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[54] **ALIGNING AND SORTING BODIES**
6 Claims, 9 Drawing Figs.
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209/74, 209/81
[51] Int. Cl. **B07c 5/344**
[50] Field of Search **209/73, 74,**
81

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ABSTRACT: Apparatus for sorting bodies on the basis of the impedance-affecting characteristics thereof, comprising an inclined trough formed by the trough-defining surfaces of a pair of closely spaced rotating rollers. The rollers are divided into three sections longitudinally, (i) an upper section of major extent connected to a source of one electrical potential, (ii) a narrow intermediate insulating section, and (iii) a lower section of minor extent connected to a source of another electrical potential. Bodies are fed into the upper section and are aligned and conveyed down the trough. When in transit through the narrow intermediate section, they come into bridging contact with an electrical circuit including the upper and lower sections of the trough. An electrical signal is produced diagnostic of the impedance-affecting characteristics of each body, and after discharge from the lower section of the trough, an air blast is actuated as required to affect the body's trajectory of fall and effect sorting. The rollers are preferably modified to increase the normal reaction applied to the bodies in the critical sampling region. The apparatus is useful for sorting low resistivity metalliferous ore from barren rock, but can also be used for sorting bodies having the same resistivity but whose physical characteristics nonetheless differ in such a way as to enable a diagnostic electrical signal to be produced when their resistivities are measured.

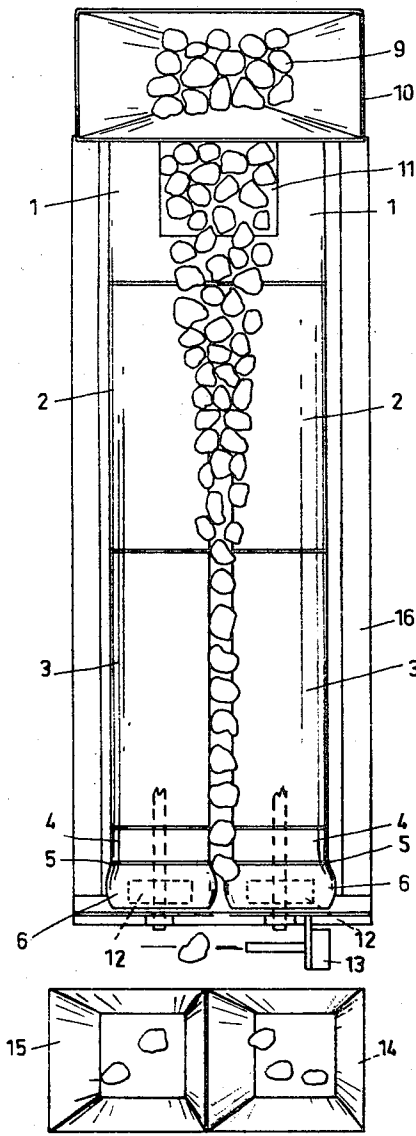
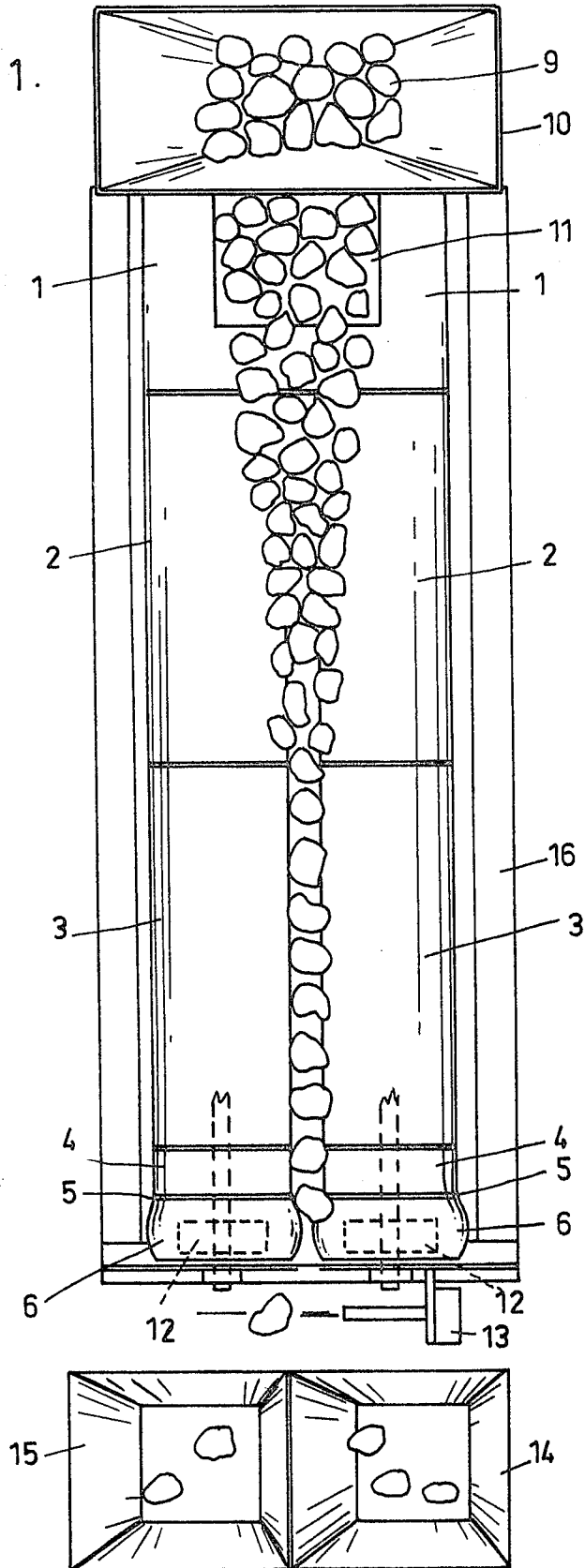
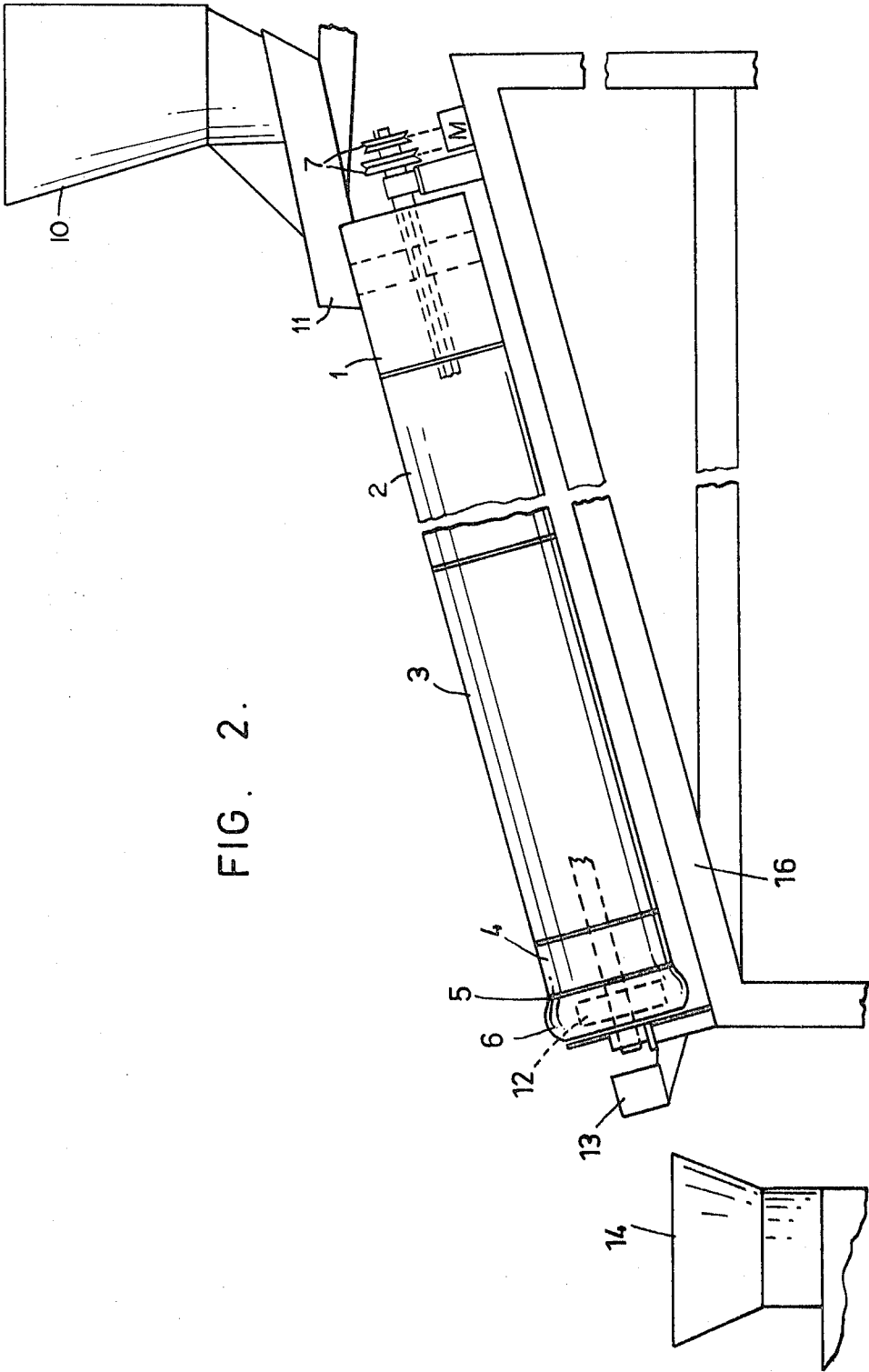


FIG. 1.





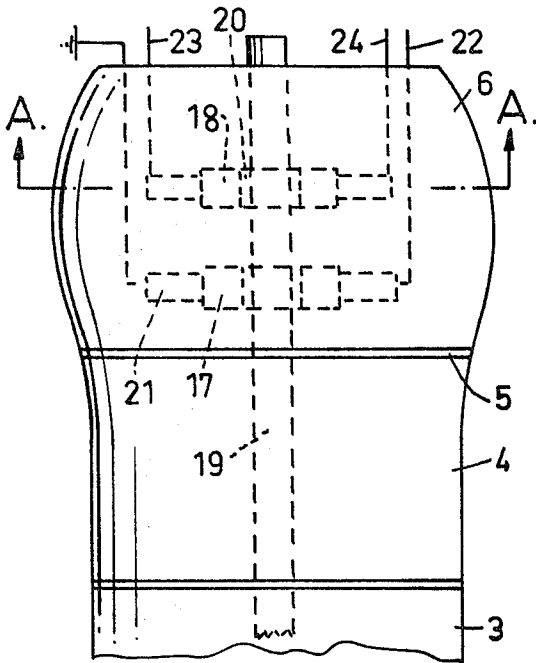


FIG. 3.

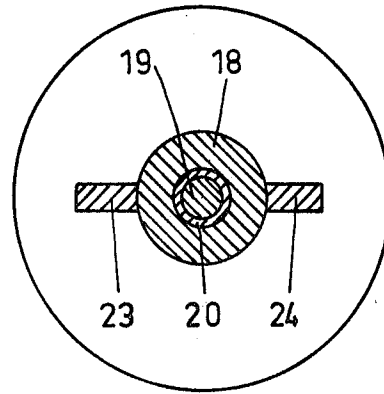


FIG. 4.

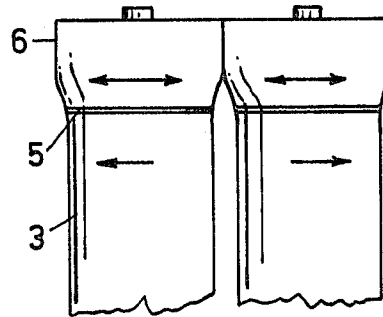


FIG. 6.

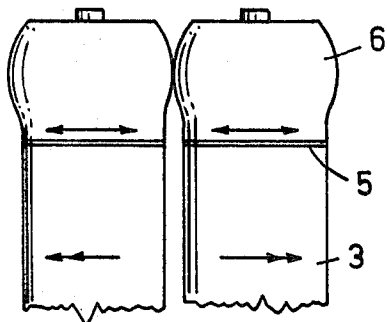


FIG. 5.

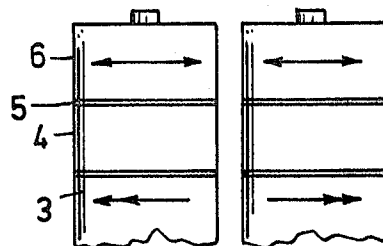


FIG. 8.

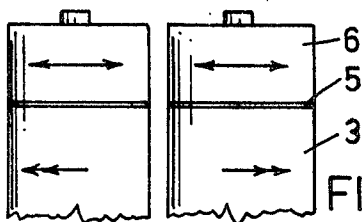
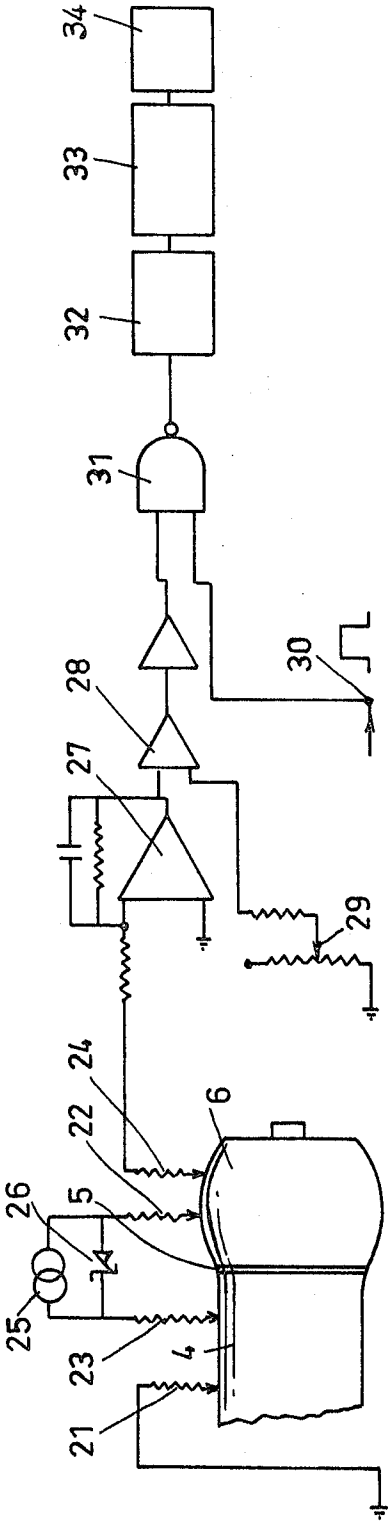


FIG. 7.

FIG. 9.



ALIGNING AND SORTING BODIES

This invention has been devised principally to provide apparatus for mechanically sorting pieces of metalliferous ore from comparably sized pieces of barren rock in a manner which takes advantage of the difference in electrical resistivities between the two types of bodies. The sorting operation made economically practicable by this application of the invention is a preliminary procedure in the overall process of extracting the valuable metalliferous component from the barren rock with which it is geologically associated.

As used herein the term "metalliferous" ore means ore having the electrical resistivity characteristics of a metal or semiconductor. An example is provided by nickel sulfide ore, which is a semiconductor and typically has a resistivity in the range from 0.1 to 10 ohm cm. (less than that of the barren rock with which it is geologically associated by a factor of the order of 10₄). Additional examples of metalliferous ores, with accompanying typical resistivities, are given in the following table.

TABLE 1

Ore	Resistivity range (ohm-cm.)
Pyrite	10-10 ⁴
Pyrrhotite	10 ⁻² -1
Magnetite	1-10 ⁴
Galena	10-10 ⁵

While the invention has major applicability in the mechanical sorting of such metalliferous ores from barren rock, it will be explained hereinafter that the apparatus according to the invention has applicability also to the sorting of bodies which may or may not have differing electrical resistivities but whose physical properties generally differ in such a way as to give rise to diagnostic electrical signals when their electrical resistivities are measured. All those characteristics of a body (including the resistivity of the body) which give rise to diagnostic electrical signals when the body's electrical resistivity is measured are referred to hereinafter as "impedance-affecting characteristics."

Methods of mechanically sorting bodies on the basis of their differing electrical resistivities have been known hitherto, but these known methods have economic disadvantages. For example, the bodies may be required to be aligned before being submitted to the sorting operation, and this has meant hitherto that two separate units of apparatus (one for aligning and one for sorting) have been required to be installed. Again, in those known methods of sorting where the electrical resistivities of the bodies are directly assessed by bringing them successively into mechanical contact with two sources of different electrical potential (thus closing an electrical circuit through the tested body), the maximum speed of sorting has been limited by the speed with which it is possible to move the two sources of potential (for example, a probe) into and out of mechanical contact with the bodies. With the types of apparatus hitherto proposed, the speed at which it has been possible to conduct this critical handling operation has been so low that the overall process of sorting has been regarded as lacking in real commercial utility.

The present invention overcomes these disadvantages and provides a single unit of apparatus in which the operations of aligning and sorting can be performed efficiently and economically at very high throughput rates.

When using the apparatus of this invention, the aligning operation is carried out by invoking a method of the type described in our prior U.S. Pat. No. 3,426,881 dated Feb. 11, 1960 in which the bodies are fed into the upper end of an inclined trough comprising the trough-defining surfaces formed by a pair of closely spaced rotating rollers, engage in frictionally differential pressure contact with the trough-defining surfaces, slide differentially down the trough and are formed progressively into a single row alignment. The sorting operation is then carried out by steps comprising sampling the

impedance-affecting characteristics of the bodies successively at the lower end of the same trough.

Broadly, the invention provides apparatus for sorting bodies on the basis of the impedance-affecting characteristics thereof, said apparatus comprising an inclined trough formed by the trough-defining surfaces of a pair of closely spaced rollers, said trough comprising longitudinally an upper section for receiving, aligning and conveying the bodies, a lower section for conveying and discharging the bodies, a narrow intermediate section between the upper and lower sections of the trough, said upper and lower sections of the trough being electrically conductive at least in respective zones adjacent said intermediate section, means for sampling the impedance-affecting characteristics of each body in transit between the upper and lower sections of the trough and for producing an electrical signal diagnostic of said sampled characteristics, means for feeding the bodies to the upper section of the trough, means for rotating the rollers to achieve said aligning and conveying of bodies, and deflector means for affecting the trajectory of bodies discharging from the trough to an extent determined by said diagnostic signal; said sampling means comprising an electrical circuit including the electrically conductive upper and lower sections of the trough, said electrical circuit comprising means for linking electrically the upper section of the trough to a source of one electrical potential and means for linking electrically the lower section of the trough to a source of another electrical potential, said intermediate section comprising means for insulating the upper section of the trough from the lower section of the trough, said electrical circuit being adapted to be closed by a said body bridging the upper and lower sections of the trough when in transit therebetween.

The bodies for sorting can be fed to the upper section of the trough in any suitable manner.

A convenient feeding system comprises a hopper associated with a vibratory feeder.

The rollers forming the upper section of the trough may be cylinders or uniformly tapering frustoconical sections, as explained in the mentioned prior patent applications. For simplicity in the present description, it is assumed that the rollers in this section are substantially cylindrical.

Each of the rollers forming the trough can be considered to comprise longitudinally a number of sections —upper, intermediate and lower —corresponding respectively to the upper, intermediate and lower sections of the trough.

Provided the described electrical circuit is always adapted to be closed by a body sliding between the upper and lower sections of the trough, it will be appreciated that several arrangements are possible, viz (i) the three sections of a given roller can be integral with each other, in which case rotation of the roller results in the three sections rotating with the same angular velocity; or (ii) they can be independent of each other but coaxially juxtaposed, in which case rotation of any one roller section can be carried out independently of the other sections and the angular velocities of the sections can all be different; or (iii) two juxtaposed roller sections can be integral with each other, in which case rotation of the integral sections can be carried out independently of the third section and the angular velocities of the integral sections and the third section can be different.

Applying the principles of velocity control formulated in the mentioned prior patent application, it has been found desirable in the practice of the present invention to divide transversely as required at least one of the upper or lower roller sections into at least two independently rotatable subsections. For reasons given below, it is particularly beneficial to divide the upper roller sections transversely into subsections in this way. Such independently rotatable subsections of a roller section, regardless of whether or not they are integral with an adjacent roller section, are hereinafter called "rolls."

By varying the angular velocities of the various independently rotatable parts of a roller, as explained in the mentioned patent application, a desired gradient of body velocity in the trough can readily be achieved.

In order to carry out satisfactory sampling of impedance-affecting characteristics, it is necessary to ensure that the bodies maintain maximum surface contact with the rollers when in transit between the upper and lower sections of the trough. For this reason, it is particularly useful to provide a gradient of increasing angular velocity longitudinally down the upper roller sections of the trough. By using such an arrangement, the bodies can be fed into the upper section of the trough in a multilayered pile with a minimum of initial bouncing. They can then be accelerated in a stepwise manner when sliding down the trough, and satisfactory sampling of the impedance-affecting characteristics can be carried out when in transit to the lower section of the trough.

The upper roller sections are selected to have a length sufficient to enable the process of alignment to be complete by the time the bodies have reached the lower end thereof.

As explained in the mentioned prior patent application, the rapid alignment of bodies in stable orientation is facilitated by using a trough formed by a pair of identical rollers contrarotating at any given position along their length with the same peripheral speed, and whose relative disposition is such that a body supported on a trough-defining surface is acted on by a component of frictional force directed away from the nip therebetween.

Preferably, the apparatus according to the present invention also has these features.

Again as explained in the mentioned patent application, the diameters of the upper roller sections and the separation therebetween are preferably selected independently in such a way with respect to the average size of the bodies that three said bodies sliding down the trough in stacked relationship at any site are always submitted to three different degrees of frictional retardation. By selecting the diameters of the upper roller sections and the clearance therebetween in this way, it is ensured that all the bodies are formed into a single row alignment in the minimum possible aligning distance, and thus the length of the upper roller sections can be correspondingly short. This arrangement is also conducive to ensuring that the bodies make maximum surface contact with the rollers when in transit between the upper and lower sections of the trough.

The provision of roller rotation means in the apparatus of the invention is for the purpose only of enabling the aligning and conveying at a desired speed of bodies for sorting. It follows therefore that, provided these objectives are achieved in any given sorting operation, various modes of roller rotation can be contemplated. For example, one or more parts of a given roller, or even a single whole roller, can be intermittently or continuously at rest, in which case reliance must be placed on the other parts or part of the roller system for effecting aligning and conveying. In use, preferably no part of a roller is continuously stationary, since otherwise such a part will be subjected to excessive localized wear from bodies sliding thereon.

The rollers, or parts thereof, can be rotated by any suitable motor acting for example through known systems of sprockets and chains. Where some parts of the rollers are required to be driven at angular velocities differing from those of other parts, this can be achieved simply by means of known gearing or belt systems.

Each body is discharged gravitationally from the lower end of the trough and, if appropriate, is then deflected from its normal trajectory of fall by known deflector means (for example, an air blast). This deflector means is responsive to the diagnostic signal arising from the passage of the body from the upper section to the lower section of the trough. It is clearly desirable for the normal trajectory of fall of the bodies to be predictable, and for this reason—as described in the mentioned prior patent application—it is preferred to discharge the bodies from a trough formed by a pair of rollers whose lower sections at least terminally are substantially frustospheroidal in shape. When this is done, the length and radius of curvature of the frustospheroidal ends can be selected interde-

pendently in such a way that the normal reaction acting on a body at discharge is positive but not substantially greater than zero. As a result of this terminal shaping of the rollers, it can be ensured that the bodies are discharged into a predictable trajectory.

In the apparatus of the present invention, at least one upper roller section and at least one lower roller section are electrically conductive at least in respective upper and lower zones adjacent the intermediate section of the trough, and they are linked electrically to sources of different electrical potential. Such roller sections, regardless of whether or not they are wholly electrically conductive, are hereinafter referred to as "electrified" roller sections.

The sources of electrical potential can be such as to provide either direct or alternating current when the circuit between them is closed. For the purpose of the present description, it is assumed that a direct current facility only is employed.

The arrangement is such that a body sliding from the upper section of the trough to the lower section of the trough can come into bridging contact with the electrical circuit involving the upper and lower electrified roller sections. The region of the trough in which a body can make a bridging contact is referred to hereinafter as the "critical sampling region." It is clear therefore that, at least when the upper and lower electrified roller sections are parts of the same roller, the narrow intermediate section between them must comprise suitable insulating material. Conveniently, such insulating material is polymethyl methacrylate or air. When the insulating material is air, it will be appreciated that the upper and lower sections of the roller are usually independently rotatable.

Suitable means for linking the roller sections to the sources of electrical potential and the electrical circuit can comprise and a system of slippings and brushes housed within, or external to, the rollers.

For example, in a preferred case where both the upper roller sections are linked to a source of one electrical potential and both the lower roller sections are linked to a source of another electrical potential, each roller of the system houses internally two electrically independent coaxial slippings and two respectively contacting pairs of brushes. Each such slipping is linked electrically via one of the brushes to a source of electrical potential, and communicates this potential to the appropriate roller section via an electrically conductive member such as the coaxial drive shaft for rotating the roller. The other brush contacting this slipping is linked electrically to that part of the electrical circuit concerned with producing a diagnostic electrical signal when a body comes into bridging contact with the upper and lower sections of the trough.

Insulation is provided where necessary within the roller to prevent short circuiting between the upper and lower electrified roller sections. For example, when the two slippings of a roller are housed within the lower roller section (as is convenient), it is clearly necessary to provide an insulating sleeve about the coaxial shaft communicating electrically with the upper roller section.

In practice, it is usually required to operate the apparatus at a high throughput rate, and in such cases particularly it is necessary to provide means for relating any given diagnostic signal to the particular body from whose sampled impedance-affecting characteristics it is derived. Suitable such means comprises photoelectric cell means associated both with the electrical circuit and the deflector means, the photoelectric cell means being so located as to register each body sliding through the critical sampling region.

In the course of experiments leading up to the invention, it has been found that contact is not continuous between a sliding body and the supporting trough-defining surfaces formed by a pair of inclined, closely spaced, rotating rollers. The degree to which contact is not maintained increases progressively as the speed of sliding is increased, and it has been found that at the high rates of throughput required for commercially acceptable sorting, the number of contacts per second (the "simple contact frequency") made between a

sliding body and the supporting surfaces can be so low as to render unworkable a method of sorting based on the body's ability to close the described electrical circuit. This is especially true when it is required to sort pieces of metalliferous ore from pieces of barren rock, in which the metalliferous pieces are characterized inter alia by one or more of the following unfavorable features: (i) low density, (ii) nonelongated shape, (iii) smooth surface topography, (iv) high degree of hardness, (v) low metalliferous content.

Clearly, the success or failure of such a method of sorting is not so much dependent on the simple contact frequency between a body and the supporting surfaces, but on the (smaller) number of circuit closing contacts per second made between the body and the electrified roller sections. This latter number of contacts per second is hereinafter referred to as the "bridging contact frequency."

It is only these closing contacts which are significant for testing the metalliferous content of a body, and if the bridging contact frequency is not high enough, it becomes difficult—if not impossible—to distinguish between pieces of ore containing a low (but valuable) metalliferous content and pieces of barren rock.

It has been found according to a further aspect of the invention that the simple contact frequency between a rapidly sliding body and the supporting trough-defining surfaces formed by a pair of inclined, closely spaced, rotating rollers can be greatly increased in any required small region by adopting one or more of the following expedients: (a) modifying the external shape of the rollers (i.e. contouring them) in that region in such a way as to increase the normal reaction applied by the supporting surfaces to the body, (b) increasing the effective weight of the body in that region, thereby increasing the normal reaction applied to the body, and (c) reducing the peripheral speed of the rollers in that region, thereby (i) again increasing the normal reaction applied to the body and (ii) retarding, or tending to retard, the sliding movement of the body. By applying such methods in the critical sampling region of the trough, it has been found possible to increase the bridging contact frequency to such an extent that the sorting by this method of metalliferous pieces of ore from pieces of barren rock can be accomplished with a high degree of efficiency even when the pieces of ore have all the previously mentioned unfavorable features.

Method (a) of increasing the bridging contact frequency can be accomplished by slightly and progressively increasing the diameters of the rollers in a downwards direction (i.e. flaring them concavely) in the critical sampling region of the trough.

Method (b) can be accomplished for example by causing a jet of air to impinge downwardly on the body in that region.

Method (c) requires that provision be made for rotating the roller parts in the critical sampling region independently of the rotation of roller parts thereabove.

In a simple arrangement illustrative of method (c), the upper section of each roller is divided into two rolls, the higher roll being rotated at a relatively high angular velocity and the lower roll being rotated at a relatively low angular velocity. The lower roll of this section is integral with (and rotates with) the intermediate roller section, and the latter in turn is integral with (and rotates with) the lower roller section.

Apparatus is described hereinafter illustrating the degree to which the bridging contact frequency can be improved by flaring the rollers concavely in a downwards direction in the critical sampling region of the trough.

The degree to which any one of these methods should be implemented in a given case naturally depends on the degree to which it is necessary to increase the bridging contact frequency to achieve satisfactory sorting.

The described electrical circuit involves the electrified upper and lower sections of the trough, and this circuit is adapted to be closed when a body of sufficiently low resistivity makes a bridging contact between them.

The circuit is associated with means for producing an electrical signal diagnostic of the body's impedance-affecting

characteristics, and such means conveniently comprises an electronic counter linked to the circuit through a threshold discriminator. When an electrically conductive body slides through the critical sampling region, the electronic counter records a characteristic pattern of pulses corresponding to the pattern of bridging contacts which occur between the body and the electrified roller sections. It is this pattern of pulses which constitutes the electrical signal diagnostic of that body under the given experimental conditions.

It has been appreciated that this electrical signal can be interpreted diagnostically in two principal ways—(i) the pulse height is proportional to the resistance of a bridging contact and is therefore indicative of the resistivity of that portion of the body which makes this bridging contact; (ii) the pulse duration and pulse frequency are together indicative of various impedance-affecting characteristics of the body, such as density, shape, surface topography, hardness, homogeneity and moisture content.

Examples of the application of these criteria are given hereinafter.

The apparatus according to the invention is now described with reference to the appended drawings in which:

FIG. 1 is a plan view of a typical apparatus for aligning and sorting bodies;

FIG. 2 is a view in longitudinal elevation of the same apparatus;

FIG. 3 is a view in longitudinal section through the lower section of a roller of the same apparatus showing two slippings and respectively associated pairs of contacting brushes;

FIG. 4 is a view in transverse section through line A-A of FIG. 3, showing a single slipping and its associated pair of brushes;

FIGS. 5–8 are plan views in part showing principally the critical sampling region and the lower section of each trough for various embodiments of the invention; and

FIG. 9 is a drawing showing schematically an electrical circuit suitable for use in the apparatus of FIGS. 1–4.

Corresponding numbering between the various FIGS. is intended to denote corresponding parts.

Referring now particularly to FIGS. 1 and 2, the drawings show an apparatus comprising an inclined trough having an upper section formed by pairs of independently rotatable electrically conductive rolls 1, 2, 3, 4; an intermediate section formed by a pair of insulating intermediate roller sections 5; and a lower section formed by a pair of electrically conductive lower sections 6 comprising frustospheroidal ends. The coaxial parts of the mentioned rolls and roller sections together form a symmetrical pair of rollers. Roll 4 and roller sections 5 and 6 of each roller are integral with each other and are therefore all adapted to rotate with the same angular velocity.

The critical sampling region includes the pair of insulating intermediate roller sections 5, and provision is made in this region for the rollers to be flared concavely in a downwards direction as shown so as to increase the normal reaction applied by the supporting surfaces to a body sliding in that region.

The rollers are rotated by means of a motor *M*, linked as shown schematically to pulleys such as 7 and associated suitable gearing (for example, a differential or epicyclic gear train) such as 8.

By this means it can be arranged that rolls 1, 2, 3 rotate with respectively increasing angular velocity down the trough, and that rolls 4 (integral with roller sections 5, 6) rotate with a reduced angular velocity, for example approximating that of rolls 1.

Bodies 9, for example mixed pieces of metalliferous ore and barren rock, are fed to the trough from a hopper 10 and vibratory feed plate 11.

Housed within each of the lower roller sections 6 is a system of slippings and brushes, schematically indicated as 12, for the purpose of connecting the upper and lower roller sections to different sources of electrical potential. This system is explained more fully below in relation to FIGS. 3, 4.

Air blast deflector means 13 is provided at the lower end of

the apparatus for affecting as required the trajectory of bodies discharged from the trough, and separate collecting bins 14, 15 are provided to receive respectively (i) bodies which have not been deflected by the air blast and (ii) bodies which have been deflected by such means.

The apparatus is supported at the desired angle of inclination by means of frame 16.

When the apparatus is designed to sort pieces of nickel sulfide ore from pieces of barren rock (minimum dimension 1 inch, maximum dimension 6 inches) at a throughput rate of 9 feet per second, it is suitable to employ a trough having the following characteristics.

The inclination of the trough to horizontal is 16°.

Rolls 1, 2, 3, 4 forming the upper section of the trough have lengths respectively of 2.5, 4, 6, 0.5 feet and angular velocities respectively of 20, 60, 190, 120 r.p.m. The intermediate and lower roller sections, 5 and 6, have lengths respectively of 0.06 inch and 0.8 feet.

The diameter of rolls 1 (say) is 2 feet, and the separation transversely therebetween is 0.5 inch.

The flared region is equispaced on either side longitudinally of the intermediate section and the total length longitudinally of this region is 6 inches. The flared region of each roller can be regarded as a surface of revolution of an arc of a circle of radius 6 feet.

The frustospheroidal ends of the lower roller sections comprise a surface of revolution of an arc of a circle of radius 10 feet.

With the exception of the intermediate roller section, all the roller parts are constructed of mild steel.

The intermediate section is constructed for example of a urea-formaldehyde resin or of rubber. In an alternative embodiment, the intermediate section can be provided by air.

Referring now particularly to FIGS. 3, 4, the system of slippings and brushes schematically indicated as 12 in FIGS. 1 and 2 is here seen to comprise two electrically independent coaxial slippings 17 and 18, respectively linked—both mechanically and electrically—to roll 4 and roller section 6. The linkage between slipping 17 and roll 4 is effected via electrically conductive drive shaft 19, and insulation 20 is provided for preventing electrical contact between slipping 18 and this drive shaft.

The slippings 17 and 18 are in contact respectively with pairs of brushes 21, 22 and 23, 24. Brushes 22 and 23 are linked to sources of different electrical potential, while brushes 21 and 24 are linked to that part of the electrical circuit concerned with producing a diagnostic signal when a body comes into bridging contact with roll 4 and roller section 6.

This electrical circuit is explained more fully with reference to FIG. 9.

Referring now to FIGS. 5—8, these drawings simply illustrate various roller assemblages and shapes at the lower end of the trough, together with preferred modes of roller rotation in the various parts.

FIGS. 5, 6, 7 show embodiments of apparatus in which there is no counterpart of roll 4 (described in relation to FIGS. 1, 2). Thus, in these embodiments the upper roller sections immediately adjacent the intermediate roller sections all rotate independently of the intermediate and lower roller sections.

In these drawings, the arrows denote preferred directions of roller rotation, indicated with respect to movement of roller surfaces above the nip. Oppositely pointing arrows denote that both directions of roller rotation are equally suitable. Single arrows as against double arrows denote relatively low angular velocity as against relatively high angular velocity (respectively). In all cases the lower and intermediate roller sections are integral with each other.

In the case of the embodiments of FIGS. 5, 7, 8, the means employed for increasing the normal reaction of bodies sliding in the critical sampling region consists only in providing the shown reduced angular velocity of (at least) the lower roller sections in the critical sampling region.

In the case of the embodiment of FIG. 6, the rollers are

flared concavely in a downwards direction in this region to achieve the same effect.

Frustospheroidal roller ends are shown in FIG. 5.

FIG. 9 illustrates schematically a suitable electrical circuit for use in connection with the embodiment illustrated in FIGS. 1—4. For convenience, as in FIGS. 3 and 4, the description is with respect to a single roller only.

Current is supplied to roll 4 and lower roller section 6, through brushes 23 and 22 respectively, from a constant current generator 25. A Zener diode 26 is provided to limit the maximum voltage across the roll and lower roller section to a value predetermined with regard to the nature of the electrical circuit.

Roll 4 is connected through brush 21 to earth, and roller section 6 is connected through brush 24 and amplifier 27 to threshold discriminator 28.

The amplifier serves both to match the input impedance of the threshold discriminator with the impedance of the roller system, and to determine the frequency response of the overall electrical circuit.

The threshold discriminator is a high gain differential comparator whose output changes state when the input from the amplifier exceeds a predetermined reference voltage set by potentiometer 29.

The output from the threshold discriminator, after inversion, is gated with a body position pulse fed in at 30.

The body position pulse is derived from the previously mentioned photoelectric means (not shown), and signals the passage of a particular body through the critical sampling region of the trough.

The output of gate 31 is fed to pulse analyzer 32, and the output of the latter communicates with "decision" circuitry 33.

When an appropriate pulse pattern is registered, the decision circuitry actuates the previously mentioned deflector means (for example, an air blast) 34 to affect the trajectory as required of a body discharging from the lower section of the trough.

Four Examples (I, II, III, IV) are now given for the purpose of illustrating methods of achieving commercially useful bridging contact frequencies (Examples I, II) and for the purpose of illustrating pulse pattern variations diagnostic of differences of density or length in bodies of the same resistivity (Examples III, IV).

The bodies referred to in all the Examples are brass cylinders having smooth surface topography (protuberances above the surface less than 1/1,000 inch).

The electrical circuit in the Examples is based on that illustrated in FIG. 9. In all cases, the threshold discriminator is set in such a way that a single pulse corresponds to a single bridging contact, and a pulse count therefore corresponds to a bridging contact count. Additionally, pulse analyzer 32 consists of an electronic counter, and the circuit differs from that shown in FIG. 9 in that the decision circuitry 33 and the deflector means 34 are omitted.

EXAMPLE I

Two independent pieces of apparatus, A and B, are assembled in accordance with the invention.

Each apparatus comprises a trough inclined 10° to horizontal. The trough-defining surfaces are formed by a pair of identical, closely spaced rollers, and means are provided for symmetrically contrarotating the rollers in such a way that a body supported on a trough-defining surface is acted on by a component of frictional force directed away from the nip.

The rollers each comprise longitudinally an upper section of copper (length 2 feet), a narrow insulating intermediate section of polymethyl methacrylate (length one thirty-second inch), and a lower section of brass (length 1½ inches). The sections of each roller are integral with one another and therefore rotate with the same angular velocity.

In apparatus A, the rollers are identical cylinders throughout their length. Their diameter is 2 inches and they

are separated by a space of five-eighths inch.

In apparatus *B*, the rollers are identical cylinders (same diameter and separation as in *A*) throughout a major extent of the upper sections thereof. They are each however flared in a downwards direction concavely through a small region of length $1\frac{1}{4}$ inch equispaced about the intermediate section, and terminate at their lower extremities in short identical cylinders of length seven-eighths inch and diameter $2\frac{1}{2}$ inches. The flared region of each roller can be regarded as a surface of revolution of an arc of a circle of radius 3 inches.

The roller system is associated with a further modification of the electrical circuit of FIG. 9 wherein the constant current generator 25 and its associated brushes 22, 23 are substituted by a source of constant voltage (2 volts) linked to brush 21 and, through a 50 ohm resistor, to brush 24.

In order to compare the bridging contact frequencies obtainable with the two pieces of apparatus, a solid brass body of cylindrical shape (length 1 inch, diameter three-fourths inch) was fed into the upper section of the trough in each case, and the angular velocity of the rollers was adjusted to cause the body to reach a selected sliding velocity in the critical sampling region. The electronic counter recorded the number of pulses for each selected velocity and, for a frequency response of the electrical circuit of 10 kHz, the results are given in the following table.

TABLE 2

Sliding velocity, inches/second	Number of pulses	
	A	B
3.....	1,900	1,250
5.....	8	570
10.....	3	170
15.....	0	40
20.....	0	40

It can be seen that, while the number of bridging contacts made between the body and the electrified roller sections is extremely high for apparatus *A* when a very low sliding velocity (3 inches/second) is employed, the number of such contacts—and hence, the possibility of detecting the body—becomes vanishingly small as the sliding velocity increases to commercially desirable values. On the other hand, while the number of bridging contacts is not as high for apparatus *B* when the same very low sliding velocity is employed, the number of such contacts achieved with this apparatus falls to a constant value (40) as the sliding velocity increases to the same commercially desirable values. This constant value, while comparatively low, is still more than adequate to enable detection of the body.

EXAMPLE II

A single apparatus is assembled in accordance with the invention.

The apparatus comprises a trough inclined 15° to horizontal. The trough-defining surfaces are formed by a pair of identical, closely spaced cylindrical rollers of diameter 2 inches and one-sixteenth inch separation therebetween. The rollers comprise longitudinally an upper section of stainless steel (length 23 inches), an intermediate section of air (length one thirty-second inch), and a lower section of brass (length 1 inch).

The upper roller sections are divided into three independently rotatable rolls of length respectively 4, 7 and 12 inches (downwards sequence). Gearing is provided to enable these rolls to be rotated with angular velocities respectively in the proportions 1:4:6.

Means are provided for (i) symmetrically contrarotating the upper roller sections in such a way that a body supported on a trough-defining surface is acted upon by a component of frictional force directed away from the nip (mode 1), and for (ii) symmetrically contrarotating the lower roller sections either according to mode 1 or in such a way that a body supported on a trough-defining surface is acted upon by a component of frictional force directed towards the nip (mode 2).

The roller system is associated with a further modification

of the electrical circuit of FIG. 9 wherein the constant current generator 25 is substituted by a source of constant voltage (3 volts) linked to brush 22 and, through a 50 ohm resistor, to brush 23.

In order to investigate the effect of angular velocity retardation on bridging contact frequency, a plurality of solid brass cylinders (length 1 inch, diameter one-half inch, mass 19.8 gram) were fed into the upper section of the trough, and the angular velocities of the roller parts were adjusted so as (i) to give a selected one of five values to the ratio of the angular velocity of the lower roller sections to the angular velocity of the 12 inch rolls of the upper sections (referred to below as the "angular velocity ratio"), and (ii) to cause the bodies to reach a selected sliding velocity in the critical sampling region.

The five values of the angular velocity ratio were: (a) 1:1, (b) 0.5:1, (c) 0.3:1, (d) positive but approximating 0, (e) 0.5:1. In cases (a), (b), (c) and (d), both the 12 inch rolls and the lower roller sections were rotating in mode (1), but in the case of (e) the 12 inch rolls were rotating in mode (1) while the lower roller sections were rotating in mode (2), hence the negative sign in the ratio.

When the angular velocity ratio is less than 1, the sliding velocity of a body tends to be reduced when in transit to the lower section of the trough, but by feeding a sufficient number of bodies into the upper section of the trough, it was ensured that constant sliding velocity was maintained in the critical sampling region.

The electronic counter recorded the number of pulses for each selected angular velocity ratio and, for a frequency response of the electrical circuit of 10 kHz., the results are given in the following table.

TABLE 3

Angular velocity of 12 inch rolls, r.p.m.	Sliding velocity, inches/sec.	Number of pulses				
		(a)	(b)	(c)	(d)	(e)
204.....	7	10	70	680	1,000	1,500
288.....	10	5	10	78	920	1,100
480.....	15	0	3	52	700	890
660.....	20	0	3	48	580	800

It can be seen from these results that as the sliding velocity increases, the number of bridging contacts is in all cases correspondingly reduced; however, the number of bridging contacts for any given sliding velocity can be markedly increased by reducing the angular velocity ratio.

EXAMPLE III

The apparatus was the same as that described in Example II.

In order to investigate the effect of varying the density of a body on the mentioned pulse pattern, five batches of brass cylinders (length 1 inch, diameter one-half inch) were fed into the upper section of the trough, and the angular velocities of the roller parts were adjusted so that the 12 inch rolls had an angular velocity of 288 r.p.m. and the angular velocity ratio was 0.3:1.

The brass cylinders of the different batches all had the same external shapes and the cylinders of any given batch all had the same mass. However, by drilling holes of different sizes into cylinders of the different batches, it was arranged that the cylinders of different batches had different masses, hence different "effective" densities.

The electronic counter recorded the number of pulses for each selected mass, and a cathode ray storage oscilloscope, connected to the output of gate 31 (see FIG. 9), recorded the duration of each pulse and the interval between pulses. The results, for a frequency response of the electrical circuit of 10 kHz., are given in the following table.

TABLE 4

Mass, grams:	Number of pulses	Pulse duration, micro-seconds	Interval between pulses, milliseconds
6.3.....	32	100	30
13.2.....	44	150	20
20.....	70	200	1.4
24.....	190	200	0.3
26.....	210	200	0.3

It is seen from these results that an increase in the mass (and hence in the "effective" density) of a body of constant cylindrical shape is accompanied by a gradual increase in the number of bridging contacts. At the same time, the pulse duration also increases gradually, while the interval between pulses decreases rapidly.

EXAMPLE IV

The apparatus was the same as that described in Example III, the roller parts also being rotated as described in that Example.

In order to investigate the effect of varying the length of a body on the mentioned pulse pattern, four batches of brass cylinders (diameter one-half inch) were fed into the upper section of the trough.

The length of the cylinders differed from batch to batch, but —by drilling holes of different sizes into the cylinders of different batches —it was arranged that the cylinders of all the batches had the same mass (19.8 ± 0.1 grams).

In a similar way to that described in relation to Example III, the following results were obtained for each tested length.

TABLE 5

Length, inches:	Number of pulses	Pulse duration, micro-seconds	Interval between pulses, micro-seconds
0.75.....	25	200	3,000
1.00.....	60	200	1,500
1.44.....	100	300	1,100
1.89.....	120	400	1,000

It is seen from the results in Table 5 that an increase in the length of a cylindrical body of constant diameter and constant mass is accompanied by a corresponding increase in the number of bridging contacts. The pulse duration correspondingly increases and the interval between pulses correspondingly decreases.

I claim:

1. Apparatus for sorting bodies on the basis of the impedance-affecting characteristics thereof, said apparatus comprising an inclined trough formed by the trough-defining surfaces of a pair of closely spaced rollers, said trough comprising longitudinally an upper section for receiving, aligning and conveying the bodies, a lower section for conveying and discharging the bodies, a narrow intermediate section between the upper and lower sections of the trough, said upper and

lower sections of the trough being electrically conductive at least in respective zones adjacent said intermediate section, means for sampling the impedance-affecting characteristics of each body in transit between the upper and lower sections of the trough and for producing an electrical signal diagnostic of said sampled characteristics, means for feeding the bodies to the upper section of the trough, means for rotating the rollers to achieve said aligning and conveying of bodies, and deflector means for affecting the trajectory of bodies discharging from the trough to an extent determined by said diagnostic signal; said sampling means comprising an electrical circuit including the electrically conductive upper and lower sections of the trough, said electrical circuit comprising means for linking electrically the upper section of the trough to a source of one electrical potential and means for linking electrically the lower section of the trough to a source of another electrical potential, said intermediate section comprising means for insulating the upper section of the trough from the lower section of the trough, said electrical circuit being adapted to be closed by a said body bridging the upper and lower sections of the trough when in transit therebetween.

2. Apparatus according to claim 1, wherein the rollers are identical and cylindrical in shape.

3. Apparatus according to claim 2, wherein the upper roller sections are each divided transversely into at least two independently rotatable rolls, and where the means for rotating the rollers comprise gearing means for rotating the rolls with a gradient of increasing angular velocity in a downwards direction.

4. Apparatus according to claim 3, modified whereby to increase the bridging contact frequency between a said body and the supporting roller surfaces, said modification comprising means for increasing the normal reaction applied by said surfaces to the body when in transit between the upper and lower sections of the trough.

5. Apparatus according to claim 4, wherein the means provided for increasing the normal reaction comprise gearing means for rotating the lower roller sections at an angular velocity less than the angular velocity of the upper roller sections immediately above the intermediate section of the trough.

6. Apparatus according to claim 4, with the modification that the rollers are flared concavely in a downwards direction through a small region including the intermediate roller sections, said flaring constituting the means for increasing the normal reaction applied by the supporting roller surfaces to a said body in the region.