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[54] **SCREENING PROCESS AND APPARATUS**

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[52] **U.S. Cl.** **209/233,** 209/275, 209/314

[51] **Int. Cl.** **B07b 1/28**

[58] **Field of Search** 209/233, 236, 237, 274, 209/275, 314, 354, 393, 395, 396, 403

[56] **References Cited**

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[57] **ABSTRACT**

A process for high-efficiency screening on vibrating apparatus of dry or moist granular or powdery substances, wherein the bed depth of the residue on the screening surface increases from a depth at an upstream point to a greater depth at a downstream point, due to the fact that the speed of advance of the residue and the width of the said surface are given values such that the product of the speed of advance and the width, decreases in proportion to the weight loss experienced by the residue between these two points and in inverse proportion to the increase in the bed depth between these same points.

4 Claims, 6 Drawing Figures

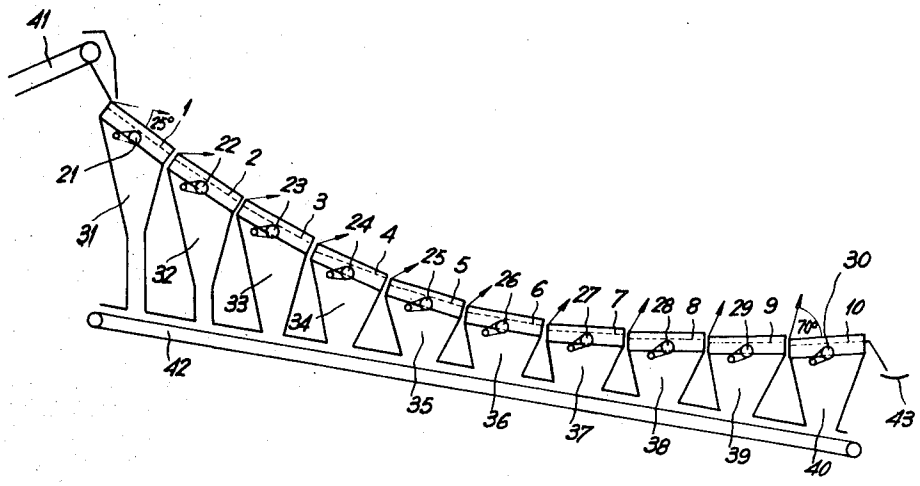


Fig.1

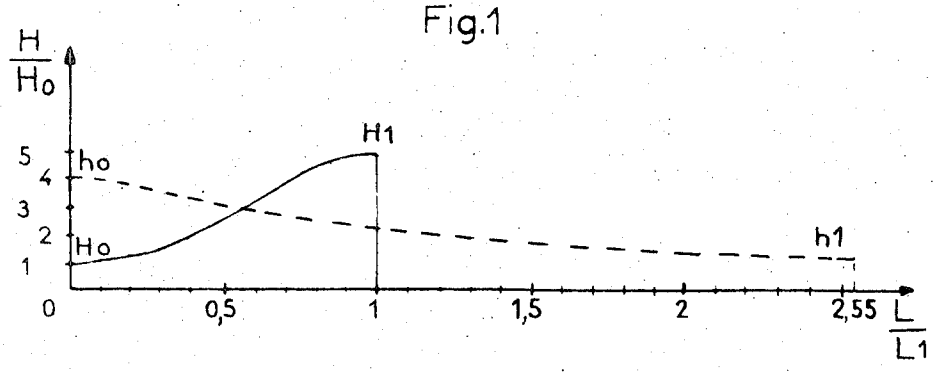
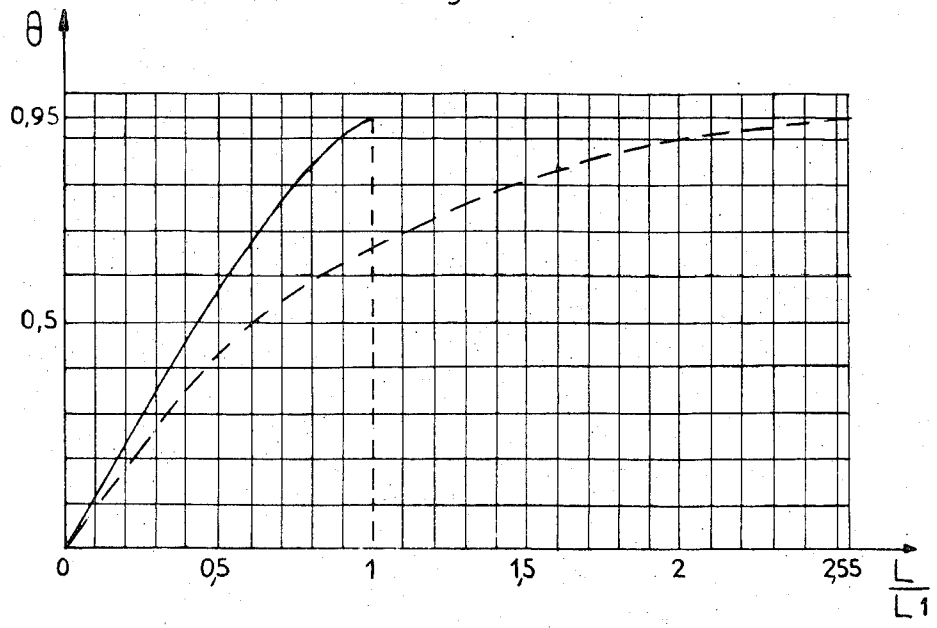


Fig.2



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Fig.3

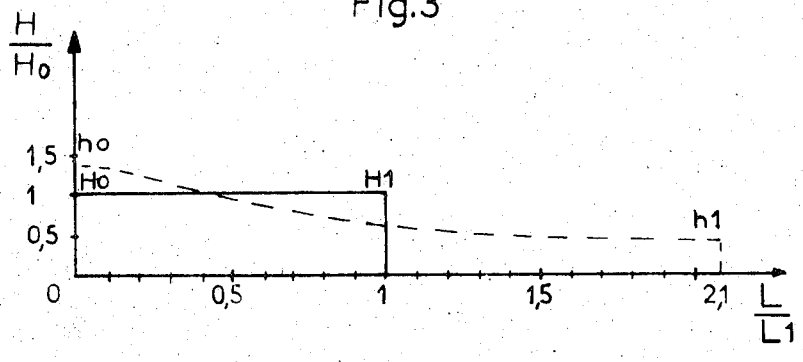
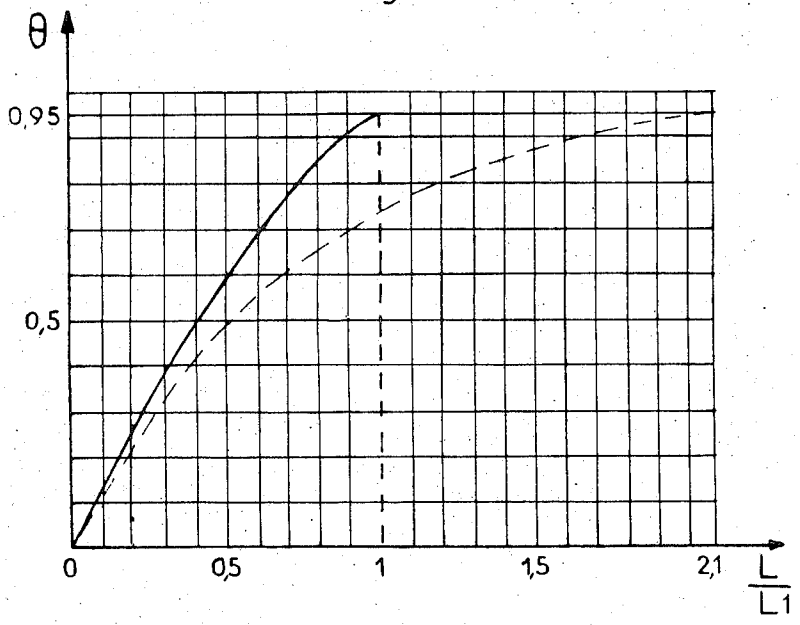
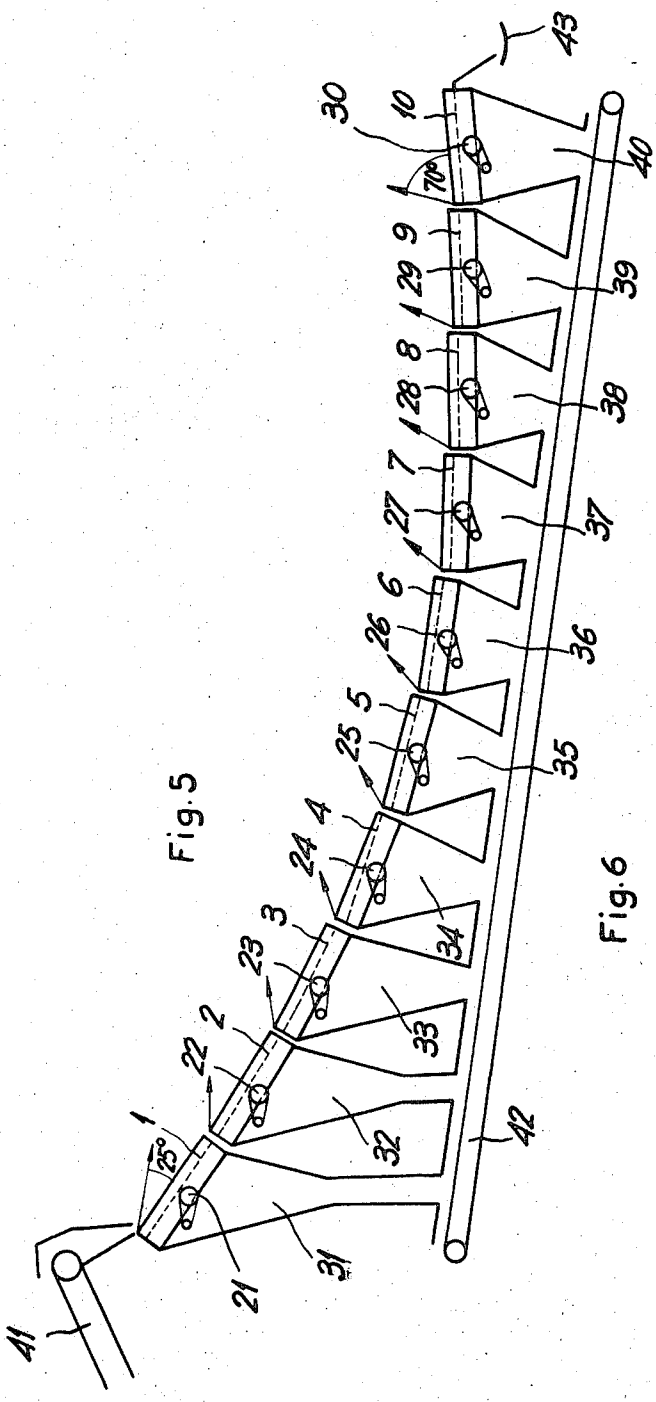


Fig.4



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SCREENING PROCESS AND APPARATUS

This is a continuation, of application Ser. No. 29,153, filed April 16, 1970, now abandoned.

The invention relates to a process for high-efficiency screening on vibrating apparatus of dry or moist granular or powdery solid substances.

Much importance is attached in industry now to the grading and classification of such substances according to grain size, whether they are raw materials such as coal, ore, rock, sand, pebbles, etc., or manufactured products such as coke, artificial fertilisers, salts, sugar, etc.

This operation is generally carried out mechanically on single or multi-deck vibratory screening apparatus. In single-deck screening apparatus, the screening surface divides the substance progressively into two granulometric fractions; the material which has passed through the screen, that is to say those particles (the "undersize") whose dimensions are smaller than the mesh and which have succeeded in traversing the screening surface progressively between the upstream part of it and a given downstream point; and the "residue", which has been unable to do so because it consists not only of particles larger than the mesh but also of smaller particles which have had no chance of traversing the screening surface before reaching the downstream point concerned. As it proceeds over the screening surface, this residue suffers, between the upstream part and the downstream point concerned, a progressive weight loss equal to the weight of the material which has passed through the screening surface during this period.

In screening apparatus having n decks, the same applies, and the progressive weight loss suffered by the n residues during their progression through the n decks is equal to the weight of the material which has passed through the screening surface of the bottom deck.

As a result, the known processes have inter alia the following characteristics:

a. As the or each residue progresses over its creening surface, its bed depth decreases from upstream to downstream. For example, in the case of a substance having a content $p = 70$ percent of particles smaller than the screening mesh, the value of the ratio h_1/h_0 between the downstream and upstream bed depths is of the order of 0.33, that is to say, the bed depth h_1 downstream of the surface is approximately three times smaller than the upstream bed depth h_0.

b. The material which passes through the screen does so at a relatively low average specific throughput, so that the surface must have a very large area, for example 100 m², in order, with a 5 mm mesh, to let through at most 800 t/h of dense, moist and clayey iron ore or 400 t/h of dry coal, although the actual passage capacity of such a surface is four to five times greater.

c. Also the known processes do not permit the construction of very large-area screening apparatus, as is now required if a single apparatus is to process the very large throughputs resulting from the present concentration of raw-material extracting and converting undertakings. In the case of the example cited above in paragraph b), for instance, at least four apparatuses arranged in parallel would be required in order to obtain a 100 m² surface, and there would be all the disadvantages which arise from sub-division of the total flow of the substance into at least four fractions.

Since the screening equipment is expensive as regards capital, operating and maintenance costs, it is highly desirable that the known screening processes should be replaced by a more effective process which increases both the average specific throughput of material through the screening surface and the dimensions of the screening apparatus.

This process consists, according to the invention, in that the bed depth of the residue on the screening surface increases from a depth H_o at an upstream point to a greater or at least equal depth H at a downstream point, due to the fact that the speed of advance V of the residue and the width l of the said surface are given values such that the product $V.l$ decreases in proportion to the weight loss experienced by the residue between these two points and in inverse proportion to the increase in the bed depth between these same points.

In order to explain the invention, two embodiments of the process will now be described by way of example only, with reference to the accompanying drawings.

FIGS. **1** and **2** are graphs relating to a viscous iron ore;

FIGS. **3** and **4** are graphs relating to a dry coal; and

FIGS. **5** and **6** illustrate diagrammatically screening apparatus which operates in accordance with the invention.

Two examples have been selected from numerous comparative tests carried out on a semi-industrial scale on very diverse substances, because they show that the values for $H/H_o > 1$ depend essentially on the viscosity of the residue and its content of fine particles, as a function of the distance covered by the residue on the screening surface.

Before a particular substance is processed, therefore, it is necessary according to the invention to plot graphs similar to those in FIGS. **1** and **2** or **3** and **4**, on the basis of tests carried out on a semi-industrial scale.

EXAMPLE I

In the case of an ore which, being very moist and clayey, is extremely viscous, which is separated on 5 mm mesh and in which the proportion p of particles smaller than this mesh is 70 percent, the best results were obtained by making H/H_o increase as indicated by the solid curve in FIG. **1**.

These results are shown by a solid line on the graph in FIG. **2**, which plots the passage yield θ of the material which has passed through the screen against the ratio L/L_1, L being the distance covered by the residue on the screening surface from upstream, and L_1 being the distance which it must cover in all if θ is to be equal to 95 percent.

The curves shown by broken lines illustrate, for comparison, how matters stand in the case of known processes operating with a ratio $h/h_o > 1$.

It will be noted that when $\theta = 95$ percent the distance which the residue must cover on the screening surface is, according to the invention, 2.55 times less than in the case of known processes. The average specific throughput of material through the screen is therefore 2.55 times greater, with the result that a 100 m² surface will, by means of the invention, let through approxi-

mately 2,000 *t/h* of the ore concerned, instead of 800 *t/h*.

EXAMPLE 2

In the case of a dry coal of no appreciable viscosity, which is screened on 5 mm mesh and in which the proportion *p* of particles smaller than this mesh is 65 percent, the best results were obtained by keeping the bed depth substantially constant as indicated by the solid curves in FIGS. 3 and 4.

By way of comparison, the curves shown by broken lines give the results obtained by conventional processes operating with a bed depth which decreases from upstream to downstream.

It will be noted that in this case the invention made it possible to increase the average specific throughput 2.1 times, so that 840 *t/h* could be passed through a 100 m^2 surface instead of 400 *t/h*.

Similar results obtained for substances of all types showed, when taken as a whole, that provided the values $H/H_o \geq 1$ are selected judiciously according to the viscosity of the substance, the average specific throughput of material through the screen is in all cases more than double that obtained in known processes.

These surprising results may be explained as follows:

If the fine particles are to pass through the screening surface, they must, of course, be brought into contact with this surface. The "phase of passage of material through the screen" is therefore necessarily preceded by a "phase of segregation of the residue", which tends to produce in the latter a stratification which progressively collects the fine particles into the lower layers and the large particles into the upper layers.

This stratification is caused by the vibratory movement of the screening surface, the jolting of which projects the large particles further than the small particles due to their different weights and their different kinetic energy.

The "speed of sedimentation" of the fine particles, that is the speed at which they fall, drops very fast when the bed depth and the viscosity of the residue increases.

As a result, the average specific throughput of material through the screen depends not on the passage capacity of the screening surface but on the rate at which the fine particles reach this surface, or, if one prefers, on the presence just above it of a stratification layer with a high content of fine particles.

In other words, if high passage throughputs are to be obtained, the surface must be correctly fed.

In known screening processes under-feeding occurs along the entire length of the apparatus. At the upstream end, where the residue has a high content of fine particles, the rate of sedimentation of these particles is too low because the excessively large bed depth greatly reduces the speed of sedimentation of the fine particles, which must cover a long distance in order to reach the screening surface. At the downstream end, underfeeding is even more evident, since because of the insufficient bed depth there are not enough fine particles. This is why, in known processes, the average specific throughput through the screening surface rarely attains one-quarter of the actual passage capacity of the screening surface.

By means of the process according to the invention, on the other hand, the screening surface is fed much more correctly, since the bed depths, which are low upstream and high downstream, correspond respectively to fine-particle contents and residue viscosities which are high upstream and low downstream, with the result that there is a very distinct increase in the average specific throughput of material through the screening surface, which may be up to 80 percent of the actual passage capacity of the screening surface.

The invention therefore makes it possible to construct the large-area, high-throughout screens which are required by modern industry.

According to the invention, the increase in the bed depth is obtained by giving the speed of advance V of the residue and the width *l* of the screening surface values such that the product V.*l* decreases according to the formula.

$$(V \cdot l)/(V_o \cdot l_o) = (H_o/H)\ (1 - \theta\ p) \tag{1}$$

in which:

- *p* is the content in the substance of particles finer than the mesh,
- θ is the average passage yield of the material which has passed through the screen, that is, the percentage of *p* which has succeeded in passing through the surface between the upstream point and the downstream point concerned,
- V_o and l_o are the values of *V* and *l* at the upstream point of the surface.

When $l = l_o$, that is to say, when the width of the surface is constant over its entire length, formula (1) becomes:

$$V/V_o = H_o/H\ (1 - \theta\ p) \tag{2}$$

The value of the product $V_o \times l_o$ is given by the formula

$$V_o \cdot l_o = K/H_o \tag{3}$$

K being a constant, different for each particular case, given by the expression:

$$K = T/3.6\ d \tag{4}$$

- in which T represents the hourly tonnage of the substance to be processed, and
- *d* represents the bulk density of this substance, *V* and V_o, *l* and l_o, H and H_o being respectively expressed in m/sec, *m* and mm.

A numerical application to the two examples cited above will now be given.

EXAMPLE 1 (FIGS. 1,2)

Screening on 5 mm mesh of 3,000 *t/h* of the extremely viscous iron ore concerned, which has 18 percent water and 9 percent clay and has a total grain-size range of 0 to 45 mm.

$d = 2.5$ $p = 0.7$

As the screening yield required is $\theta = 0.95$, the necessary screening surface area is of the order of 100 m^2, that is to say, a constant width $l = l_o = 3$ m for a length $L_1 = 33$ m.

According to formula (4), $K = (T/3.6\ d) = (3{,}000)/(3.6 \times 2.5) = 333$

Since the substance is highly viscous, H_o should preferably not exceed the size of the largest particle contained in the substance, that is, $H_o = 45$ mm.

According to formula (3), $V_o = K/(l_o \cdot H_o) = 333/(3 \times 45) = 2.47$ m.

According to formula (2)

$V = V_o\ (H_o/H)\ (1 - \theta\ p) = 2.47\ (H_o/H)\ (1 - 0.7\ \theta)$.

The experimental graphs given in FIGS. 1 and 2 give the values for H/H_o and for θ.

For			
L/L_1=	0	0.5	1, one has respectively:
H/H_o=	1	2.55	5
θ=	0	0.57	0.95

hence $V_o = 2.47$ m/s

$V_{0.5} = 2.47 \times (1/2.55) \quad (1 - 0.7 \times 0.57) = 0.58$ m/s

$V_1 = 2.47 \times 1/5 \quad (1 - 0.7 \times 0.95) = 0.16$ m/s

EXAMPLE 2 (FIGS. 3,4)

Screening on a 5 mm mesh of 1,350 *t/h* of the dry coal of very low viscosity concerned, which has a total grain size range of 0 to 30 mm

$d = 0.7 \qquad P = 0.65$

Since the required passage yield of material through the screen is $\theta = 0.95$ the required surface area is of the order of 100 m², that is, the surface must have a constant width l=3 m if its length is $L_1 = 33$ m.

According to formula (4),

$K = (T/3.6\ d = 1{,}350/(3.6 \times 0.7) = 537$

Since the viscosity of the coal is very low, H_o may be equal to four times the size of the largest particle contained in the substance, that is, $H_o = 120$ mm.

According to formula (3),

$V_o = (K)/(l_o \cdot H_o) = 537/(3 \times 120) = 1.50$ m/s

According to formula (2),

$V = V_o\ (H_o/H)\ (1 - \theta\ p) = 1.50\ (H_o/H)\ (1 - 0.65\ \theta)$

The experimental graphs in FIGS. 3 and 4 give the values for H/H_o and for θ.

For			
L/L_1=	0	0.5	1 has one respectively
H/H_o=	1	1	1 and
θ=	0	0.60	0.95

Hence $V_o = 1.50$ m/s

$V_{0.5} = 1.50\ (1 - 0.65 \times 0.6) = 0.92$ m/s

$V_1 = 1.50\ (1 - 0.65 \times 0.95) = 0.57$ m/s

The process may be carried out in various ways, for example:

In the case of a screening surface of constant width:

a. When the screening surface is inclined from upstream to downstream, the descending and ascending slopes of the surface are selected in order to give the speeds defined by formula (2).

b. When the surface has a plurality of sections, each having its own driving mechanism, these independent mechanisms cause the different sections to carry out different vibratory movements of which the amplitudes, frequencies and angles of projection are selected in order to give the speeds defined by formula (2).

c. When the surface is inclined and has a plurality of sections, each having its own driving mechanism, the downward and upward slopes, the amplitudes, the frequencies and the angles of projection are selected in order to give the speeds defined by formula (2). More generally, one might have a screening surface of variable width and with a plurality of sections, each having its own driving mechanism, downward slopes, upward slopes, amplitudes, frequencies, and angles of projection, the whole being so determined that the product $V \cdot l$ decreases in accordance with the formulas (1), (3) and (4).

It is also possible to act on the speed at which the substance arrives upstream of the surface and to act on the flow of residue in the downstream portion of the surface by providing baffles.

For example, to give a speed of the order of 2.50 m/s, such as may be necessary upstream of a large screening surface 40 m long and sub-divided into 10 sections, these sections will preferably be made to carry out a rectilinear or elliptical vibratory movement, also notable for high acceleration and a large amplitude. The surface will be given an inclination of the order of 35°, and the substance will arrive at a speed of the order of 2.90 m/s. To give a speed of the order of 0.03 m/s, such as may be necessary on the downstream section of the same large-area apparatus, on the other hand, the screening surface will be made to carry out a vibratory movement having a high frequency and a low amplitude, its inclination will be nearly horizontal, and the discharge of the residue will be braked by means of baffles (which will also cause turbulence, promoting efficient screening of the finished residue).

To give speeds decreasing from 1.20 m/s upstream to 0.30 m/s downstream, such as are often suitable for a screening surface of average size, having a length of 20 m and 6 sections, it may be necessary to act on only one of the factors, for example the inclinations or the different movements of the sections.

In conclusion, the advantages of the invention are as follows:

a. For a given hourly tonnage of a substance processed, the screening surface is reduced by at least 50 percent.

b. For a given screening surface, the hourly tonnage is at least doubled.

c. By means of the invention, it is now possible to construct screening apparatus having high specific throughputs and a very large surface area.

Of these three advantages, the last is the most useful, since, for the same hourly tonnage processed, a single 100 m² apparatus will replace at least eight 25 m² apparatuses arranged in parallel, so greatly reducing the bulk, capital costs and production costs.

This description of the invention will now be completed with a brief description, by way of example only, of high-efficiency screening apparatus, illustrated in elevation and in plan in FIGS. 5 and 6.

Its screening surface has an area of approximately 100 m², that is, a length L = 33 m and a constant width l = 3 m.

This surface is sub-divided into ten sections 1 to 10, fixed in frames 11 to 20.

These sections have the following inclinations relative to the horizontal:

35° in the case of section **1**
31.5° in the case of section **2**
27° in the case of section **3**
21.5° in the case of section **4**
15.5° in the case of section **5**
8.5° in the case of section **6**
2.5° in the case of section **7**
0° in the case of section **8**
−2° in the case of section **9**
−5° in the case of section **10**

Mechanisms **21** to **30** mounted on the frames cause each section to carry out a different, preferably rectilinear or elliptical vibratory movement. In the case of section **1,** this movement has the following characteristics:

angle of projection 25°
stroke 25 mm
frequency 650 *t/m*

(the angle of projection being the angle at which the particles in the residue are projected into the air relative to the surface).

In the case of section **10,** on the other hand, these characteristics are as follows:

angle of projection 70°
stroke 6 mm
frequency 1,400 *t/m*

The characteristics of the movements for the intermediate sections **2** to **9** vary in regular fashion between the two extreme values given above.

The substance is supplied to the screening surface by a conveyor **41.**

The undersize, consisting of those particles smaller than the mesh which have succeeded in passing through the screening surface, falls down chutes **31** to **40** onto a conveyor **42.** The oversize (the particles larger than the mesh) and the ungraded undersize, that is the fine particles which have not succeeded in passing through the screening surface, fall onto a conveyor **43.**

I claim:

1. A method for screening a mixture of particles of different sizes advancing in the form of a continuous bed on a screening surface formed by successive sections having calibrated openings, vibrating said surface, thereby insuring the agitation of the bed and its onward movement, entirely feeding said mixture on the screening surface at the upstream end thereof, and reducing the product of speed of advancement of the bed by its breadth so that the ratio of the bed depths at the downstream end with respect to the upstream end of said screening surface is rendered at least equal to 1.

2. A screening method according to claim **1** wherein the screening surface is of a constant breadth and the sections are similar, subjecting the sections to the same vibratory characteristics, and varying the downward and upward slopes of the sections to obtain the desired variations in speed for rendering the ratio of the bed depth at the downstream end with respect to the upstream end of the screening surface at least equal to 1.

3. A screening method according to claim **1** wherein the screening surface is of a constant breadth, subjecting the sections to different vibratory characteristics, and varying said vibratory characteristics to obtain the desired variations in speed for rendering the ratio of the bed depths at the downstream end with respect to the upstream end of the screening surface at least equal to 1.

4. A screening method according to claim **1** wherein the screening surface is of a constant breadth, subjecting the sections to different vibratory characteristics, both varying the downward and upward slopes of the sections and varying said vibratory characteristics to obtain the desired variations in speed for rendering the ratio of the bed depth at the downstream end with respect to the upstream end of the screening surface at least equal to 1.

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