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Dwyer et al.

[11] **3,712,469**

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[54] **HIGH SPEED SORTING**

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[51] **Int. Cl.**..**B07c 5/342**

[58] **Field of Search**....356/72, 73; 209/111.5, 111.6, 209/111.7, 111.8, 75; 250/223

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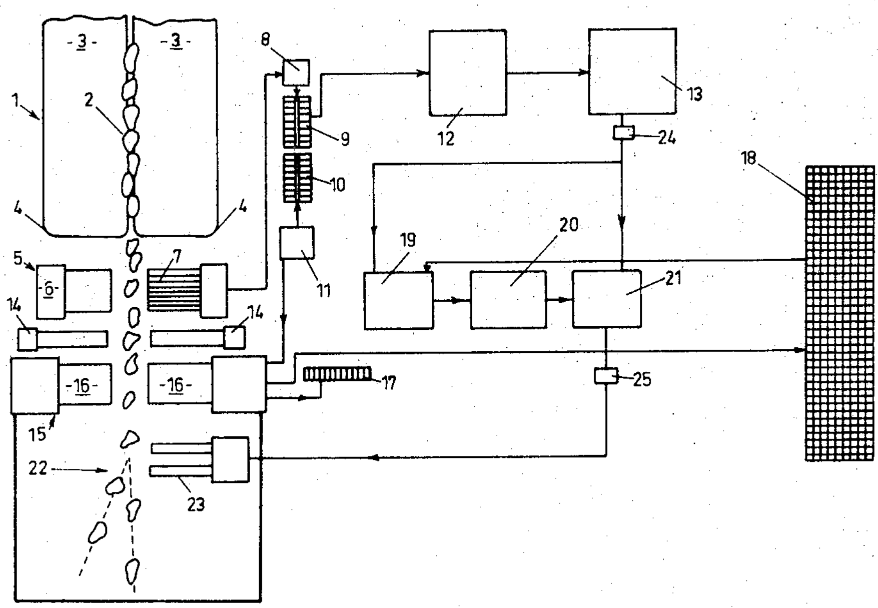
[57] **ABSTRACT**

Apparatus for rapidly and reliably sorting valuable bodies from non-valuable bodies on the basis of a detectable parameter thereof. The apparatus comprises means for inferring the profile/locations and paths with respect to time of actually individual bodies when moving as a closely packed stream at a known rate; for obtaining value/location signals with respect to time diagnostic of value sources within the stream; for relating the time base value/location signals to actually individual bodies having corresponding time base profile/locations; for assigning valuable or non-valuable nominations to appropriate such bodies; and for precisely deflecting say the nominated valuable bodies from the stream. The invention is particularly applicable to the high speed sorting of size-classified rocks, such as pieces of ore, and provides a technique of logically distinguishing between the component rocks of a clustered association moving as a spurious unit in the stream. By separating out the component rocks of a spurious unit, it becomes possible according to the invention precisely to assign value nominations thereto and to effect sorting with accuracy.

9 Claims, 6 Drawing Figures



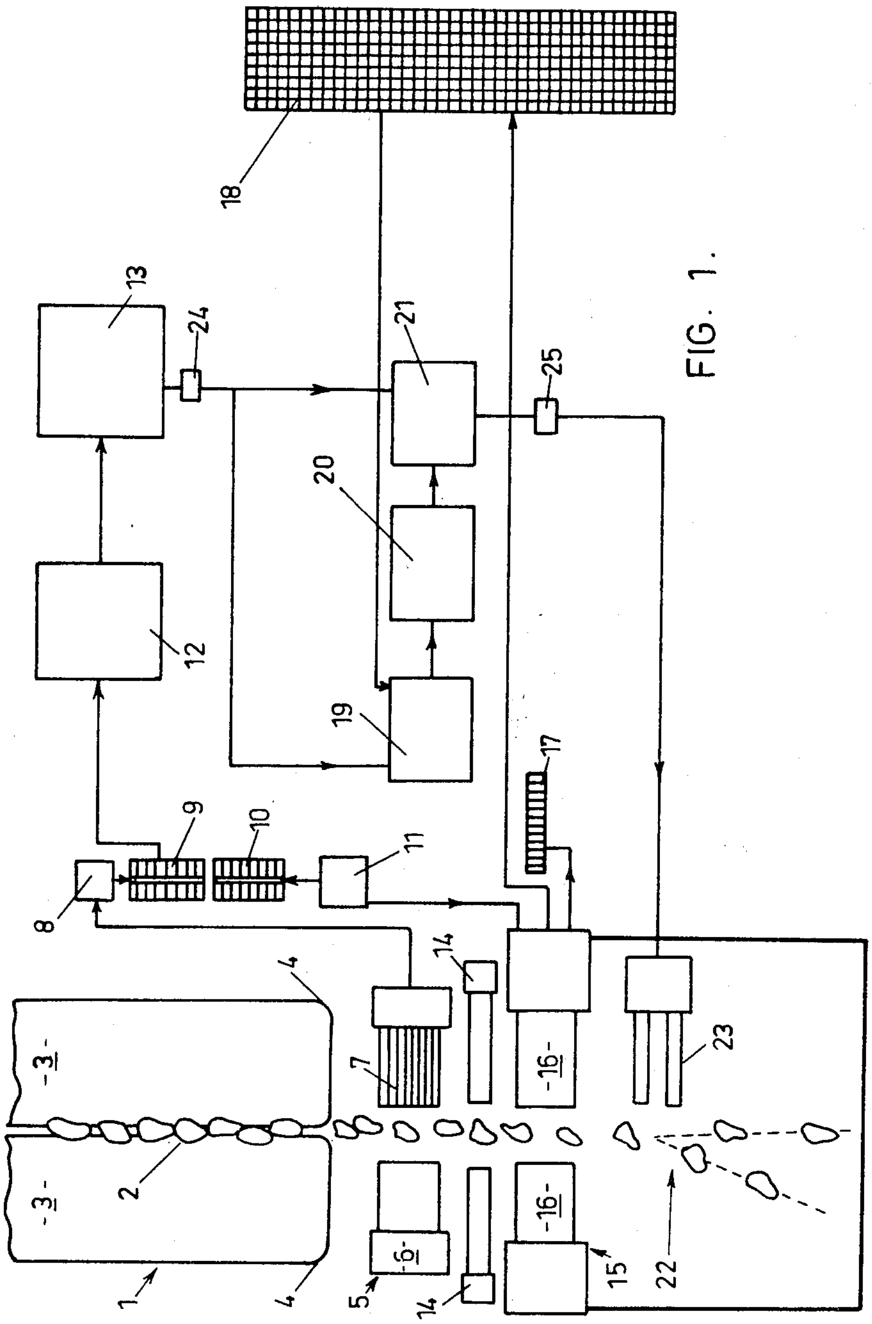


FIG. 1.

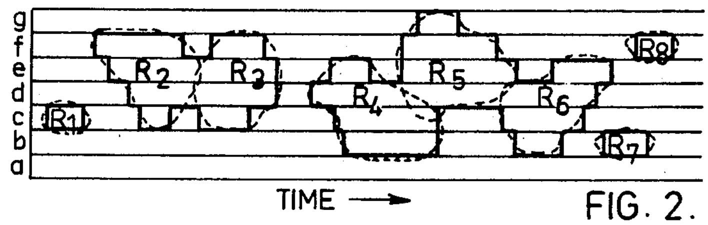


FIG. 2.

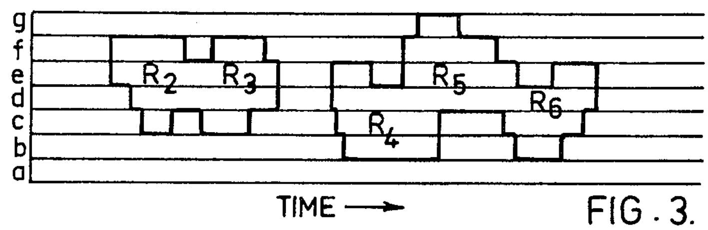


FIG. 3.

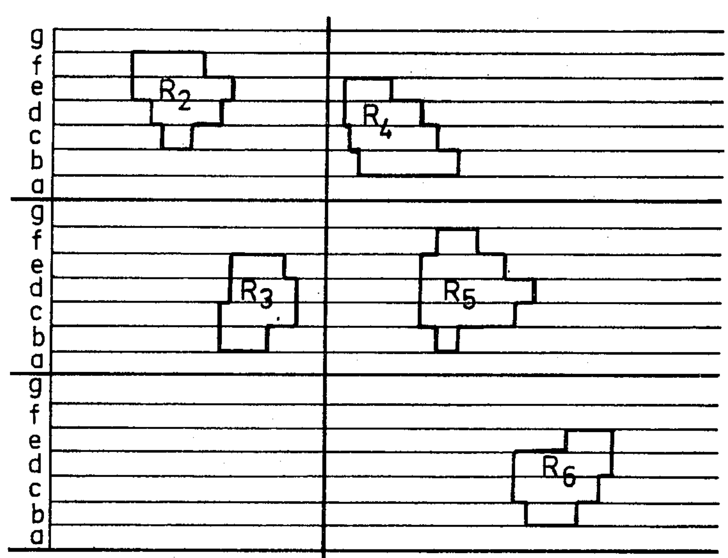


FIG. 4.

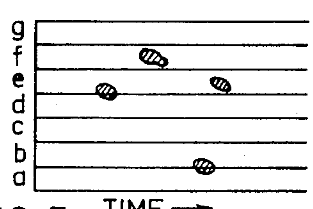


FIG. 5.

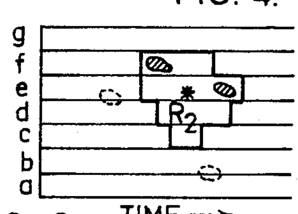


FIG. 6.

HIGH SPEED SORTING

This invention relates to an apparatus for effecting the sorting of bodies generally on the basis of a detectable parameter thereof.

The invention has been devised for the purpose inter alia of facilitating the high speed sorting of valuable rocks from non-valuable rocks on the basis of a parameter of radiation, and is described herein principally with respect to such bodies and parameters. As used herein, a rock is a mined piece of ore which hopefully contains, but which may or may not contain, a desired mineral.

It is to be understood that the terms "valuable" and "non-valuable" are relative and that what may be valuable according to one criterion may be non-valuable according to another.

By way of example in relation to bodies which are edible nuts, the criterion of value may be selected on the basis of size and/or shape, whole nuts of a certain size being valuable and nut fragments or whole nuts of an inferior size being non-valuable.

By way of example in relation to rocks, the criterion of value in some circumstances may be selected on the basis of mineral concentration, in which case a rock containing a given quantity of mineral may be considered valuable only when the rock does not exceed a predetermined size. In other circumstances, the criterion of value may be selected on the basis of absolute mineral content, in which case a rock containing a given concentration of mineral may be considered valuable only when the absolute mineral content of the rock exceeds a predetermined level. In still other circumstances, the criterion of value may take into account both the overall concentration and the absolute content of mineral in a rock.

As used herein, the "mineral concentration" and "absolute mineral content" of a rock are to be understood as interpretations based on a parameter of radiation of the rock, and consequently they are usually relevant only to the mineral present in those surfaces of the rock which have reflected or emitted the radiation in question.

In particular, the invention relates to the high speed sorting of rocks wherein the mineral, if present, occurs in localized regions and is in overall low concentration. Typical ones of this type to which the invention can be applied with great success are those containing the asbestos minerals crocidolite and chrysotile. The commercial importance of these minerals is such that the criterion of value is here often selected on the basis of the absolute mineral content of the rocks, but the fact that this mineral content occurs in localized regions and in overall low concentration has hitherto militated against the application of automatic sorting techniques to rocks of this type.

The detectable parameters which are relied on for sorting by the apparatus according to the invention can be of different kinds without limitation. They include not only radiation, but also — by way of example — conductivity, induced polarization, dielectric constant, dielectric loss, magnetic permeability, coercivity, sonic (or ultrasonic) reflection or absorption, surface topography, and surface hardness.

In the case of radiation, the invention can be used for sorting bodies on the basis of a parameter of the radiation that is reflected by, or emitted from, the bodies either in response to radiation incident thereon or as a result of radio-active transformations occurring naturally therein. Suitable such parameters are provided for example by the intensity, and wave length or nature of such radiation. In the case of crocidolite ore for example, the invention can be used for the sorting of valuable rocks from non-valuable rocks on the basis (as explained in our prior Australian Pat. No. 286675) of the differential infra-red radiation emitted from the rocks when submitted briefly to a heat flux.

The commercial attractiveness of an automatic ore sorting operation lies principally in the economics that can be achieved by sorting rocks at a high throughput rate with a minimum manpower requirement. The higher the throughput rate for a given efficiency, the more satisfactory is the operation. Efforts have therefore been directed in recent years to providing apparatus that can handle rocks for sorting at an increasingly high throughput rate while avoiding a loss of efficiency.

It is well known that the throughput rate of ore in an automatic ore sorting operation is generally dependent on the size of the rocks being sorted. However, an upper limit is inherently imposed on rock size by virtue both of the physical limitations of the sorting apparatus (it must be able to accommodate the rocks at all stages) and the economic limitations of the whole process of mineral recovery (the rocks must be small enough to make their sorting profitable). For this reason, it is usual before sorting on the basis of mineral content to screen out those rocks which do not fall within a predetermined size classification. If the ore as mined comprises an unacceptably high proportion of rocks exceeding the nominated upper size limit of this classification, it is obvious that a crushing step must be carried out before screening.

It is usual in an automatic ore sorting apparatus to provide -

i. feeding means, for forming the size-classified rocks substantially into a monolayer moving as a stream longitudinally at a known rate; said feeding means for example comprising means for aligning the size-classified rocks substantially in a single row longitudinally (the case of a transversely narrow monolayer) and forming a gravitationally falling stream thereof;

ii. a value monitoring zone, having detector means for monitoring the value of the rocks viewed from an aspect transversely of the moving stream at a known time; said monitoring being on the basis of a parameter of radiation of the rocks; said radiation for example being in response to radiation incident thereon;

iii. a deflection zone, having air blast deflection means, associated with the value monitoring means, for deflecting say nominated valuable rocks from the moving stream, whereby to separate such rocks from nominated non-valuable rocks in the stream.

For convenience hereinafter, rocks which are to be deflected from the stream (which may be valuable or non-valuable, depending on the criterion adopted) are all referred to as "valuable."

It has been appreciated more recently that successful ore sorting is contingent on timing the operation of the deflection means with precision so that only nominated valuable rocks are affected by the air blast and so that the magnitude and/or duration of the air blast takes account of the size of the rocks to be deflected. For this reason, some automatic ore sorting apparatus has recently included additionally -

iv. a dimension/location monitoring zone, having means, associated with the value monitoring means and the air blast deflection means, for monitoring the maximum dimensions and the positions both longitudinally and transversely at a known time of rock material for which a value determination has been, or is to be, made, whereby to facilitate timing of the air blast as appropriate to deflect the valuable rock material from the stream.

The sorting apparatus according to the present invention is akin to the apparatus of this general type comprising the four mentioned means. Apparatus of said general type in hereinafter called the known apparatus.

When the known apparatus is used for sorting on the basis of a parameter of light reflected by the rocks, the value monitoring means comprises a light source for directing incident light on to the rocks and photo-electric means for detecting the light reflected thereby.

Conveniently, the dimension/location monitoring means also comprises a light source and photo-electric detector means, and these can be the same as, or different from, the light source and photoelectric detector means of the value monitoring means. It will be appreciated that, correspondingly, the two monitoring zones can be coincident with one another or separated from one another.

Typically, the air blast deflection means of the known apparatus comprises a source of compressed air coupled to nozzles through high speed valves, the arrangement being such that when the valves are operated a blast of compressed air is caused to issue from the nozzles.

Preferably, the rocks pass through the deflection zone in a gravitationally falling stream, and their trajectories can then easily be affected by the air blast. By actuating the air blast deflection means as above explained in co-ordinated response to signals from the value monitoring means and the dimension/location monitoring means, the trajectories of nominated valuable rocks can be affected by the air blast so that they fall into a collection area different from that of the other rocks, and a separation is thereby achieved.

Hitherto, it has been considered that efficient sorting could only be achieved if bodies were adequately separated from each other — if relevant, both longitudinally and transversely — when being monitored for value and dimension/location. For this reason, when the feeding means of the known apparatus is of the type that forms the rocks immediately into a gravitationally falling stream, it has been customary to position the monitoring zones sufficiently below the feeding means to take advantage of the increasing separations both longitudinally and transversely that can be achieved naturally between bodies when falling successively from a given site under the influence of gravity.

However, firstly, if it is desired to have sorting apparatus capable of a high throughput rate, the required separations between bodies can only be achieved by locating the monitoring zones so very far below the feeding means that the overall dimensions of the apparatus become impractically great. Secondly, in spite of adopting such measures, it has not been found possible to guarantee an adequate separation either longitudinally or transversely between any given body and its neighbors in the gravitationally falling stream.

In regard to the latter point, it has been found that small associations of bodies both longitudinally and transversely are inherently liable to be formed in the gravitationally falling stream, irrespective of the particular feeding means that may be selected. Such associations are hereinafter sometimes termed "-clusters." When, for example, the feeding means comprises aligning means, the phenomenon of cluster formation is attributable to unavoidable irregularities in the formation of an aligned row and in the discharge thereof from the aligning means. While such irregularities are particularly prone to occur when the rate of feeding is high, it is found that they cannot be entirely avoided by simply reducing this rate.

It has been appreciated by the present inventors that, for an automatic ore sorting operation using the known apparatus, the throughput rate of ore is limited by a number of contributory rate factors. Principal among these are -

1. the rate at which rocks can be formed into a monolayer moving as a stream longitudinally at a known rate;
2. the rate at which rocks in the moving stream can pass through the value monitoring zone and the dimension/location monitoring zone while still having values correctly assigned thereto; and
3. the rate at which it is possible to turn the air blast deflection means on and off as appropriate in coordinated response to signals from the value monitoring means and the dimension/location monitoring means for correctly deflecting nominated valuable rocks.

Suitable feeding apparatus has recently become available which is capable firstly of providing a rapid alignment of rocks substantially in contact with one another in a substantially single row longitudinally, and secondly, of discharging the aligned row in a gravitationally falling stream having a substantially predictable trajectory. Such apparatus comprises a pair of inclined, closely spaced, rotatable rollers which are frusto-spheroidally shaped at their lower (discharge) ends (this apparatus is explained in for example our Australian Pat. No. 415239). Furthermore, a suitable high speed valve has also become available which is capable of turning the air blast deflection means on and off at a speed suitable for deflecting nominated valuable rocks as required from a rapidly moving gravitationally falling stream of even substantially contacting rocks (this valve is explained in our Australian Pat. No. 413228).

Unfortunately, any increase in the rate at which rocks are aligned and formed into a gravitationally falling stream, is accomplished inevitably by two increasing tendencies, both of which are disadvantageous from the point of view of prior practice.

These are firstly, that there is the increasing tendency previously mentioned for some rocks of the stream to be clumped together as a cluster during their passage through the monitoring zones; and secondly, that — from any selected monitoring aspect — there is an increasing tendency form some non-associated rocks of the stream to appear to be clumped together as a cluster during their passage through the monitoring zones. It will be appreciated that a cluster — whether real or merely apparent — presents the hazard for sorting of being a spurious unit of rock material.

Because of the first increasing tendency (real cluster), it becomes intrinsically more difficult to determine the positions both longitudinally and transversely of the individual rocks of the stream, and more difficult to assign values correctly thereto. A factor contributing to this difficulty is that the apparatus cannot easily be isolated from stray interference, hence some of the signals recorded by the value monitoring detectors are liable to be spurious, arising from optical or electrical effects which owe nothing to the rocks requiring to be sorted. It follows that, the more nearly in contact are the rocks with each other, the more likely it is that (i) values will be assigned incorrectly and that (ii) spurious value signals will be related to them.

Because of both the first and second increasing tendencies (real cluster and apparent cluster), it becomes increasingly difficult to predict with accuracy when the individual rocks of the stream will be in a position to be acted on as required by the air blast deflection means, and this leads to difficulties in operating the air blast deflection means in a manner appropriate to affect the trajectories only of those rocks which have been nominated as valuable.

Because of these known effects, it has not been possible hitherto for advantage fully to be taken of the mentioned recent advances in the rates of feeding and deflection. Consequentially, in the case of many ores, it has not been considered possible hitherto for commercially satisfactory throughput rates to be achieved when using automatic ore sorting techniques. This has been particularly true of ores wherein the desired mineral occurs in localized regions of rock and in overall low concentration, and where it is particularly difficult — even in the best of circumstances — to distinguish between any one rock containing such localized small regions and a neighboring such rock.

It is accordingly a general object of the invention to provide an improved apparatus for enabling the reliable sorting of bodies.

It is a more particular object of the invention to provide an apparatus for enabling the reliable high speed sorting of bodies which have been formed substantially into a monolayer moving as a stream longitudinally at a known rate, the required monitoring of the bodies being carried out indifferently at a time when some neighboring bodies may be clumped together as spurious units.

It is a further more particular object of the invention to provide an apparatus for enabling the reliable high speed sorting of rocks wherein the desired mineral occurs in localized regions of rock and in overall low concentration, said rocks having been formed substantially into a single row alignment moving longitudinally as a gravitationally falling stream, the required monitoring of the rocks being carried out indifferently at a time when some neighboring rocks may be clumped together as spurious units or at a time when some neighboring rocks may be separated to some extend transversely.

In the course of experiments leading up to the invention it has been found that, by observing the criteria given below (expressed with respect to the known apparatus), it is possible satisfactorily to effect the reliable high speed sorting of a substantially single row alignment of rocks moving longitudinally as a gravitationally falling stream, some neighboring rocks of which may be clumped together as spurious units or may be separated to some extent transversely. It has now also been found that, by observing these criteria, the same is possible for a transversely extensive monolayer of rocks moving as a stream longitudinally at a known rate. The criteria are -

a. that rock material be monitored for information regarding both profile and location with respect to time at some stage prior to entering the deflection zone, and that the monitoring be in sufficient detail to enable substantially all component rocks thereof to be separated logically from one another as independent bodies;
b. that value signals be derived for, and correctly assigned to, the respective logically separated component rocks; and
c. that it be predicted accurately when component valuable rocks are in a position appropriate for deflection by the air blast deflection means, the magnitude and/or duration of the air blast then triggered for this purpose being sufficient to deflect such rocks.

It will be noticed in particular that monitoring according to criterion (*a*) contrasts with the previously known type of monitoring in which, as previously explained, the maximum dimensions and the positions both longitudinally and transversely of rock material are determined at a known time, but in which precautions are not taken to ensure the this rock material does not comprise a spurious unit.

Part of the problem associated with meeting criterion (*a*) is a problem of pattern recognition which, it is not appreciated, can be solved by reference to known data concerning typical and atypical rock shapes.

For example, the silhouette of a single rock is statistically likely to have no holes within its boundary, and the boundary is likely to be substantially convex throughout its extent. Again, when two rocks are in contact with one another longitudinally, their combined silhouette viewed transversely is statistically likely to conform to one or other of a comparatively small number of shapes, the most common shape being that substantially of a dumb-bell. Since dumb-bell shaped rocks are atypical, it follows that a silhouette conforming to a dumb-bell can be logically separated into two bodies on either side longitudinally of the transversely viewed opposing concavities of the dumb-bell. Another statistically likely shape for the combined silhouette of two longitudinally contacting rocks is a shape comprising a diagonal cleft. Since rocks having clefts are atypical, a silhouette conforming to a shape having such a cleft can be separated logically into independent rocks or either side longitudinally of the diagonal cleft.

It has now been found that by using a transversely extensive detector system as explained below, it is possible for rocks to be monitored progressively for information regarding both profile and location with respect to time, this information being adequate when related to known data to enable substantially all the rocks of a moving stream to be separated logically from one another as independent bodies.

It has been appreciated furthermore that, for this purpose, it is necessary only for those profile/location features to be identified which — when considered in sequence — are statistically likely to be sufficient to enable spurious units of rock to be distinguished from single rocks. Since such features are small in number, as above foreshadowed, it is possible progressively to develop aggregations of rock profile/location data as the rocks are passing through the dimension/location monitoring zone, and according to one preferred embodiment it is these developing aggregations of data only that form the basis for the high speed sorting which can be achieved by the use of the apparatus according to the invention.

In its most usual form, explained in greater detail in the overall context of the invention subsequently herein, the mentioned system comprises a dimension/location monitoring zone having a source of transversely extensive light and an associated transversely extensive rectilinear array of photocell detectors for exposure to the light, the arrangement being such that members of the moving stream of rocks occult the light according to profile when passing therethrough.

As a result of providing the mentioned array of photocell detectors, digital aggregations of rock/no-rock signals can be developed conveniently with respect to a time base as the stream of rocks progressively occults the light. When these digital signal aggregations are interpreted by appropriate logic means, very clear profile/locations of the rocks can be inferred with respect to time, and from the latter the paths of actually individual rocks can be accurately predicted.

The arrangement of photocell detectors and the associated logic means should be selected in such a way as to enable a profile/location to be inferred for any rock material of predetermined size classification occulting the light, this profile/location being sufficiently detailed to enable even contacting rocks (with rare exceptions) to be separated from each other logically as independent bodies.

By providing such a system, it becomes inherently possible to meet criteria (*b*) and (*c*).

Rock material is characterized generally by various irregularities in its surface topography (for example, small protrusions above a general body of rock). Moreover, it has a tendency to suffer fragmentation during mechanical handling, as in a sorting operation, and numerous of the fragments are typically of a size less than the minimum of the desired size classification. It is particularly desirable in a process of high speed sorting to ignore all such surface irregularities and undersized fragments; and the apparatus according to the invention can easily be adapted for this purpose by providing suitable logic means associated with the dimension/locations monitoring means whereby rock material is ignored unless it is of a size for example to occult the light illuminating at least two adjacent photocell detectors. The provision of such associated logic means has the further desirable result that stray interference can also be ignored. This stray interference can be of the type previously mentioned, but also includes for example small scale malfunctioning of the photocell detector system.

Considered broadly, the invention provides an apparatus for sorting valuable bodies from non-valuable bodies in a mixture thereof on the basis of a detectable parameter thereof, said apparatus comprising in combination:

feeding means, for forming the bodies substantially into a monolayer moving as a stream longitudinally at a known rate, the paths transversely of the stream of individual bodies being within predetermined limits;

means for inferring the profile/locations and paths with respect to a time base of actually individual bodies of said mixture in said monolayer;

means for obtaining signals diagnostic of values within said stream based on a said detectable parameter of said bodies and for monitoring the source locations of said value signals with respect to said time base;

means for relating said time base value/location signals to actually individual bodies having corresponding said time base profile/locations;

means for assigning valuable or non-valuable nominations as appropriate to said corresponding actually individual bodies on the basis of a predetermined criterion of value for a said valuable body; and

means for separating said nominated valuable bodies from said nominated non-valuable bodies in the stream.

Considered more particularly, the invention provides an apparatus for sorting valuable bodies from non-valuable bodies on the basis of a detectable parameter thereof, said bodies being in a size-classified mixture, said apparatus comprising in combination:

A. feeding means, for forming the size-classified bodies substantially into a monolayer moving as a stream longitudinally at a known rate, the paths transversely of the stream of individual bodies being within predetermined limits;

B. a dimension/location monitoring zone, having means for continuously monitoring the instantaneous dimensions transversely and locations transversely of apparently individual bodies viewed from a first aspect transversely of the stream, said monitoring being with respect to a time base; said dimension/location monitoring means comprising (i) a transversely extensive radiation source and (ii) a co-operating transversely extensive detector system for exposure to the radiation, the bodies occulting the radiation according to profile when passing therethrough; the transverse extents of both the radiation source and the detector system being selected with respect both to the known size classification of the bodies and to the said predetermined limits of the paths transversely so that the output signals from the detector system in combination are diagnostic of said instantaneous dimensions and locations;

C. first memory means for recording profile-making signals of said instantaneous dimensions and locations with respect to said time base, said profile-making signals comprising digital signal aggregations derived from the instantaneous dimensions transversely of the bodies;

D. first logic means associated with said first memory means for (i) continuously comparing said digital signal aggregations of apparently individual bodies with a predetermined repertoire of probable said digital signal aggregations for hypothetical individual bodies of a said mixture when thus formed substantially into a monolayer and monitored; for (ii) inferring from said continuous comparisons the profile/locations with respect to time of actually individual bodies thus formed substantially into said monolayer and monitored; and for (iii) inferring from said inferred time-base profile/locations the paths of actually individual bodies;

E. second memory means for recording said inferred time-base profile/locations and said inferred paths of actually individual bodies;

F. a value/location monitoring zone, having means (*a*) of a type known per se for continuously obtaining signals diagnostic of the value of a body based on a said detectable parameter thereof, and means (*b*) of a further type known per se for continuously monitoring the instantaneous locations transversely of the sources of said value signals in the stream of bodies, said value/location monitoring being with respect to said time-base, and said sources being viewed from a second aspect transversely of said moving stream, said second aspect being substantially equivalent for said monitoring to said first aspect;

G. third memory means for recording said value signals and said instantaneous source locations with respect to said time base;

H. second logic means associated with said second and third memory means for relating said value signals to the recorded said inferred time-base profile/locations of actually individual bodies;

I. comparator means associated with said second logic means for comparing said recorded value signals with a predetermined criterion of value for a said valuable body and for assigning valuable or non-valuable nominations as appropriate to actually individual bodies having said inferred time-base profile/locations;

J. a deflection zone, having means associated with said comparator means, for deflecting say nominated valuable bodies from the moving stream whereby to separate such bodies from nominated non-valuable bodies in the stream; delay means and third logic means being provided, said third logic means being associated with said second memory means, for causing the deflection means to operate at a time coincident with the predicted arrival of a nominated valuable body, said arrival being predicted on the basis of the inferred path thereof, and the intensity of the deflection being appropriate for the inferred profile/location thereof.

As above foreshadowed, the apparatus preferably also comprises auxiliary logic means, associated with the dimension/location monitoring means, for suppressing any unwanted signals from the detector system. These unwanted signals arise for example from undersized body fragments possibly present in the stream or from stray interference, for example of an optical or electrical kind.

It will be seen that the first logic means of the apparatus provides access for comparative purposes to a predetermined repertoire of digital signal aggregations for hypothetical bodies of a mixture when formed substantially into a monolayer and monitored in the dimension/location monitoring zone.

Successful high speed sorting by means of the apparatus is contingent on the inclusion in this reference repertoire of an adequate collection of data concerning those profile/making features which — when considered in sequence — are statistically likely to be sufficient to enable spurious body units to be distinguished from single bodies when so treated. As is obvious, the detailed content of the repertoire must depend on the nature of the bodies to be sorted and on the degree of sorting efficiency that is required for the desired rate of throughput. However — as above foreshadowed, and as explained more fully hereinafter — it has now been found that a sufficient repertoire for practical purposes is provided when the digital signal aggregation information included therein is limited in kind to that concerning the instantaneous dimensions transversely of hypothetical bodies at the leading and trailing edges longitudinally thereof. When this limitation is imposed, the comparisons to be made by the first logic means can be correspondingly abridged. It will be appreciated that this is particularly advantageous when a high speed sorting operation is in question and it is required to achieve a logical separation of the actually individual bodies of a stream in a period of time of the order of milliseconds.

By way of illustration, the content requirement of the repertoire is now discussed in relation to bodies which are rocks.

For the purpose of this discussion, it is assumed -

that the rocks have been formed into a transversely extensive monolayer moving as a gravitationally falling stream (for example, by discharge from the end of a horizontally disposed conveyor belt);

that the direction of movement of the stream is vertical;

that the stream is passed through a dimension / location monitoring zone comprising (i) a transversely extensive horizontal light beam illuminating (ii) a transversely extensive rectilinear array of seven photocell detectors, identified as *a,b,c,d,e,f,g* respectively in a pattern considered from left to right;

that the rectilinear array of photocell detectors is perpendicular to the direction of movement of the stream;

that the transverse extent of the rectilinear array of photocell detectors is sufficient for all the bodies of the stream to occult the light according to profile;

that the rocks passing through the zone comprises a mixture of actually individual rocks and spurious units thereof;

that the monitored profile of any rock material — whether an actually individual rock or a spurious unit thereof — comprises a plurality of edge elements, those occulting the light first and last being leading edge and trailing edge elements respectively; and

that output signals from the photocell detectors, expressed digitally as the information bits **1** or **0**, are diagnostic respectively of rock or no-rock occulting the light.

Set in this defined context, the content requirement of the reference repertoire desirably includes data deflecting the axioms and statistically likely postulates given hereunder. It will be appreciated that this summary is in no way exhaustive and that in practice other axioms and postulates may be included additionally in the reference repertoire.

The output signals in sequence from any single photocell detector of the array can be of the types (i) **00**, (ii) **01**, (iii) **11**, and (iv) **10**. These sequences are diagnostic of the passage through the light illuminating that photocell detector of respectively (i) no-rock, (ii) a leading edge element, (iii) rock, and (iv) a trailing edge element. It is an axiom that the signal sequence **01** must be followed in train by the signal sequence **10**; and it is at least statistically likely that actually individual rocks are involved when the signal sequence **01** is followed in train by the signal sequence **10**.

At any one instant, the output signals from the entire array of photocell detectors, *a* to *g*, are diagnostic only of a transverse aggregation of no-rock or rock then occulting the light to those detectors. For example, an instantaneous aggregation of output signals from the detectors respectively such as **0110011** is diagnostic of no-rock occulting photocell detectors *a,d,e* and of rock occulting photocell detectors *b,c,f,g*. Additionally, it is implied in this example that the instantaneous pairs of signals from detectors *a,b*, and *e,f* are both diagnostic of left edge rock elements, while the instantaneous pair of signals from detectors *c,d* is diagnostic of a right edge rock element.

Just as the output signals in sequence from any single photocell detector can be of four types, so also the aggregations of output signals in sequence from the array of detectors must be subject of the same possibilities. The result is that the sequence of aggregations in time comprises a developing matrix of rock/no-rock signals.

For example, where aggregations of signals from the array of detectors are related to succeeding points in time (t_1,t_2... etc.), a developing matrix of rock/no-rock signals can be of the type:

	a	*b*	*c*	*d*	*e*	*f*	*g*
t_1:	0	1	0	0	0	0	0
t_2:	1	1	1	0	0	1	1
t_3:	1	1	1	0	1	1	1
t_4:	1	0	0	1	1	1	1
t_5:	0	0	1	1	1	0	0
t_6:	0	0	1	1	1	1	0
t_7:	0	0	0	1	1	1	0
t_8:	0	0	0	0	1	0	0

It is an axiom that the leading edge elements of any actually individual rock contribute to a common profile, and it is at least statistically likely (i) that such a profile is generally convex, and (ii) that the overall silhouette comprising it is continuous throughout (i.e., contains no holes).

Having regard to the above axiomatic and statistically likely postulates, it can be inferred that three actually individual rocks of the stream have contributed to the above illustrated matrix, two of them overlapping (the case of a spurious unit) as monitored by photocell detectors *d* and *e* at time t_4 and t_5.

The apparatus of the invention is particularly applicable for sorting valuable rocks from non-valuable rocks on the basis of a parameter of radiation, and in the preferred embodiment described below it is applied to the sorting of rocks of crocidolite ore on the basis of the intensity of radiation emitted therefrom at a given infra-red wave length. In order to prepare the rocks for sorting in this way, they are first rendered differentially infra-red emissive (as explained in our Australian Pat. No. 286675) by being exposed to a heat flux for an appropriately brief period of time.

The invention in the mentioned preferred embodiment is now discussed with reference to the accompanying drawings, in which -

FIG. **1** is an essentially schematic drawing of the overall apparatus.

FIG. **2** shows the silhouettes of a section of the rock stream as monitored by the dimension/location monitoring means.

FIG. **3** shows the silhouettes of the same section of the rock stream as recorded in the first memory means after suppression of undersized silhouettes by the auxiliary logic means.

FIG. **4** shows the inferred silhouettes of actually individual rocks as recorded in the second memory means after an operation by the first logic means on the silhouettes recorded by the first memory means.

FIG. **5** shows the value/locations monitored for a portion of the same section of the rock stream by the value/location monitoring means and as recorded by the third memory means.

FIG. **6** shows the same value/locations superimposed on the appropriate portion of the rock silhouette drawing of FIG. **4**, i.e. the result of an operation by the second logic means on the information recorded by the second and third memory means.

Turning now to FIG. **1**, the drawing is an essentially schematic representation of an apparatus according to the invention as applied to the sorting of a size-classified mixture of crocidolite-containing rocks.

Conveniently, the rocks have minimum and maximum dimensions in the ranges respectively 2½ to 3 inches and 6 to 7 inches, and it will be understood that the proportions of the apparatus overall are selected appropriately in relation to this size classification.

The apparatus includes feeding means for receiving the rocks from a suitable source (for example, a discharging hopper) and forming them substantially into a monolayer. In the preferred embodiment, the feeding means comprises means (**1**), for aligning the rocks substantially in a single row longitudinally (**2**), and forming a gravitationally falling stream thereof.

Specifically, the aligning means is provided by a pair of inclined, closely spaced, rotatable rollers (**3**) having frusto-spheroidal ends (**4**), and it will be understood that suitable means (not shown) are provided for causing the rollers to rotate whereby to facilitate the aligning operation. As previously noted, aligning means of this type is explained in our Australian Pat. No. 415239.

So far as for example the aligning rollers and the gravitationally falling stream of rocks are concerned, it will be appreciated that the drawing is a plan view thereof projected on to a horizontal plane.

A dimension/location monitoring zone (**5**) for the rocks is provided at a position appropriately below, and in advance of, the aligning rollers. The radiation source in this zone is provided by a high intensity incandescent lamp (6) for directing seven parallel light beams into respective members of a rectilinear array of seven photocell detectors (7).

The orientation of inter alia the rectilinear array is selected appropriately so that the seven light beams inside in a plane perpendicular to the direction of movement of the stream. The dimensions and arrangement of both the light beams and the detectors are also selected so that all rocks of the stream having the mentioned size classification occult the light according to profile when passing through the zone. Conveniently, the beams of light collectively have a width transversely of 6½ inches; the photocell detectors are each ½ inch in diameter and are spaced apart by ½ inch.

It will be understood that standard lens systems are associated with the light source for forming the light into the mentioned parallel beams, and with the photocell detectors for focussing the light beams thereon.

When the light illuminating a photocell detector is occulted by rock material passing through the zone, an electrical output signal is generated. After amplification, this signal is fed into a threshold discriminator and is transformed thereby into the appropriate digital signal (i.e. the information bit **1**).

The digital signal is passed to the auxiliary logic means (8), comprising an exclusive OR gate linked to appropriate adder and shift register means. It is the function of the auxiliary logic means to suppress unwanted output signals from the photocell detectors arising from inter alia any undersized rock fragments, and in the present context this is achieved by suppressing all instantaneous aggregations of output signals from any three adjacent photocell detectors consisting of **010**.

All digital signals which have not been suppressed in this way are now recorded in the first memory means. Conveniently, this memory means is provided by two standard 8-bit registers (9), capable of recording both the current and the immediately preceding aggregations of such instantaneous digital signals. The instantaneous dimension/locations of rock material occulting the light beams are reflected by the instantaneous pattern of bits in the two registers.

The time at which any instantaneous bit pattern is recorded in the first memory means is recorded simultaneously by associated counter means (10), the overall time base being referred to a clock (11).

When a change occurs in the recorded instantaneous bit pattern, an appropriate signal is transmitted to the first logic means (12). The latter comprises means for comparing the changing bit patterns with a suitable reference repertoire of data of the type previously described. This repertoire is realized in the first logic means as a programme sequence in a first part of the memory of a digital computer. By operation of this means, rock material occulting the light beams is separated logically as required into actually individual rocks having intrinsically defined time base profile/locations.

This information is now recorded in the second memory means (13), conveniently provided by a second part of the memory of the digital computer.

Those parts of the apparatus are now considered which enable the time base value/location information to be recorded.

As previously noted herein, rocks of crocidolite ore are prepared for sorting as explained in Australian Pat. No. 286675 by being exposed briefly to a heat flux.

Means for providing this heat flux conveniently comprise two high intensity fuel oil burners (14) on opposing sides of the gravitationally falling rock stream. It will be appreciated that, while such means have been illustrated schematically in the drawings, they form no part of the present invention.

When the rocks have been rendered differentially infra-red emissive, they are in a condition suitable for being monitored for value in terms of the selected parameter of radiation. The value/location monitoring zone (15) is therefore provided immediately below, and in advance of, the burners.

Suitably, the value/location monitoring means comprises two opposing scanning systems (16) of infra-red sensitive cells linked to the clock and to another counter (17). By operation thereof, the infra-red radiation emitted from the rocks is detected and the locations of the detected radiation values with respect to the time base are identified.

The time base value/location signals are recorded in the third memory means (18), which is conveniently provided by a third part of the memory of the mentioned digital computer.

Second logic means (19) is provided within the same digital computer for now relating the time base value/location information in the third memory means to the time base profile/location information in the second memory means.

Comparator means (20) is associated with the second logic means for comparing say the sum of the values per unit area of rock source with a predetermined criterion of value, and third logic means (21) is provided for assigning valuable nominations as appropriate to individual rocks having corresponding time base profile/locations as recorded in the second memory means.

Nominated valuable rocks are deflected from the falling stream in the deflection zone (22), suitable air blast deflection means (23) comprising the previously mentioned high speed valves being provided for this purpose.

Suitable delay means (24,25) are included in the circuitry for appropriately timing the activation of the second logic means, the comparator means, the third logic means, and the deflection means as required to achieve the appropriate deflection of the nominated valuable rocks. It will be appreciated that the actual delays involved must take into account the trajectories of the rocks and the separations between the various zones of the apparatus.

The remaining Figures are essentially self-explanatory and, when viewed in sequence, show the results of the various logical operations performed on a sample of the rock stream by the described apparatus according to the invention.

Inferred actually individual rocks are identified in these drawings as R_1 to R_8 respectively, possible actual profiles of the rocks being shown in FIG. 2 as dotted line shapes.

Rocks identified as R_1, R_7, R_8 are undersized. The remaining rocks are grouped in two spurious units, comprising respectively rocks identified as R_2, R_3 and as R_4, R_5, R_6.

The logically separated component rocks are shown in the various sections of FIG. 4, and value/locations for the section comprising the rock identified as R_1 are shown in FIG. 5. FIG. 6 distinguishes between the value/locations falling within the corresponding rock profile/locations and those spurious values at locations falling outside such profile/locations (dotted line values).

In the case particularly where it is required to deflect from the stream a single rock only from the component rocks constituting a spurious unit (for example, R_2 from the spurious unit comprising R_2, R_3), it has been shown to be highly desirable to confine the area of air blast impingement of that rock to an optimally selected small region thereof. Preferably, this small region is selected with regard to an inferred center of gravity of the rock.

For practical purposes, this center of gravity can be inferred as a point within the inferred profile of the rock substantially equidistant from the edges thereof, for example the point at the asterisk in R_2 in FIG. 6. One of the virtues of confining the area of air blast impingement in this way is that the energy thereof can be expended to best advantage, for example to cause the translational (rather than merely rotational) movement of the rock.

It will be appreciated that such a highly selective operation of the air blast deflection means has only now been made possible by using the apparatus of the present invention to infer the precise profile/locations of actually individual rocks of a stream.

Additionally, it will be apparent that the intensity of an optimally directed air blast is desirably selected with regard to the mass of the rock. Since the mass of a rock is related to the extent thereof as given by the inferred profile, it will be appreciated that the invention also makes possible a highly appropriate selection of air blast intensity whereby to deflect nominated valuable rocks in the most appropriate way possible.

In fact, it will be appreciated in general that, by using the apparatus according to the invention in which profile/locations are inferred for actual rocks of the required size classification and value signals are related respectively and only thereto, the inherent difficulties previously associated with automatic ore sorting can be made virtually to disappear. The advance thus enabled by the invention is particularly noteworthy in the case of ores wherein the desired mineral occurs in localized regions of rock and in overall low concentration. Such ores can now be seen to present neither more nor less difficulty for automatic sorting than ores in which the mineral is more favorably concentrated.

For the reasons previously elaborated, the invention has particular relevance to the sorting of rocks at high throughput rates, and an indication of the success of the invention is provided by the fact that the apparatus described in relation to FIG. 1 can be used to achieve the reliable sorting of the mentioned crocidolite rocks at a throughput rate of as high as 120 tons per hour.

It has been shown above additionally that difficulties arise when sorting rocks according to prior practice even when throughput rates are selected which, hopefully, are low enough to enable rocks to pass through the monitoring zones in longitudinally spaced apart relationship. These difficulties are overcome by using the techniques of the present invention, and it will appear therefore that the invention has a niche not only in the particular field of high speed sorting but in the field of sorting generally, i.e. irrespective of the throughput rate that may be desired.

The invention has been described above particularly in relation to the sorting of bodies which have been formed into a substantially single row alignment and then into a gravitationally falling stream. Further, the dimension/location monitoring means has been described particularly as involving a combination of a light for occulting by the bodies and an associated array of photocell detectors; the value monitoring has been described particularly in relation to a parameter of radiation of the bodies; and the deflection means has been described particularly as means for producing an air blast.

It will be appreciated however, that the invention provides a technique generally for inferring the profile/locations and paths of moving bodies; for assigning value nominations to respective such bodies on the basis of any detectable parameter thereof; and for sorting correctly such bodies according to value nominations.

For example, because the apparatus according to the invention always enables transversely extensive monitoring, it is a matter of indifference whether the feeding means selected for use therein is one that forms a transversely narrow single row monolayer of bodies or one that forms a transversely extensive monolayer thereof. Thus, the invention is generally applicable to the sorting of bodies which have been formed substantially into a monolayer moving as a stream longitudinally along a predictable path at a known rate (the case for example of a transversely extensive monolayer of bodies moving horizontally on a conveyor belt).

Again, the dimension/location monitoring zone can comprise generally any transversely extensive radiation source and a co-operating transversely extensive detector system for exposure thereto. By way of further example — particularly appropriate when the prevailing conditions make light transmission Impossible — the monitoring zone in an alternative embodiment can comprise a transversely extensive rectilinear array of ultrasonic transducers and an associated array of ultrasonic detectors. In other alternative embodiments, the function of the transversely extensive detector system is provided by a single detector and suitable scanning means (such as a scanning wheel) for transversely extending it.

While, for convenience, the invention has been described hereinbefore particularly in relation to apparatus for sorting bodies on the basis of a remotely detectable parameter of radiation thereof, it will be appreciated that the invention can also be applied to the sorting of bodies on the basis of any detectable parameter thereof — including those parameters whose detection involves direct physical contact with the bodies.

Again, while only air blast deflection means has been illustrated, it is clear that suitable deflection means can comprise generally any means for deflecting appropriately those bodies which have been nominated for deflection from the stream — including for example mechanical finger deflectors.

It will also be appreciated that those other means which have been mentioned broadly in relation to the preferred embodiment of the invention — memory means, logic means, value/location monitoring means and comparator means — can all be of any suitable type generally available. For reasons of flexibility however, the memory means, logic means and comparator means are all preferably provided by a digital computer.

Furthermore, the relationship between the dimension/location monitoring zone and the value/location monitoring zone, as described in relation to the preferred embodiment, is such that the rocks pass through these zones in the sequence given. However, this is not an essential requirement, and provided suitable memory circuits are included in the apparatus it is possible alternatively for this sequence of monitoring to be reversed. Once the trajectories of the rocks become known, value signals can be correctly assigned retrospectively to the member rocks of the stream, and the timing of the air blast can be appropriately controlled.

The invention has also been described only in relation to the sorting of bodies in terms of a binary selection, i.e. valuable as against non-valuable. It will be appreciated however, that the invention is particularly well adapted for sorting if required in terms of a multiple selection. For example, the invention is applicable to the sorting of apples in terms of a combination of parameters, such as size (say, two grades) and color (say, two grades). For this purpose, it will be understood that the deflection means must be designed correspondingly to cope with the required separation into multiple categories.

We claim:

1. An apparatus for sorting valuable bodies from non-valuable bodies in a mixture thereof on the basis of a detectable parameter thereof, said apparatus comprising in combination:

feeding means, for forming the bodies substantially into a monolayer moving as a stream longitudinally at a known rate, the paths transversely of the stream of individual bodies being within predetermined limits;

means for inferring the profile/locations and paths with respect to a time base of actually individual bodies of said mixture in said monolayer;

means for obtaining signals diagnostic of values within said stream based on a said detectable parameter of said bodies and for monitoring the source locations of said value signals with respect to said time base;

means for relating said time base value/location signals to actually individual bodies having corresponding said time base profile/locations;

means for assigning valuable or non-valuable nominations as appropriate to said corresponding actually individual bodies on the basis of a predetermined criterion of value for a said valuable body; and

means for separating said nominated valuable bodies from said nominated non-valuable bodies in the stream.

2. An apparatus for sorting valuable bodies from non-valuable bodies on the basis of a detectable parameter thereof, said bodies being in a size-classified mixture, said apparatus comprising in combination:

A. feeding means, for forming the size-classified bodies substantially into a monolayer moving as a stream longitudinally at a known rate, the paths transversely of the stream of individual bodies being within predetermined limits;

B. a dimension/location monitoring zone, having means for continuously monitoring the instantaneous dimensions transversely and locations transversely of apparently individual bodies viewed from a first aspect transversely of the stream, said monitoring being with respect to a time base; said dimension/location monitoring means comprising (i) a transversely extensive radiation source and (ii) a co-operating transversely extensive detector system for exposure to the radiation, the bodies occulting the radiation according to profile when passing therethrough; the transverse extents of both the radiation source and the detector system being selected with respect both to the known size classification of the bodies and to the said predetermined limits of the paths transversely so that the output signals from the detector system in combination are diagnostic of said instantaneous dimensions and locations;

C. first memory means for recording profile-making signals of said instantaneous dimensions and locations with respect to said time base, said profile-making signals comprising digital signal aggregations derived from the instantaneous dimensions transversely of the bodies;

D. first logic means associated with said first memory means for (i) continuously comparing said digital signal aggregations of apparently individual bodies with a predetermined repertoire of probable said digital signal aggregations for hypothetical individual bodies of a said mixture when thus formed substantially into a monolayer and monitored; for (ii) inferring from said continuous comparisons the profile/locations with respect to time of actually individual bodies thus formed substantially into said monolayer and monitored; and for (iii) inferring from said inferred time-base profile/locations the paths of actually individual bodies;

E. second memory means for recording said inferred time-base profile/locations and said inferred paths of actually individual bodies;

F. a value/location monitoring zone, having means (*a*) of a type known per se for continuously obtaining signals diagnostic of the value of a body based on a said detectable parameter thereof, and means (*b*) of a further type known per se for continuously monitoring the instantaneous locations transversely of the sources of said value signals in the stream of bodies, said value/location monitoring being with respect to said time-base, and said sources being viewed from a second aspect transversely of said moving stream, said second aspect being substantially equivalent for said monitoring to said first aspect;

G. third memory means for recording said value signals and said instantaneous source locations with respect to said time base;

H. second logic means associated with said second and third memory means for relating said value signals to the recorded said inferred time-base profile/locations of actually individual bodies;

I. comparator means associated with said second logic means for comparing said recorded value signals with a predetermined criterion of value for a said valuable body and for assigning valuable or non-valuable nominations as appropriate to actually individual bodies having said inferred time-base profile/locations;

J. a deflection zone, having means associated with said comparator means, for deflecting say nominated valuable bodies from the moving stream whereby to separate such bodies from nominated non-valuable bodies in the stream; delay means and third logic means being provided, said third logic means being associated with second memory means, for causing the deflection means to operate at a time coincident with the predicted arrival of a nominated valuable body, said arrival being predicted on the basis of the inferred path thereof, and the intensity of the deflection being appropriate for the inferred profile/location thereof.

3. Apparatus according to claim 2, wherein said feeding means comprises a pair of inclined, closely spaced, rotatable rollers for aligning the size-classified bodies substantially in a single row longitudinally and forming a gravitationally falling stream thereof, said rollers being frusto-spheroidally shaped at the lower ends thereof.

4. Apparatus according to claim 2, wherein the detector system of said dimension/location monitoring means comprises a transversely extensive rectilinear array of detectors.

5. Apparatus according to claim 2, wherein auxiliary logic means is associated with said dimension/location monitoring means for suppressing any unwanted said output signals from the detector system.

6. Apparatus according to claim 2, wherein the first logic means is adapted to infer said profile/locations with respect to time on the basis only of comparisons involving digital signal aggregations derived from said instantaneous dimensions transversely of the bodies at the leading and trailing edges longitudinally thereof.

7. Apparatus according to claim 2, wherein the dimension/location monitoring zone is spaced from the value/location monitoring zone, the arrangement of said two spaced zones being such that in use the bodies of said mixture pass in sequence from the dimension/location monitoring zone to the value/location monitoring zone.

8. Apparatus according to claim 2, wherein the deflection zone comprises air blast deflection means, the delay means and the third logic means being adapted whereby to confine the area of air blast impingement on a nominated say valuable body to a small region thereof comprising an inferred center of gravity.

9. Apparatus according to claim 2, wherein the memory means, the logic means and the comparator means are all provided by a digital computer.

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