inner magnetic pole having a plurality of spaced apertures extending therethrough, an outer magnetic pole encircling said inner pole, a valve comprising a plurality of spaced, electrically interconnected turns of conductive material, said turns extending about the periphery of said first member generally transverse to the elongated dimension thereof, the axial spacing between said turns being approximately equal to the axial spacing between said apertures and the axial length of said conductive material being at least equal to the axial length of said apertures, a rotatable capstan encircling said

inner pole, said capstan having a plurality of apertures therethrough generally in alignment with said apertures in said inner pole, means for connecting said apertures in said inner pole to a suitable source of pressure, means for establishing a first axial position of said valve in which said turns cover said apertures, means for establishing a second axial position in which said turns are remote from said apertures, and means for applying a current to said valve to shift said valve axially from one of said positions to the other of said positions.

11. The combination according to claim 10 wherein said capstan is disposed between said poles.

12. The combination according to claim 10 wherein said capstan also encircles said outer pole.

13. In combination, a first member having a predetermined cross-sectional configuration and at least one aperture in a surface defining at least in part said cross-sectional configuration, a first region whose fluid pressure is to be controlled, said first region being located adjacent to and normally in communication with said aperture, means adapted to connect said aperture to a source of fluid pressure, a coil valve including a coil having at least one turn of conductive material, said coil contacting said

surface of said member in the region of said aperture and being movable relative to said aperture, means for establishing a magnetic field across said coil, means for establishing first and second positions of said coil relative to said aperture, means for applying electric currents to said coil to shift it between said first and second positions, said coil being disposed between and arranged to interrupt communication between said first region and said aperture when said coil is in said first position only.

10 14. The combination according to claim 13 further comprising a second member at least partially enclosing said first member, said first region being disposed between said members, and wherein said coil covers said aperture when in its second position.

15 15. The combination according to claim 1 further comprising a first region whose pressure is to be controlled and wherein said second cylinder has a plurality of apertures therein extending between said first region and the region between said cylinders.

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