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Benowitz

[11] **3,824,516**

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[54] **ELECTROMAGNETIC MATERIAL HANDLING SYSTEM UTILIZING OFFSET POLE SPACING**

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[52] **U.S. Cl.** **335/284,** 335/289, 209/212, 198/41

[51] **Int. Cl.** **H01f 13/00**

[58] **Field of Search** 335/219, 250, 289, 290, 335/284; 198/41; 209/212

[56] **References Cited**

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2,731,212	1/1956	Baker	198/41 X
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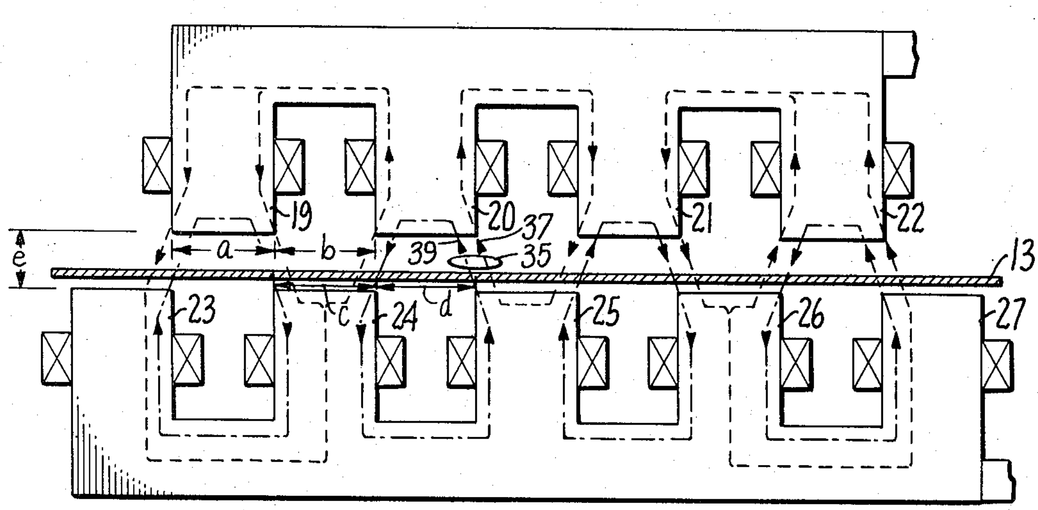
Attorney, Agent, or Firm—Limbach, Limbach & Sutton

[57] **ABSTRACT**

A technique of moving electrically conductive non-magnetic particles wherein a plurality of electromagnets are positioned on either side of an air gap with each electromagnet facing a non-magnetic space between electromagnets on the opposite side of the air gap. The electromagnets are energized with polyphase current in a manner to generate a sweeping magnetic flux down the air gap for moving particles therealong. Eddy currents generated by one magnetic field relative phase reacts with flux of another magnetic field relative phase to provide motion of the article. Two specific utilizations of this technique are described; the separation of conductive non-magnetic particles from waste material and the movement of aluminum can lids.

13 Claims, 9 Drawing Figures



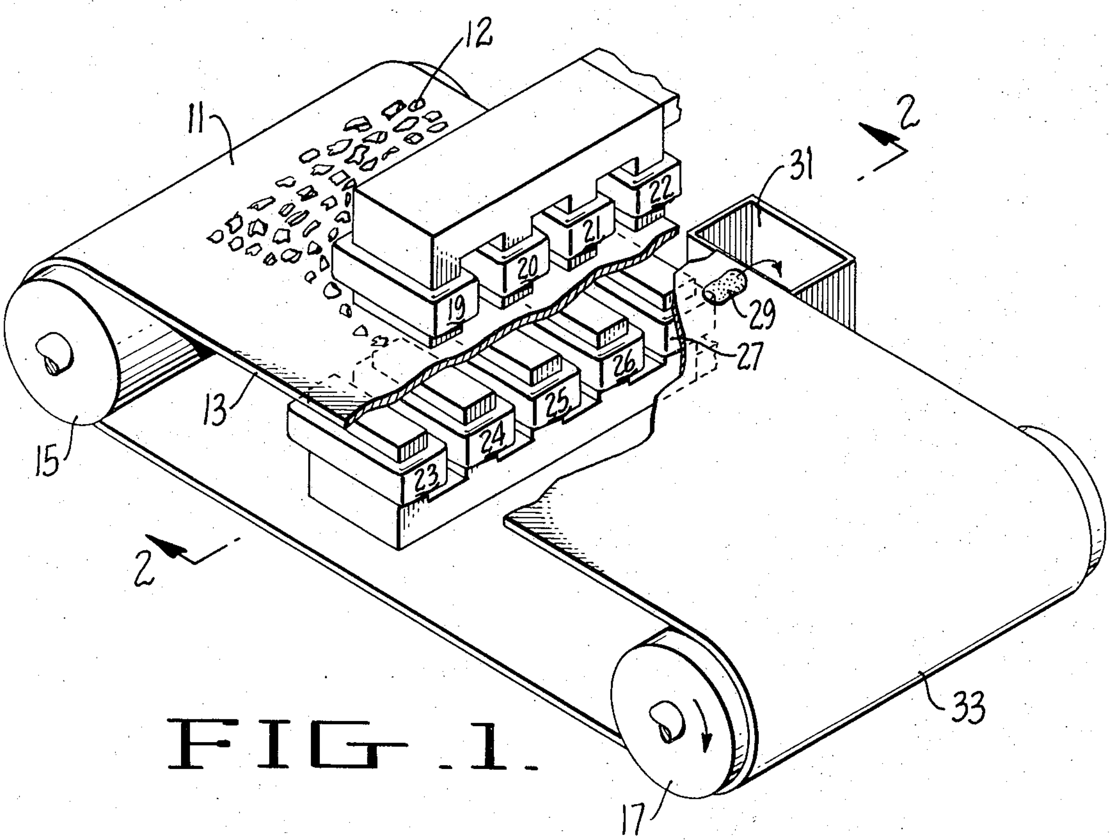

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FIG. 1.

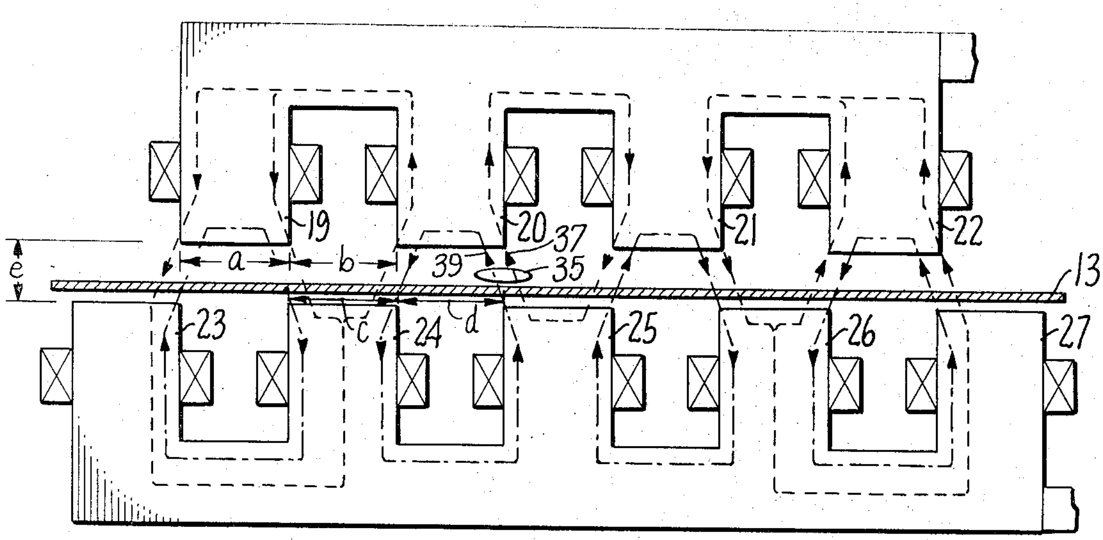
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FIG. 2.

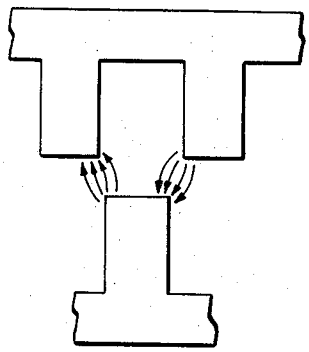

FIG. 3.

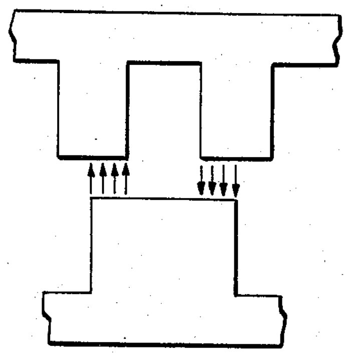

FIG. 4.

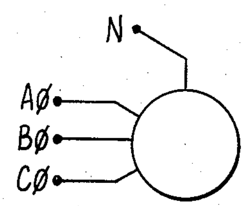

FIG. 5.

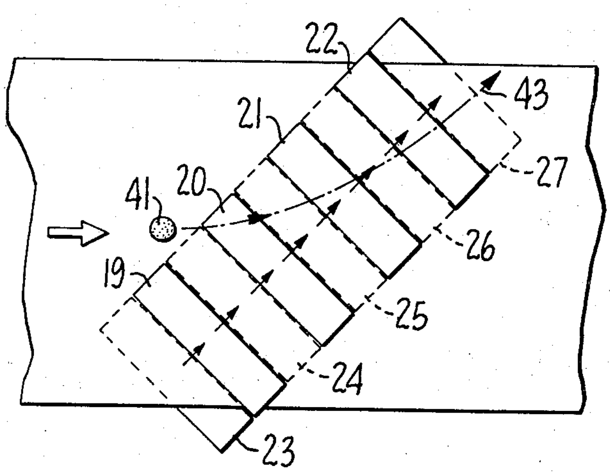

FIG. 6.

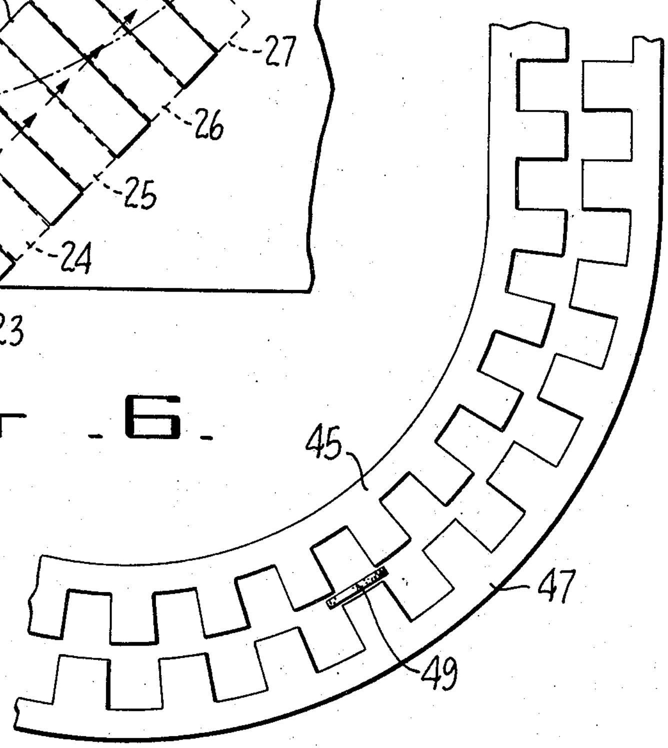

FIG. 7.

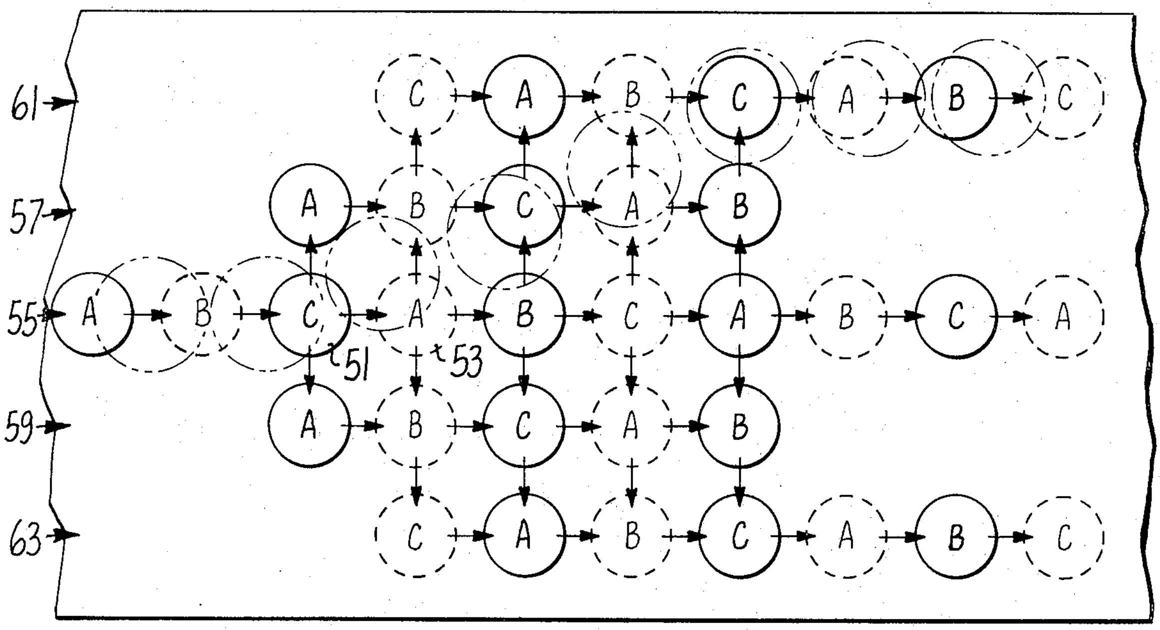

FIG. 8.

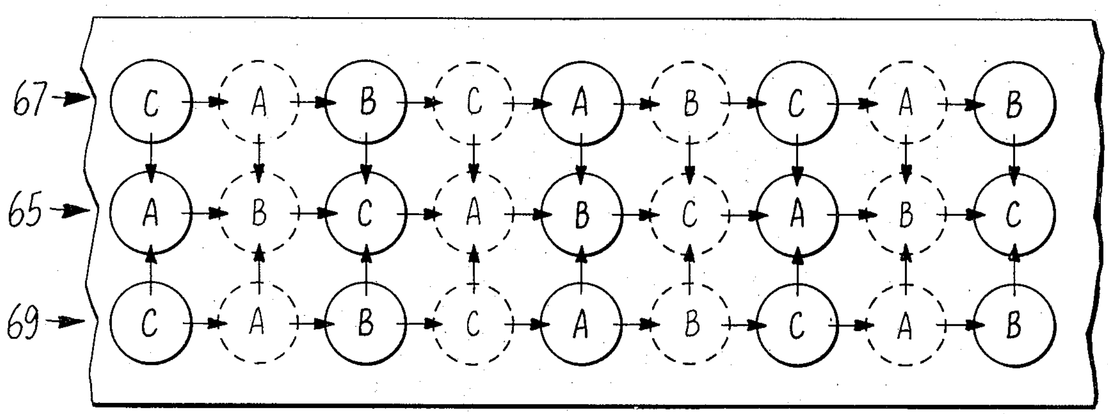

FIG. 9.

ELECTROMAGNETIC MATERIAL HANDLING SYSTEM UTILIZING OFFSET POLE SPACING

BACKGROUND OF THE INVENTION

This invention is related generally to electromagnetic eddy current article moving techniques.

The recent emphasis on recycling and reuse of waste material as much as possible has created a need for removing from garbage and other waste material its more valuable components. There have been many recent advances in solid waste processing techniques. A first step in waste processing is generally to shred the incoming raw waste for reducing the physical size of the waste material particles. The shredded waste material is then passed through an air classifier for removal of the light fractions such as paper. The heavier fractions, such as metals, glass, wood, rubber, plastics and rocks, remain for separation into their various constituents. Ferrous metals are easily removed with existing magnetic equipment.

Separation of non-ferrous metal particles from the heavier fractions of shredded waste material is more difficult. Non-ferrous metals include valuable aluminum and copper. Manual separation is possible but this is tedious and expensive. A flotation process is available for separation on the basis of specific gravity, but such wet process is difficult to control and it is messy. A dry process based upon eddy current reactions is described in U.S. Pat. No. 3,448,857 but such a process is limited to very small sized non-magnetic particles.

Therefore, it is an object of the present invention to provide a method and apparatus for removal of electrically conductive, non-magnetic metal particles of a wide range of sizes from shredded waste material in a simple and inexpensive manner.

Problems similar to the separation of waste material exist in other areas in industry for handling odd shaped electrically conductive non-magnetic articles. For example, aluminum can ends are widely employed both with aluminum can bodies and steel can bodies in forming completed can. Aluminum can ends are fabricated by automatic machinery at a high rate of speed and in a large volume. Conveying systems are used for moving and storing the can ends between work stations, storage areas and assembly areas. Presently, can ends are generally propelled with air jets or moved on conveyor belts that are provided with holes through which a vacuum provides a holding force for the can ends on the conveyor. Three existing systems are cumbersome, noisy and require continuous maintenance. Furthermore, they are limited to straight line motions of the can ends. Therefore, it is another object of the present invention to provide an electromagnetic conveying method and apparatus for moving non-magnetic, electrically conductive articles such as aluminum can ends from one location to another.

It is a primary and more general object of the present invention to provide an improved electromagnet assembly for efficient movement of electrically conductive, non-magnetic articles.

SUMMARY OF THE INVENTION

Briefly, these and additional objects are accomplished by the techniques of the present invention wherein an air gap is formed between two rows of electromagnetic poles, each row having wide spaces of non-magnetic material between successive magnetic poles, and the poles of one row are positioned to be opposite a space between poles of the other row. Each pole has a width that is about the same as its opposing non-magnetic space. The electromagnets are excited in a way to provide alternating magnetic fluxes of two different relative phases travelling across the air gap between adjacent pole edges.

This particular magnetic pole arrangement permits wide air gaps to be employed. With an ordinary linear induction motor, only one row of electromagnetics are provided, or two rows of electromagnets are provided on either side of an air gap with their electromagnet poles and spaces on opposite sides of the air gap being aligned. As the air gap of existing linear induction motors is increased, more and more flux is diverted across the non-magnetic space between adjacent magnetic poles of a given row. For wide air gaps, therefore, wide spaces between poles are required. This is undesirable for the movement of small articles because wide pole spacing results in large areas along the air gap which has insufficient flux density. By off-setting the poles on opposite sides of the air gap according to the technique of the present invention, the regions along the air gap that contain magnetic flux of two relative phases are substantially increased for a given number of electromagnetic poles. It is the regions of two relative magnetic flux phases that propel a conductive non-magnetic article when positioned therein. If these regions are too far apart, small articles cannot be propelled, for if an article having a dimension significantly less than the distance between successive dual phase flux regions, the article may not be moved at all.

If a standard linear motor construction is employed in order to obtain dual flux regions close enough together by reducing the non-magnetic space between poles, the air gap must be made smaller than desirable for many applications in order to prevent a significant amount of flux from travelling between adjacent poles rather than going across the air gap. In waste separation, a large air gap is desirable so that large waste material may pass therethrough for separation of electrically conductive non-magnetic particles therefrom. A close spacing of dual magnetic flux phase regions is also desirable for waste material separation so that small articles will be moved by the magnetic forces. A wide air gap is desirable for moving articles such as aluminum can ends, especially if the air gap is in a curved pattern. The magnetic poles arrangement of the present invention permits such effective waste separation and article moving systems.

The off-set magnetic pole technique of the present invention has a further advantage that the flux crossing the air gap does so at the edges of the magnetic poles. This flux is thereby of a higher density level than that which occurs in ordinary existing linear induction motors. High flux density is important since the forces imparted on an article within the air gap vary as a square of the flux density acting upon the article.

Additional feature, objects and advantages of the present invention will become apparent from the following description of its preferred embodiments which should be taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows magnetic pole arrangement utilized for the separation of waste material;

FIG. 2 is a schematic diagram of the magnetic poles of FIG. 1 taken across section 2—2 thereof;

FIG. 3 and 4 schematically illustrate modifications in the pole arrangements of FIG. 2;

FIG. 5 shows a voltage source for the electromagnets of FIG. 1 and 2;

FIG. 6 illustrates schematically an alternate arrangement of the magnets of FIG. 1;

FIG. 7 shows a curved article moving path of magnetic poles;

FIG. 8 schematically illustrates a complex magnetic force article moving system; and

FIG. 9 illustrates another specific complex force article moving system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a specific embodiment of the magnetic techniques of the present invention is described for separation of electrically conductive non-magnetic components of garbage or other waste material. The lightweight components of the waste material (such as paper) and ferrous metals have already been removed by other components (not shown) of a complete waste material processing and recovery system. The remaining waste material **12** is deposited at an end **11** of a conveyor belt **13.** The conveyor belt **13** is driven by rollers **15** and **17** at opposite ends thereof. At least one of the rollers is given motion by some appropriate driving mechanism (not shown). As the conveyor advances, the waste material **12** deposited at the end **11** passes through an air gap formed between two rows of electromagnets. A first row of electromagnets **19, 20, 21,** and **22** is positioned across the width of the conveyor belt **13** at a distance above it to permit the waste material to pass thereunder under the influence of the conveyor belt. A second row of electromagnets **23, 24, 25** and **27** are positioned immediately beneath the conveyor belt **13** at a position across the conveyor belt **13** directly beneath the first row of electromagnets **19–22.** Other specific numbers of magnets may be utilized but nine electromagents as illustrated in FIGS. **1** and **2** is convenient for energization by a three phase source.

The rows of magnets of FIG. **1** generate eddy currents in non-magnetic electrically conductive material that is positioned in the air gap on the conveyor belt **13.** These eddy currents then generate a magnetic field which interacts with the magnetic fields existing in the air gap in a manner which tends to move a non-magnetic electrically conductive article, such as an article **29** of FIG. **1,** off the side of the conveyor belt **13** and into some appropriate receptacle **31.**

Other elements of the waste material travelling along the conveyor **13,** such as glass, wood, rubber, plastics, rock, etc. are discharged off an end **33** of the conveyor belt **13.** The separated non-magnetic metals that are collected in the receptacle **31** may then be recycled and used again.

Referring to FIG. **2,** the magnetic poles of the electromagnets shown in FIG. **1** are schematically illustrated in a section to show the relative positions of the various magnetic poles. These positions are important in realizing the maximum separation potential of the mechanism of FIG. **1.** Each of the magnetic poles **19–22** of the first row have a width *a* in a direction along the length of the row while a non-magnetic space having a width *b* is provided between adjacent magnetic poles of the first row. Similarly, the magnetic poles **23–27** of the second row have a width *c* and a space between adjacent poles of non-magnetic material a width *b*. An air gap is formed by spacing between the first and second rows of poles, the width of this air gap being denoted in FIG. **2** by *e*. The poles of each row are positioned in a direction across the conveyor belt **13** opposite non-magnetic spaces between poles of the other row of magnetic poles.

In the very specific example of the techniques of the present invention as illustrated in FIG. **2,** the pole widths *a* and *c* are equal to each other and to both of the pole spacings *b* and *d*. The air gap dimension *e* can be as large as the magnitude of the pole spacing *b* or *d* as required for the specific application. The extremities of each pole face are positioned substantially directly opposite the extremities of its opposing non-magnetic space.

In order to move electrically conductive non-magnetic articles under the influence of the magnetic fields, the first row of electromagnets **19–22** is excited with one relative phase of alternating current while the second row of electromagnetics **23–27** are excited with a second relative phase of alternating current. The alternating current relative phases may differ by 90°, a convenient amount because of standard two-phase electrical supply equipment. The result is that the first row of electromagnets **19–22** generate one alternating magnetic flux path **37.** Similarly, the second row of electromagnets **23–27** generates a second alternating magnetic flux in the path **39.** The alternating magnetic flux in the paths **37** and **39** are out of phase by the phase difference in the alternating current excitation. The result is that in an area **35** encompassing both of the magnetic paths **37** and **39,** magnetic flux of two relative phases exist. A non-magnetic, electrically conductive article which finds its way into the dual phase flux region **35** will have an electrical current generated therein by one of the magnetic flux phases which then generates a magnetic field that coacts with the other of the magnetic relative flux phases to propel the article the length of the air gap.

A dimensional variation of the specific example of FIG. **2** is shown in FIG. **3** wherein each of the pole faces has an equal width but one which is slightly less than the width of the spaces between the poles. It has been found that a specific pole width of 1.25 inch, a pole spacing of 1.5 inch, an air gap of from 1.75 to 2 inches operates satisfactorily in the embodiment of FIG. **1** to remove non-magnetic metal particles from shredded waste materials.

It is preferable that the pole widths be equal to or somewhat less the width of the opposing pole spaces. Although some overlap of pole faces, such as shown in an exaggerated form in FIG. **4,** may be satisfactory in certain circumstances, it is not preferred where a wide air gap is required or desired. It can be seen from FIG. **4** that a plurality of large pole widths results in small non-magnetic spaces between pole widths of this row. This limited pole spacing requires an appropriately small air gap in order to prevent a substantial amount of magnetic flux from travelling across spaces between poles. For this reason, it is preferred that no overlapping of magnetic pole faces occurs.

It will be noted from FIG. **2** that there are substantially the same number of dual phase magnetic flux areas along the length of the air gap as there are electromagnetics. There are eight such regions generated by nine electromagnetics.

In order to get an equal number of dual phase magnetic flux areas across the conveyor belt **13** by using ordinary linear induction motor techniques, twice as many electromagnets would have to be utilized thereacross as shown in FIGS. **1** and **2.** However, this would make the poles and spaces therebetween very small. This would be unsatisfactory in the examples described herein since the maximum permissible air gap would then be severely reduced. The maximum size of the air gap is limited by the spaces between electromagnetic poles in each row.

A further advantage of the basic magnetic pole arrangement of the present invention is illustrated with respect to FIG. **3.** Since flux passes between sharp corners at the edges of opposing magnetic poles, the magnetic flux is concentrated over a smaller area. The resulting increased flux density thus provides additional propelling force to non-magnetic pieces in the air gap since such a propelling force is proportional to the square of the magnetic flux density. This is an advantage over a configuration of poles such as that shown in FIG. 4 wherein opposing poles overlap each other. In FIG. **4,** the magnetic flux passes between the parallel faces of the opposing pole portions and is thus not as concentrated as in the configurations of FIGS. **2** and **3.** Also, since the magnetic flux between poles of FIG. **3** is concentrated and its density high there is some fringing flux in the air gap between poles that increases the area somewhat through which flux passes. This in combination with the large number of dual phase magnetic flux areas **35** along the width of the conveyor **13** means that very small articles can be moved by the magnetic fields even with a larger air gap that has been heretofore possible.

It may be noted that the configuration of FIG. **2,** as opposed to positioning the magnetic pole faces opposite one another, results in reducing the speed of a travelling magnetic field across the width of the conveyor belt **13.** This reduced magnetic field speed results in less slip and consequently more effective forces for conveying non-magnetic metal along the air gap. Also in the embodiment of FIG. **2,** there is an upward/downward travelling field at the entry and exit of the air gap as the material is being moved therethrough by the conveyor **13.** These transitory travelling fields result in a vibratory or shaking motion on non-magnetic metals being carried by the conveyor **13** and this has the beneficial result of tending to reduce static friction so that the non-magnetic metal may be easily removed from the conveyor belt **13.**

The direction of forces on electrically conductive non-magnetic articles within the air gap of the rows of electromagnets shown in FIGS. **1** and **2** depends upon the relative phases of the two-phase energization thereof. If the phases are reversed between the first and second rows of electromagnets, the direction of travel across the width of the conveyor belt **13** will be reversed. Other useful moving and guiding functions may be performed by the electromagnet by even different phasing. If the electromagnets **19** and **20** are energized with one phase of a two-phase alternating current supply which results in moving a non-magnetic metal to the right in FIG. **2,** the energization of electromagnets **21** and **22** with the other alternating current supply phase tends to move such articles in their regions of influence to the left. The result is the tendency to center electrically conductive non-magnetic articles on the conveyor belt **13** as the articles pass through the air gap. By reversing the relative phases of the electromagnets **19–22** once again, such articles can be forced off of both edges of the conveyor belt **13.** Many such possibilities of movement of such articles are possible by various phase relationships of alternating current excitation of the electromagnets.

Rather than using a two-phase alternating current electrical supply for driving the electromagnets, it is generally more convenient to use a three-phase supply, illustrated with respect to FIG. **5,** since three-phase power is available directly from most power companies. The following table indicates the relative phase connections of the electromagnets of FIGS. **1** and **2** in order to produce forces on articles from the left to the right of FIG. **2**:

Electromagnet:	23	19	24	20	25	21	26	22	27
Phase A	X			X			X		
Phase B		X			X			X	
Phase C			X			X			X

If it is desired to produce forces from the right to the left in FIG. **2,** the various electromagnets are phased as follows:

Electromagnet:	23	19	24	20	25	21	26	22	27
Phase A			X			X			X
Phase B		X			X			X	
Phase C	X			X			X		

If it is desired to produce forces from either end of the rows of electromagnets toward the center, the following relative phasing is applied:

Electromagnet:	23	19	24	20	25	21	26	22	27
Phase A	X			X		X			X
Phase B		X			X			X	
Phase C			X				X		

If it is desired to have forces on articles directed from the center of the rows of electromagnets to both ends, the following relative phasing of the electromagnets is applied:

Electromagnet:	23	19	24	20	25	21	26	22	27
Phase A			X				X		
Phase B		X			X			X	
Phase C	X			X		X			X

In the embodiment of FIGS. **1** and **2,** very small pieces of non-magnetic metal to be removed from the conveyor belt **13** could possibly avoid strong dual phase magnetic flux areas in the air gap and thus not be diverted off of the conveyor. In order to remove more of the very small pieces, in the order of one-half the width of the pole face, the poles may be angled as shown in FIG. **6,** which is a top view of a conveyor belt installation. Since the operable areas of dual phase flux occur at the corners of opposing poles, it is seen that a non-magnetic metal piece **41** travelling on the conveyor belt **13** crosses through several such dual phase magnetic flux areas and is thrown off the conveyor belt by travelling in a path **43.**

It should be understood that a number of magnetic removal stages may be employed along the conveyor belt **13**, some angled as in FIG. **6** and some straight as in FIG. **1**. The various stages could have different air gap sizes depending upon the expected sizes of material at the various stages along the conveyor belt. Furthermore, not all of the stages need to have an electromagnetic pattern to throw the articles off the conveyor belt but rather one stage could merely guide all non-magnetic electrically conductive articles into the center of the conveyor belt for separation by a later stage. The possibilities for various combinations of stages of magnetic poles according to the present invention are numerous depending upon the specific article movement job that is required to be done. Additionally, the waste material can be allowed to drop by gravity through a properly positioned magnetic air gap rather than using a conveyor belt for propulsion.

Besides applications to waste removal systems, the magnetic pole configuration described with respect to the Figures may also be applied for moving electrically conductive non-magnetic articles, such as aluminum can lids, from one point to another. Thp more efficiently generated electromagnetic forces are utilized as a primary moving source rather than as a mere diversion from some other primary moving force such as a conveyor belt. Referring to FIG. **7**, one application of moving aluminum can lids is illustrated wherein one very long row of poles **45** opposes spaces between magnetic poles of a second row **47**. Such a configuration can be used, with the addition of some can lid supporting surface, for moving an aluminum can lid **49** from one point to another between ends of the rows of magnets. The magnets can be laid out to form a flat horizontal path in which the aluminum can lid **49** is propelled in a horizontal position, or the magnets may be placed so that the air gap is vertical and the aluminum can lid is somewhat rolled along in the air gap. The relative energization of the magnets along the aluminum can lid path is preferably with three-phase electric current in a manner described with respect to FIG. **2**.

Since large air gaps are possible with the system of the present invention, the opposing rows of magnets for an aluminum can lid propelling system may be curved as specifically shown in FIG. **7**. Such a curved section is especially useful in a can plant for moving aluminum can lids since a continuous path is possible, including a path from a work station up and over an aisle and back down to another work station. The curved sections such as shown in FIG. **7** make such continuous movement possible. Presently, discrete straight line conveying systems are used wherein the output of one conveying section becomes the input to another, etc., in a very complicated and noisy system.

In conjunction with the magnetic propulsion system for articles such as can ends, the techniques of the present invention may be applied to form an additional guiding, centering, or diverting capability. Referring to FIG. **8**, the solid circles, such as a circle **51**, represent a magnetic pole above the articles to be conveyed. The dotted circles, such as a circle **53** of FIG. **8**, represent a magnetic pole beneath the articles to be conveyed. The letters on the center of the schematic circle representations of magnetic poles specify the relative of alternating current excitation from a three-phase source, such as that illustrated in FIG. **5**.

A center row **55** of electromagnets positioned according to the techniques of the present invention is provided for propelling an article such an an aluminum can end **57** from the left to the right along the row **55**. In conjunction with this, however, are rows **57** and **59** of electromagnets which are phased to also provide a propelling force from left to right. Additionally, the relative phases of the electromagnets of the rows **57** and **59** are chosen with respect to the relative phases of the row **55** to provide diverting electromagnetic forces therebetween, as shown by the arrows. That is, the rows **55** and **57**, for instance, are both phased to provide propelling forces from left to right and the relative phases between the adjacent magnets of the rows **57** and **55** are such to provide lateral forces that tend to propel an article out of row **55** and into the row **57**. Both of the rows **57** and **59** would not be energized to divert can lids alternately from row **56** to row **57** and then to row **59**.

Additional rows of electromagnets **61** and **63** are provided in order to complete the diversion of articles from the center row **55**. Of course, further rows of electromagnets could be provided depending upon the magnitude of the lateral diversion of articles such as can lids that is desired.

It will be recognized that by changing phases of adjacent magnets that forces can be altered and thus a desired path of movement of an article can be controlled. One such modification is to reverse the left to right forces of the magnets by changing the phasing so that the propelling forces on articles is from the right to the left of the example of FIG. **8**. Relative phasing would also be changed so that the lateral forces between rows tended to move can lids from the extreme rows **61** and **63** to the center row **55**. Can lids from two separate source rows are then propelled to the left of FIG. **8** and into a common stream in the center row **55**.

Referring to FIG. **9**, another variation of lateral diverting magnetic forces is illustrated. A center row **65** of electromagnets arranged according to the offset pole concepts of the present invention are connected to a three-phase alternating current source in a manner to provide propelling forces from the left to the right of FIG. **9**. Rows of magnets **67** and **69** on alternate sides of the middle row **65** are also connected to have relative phases in order to provide propelling forces from left to right. Additionally, the rows **67** and **69** are phased with respect to the center row **65**, as shown by the arrows of FIG. **9**. The result of the configuration shown in FIG. **9** is to provide electromagnetic centering of articles as they are propelled from left to right. This eliminates the necessity for mechanical or other forms of centering guides and thus eliminates a great source of noise in such conveying systems.

Although the various aspects of the present invention have been described with respect to specific examples thereof, it will be understood that the invention is entitled to protection within the full scope of the appended claims.

I claim:

1. A magnetic pole arrangement for giving motion to electrically conductive materials, comprising:

a first row of a plurality of electrically excitable magnetic pole faces forming one side of an air gap, said first row pole faces being positioned with spaces therebetween along said first row, a second row of a plurality of electrically excitable magnetic pole faces forming an opposite side of said air gap, said second row pole faces being positioned with spaces therebetween along said second row,

each pole face of the first row being positioned opposite a space of said second row and having a width substantially equal to that of said opposite space, and

each pole face of the second row being positioned opposite a space of said first row and having a width substantially equal to that of said opposite space.

2. The magnetic pole arrangement of claim 1 which additionally comprises means for electrically exciting the magnetic pole faces with alternating current to provide magnetic flux of two distinct relative phases between each pole face and those pole faces adjacent a space opposite said pole face.

3. The magnetic pole arrangement of claim 1 which additionally comprises means connecting the electrically excitable magnetic pole faces to a poly-phase alternating electrical power source for producing a magnetic field therefrom having one of a plurality of relative alternating phases, each pole face of the second row generating a magnetic field having a relative phase different from that of two poles of the first row on either side of a pole space located opposite said each pole.

4. The magnetic pole arrangement of claim 1 wherein all of said spaces between pole faces are substantially equal in width along their respective rows and wherein said gap width between said first and second row of pole faces is substantially equal to the width of said spaces.

5. Apparatus for removing electrically conductive particles from a stream of waste material, comprising:

means for forming waste material including electrically conductive and electrically non-conductive particles into a stream along a given path,

a plurality of electromagnetic poles arranged in a first row extending across said stream given path with non-magnetic material spaces between said poles,

a plurality of electromagnetic poles positioned in a second row extending across said stream given path on its side opposite to the location of the first row and having non-magnetic material spaces between said poles, the poles of each row being oriented directly opposite a space of the other row, and

means for energizing said electromagnets of the first and second rows with alternating current of various relative phases in a manner to exert force upon electrically conductive particles positioned in said stream that is in a direction along said rows, whereby conductive particles are removed out of a stream of waste material.

6. Apparatus according to claim 5 wherein each pole has a dimension along its row that is substantially equal to a space of the other row opposing said each pole.

7. Apparatus according to claim 5 wherein said stream forming means includes a substantially horizontal conveyor belt with said first row of electromagnetic poles extending across the belt on its underside and said second row of electromagnetic poles extending across the belt a distance above its top side.

8. Apparatus according to claim 7 wherein said first and second rows are oriented at a finite angle less than 90° with the conveyor belt.

9. Apparatus for giving motion to electrically conductive non-magnetic articles such as aluminum can lids, comprising:

a first row of a plurality electromagnetic poles extending along a path over which said articles are to conveyed, said poles being separated along the path by spaces of non-magnetic material,

a second row of a plurality electromagnetic poles extending along said path and separated from said first row by an air gap through which said articles are given motion, the poles of the second row being separated along the path from each other by spaces of non-magnetic meterial,

each of the poles of said first and second rows being positioned opposite a space of the opposing row of poles, and

means for energizing the electromagnetic poles with alternating current of various relative phases in a manner to exert force on an article in the air gap in a direction along said path.

10. Apparatus according to claim 9 wherein said path includes a curved section.

11. Apparatus according to claim 9 which additionally comprises:

a third row of electromagnetic poles positioned alongside said first row, said third row of poles being separated by spaces of non-magnetic material and oriented with poles and spaces aligned with those of the first row,

a fourth row of electromagnetic poles positioned alongside said second row, said fourth row of poles being separated by spaces of non-magnetic material and oriented with poles and spaces aligned with those of the second row, thereby to form a second path along which said articles may be conveyed in an air gap between said third and fourth rows, and

wherein said energizing means includes means for energizing the electromagnetic poles of the first, second, third and fourth rows to simultaneously exert forces on an article along the lengths of said paths and between said paths, whereby an article may be given complex motion.

12. Apparatus according to claim 5 wherein said energizing means provides magnetic flux of two distinct relative phases between each pole face and those pole faces adjacent a space opposite said pole face.

13. Apparatus for giving motion to an electrically conductive non-magnetic article, comprising:

a first row of a plurality electromagnetic poles extending along a defined path over which said article is to be moved, said poles being separated along the path by spaces of non-magnetic.

a second row of a plurality electromagnetic poles extending along said path and separated from said first row by an air gap through which said article is to be moved, the poles of the second row being separated along the path from each other by spaces of non-magnetic material.

each of the poles of said first and second rows being positioned opposite a space of the opposing row of poles, and

means for energizing the electromagnetic poles with alternating current to provide magnetic flux of two distinct relative phases between each pole face and those pole faces adjacent a space opposite said each pole face.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,824,516 Dated July 16, 1974

Inventor(s) Sander Benowitz

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 49, "Three" should read -- These --. Column 7, line 23, "Thp" should read -- The --. Column 10, line 9, after "to" insert -- be --; line 55, after "non-magnetic" insert -- material --.

Signed and sealed this 29th day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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