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Hoover et al.

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[54] **SORTING MACHINE**

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[52] **U.S. Cl.** **209/73,** 209/111.6

[51] **Int. Cl.** **B07c 1/04,** B07c 5/342

[58] **Field of Search** 209/73, 111.6, 111.7, 209/74; 222/566

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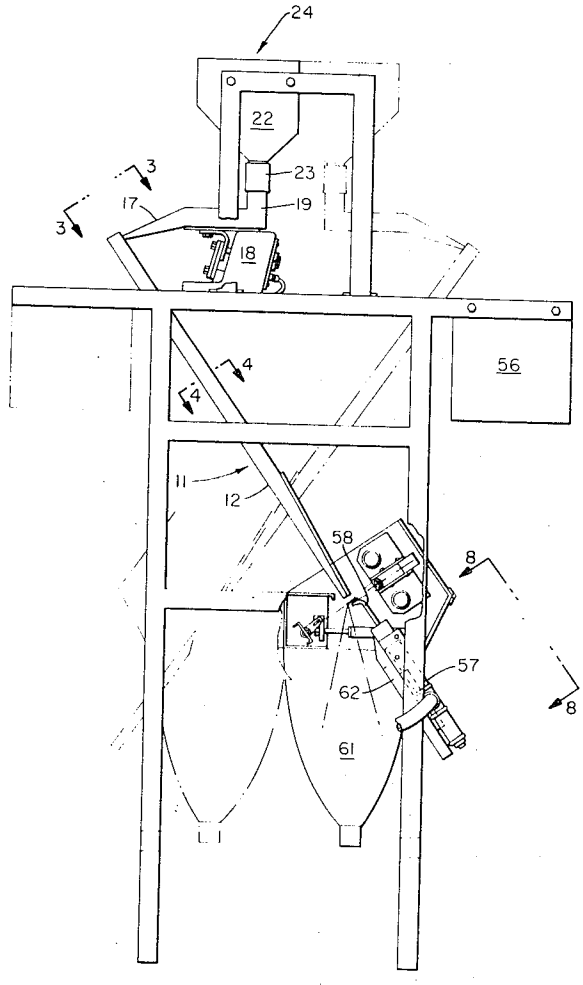
[57] **ABSTRACT**

A number of steeply inclined tapered slides are arranged for gravity assisted singulation and alignment of items such as rice grains that are introduced at the top from vibrating chutes that are gently inclined in the opposite direction. The chutes extend from a common vibrating feed tray and have adjustable entrance gates to equalize the flow rates of the items. A stationary hopper supplies the feed tray through a flexible coupling. At the bottom of each slide, a photoelectric viewer is arranged to operate an ejector for diverting grains having dark spots. A variable background is provided and is adjusted so that the signal induced thereby is identical to that of the mid-portion of an acceptable grain. Light sources are positioned both above and below the photoelectric means so as to provide extra illumination for the leading and trailing ends of each grain, thus to avoid spurious signals similar to those induced by dark spots but caused by the rounded ends of acceptable grains.

10 Claims, 9 Drawing Figures



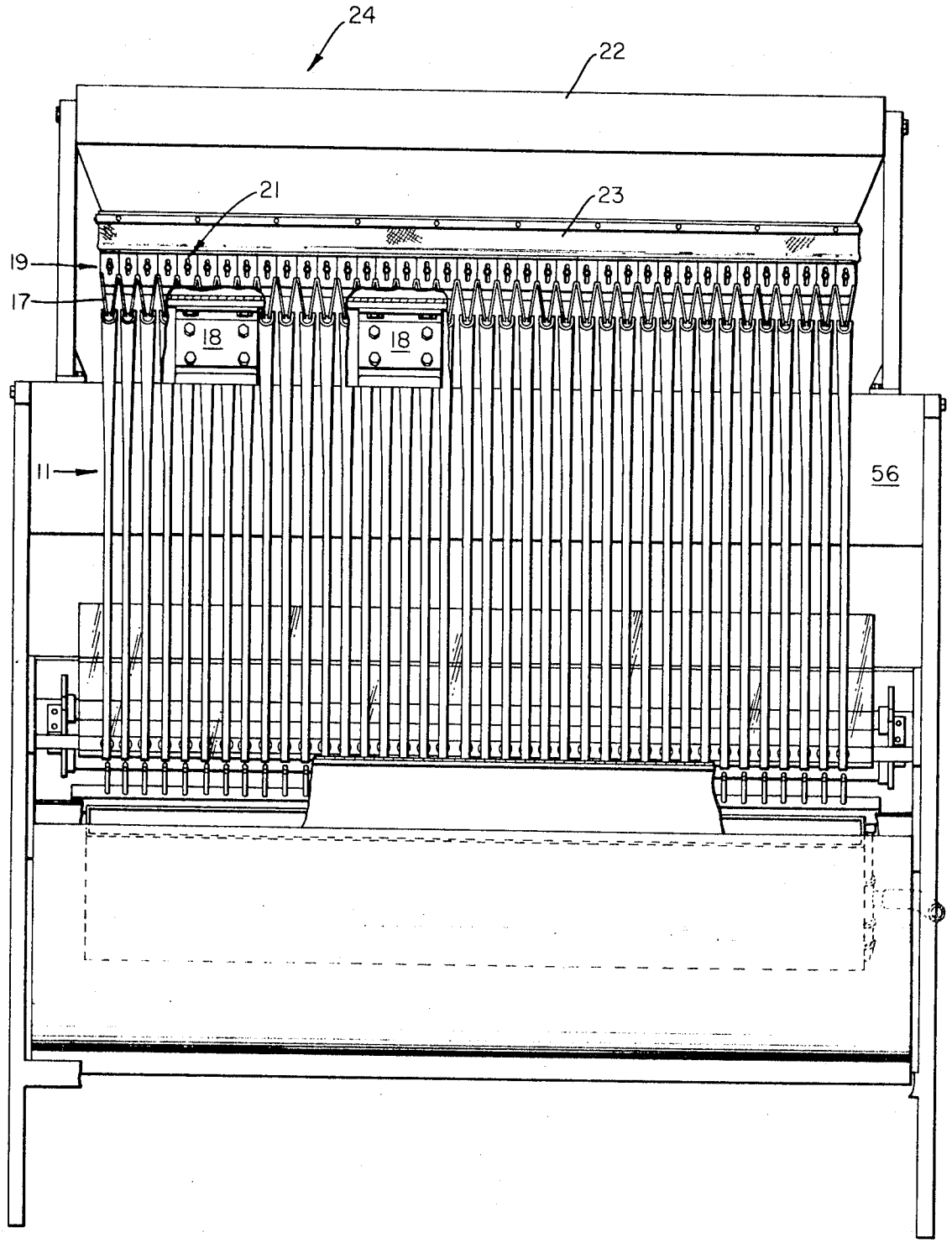


FIG_1

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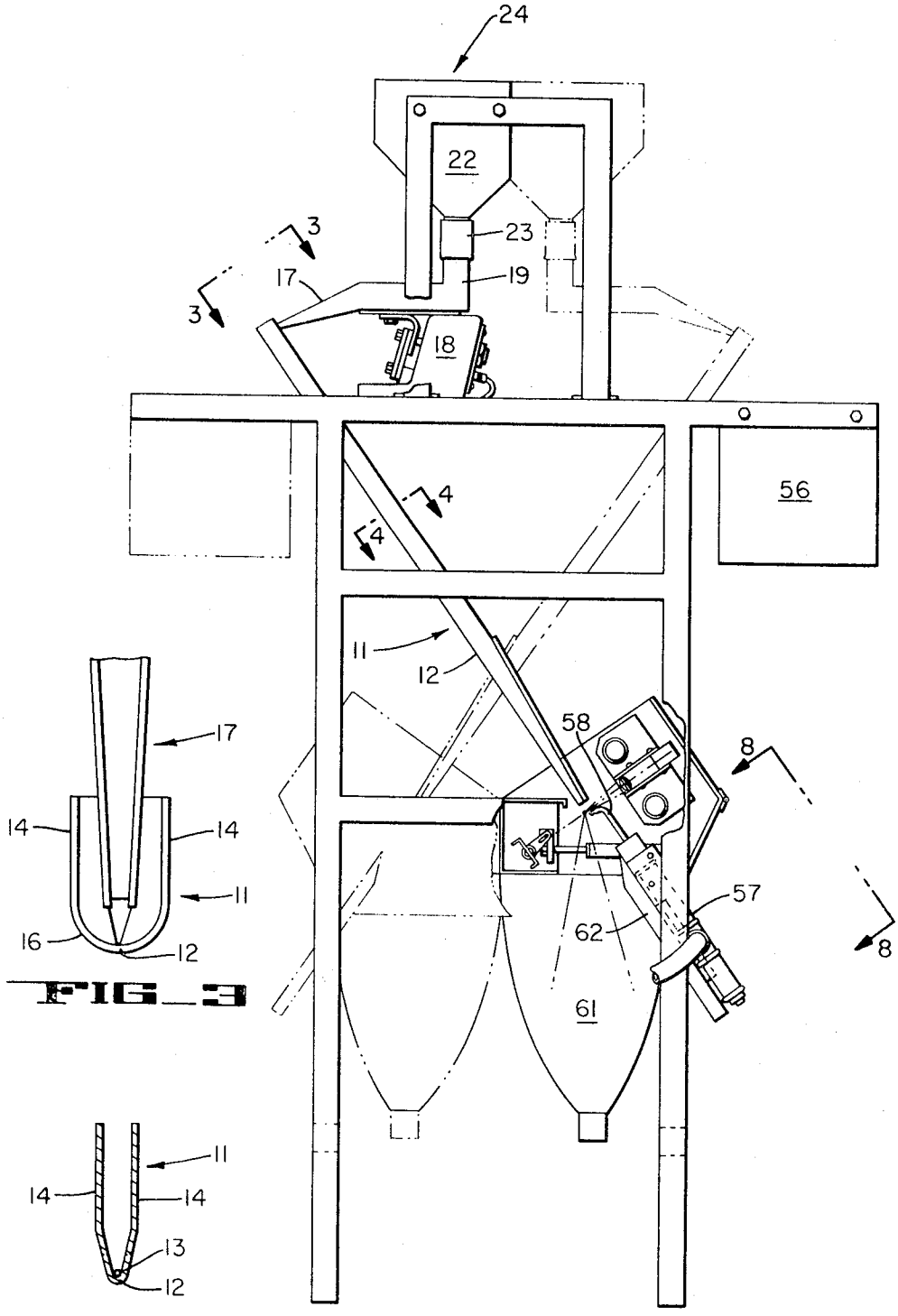

FIG_2

FIG_3

FIG_4

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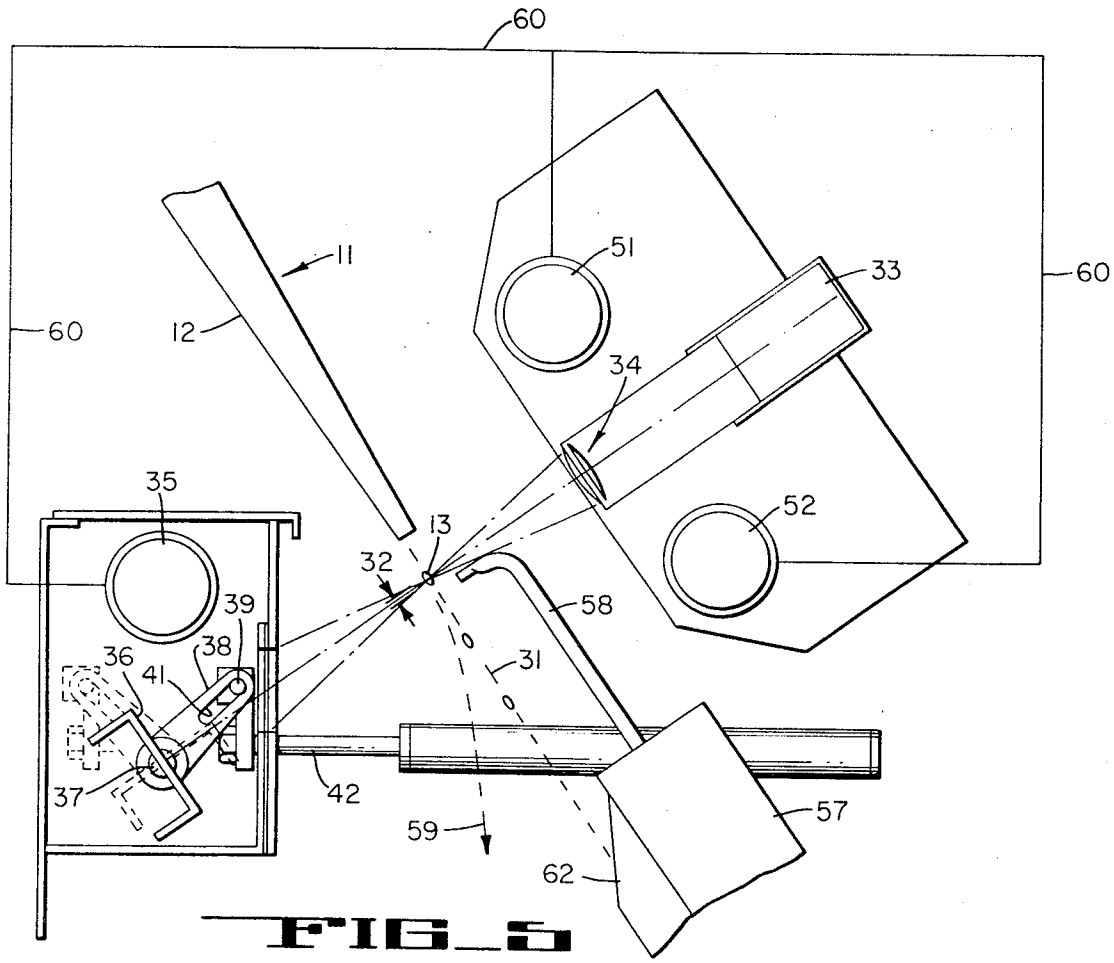

FIG_5

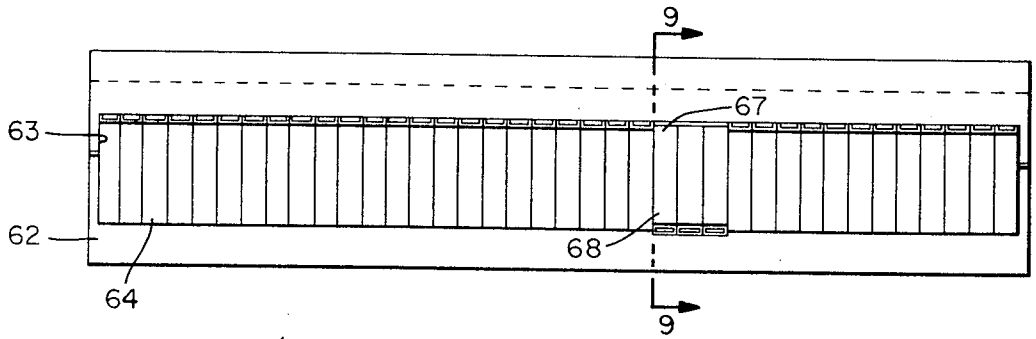

FIG_8

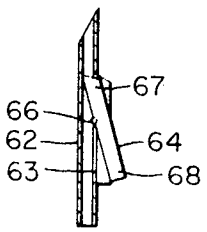

FIG_9

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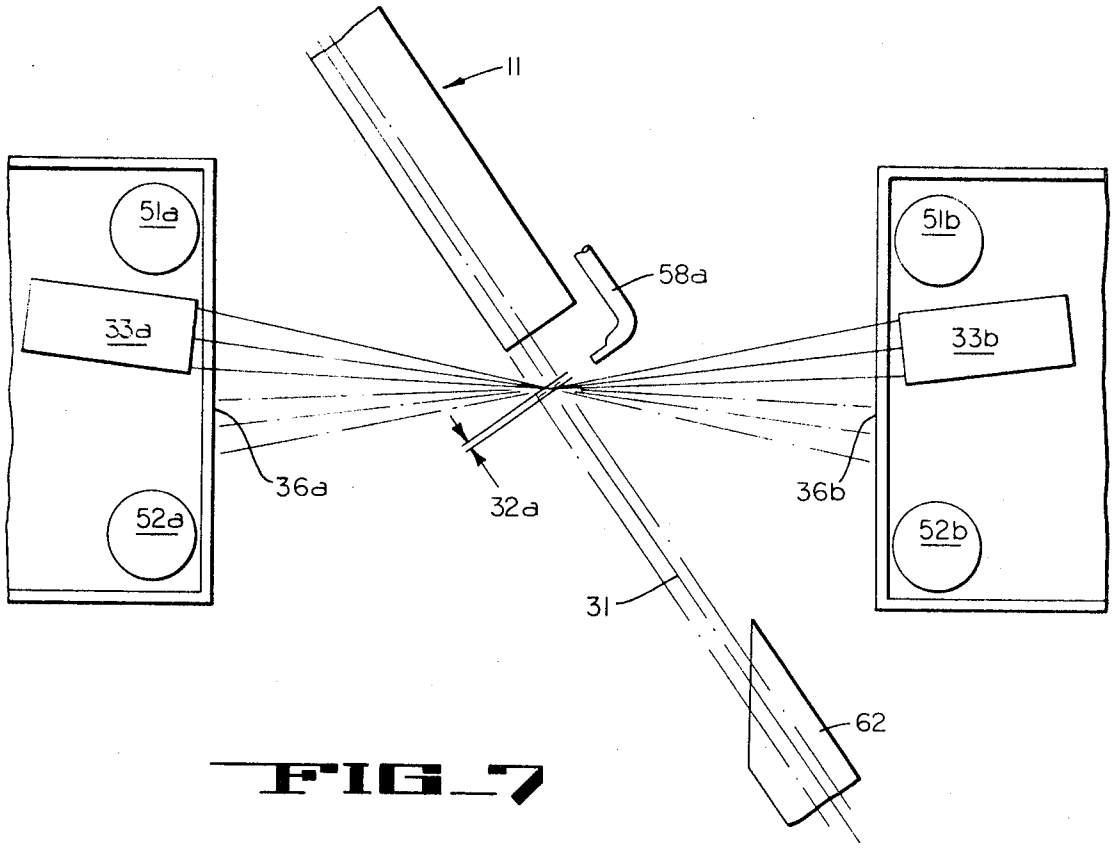

FIG_7

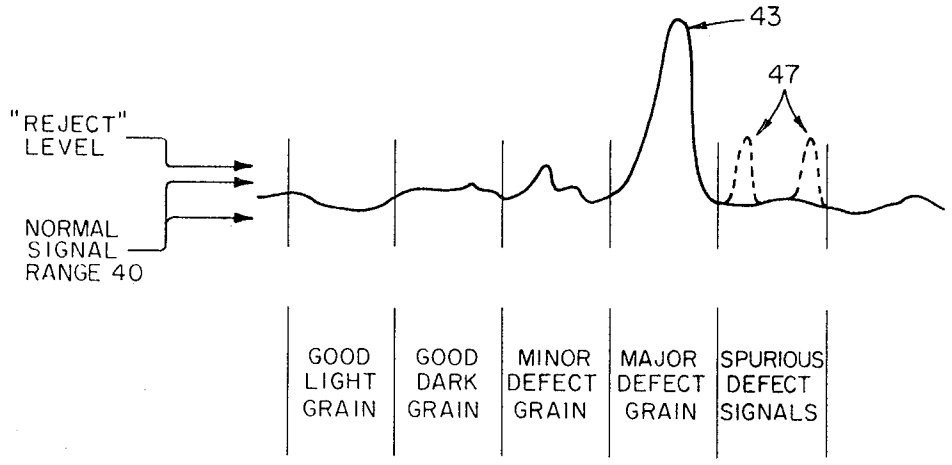

FIG_6

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SORTING MACHINE

BACKGROUND OF THE INVENTION

This invention relates to sorting machines and particularly to such machines adapted for gravity assisted singulation of the items to be sorted.

Previously, sorting machines for tiny items such as grains of rice, have comprised rotating suction wheels or other rotation or reciprocation mechanisms for singulating (i.e. separating and aligning in serial order) the grains for individual viewing by photoelectric means. While most such machines have operated satisfactorily, their volume or time-rate of sorting per ton is low when compared with the rate that is achievable for items of larger size. To increase the sorting rate, it is usually necessary to arrange a large number of sorters in parallel. With rotating and reciprocating mechanisms such as are known to the prior art, the space that is required for parallel arrangement is extremely great and is usually out of proportion to the requirements of economy and efficiency.

Accordingly, it is an object of the invention to provide a compact high speed sorting apparatus for small items.

It is another object of the invention to provide such a sorting apparatus that is adaptable for parallel arrangement and operation of a large number in a small space.

SUMMARY OF THE INVENTION

These and other objects are provided in an apparatus described as follows. A number of steeply inclined tapered slides are arranged for gravity assisted singulation and alignment of items such as rice grains that are introduced at the top from vibrating chutes that are gently inclined in the opposite direction. The chutes extend from a common vibrating feed tray and have adjustable entrance gates to equalize the flow rates of the items. A stationary hopper supplies the feed tray through a flexible coupling. At the bottom of each slide, a photoelectric viewer is arranged to operate an ejector for diverting grains having dark spots. A variable background is provided and is adjusted so that the signal induced thereby is identical to that of the mid-portion of an acceptable grain. Light sources are positioned both above and below the photoelectric means so as to provide extra illumination for the leading and trailing ends of each grain, thus to avoid spurious signals similar to those induced by dark spots but caused by the rounded ends of acceptable grains.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation view partly broken away of an apparatus according to the invention;

FIG. 2 is a right side elevation view, partly broken away, of the apparatus of FIG. 1;

FIG. 3 is an enlarged view taken along the plane of lines 3—3 of FIG. 2;

FIG. 4 is an enlarged cross sectional view taken along the plane of lines 4—4 of FIG. 2;

FIG. 5 is an enlarged view of a portion of the apparatus shown in FIG. 2;

FIG. 6 is a schematic view illustrating the operation of the invention;

FIG. 7 is a view illustrating a variation of the apparatus of FIG. 5;

FIG. 8 is an elevation view taken on the plane of lines 8—8 of FIG. 2; and

FIG. 9 is a sectional view taken on the plane of lines 9—9 of FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. 1–4 there are shown a number of elongated, tapered slides 11, each of which has a central longitudinal generatrix 12 steeply inclined (e.g., 35° from the vertical) for gravity assisted separation of small granular items such as grains 13 of rice sliding downwardly thereon. In the art of sorting granular items, it is of the utmost importanct to be able to separate the items and space them out in serial order (i.e. "singulate") so that they may be viewed one at a time and so that a rejection operation takes effect only for the one grain that is defective. In the present invention the elongation of the slides 11 and their considerable vertical extent (e.g., about 40 inches in an actual machine) enlists the separation assistance of gravity in the following way. It is well known that falling bodies accelerate at a constant and substantial rate, so that if two bodies begin falling from the same point at slightly different intervals of time, it follows that the vertical separation between them increases as a function of the acceleration g of gravity and the square of the time (t^2) of fall. If two grains of rice are each 0.25 inches long, and one begins to fall at time t_o and the other begins to fall 1 millisecond later (i.e., at time $t_1 = t_o + .001$ sec.), then when the second grain has fallen 40 inches, its leading end must be spaced behind the leading end of the first grain by one-fourth inch. In other words, a suitable separation equal to the length of one rice grain can be achieved in a fall of 40 inches even when the grains begin to fall only 1 millisecond apart in time. This minimum time-spacing is equivalent to only about four ten-thousandths of an inch (0.0004 inches) in terms of the initial falling distance of one grain, i.e., when the second grain begins to fall, the first has already fallen 0.0004 inches. In 40 inches of fall, then, the initial spacing is increased nearly 6,000-fold, from 0.0004 to 0.2500 inches. The usefulness of gravity assistance for separating the grains is therefore evident.

In the present invention, the grains are expected to slide down the inclined slides 11 rather than falling perfectly freely, so of course the slight frictional retardation of the grains on the slide tends to diminish the separation achievable by gravity. However, dry friction does not increase substantially with velocity, so its effects may be reckoned as constant and slight. We have seen that for free fall the grains of rice must be spaced apart for time intervals of greater than 1 millisecond at the top of the slide. If the effect of friction adds merely another millisecond to this minimum requirement, there is little disadvantage, for by far the overwhelming bulk of grains coming into the top of each slide 11 are spaced apart in time for greater than 2 milliseconds. Besides the above consideration, the frictional effect of the inclined slides 11 is more than offset by the channeling effect of the tapering shape of the slide. In FIG. 3 it is shown how the slide has an upper-end cross section of U-shape defined by two side walls 14 and a rounded bottom portion 16 of a radius much larger than the transverse radius of a rice grain 13. About one-third of the way down from the top, the slide has narrowed to a bottom portion just precisely fitting the rice grain cross section, and the side walls have con-

verged to define a close-spaced generally V-shaped cross section. Clearly, then even if two grains of rice fell into the upper end of the slide **11** at times less than 2 milliseconds apart, they would nonetheless strike different portions of the slide bottom and, what with the effect of impact forces and the jostling effect produced in the grains by the tapering sides **14**, the grains are still constrained to align themselves one behind the other in serial order before they reach the bottom. In fact, it may be said that even if two grains begin their falls at precisely the same instant in time, it is substantially impossible for them to arrive at the bottom end of the slide **11** without being suitably spaced apart in serial order.

If the grains are to derive the maximum effect from their initial time spacing, they should begin their falls from a condition of zero vertical component of velocity. Also it is desirable to reduce impact effects of the grains in the upper end of the slides **11** as much as possible, which requirement calls for the smallest possible horizontal component of velocity as well. Ideally, the grains would drop into the upper part of the slide **11** from a portion of the structure (i.e., the chutes **17**) in which they occupied a position at rest (zero velocity in any direction) at the instant immediately before the fall began. This condition is approximately achieved by giving the chutes **17** the gentlest possible slope downward at an inclination in the opposite direction from that of the associated slides **11.** The minimum inclination of the chutes **17** is the least inclination at which the grains will slidingly migrate downwardly at a reasonable processing rate when the friction is reduced as by vibrating the chutes **17,** as with eccentrically loaded vibrating motor means **18.** The chutes **17** are also tapered somewhat, but still at their open ends permit the random showering of grains into the slides **11.** A further effect that has been noted with this structural geometry is that bouncing grains strike one another and tend to thus damp or decrease the bouncing effect.

To make utmost use of the space saving structure of slides **11** and chutes **12,** a large number of each are arranged in parallel, and the chutes **17** are mounted to extend from a common feed tray **19,** from which the chutes are partitioned by adjustable gates **21.** Four motors **18** are used in the illustrated device, attached to the tray **19** (only two are shown in FIG. **1**). Because the induced vibrating effect varies from chute to chute as a function of mechanical and mass characteristics of the chute, and distance of the chute from the motor, the gates **21** are adjusted individually in actual operation until the rates of flow of grains in all of the chutes are equalized and optimum (about 50 lbs. per hour per chute).

Above the tray **19** is fixedly mounted a hopper **22** for reception of the grains, and a flexible coupling **23** connects the stationary hopper **22** with the vibrating tray **19,** so that a closed conduit for the grains is formed from the upper opening **24** of the hopper to the gates **21** of the chutes **17.** The slides **11** do not vibrate, nor do any other portions of the apparatus except the coupling **23,** tray **19,** chutes **17** and motors **18.**

As illustrated in phantom in FIG. **2,** the tapering of the slides **17** enables a double saving of space in that two full banks of slides **11** may be criss-crossed at the narrower portions thereof, while the wider chutes **17** are divided between two opposite sides of the machine and are abutted side-by-side.

At the bottom end of each slide **11,** the rice grains shoot out with considerable velocity upon a trajectory or path **31** (FIG. **5**) which is substantially a straight prolongation of the generatrix **12,** at least in the region of the predetermined viewing zone **32** adjacent the end of the slide. Each grain **13** is also invariably oriented with its length along the path **31** and is thus viewed from the same angle by a photoelectric viewing means **33** of standard type, disposed at the side of path **31** and provided with lens means **34** to define the zone **32** of view.

Because rice grains are of generally gray-white coloring if acceptable, and are generally translucent, and because unacceptable grains are usually distinguishable by the appearance of dark spots visible from all sides under proper illumination through the translucent interior, it is necessary to illuminate and inspect each grain from only one of its longer sides. To obtain a voltage signal from the photocell **33** indicative of an acceptable grain, the present invention provides a light source **35** shielded from the viewing zone **32** and illuminating a generally gray-white background **36** which is rotatable on an axis **37** abnormal to path **31** so that the background shade can be matched with that of an acceptable grain, and the voltage level **40** of the photocell signal is the same when an acceptable grain is in view as it is when there is no grain in view (FIG. **6**). As shown in FIG. **5,** the background **36** is rotatable through about 90° by means of a bell crank **38** operated by a pin **39** sliding in a slot **41** on the bell crank and extending from a piston **42.**

The illustrative apparatus is of the dark-trip type and provides a positive signal pulse **43** when a dark spot in an unacceptable grain passes through the viewing zone **32.** However if the grain is illuminated from only one position adjacent the photocell **33,** as is usual in the prior art, the rounded leading and trailing ends of the grain reflect a lesser amount of light to the photocell **33** than comes from the mid-portion of the grain. At the same time, the leading and trailing ends of the grain are cutting off the reflected light from the background **36.** The viewing zone is of course as narrow as possible and extends for a considerably less distance in the direction of path **31** than the length of the rice grain, in order to obtain the maximum signal level from the smallest dark spot. But the result of this combination of conditions, when only a single lamp is used, is that the ends of the rice grain appear as dark spots to the photocell and cause spurious defect signals **47** even though the grain may actually have no dark spots.

The precise mechanism of this phenomenon is not fully understood, but it is believed to be caused partly by specular reflection at flat angles of illumination near the extreme tips of the grains, which denies entry of this portion of incident light into the interior of the translucent or "transluminescent" grain, from whence it would ordinarily be glowingly and diffusedly reflected back to the photocell. Since less light gets back from the grain ends, a spurious dark spot is signalled. Also believed to be a cause, is the fact that less light is directly reflected back to the photocell from irregularities on the surface of the ends of the grain, where the surface is at a different angle than that of the long stretch of the mid-portion of the grain. In any event, it has been found experimentally that with only one lamp for illumination, spurious signals do appear.

Accordingly, the invention contemplates the use of at least two light sources **51** and **52** mounted respectively

above and below the viewing means **33, 34** so as to provide extra illumination to the ends of the rice grain. The leading end of the grain is given extra illumination by light source **52** to compensate for the loss in illumination that the leading end receives from light source **51.** As for the mid-portion of the grain **13,** the combined illumination it receives and reflects to the photocell from both light sources adds up to produce a signal of the same general voltage level as that received from the leading end as a result of the more direct illumination of light source **52** above. A similar effect is produced by light source **51** on the trailing end of the grain. The result is an undisturbed steady voltage level signal **40** as the acceptable grain enters the viewing zone, passes through it, and departs. Only if a grain with a true dark spot appears does the photocell produce a deviating positive signal **43** to initiate rejection of the defective grain.

Upon receiving a rejection signal **43,** the programmed logic of an electronic controller **56** causes the operation of a compressed-air value **57** and nozzle **58** to emit a quick sharp brief jet or blast of air directed against the side of the grain **13** transversely to the path **31** so as to blow the defective grain along a deviating or deflected path **59** into a reject hopper **61.** If, however, the grain **31** is not defective and no signal pulse **43** is produced, the grain continues along path **31** to an acceptable product tube **62,** which is laterally elongated so as to be common to all channels, and may in turn be coupled to a bag or other packaging, transporting or storage apparatus.

In the illustrated apparatus, the light sources **35, 51** and **52** are fluorescent tubes operated at high frequency (e.g., 20 kilohertz) and having the ballasts synchronized as by a common coupling **60.**

Occasionally, while the apparatus is operating, it is desirable to be able to sample the product that is being accepted in each individual channel of the machine. For this purpose, the tube **62** (FIGS. **8** and **9**) is formed with a side opening **63,** and a number of individual sampling tubes **64** are mounted to cover the opening **63** in the normal operating condition of the machine, but without interfering with the flow of grains downwardly through the tube **62.** The sampling tubes **64** are pivoted as at **66** however, so that the upper ends **67** can be individually tipped inwardly to catch the grains and divert them outwardly through the now-protruding open lower ends **68** and into the hand of the sampler.

Referring now to FIG. **7,** an alternative arrangement is shown for use with opague products that must be examined from both sides. A pair of photoelectric examining devices **33*a*** and **33*b*** are placed on opposite sides of the path **31** from slide **11,** and each phototube has a pair of light sources **51*a*, 52*a*, 51*b*** and **52*b***, respectively, associated therewith, above and below the phototube. Each phototube is directed toward a background **36*a*** and **36*b***, respectively, shown in the FIGURE as fixed in position. Alternatively, adjustable backgrounds such as background **36** of FIG. **5** could be used. Finally, a compressed air-jet nozzle **58*a*** is mounted above the viewing zone **32*a***, as shown.

What is claimed is:

1. A semi-free-fall sorting apparatus for granular items, comprising:

an elongated slide tapering downwardly to the diameter of said items and having a central longitudinal generatrix that is steeply inclined for gravity separation of said granular items sliding downwardly thereon, and for aligning said sliding items in serial order along a common path corresponding to said central generatrix;

the upper end of said slide having a gently rounded bottom portion as seen in cross-section along the line of said central generatrix, the curvature radius of said bottom portion being substantially greater than the mean radius of said granular items;

said slide tapering from upper to lower end so that the cross section along the direction of said central generatrix at the lower end displays a curved bottom portion of curvature radius substantially in the same order as said mean radius of said granular items;

means for introducing said items in a random shower into the upper end portion of said slide; and

means for examining and sorting said items aligned in said serial order.

2. An apparatus as recited in claim **1** wherein:

said slide has spaced side walls extending from said curved bottom portion to define a U-shaped cross section at said upper end;

said side walls being angled to converge downwardly toward one another to define a generally V-shaped cross section at said lower end.

3. Apparatus as recited in claim **1** wherein:

said means for introducing said items to the upper end of said slide includes a vibrating tapered chute in the same vertical plane as said slide but gently inclined in the opposite direction so as to discharge said granular items into said slide with the least possible vertical component of velocity and a horizontal component of velocity oppositely directed to the horizontal velocity component that is to be induced in said items by said slide.

4. The combination recited in claim **3,** wherein said apparatus also includes:

a plurality of said slides and said examining and sorting means arranged in parallel and a corresponding plurality of said chutes also in parallel;

said chutes extending from a common feeding tray mounted for vibration;

motor and eccentric mass vibrating means mounted to vibrate said tray and chutes; and

each of said chutes having an adjustable gate at the tray end thereof to equalize the flow rate of said items despite differences in the vibrating effect resulting from differences in the chutes and their distances from the vibrating means.

5. The combination recited in claim **4,** wherein said apparatus also includes:

stationary hopper means mounted above said tray for reception of said granular items;

flexible coupling means between said hopper means and said tray;

said hopper means, flexible coupling means and tray being arranged to define a closed conduit for said granular items from the entrance to said hopper means to the opening of said adjustable gates to said chutes.

6. The combination recited in claim **5,** wherein:

said slides are arranged in two criss-crossed banks;

the chutes for said respective banks extending from opposite sides of a feeder tray and hopper means;

said examining and sorting means being arranged in two corresponding banks beneath said slides.

7. The combination recited in claim 1, wherein said examining and sorting means includes;

photoelectric viewing means disposed beside said path for viewing a zone of said path no longer than the mean length of said granular items in their sliding orientation with respect to said slide;

at least two light sources disposed respectively above and below said photoelectric means along the length of said path;

ejection means adjacent said path for selectively diverting said items therefrom upon signal from said photoelectric means;

receptacle means on said path below said ejection means for receiving undiverted items;

a third light source positioned on the opposite side of said path from said viewing means and shielded from said viewing zone;

variable background means positioned adjacent said path directly opposite said viewing means and illuminated by said third light source and adjustable to induce a signal from said photoelectric means that is substantially identical to the signal induced by passage of the mid-portion of an acceptable one of said items;

said ejection means being adapted to operate only when the signal from said photoelectric means differs appreciably from said background-induced signal;

said background means including a flat-surfaced background uniformly colored in the same general color as said acceptable items;

said background being rotatably adjustable about an axis abnormal to said flat-surface so as to deepen or lighten the apparent shade of said background as viewed by said photoelectric means, thus to induce said signal identical with that of an acceptable item.

8. The combination recited in claim 7 and adapted for the sorting of elongated gray-white rice grains as said items, wherein:

said background is of generally gray-white color and is rotatable to reflect light to said photoelectric means in the same intensity as an acceptable grain of said rice;

said ejection means being calibrated to operate upon reception of a signal indicating a dark spot in one of said rice grains, said signal having a voltage amplitude level differing appreciably from that provided by said background.

9. The combination recited in claim 7, wherein:

two of said viewing means are provided on opposite sides of said path for viewing opaque items; and

four light sources are provided, one above each viewing means, and one below each viewing means; and

two background means are provided, each aligned with one of said viewing means and said viewing zone.

10. The combination recited in claim 7, wherein said receptacle means for receiving acceptable undiverted items includes:

a first elongated tube aligned on said path and having an opening in the upper side thereof; and

a second elongated tube pivoted on the upper side of said first tube so as to cover said opening in a normal position of said second tube aligned parallel to said first tube;

said second tube being pivotable to a sampling position wherein the upper end of said second tube intrudes through said opening into said first tube and diverts said acceptable items into said second tube for examination as a sample.

* * * * *