July 18, 1961 H. W. BUUS ET AL 2,992,733

MAGNETIC PULLEY AND PERMANENT MAGNET THEREFOR

Filed Oct. 9, 1957 2 Sheets-Sheet 1

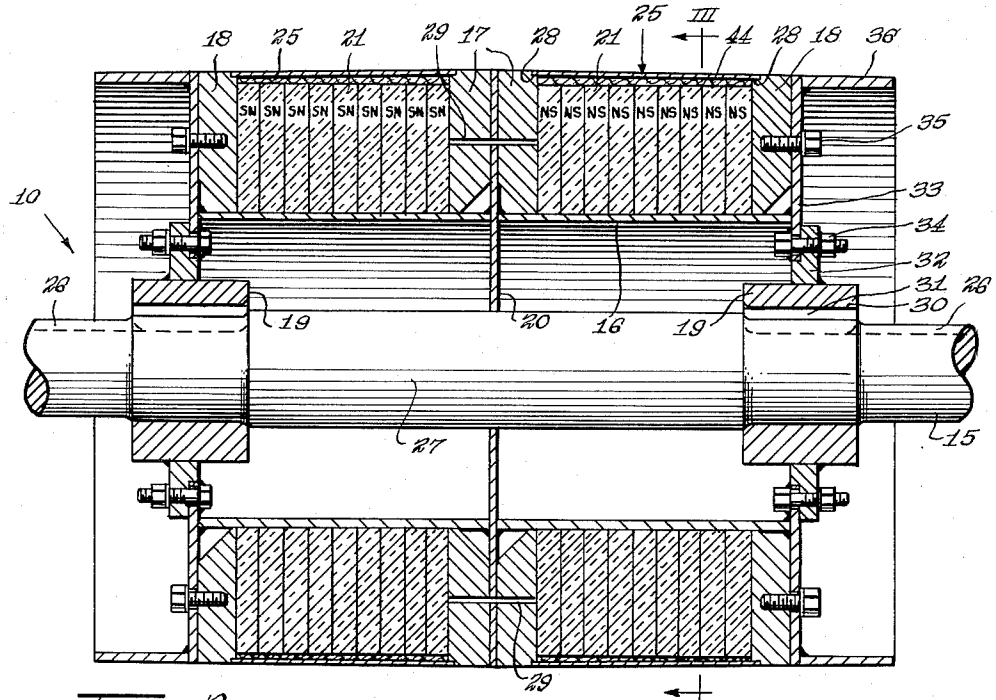


Fig. 2

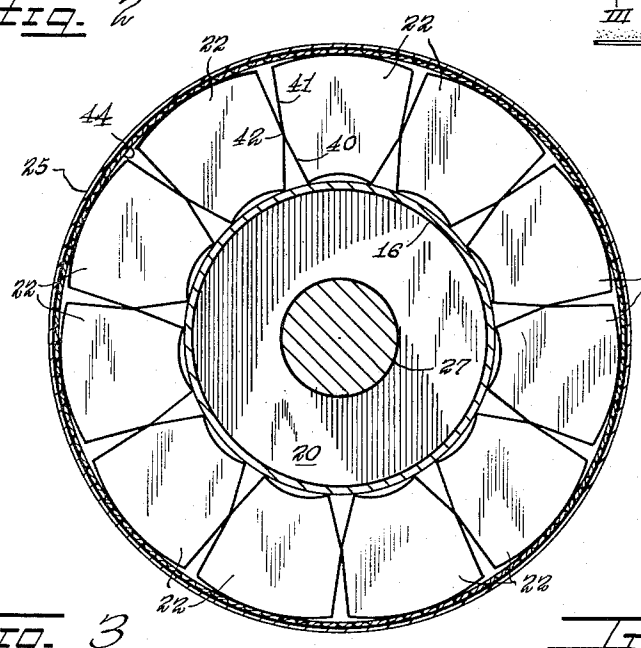


Fig. 3

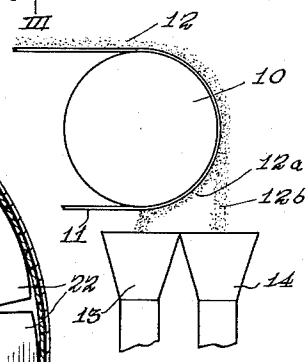


Fig. 1

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2 Sheets-Sheet 2

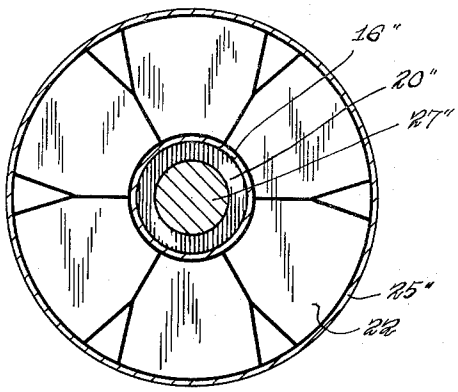


Fig. 4

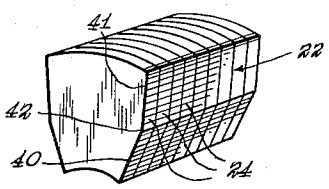


Fig. 6

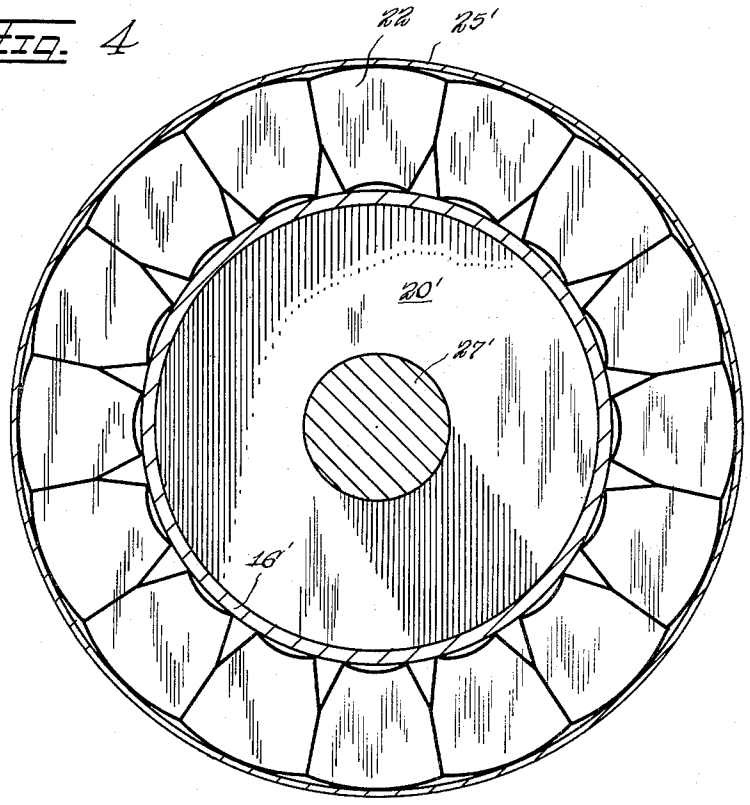


Fig. 5

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2,992,733

MAGNETIC PULLEY AND PERMANENT MAGNET THEREFOR

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14 Claims. (Cl. 209—219)

This invention relates generally to magnetic pulleys, and more specifically to an improved permanent magnet incorporated therein.

Although the principles of the present invention may be included in various devices, a particularly useful application is made in magnetic pulleys, for example of the type used in magnetic separators.

Broadly speaking, magnetic pulleys and separators are old in the art. However, the instant invention contemplates the utilization of an annular permanent magnet magnetized axially and disposed immediately adjacent to the outer periphery of the pulley. The axially directed pole faces communicate with magnetically permeable pole pieces which extend radially to the surface of the pulley. Preferably, the region intermediate the pole pieces and adjacent to the permanent magnet is enclosed by a cover which affords mechanical protection to the magnets, and which preferably has a greater coefficient of friction with respect to the material with which the pulley is used than do the magnets.

The present invention also contemplates the use of a magnetic wafer or element wherein one specific shape and size may be used to produce a wide variety of diameters and lengths of permanent magnets, and hence may be used in a wide variety in shapes and lengths of magnetic pulleys.

Accordingly, it is an object of the present invention to provide an improved magnetic pulley provided with a permanent magnet.

Another object of the present invention is to provide an improved permanent magnet.

Yet another object of the present invention is to provide a magnetic element from which a variety of sizes of permanent magnets may be constructed.

Many other advantages, features and additional objects of the present invention will become manifest to those versed in the art upon making references to the detailed description and the accompanying sheets of drawings in which a preferred structural embodiment incorporating the principles of the present invention is shown by way of illustrative example.

On the drawings:

FIGURE 1 is a view schematically illustrating one manner in which the present invention may be utilized with a conveyor belt for separating magnetizable and non-magnetizable materials;

FIGURE 2 is an enlarged cross-sectional view, partly in elevation, of the pulley shown in FIGURE 1;

FIGURE 3 is a cross-sectional view taken along line III—III of FIGURE 2;

FIGURES 4 and 5 are generally similar to FIGURE 3, and show smaller and larger permanent magnets respectively made from the same element as that shown in FIGURE 3; and

FIGURE 6 shows a perspective view of a magnet segment.

As shown on the drawings:

The principles of this invention are particularly useful when embodied in a magnetic pulley used as a magnetic separator in a manner indicated diagrammatically in FIGURE 1. A magnetic pulley 10 is installed as the head pulley, or pulley in a discharge position of a conveyor, and therefore rotates with the movement of the conveyor

belt 11. As the bulk materials 12 carried on the conveyor belt 11 approach the influence of the magnetic field of the magnetic pulley 10, the magnetically responsive materials 12*a* are attracted to the belt because of the magnetic attraction of the magnetic pulley 10 from the other side of the belt 11. As the non-magnetic material 12*b* flows over the magnetic pulley 10, it discharges in its usual path or trajectory because it is not influenced by the magnetic field. The magnetically attracted materials 12*a* are transported around the pulley with the belt beyond the area of normal discharge of the non-magnetic materials. The moving belt 11 on the return or downward side, transports the magnetically responsive material 12*a* beyond the influence of the magnetic field so that it drops off by the force of gravity into a suitable collection chamber or hopper 13 separated from an adjacent hopper 14 for the non-magnetic materials.

Referring now to FIGURE 2, the structure of the pulley 10 is shown in detail. The pulley 10 includes a shaft 15 which extends through a cylindrical or tubular member 16 about which extends at least one pair of magnetically permeable pole pieces 17, 18 which are connected to the shaft 15 by a pair of hubs 19 and 20. Between the pole pieces 17 and 18, there is disposed a cylindrical or tubular magnet 21 which comprises a plurality of segments 22 as best seen in FIGURE 3 which may in turn be made up from a plurality of wafers 24 as best seen in FIGURE 6, all of which are enclosed in a tubular non-magnetic cover 25 as best seen in FIGURES 2 and 3.

The shaft 15 has a key slot 26 at each of the ends thereof for driving connection with a motor, a gear, or the like (not shown), and has an enlarged central portion 27 intermediate the slots 26. The shaft 15 preferably comprises non-magnetic material, because if magnetic material be utilized, the shaft would provide a flux leakage path.

The tubular member 16 comprises non-magnetic material. It will be appreciated that it may be disposed either interiorly of the tubular magnet 21, or externally thereof. However, it is preferable to dispose it as indicated.

The instant embodiment includes two complete permanent magnets 21. It is to be understood that any number of such magnets may be utilized as may be desired. For each such magnet used, there is a magnetically permeable pole piece, such as the annular members 17 and 18. Each of the members 17 and 18, in this embodiment, have been provided with a small groove 28 at a peripheral corner thereof, which jointly define with the magnets 21 an annular recess in which the tubular non-magnetic cover 25 is received. The magnetically permeable pole pieces 17 and 18 may be secured directly to the cylinder 16 if desired. However, in the instant embodiment, they have been secured to one of hubs 19 or 20 respectively.

The hub 20 comprises a non-magnetic plate secured at the center of the tubular member 16 as by welding, and extending radially toward the enlarged portion 27 of the shaft 15 for support. The hub plate 20 also extends outwardly radially between the pole pieces 17 of the adjacent magnets. The pole pieces may then be secured to the hub plate 20 in any convenient means, for example by a pin 29. The hub 19 includes a slotted body portion 30 which, with the keyway 26, receives a key 31 to form a driving connection between the hub 19 and the shaft 15. The body 30 includes an annular flange 32 to which an annular non-magnetic ring 33 is secured, for example by nut and bolt assemblies 34. Where the shaft 15 comprises magnetic material, it is essential that at least a portion of the hub 19 constitutes non-magnetic material. Thus either the body portion 30, the flange 32, or the annular ring 33 may be non-mag-

netic, the annular ring 33 being non-magnetic in the instant embodiment. The pole piece 18 is secured to the annular ring 33 as by a screw 35. If desired, a tubular extension 36 may be secured as by welds, to the outer periphery of the annular plate 33 to widen the pulley.

As shown in FIGURE 2, an annular permanent magnet 21 is received intermediate the magnetic members 17 and 18. Preferably, the end faces of the magnet 21 have the same area as do the abutting faces of the pole pieces 17 and 18. The magnet 21 is axially magnetized, one end having north magnetic polarity and the opposite end having south magnetic polarity. Thus the magnet is cylindrical or tubular, has axially directed magnetic pole faces which are spaced apart by the length of the magnet 21, and where it is tubular, the magnet 21 is radially spaced from the shaft 15 and preferably disposed exteriorly of the tubular member 16.

In a preferred embodiment, the magnet 21 comprises permanently magnetic ceramic material. Since there are inherent limitations in the size, particularly the thickness, in which cast ceramic magnets may be made, the instant embodiment contemplates that the magnet 21 be built up from a plurality of individual pieces of magnetic ceramic material. Accordingly, as shown in FIGURE 3, the magnet 21 includes a plurality of radially extending segments 22 disposed adjacent to each other about the cylinder 16. One of these segments is illustrated in FIGURE 6. Each of the segments 22 is made up from a plurality of ceramic wafers 24 having substantially flat faces in flatwise contact with each other, each of the wafers 24 has generally convex sides which may abut against each other as shown in FIGURE 3. In the instant embodiment, the convex sides comprise radial sides having inner and outer portions 40 and 41 which form an obtuse angle 42 therebetween.

The individual wafers 24 may be magnetized before they are arranged as a segment 22 which holds itself together. However, it is somewhat more efficient to pre-assemble the wafers 24 as a segment as shown in FIGURE 6, cementing the individual wafers together if desired, and then to magnetize the group of wafers simultaneously as a segment 22. In the instant embodiment, the segment 22 has been magnetized axially, with the opposite ends or faces thereof having opposite magnetic polarities.

The non-magnetic cover 25, in this embodiment, includes a suitable fabric 44 or other non-magnetic cementing material which extends around the entire circumference of the magnet 21, and a final cover of rubber, non-magnetic metal, or other material secured to the fabric 44 within the recesses 28 to provide a total smooth surface having good frictional properties.

Accordingly, when assembled as shown in FIGURE 2, magnetic lines of flux pass through the hole pieces 18 which take a south polarity, and pass through the pole pieces 17 which take a north polarity, thereby holding the magnet 21 in place. The cover 25 also cooperates with the various segments to hold them in place. Thus it will be appreciated that the pole pieces 17 and 18 are magnetically isolated from the remainder of the pulley, whereby a strong magnetic field exists at the outer periphery or surface of the pulley for acting on a substantial burden of material if the pulley is used as a magnetic separator, or for applying a substantial magnetic attractive force, if the pulley is used in a different type of application.

It is also apparent that by loosening of the nuts in the nut and bolt assemblies 34, the hub 19 may be readily removed, so that the shaft 15 may also be easily withdrawn.

It is to be understood that the number of segments 22 used in the permanent magnet 21 is illustrative. One of the advantages of this type of wafer 22 is that any number of wafers may be added axially to form any length of segment which may be desired. Furthermore, any number of magnets 21 may be added axially to form any length of pulley which may be desired. Thus the length of the pulley and the strength of the magnetic field may be varied at will, a single type of wafer being used to build up such a magnet.

Further, by varying the number of segments, different diameter pulleys may be made up from the same element. Referring now to FIGURES 4 and 5, permanent magnets are illustrated wherein six and sixteen segments of the same size as shown in FIGURE 3 are utilized. Of course, it is to be understood that these numbers are also illustrative, and that their number may be further varied. Thus, a still smaller number of segments, or a still larger number of segments, or any intermediate number of segments may be utilized in the construction of the permanent magnet.

Accordingly, we have provided a magnetic pulley which has a particularly strong magnetic field in that it has more total magnetic flux which provides a particularly deeper magnetic field for penetrating through deep burdens of materials carried upon conveyors. Further, we have provided a novel magnetic element which may be utilized in building up various permanent magnets.

Although various minor modifications might be suggested by those versed in the art, it should be understood that we wish to embody within the scope of the patent warranted hereon, all such embodiments as reasonably and properly come within the scope of our contribution to the art.

We claim as our invention:

1. A magnetic pulley for attracting magnetic material comprising in combination: a non-magnetic tubular member adapted for rotation about its axis; a cylindrical permanent magnet, having its axis of rotation substantially coincident with the axis of said tubular member and having magnetic poles at opposite ends thereof with respect to the direction along the axis of said magnet; and a magnetically permeable pole piece disposed at each pole of said magnet and supported by said member; said magnet including a plurality of radially extending segments magnetized in an axial direction generally parallel to the axis of said magnet, said segments each having a pair of generally convex sides disposed adjacent to a similar side of the adjacent segment.

2. A magnetic pulley for attracting magnetic material comprising in combination: a non-magnetic tubular member adapted for rotation about its axis; a cylindrical permanent magnet, having its axis of rotation substantially coincident with the axis of said tubular member and having magnetic poles at opposite ends thereof with respect to the direction along the axis of said magnet; and a magnetically permeable pole piece disposed at each pole of said magnet and supported by said member; said magnet including a plurality of radially extending segments magnetized in an axial direction generally parallel to the axis of said magnet, said segments each having a pair of generally radially directed sides disposed adjacent to a similar side of the adjacent segment, the inner portion of said radial sides forming an obtuse angle with the outer portion thereof.

3. A magnetic pulley for attracting magnetic material comprising in combination: a non-magnetic tubular member adapted for rotation about its axis; a cylindrical permanent magnet having its axis of rotation substantially coincident with the axis of said tubular member and having magnetic poles at opposite ends thereof with respect to the direction along the axis of said magnet; and a magnetically permeable pole piece disposed at each pole of said magnet and supported by said member; said magnet including a plurality of radially extending segments magnetized in an axial direction generally parallel to the axis of said magnet, said segments each comprising a plurality of magnetic ceramic wafers, each wafer lying generally in a plane at right angles to the axis of said

magnet with the thickness dimension of each wafer extending generally parallel to the axis of said magnet and the wafers of each segment being magnetized in the same direction through their thickness dimensions; each of said wafers having a pair of generally radially directed sides disposed adjacent to a similar side of the adjacent wafer, the inner portion of said radial sides forming an obtuse angle with the outer portion thereof.

4. A cylindrical permanent magnet comprising, in combination: a plurality of segments disposed about a central axis and magnetized in an axial direction generally parallel to said central axis, each of said segments including a plurality of magnetic ceramic wafers, each of said wafers having a pair of generally radially directed sides disposed adjacent to a similar side of the adjacent wafer, the inner portion of said radial sides forming an obtuse angle with the outer portion thereof.

5. An element from which tubular permanent magnets of a variety of lengths and diameters may be constructed, comprising: a sector wafer of permanently magnetic material, said wafer having a pair of generally radially directed sides for engaging similar sides of arcuately adjacent wafers, the inner portion of said radial sides forming an obtuse angle with the outer portion thereof, and said wafer having a pair of opposite faces for engaging similar faces of adjacent wafers.

6. A magnetic pulley comprising a shaft, a pair of pole piece structures of magnetic material having generally flat lateral faces disposed in spaced generally parallel relation and defining an axial space therebetween of annular configuration, means for mounting said pole piece structures in fixed relation with respect to said shaft, and a multiplicity of stacks of wafers of permanent magnet material substantially completely filling the axial space between said pole piece structures, each stack extending axially between said pole piece structures and the stacks being arranged successively about the circumference of said space, and said stacks of wafers having a tubular cover of non-magnetic material surrounding said axial space in close covering relation to said stacks between said pole piece structures.

7. A magnetic pulley comprising a shaft, a pair of pole piece structures of magnetic material having generally flat lateral faces disposed in spaced generally parallel relation and defining an axial space therebetween of annular configuration, means for mounting said pole piece structures in fixed relation with respect to said shaft, and a multiplicity of stacks of wafers of permanent magnet material substantially completely filling the axial space between said pole piece structures, each stack extending axially between said pole piece structures and the stacks being arranged successively about the circumference of said space, said wafers being of identical configuration and having flat lateral faces for engaging flatwise with adjacent wafers, the respective end wafers of each stack engaging flatwise with said lateral faces of said pole piece structures.

8. A magnetic pulley comprising a shaft, a pair of pole piece structures of magnetic material having generally flat lateral faces disposed in spaced generally parallel relation and defining an axial space therebetween of annular configuration, means for mounting said pole piece structures in fixed relation with respect to said shaft, and a multiplicity of stacks of wafers of permanent magnet material substantially completely filling the axial space between said pole piece structures, each stack extending axially between said pole piece structures and the stacks being arranged successively about the circumference of said space, said stacks of wafers having a tubular cover of non-magnetic material surrounding said axial space in close covering relation to said stacks between said pole piece structures, and said pole piece structures having generally cylindrical radially outer surfaces flush with the outer surface of said tubular cover.

9. In a magnetic separator comprising a conveyor arranged for travel along a curved path and a permanent magnet assembly disposed in operative relation to the conveyor at the inner side thereof for tending to attract magnetic material toward the outer side of the conveyor for travel therewith along said curved path, the improvement characterized by said permanent magnet assembly comprising a series of wafers of permanent magnet material disposed in stacked relation and extending along said conveyor in close relation thereto for establishing a magnetic field at the outer side of said conveyor, said wafers being magnetized in a direction extending through said series of wafers with the magnetomotive forces of the successive wafers in aiding relation.

10. In a magnetic separator comprising a conveyor arranged for travel along a curved path and a permanent magnet assembly disposed in operative relation to the conveyor at the inner side thereof for tending to attract magnetic material toward the outer side of the conveyor for travel therewith along said curved path, the improvement characterized by said permanent magnet assembly comprising a series of wafers of permanent magnet material disposed in stacked relation and extending along said conveyor in close relation thereto for establishing a magnetic field at the outer side of said conveyor, said permanent magnet assembly further comprising a pair of pole pieces at the respective ends of said series of wafers having lateral surfaces in flatwise engagement therewith and having polar edges terminating adjacent the inner side of said conveyor, said wafers being magnetized in a direction extending through said series of wafers with the magnetomotive forces of the successive wafers in aiding relation between said pair of pole pieces.

11. A magnetic pulley comprising a shaft, a pair of pole piece structures of magnetic material having lateral faces disposed in spaced generally parallel relation and defining an axial space therebetween, means for mounting said pole piece structures in fixed relation with respect to said shaft, and a multiplicity of stacks of wafers of permanent magnet material substantially completely filling the axial space between said pole piece structures, each stack extending axially between the lateral faces of said pole piece structures, and said stacks being disposed directly at the periphery of said pulley, the wafers of each stack being of ceramic permanent magnet material and each having opposite lateral faces separated by a thickness dimension, the thickness dimensions of the wafers of each stack extending generally in the direction along said shaft, and the outer lateral faces of the outer wafers of each stack being in confronting relationship to the respective lateral faces of said pole piece structures, the wafers of each stack being magnetized in the direction through their thickness dimension and with the same polarity of magnetization.

12. A magnetic pulley comprising a shaft, first and second tubular members of different diameter encircling said shaft and defining an annular space therebetween, means mounting said first and second tubular members on said shaft for rotation therewith, flat ring-shaped pole pieces spaced along said shaft and having flat annular faces defining opposite ends of the annular space between said first and second tubular members, and stacks of wafers of ceramic permanent magnet material substantially filling said annular space, the wafers of each stack each having opposite lateral faces disposed substantially in a plane at right angles to the shaft and separated by a thickness dimension extending generally parallel to said shaft, the lateral faces of successive wafers of each stack being in flatwise contact and the outer lateral faces of the outer wafers of each stack being in flatwise contact with the flat annular faces of said ring-shaped pole pieces, each stack occupying a fraction of the total circumferential extent of the annular space between the first and second tubular members, and the wafers of each stack being magnetized in the direction through their thickness dimension and with the same polarity of magnetization.

13. A magnetic pulley comprising a shaft, first and

second tubular members of different diameter encircling said shaft and defining an annular space therebetween, means mounting said first and second tubular members on said shaft for rotation therewith, flat ring-shaped pole pieces spaced along said shaft and having flat annular faces defining opposite ends of the annular space between said first and second tubular members, and stacks of wafers of ceramic permanent magnet material substantially filling said annular space, the wafers of each stack each having opposite lateral faces disposed substantially in a plane at right angles to the shaft and separated by a thickness dimension extending generally parallel to said shaft, the lateral faces of successive wafers of each stack being in flatwise contact and the outer lateral faces of the outer wafers of each stack being in flatwise contact with the flat annular faces of said ring-shaped pole pieces, each stack occupying a fraction of the total circumferential extent of the annular space between the first and second tubular members, and the wafers of each stack being magnetized in the direction through their thickness dimension and with the same polarity of magnetization, the wafers being identical and having opposite edge faces joining the lateral faces thereof and each comprising a radially inner and a radially outer planar face portion defining an obtuse angle therebetween, the radially inner planar face portion of each wafer defining planes which intersect a point relatively close to the wafer in comparison with the radial dimension of the

wafer and the radially outer planar face portions of each wafer defining planes which intersect at a point substantially farther from the wafer for adapting the wafers to different diameter annular spaces.

14. An element from which tubular permanent magnets of a variety of lengths and diameters may be constructed, comprising a sector wafer of ceramic permanent magnet material having opposite flat lateral faces separated by a thickness dimension and having edge faces joining said lateral faces, each edge face comprising first and second planar edge face portions forming an obtuse angle therebetween, the first edge face portion defining planes which converge and intersect at one side and relatively close to the wafer and the second edge face portions defining planes which converge at said one side of said wafer and intersect at a point substantially more remote from said wafer.

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