Jan. 16, 1968 I. J. CLARKE-POUNDER 3,363,759

SCREENING APPARATUS WITH ROTARY PULSING MEMBER

Filed April 29, 1964 7 Sheets-Sheet 1

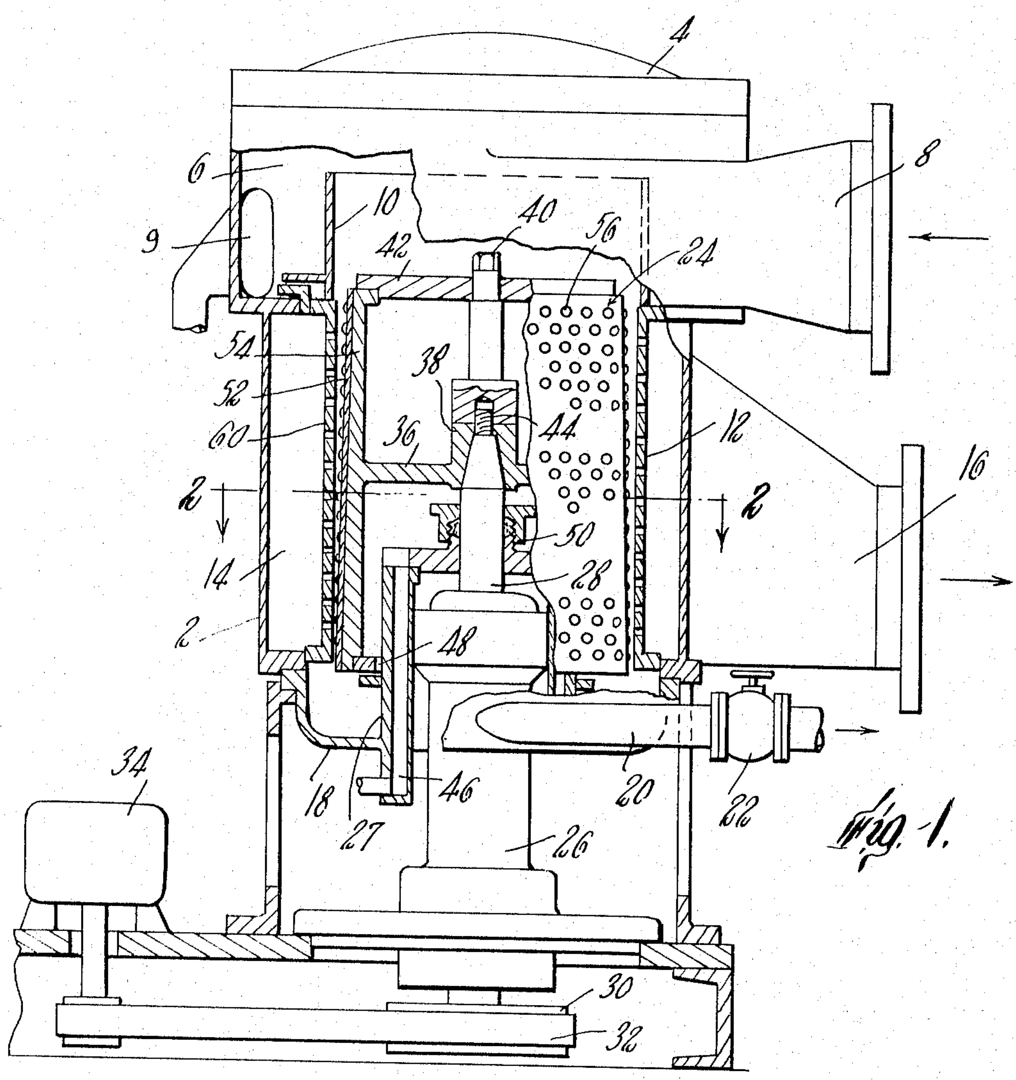


Fig. 1.

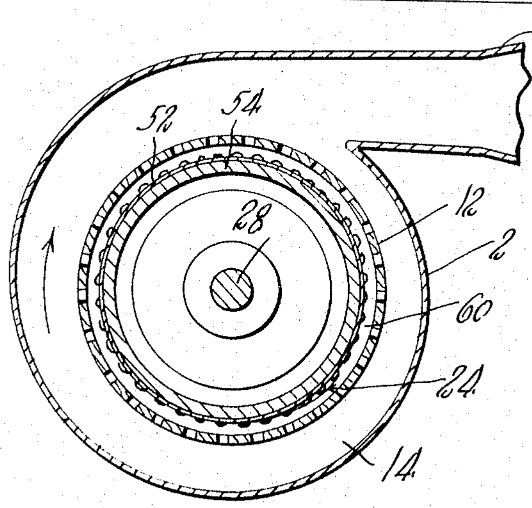


Fig. 2.

SCREENING APPARATUS WITH ROTARY PULSING MEMBER

Filed April 29, 1964

7 Sheets-Sheet 2

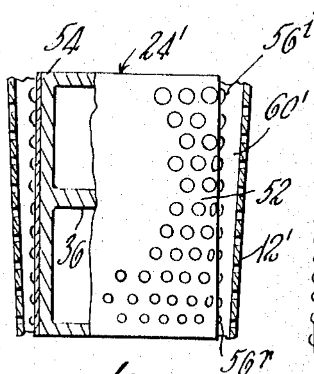


Fig. 7.

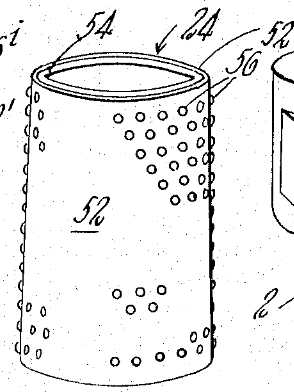


Fig. 4.

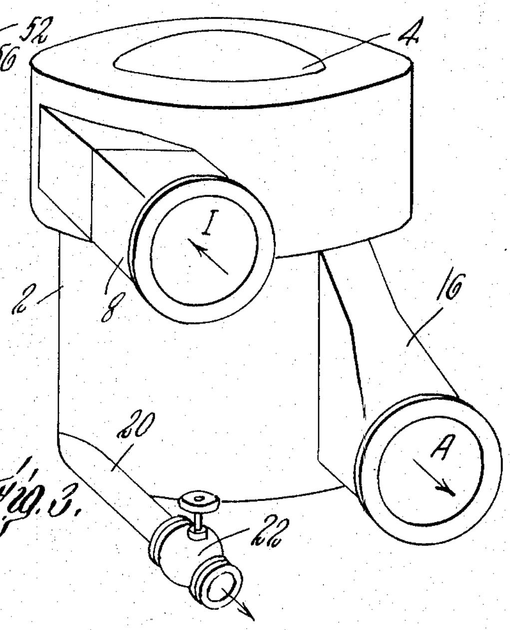


Fig. 3.

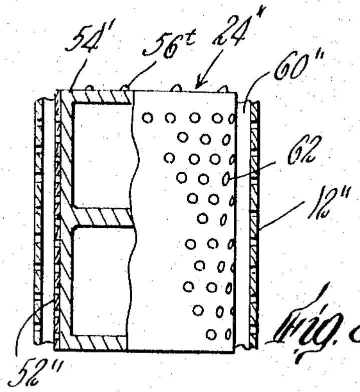


Fig. 8.

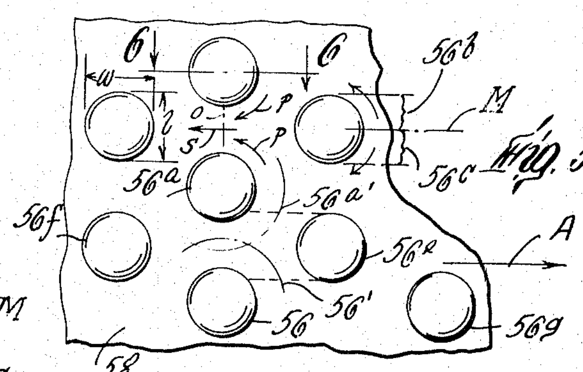


Fig. 5.

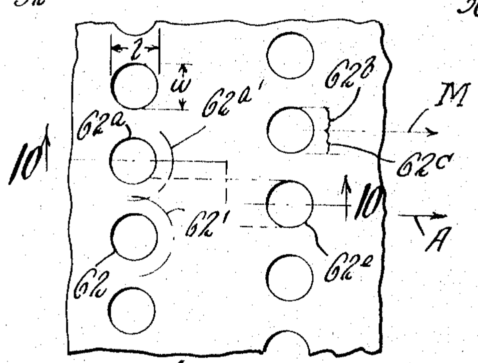


Fig. 9.

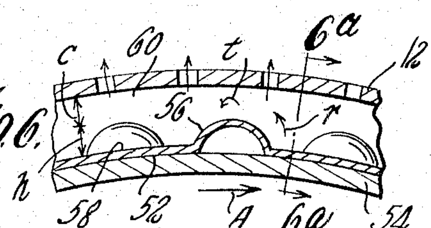


Fig. 6.

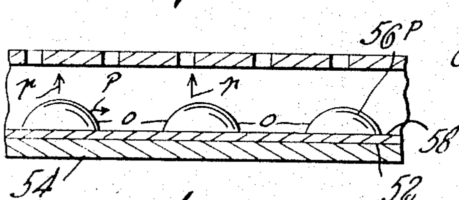


Fig. 6a

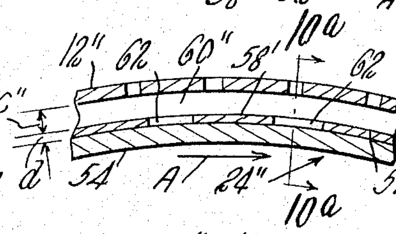


Fig. 10.

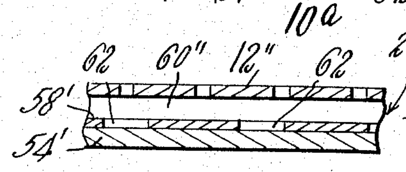


Fig. 10a

Fig. 11.

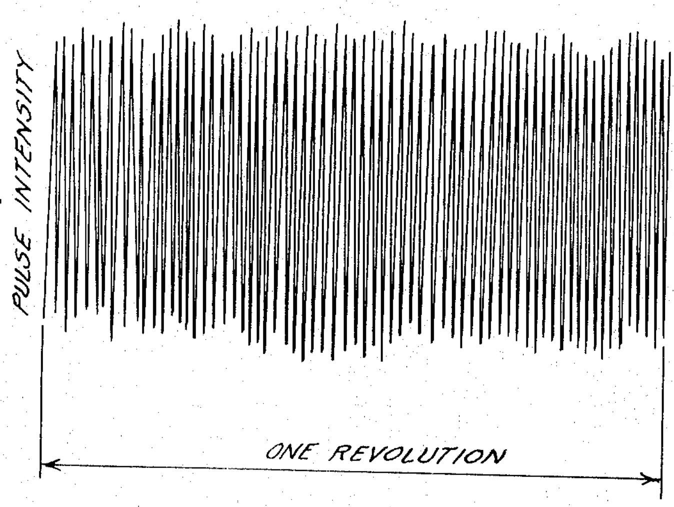


Fig. 13.

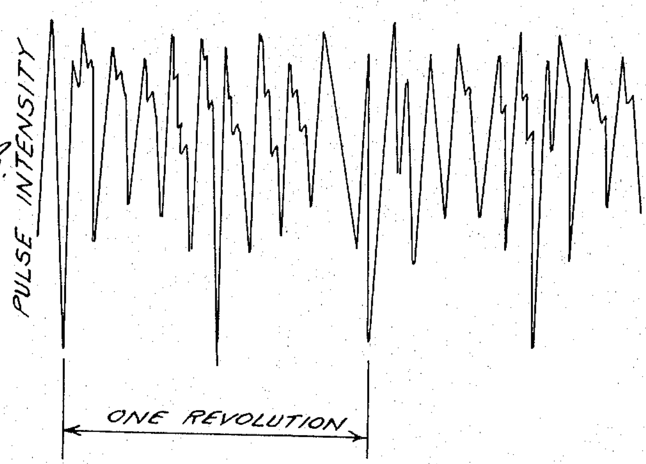
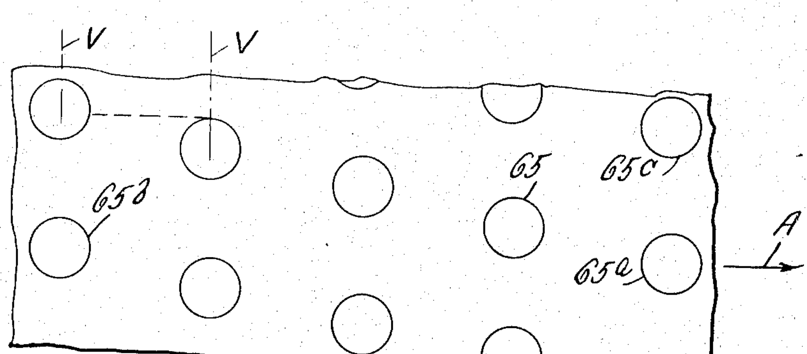


Fig. 12.



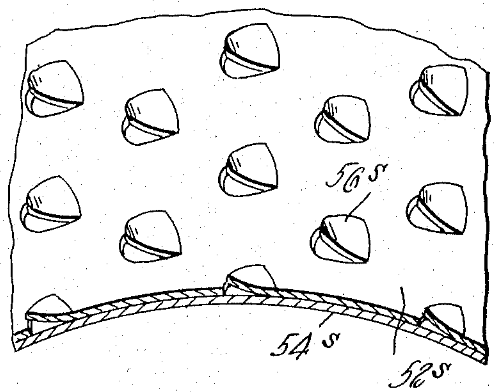


Fig. 14.

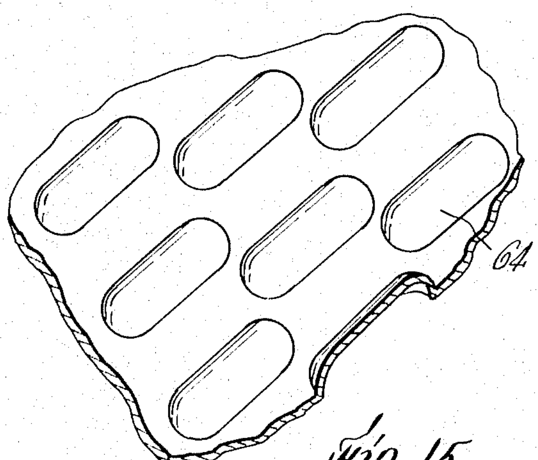


Fig. 15.

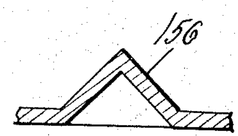


Fig. 16.

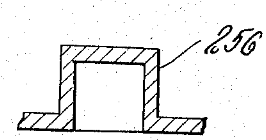


Fig. 17.

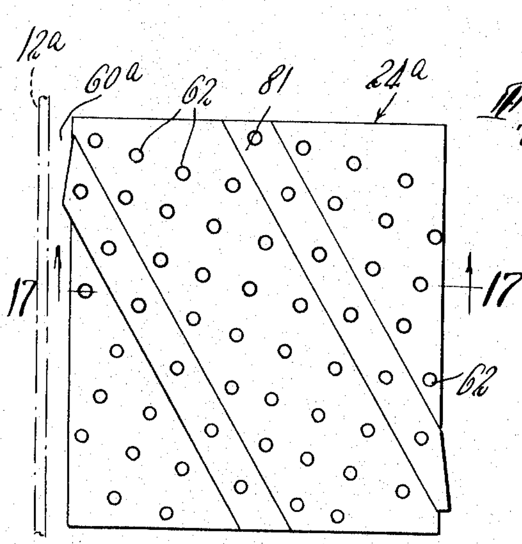


Fig. 18.

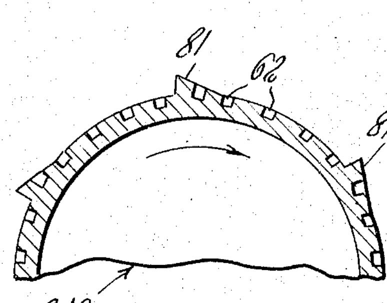


Fig. 19.

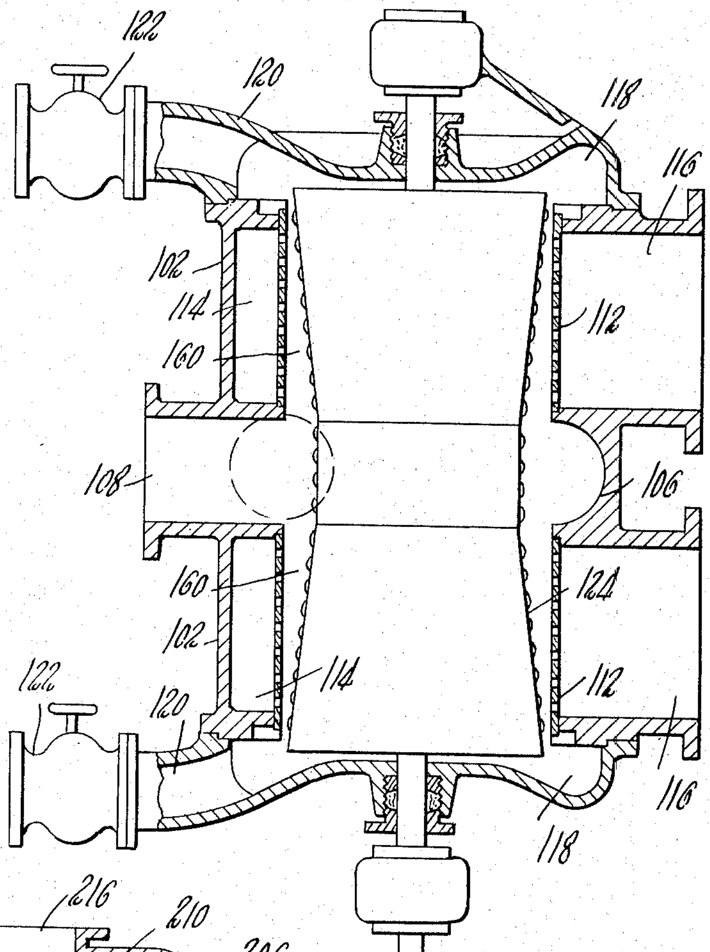

122
120
118
116
102
114
112
160
108
106
160
124
102
122
120
114
112
118
116

Fig. 20.

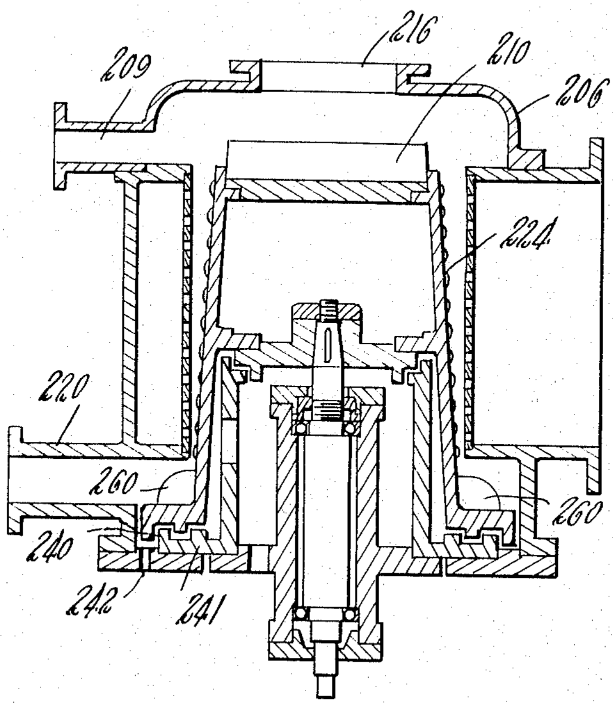

216
210
209
206
224
220
260
260
240
242
241

Fig. 21.

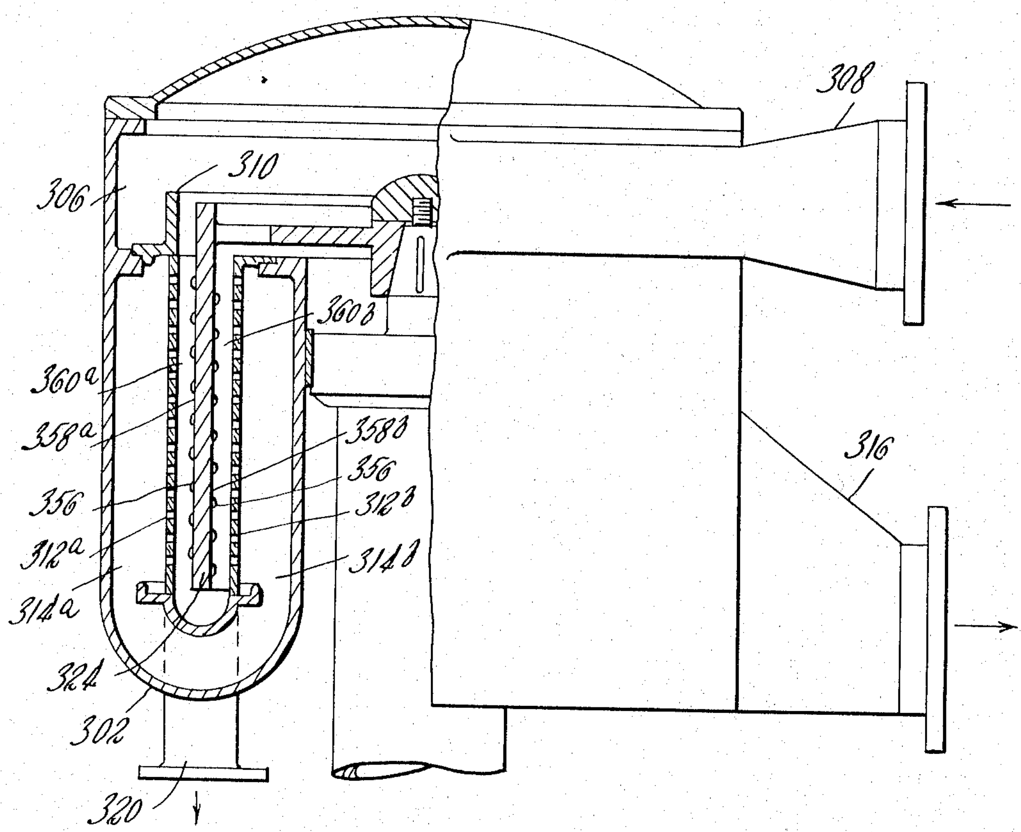

308
310
306
360b
360a
358a
358b
356
356
312b
312a
314b
314a
316
324
302
320

Fig. 22.

Jan. 16, 1968   I. J. CLARKE-POUNDER   3,363,759

SCREENING APPARATUS WITH ROTARY PULSING MEMBER

Filed April 29, 1964   7 Sheets-Sheet 7

Fig. 23.

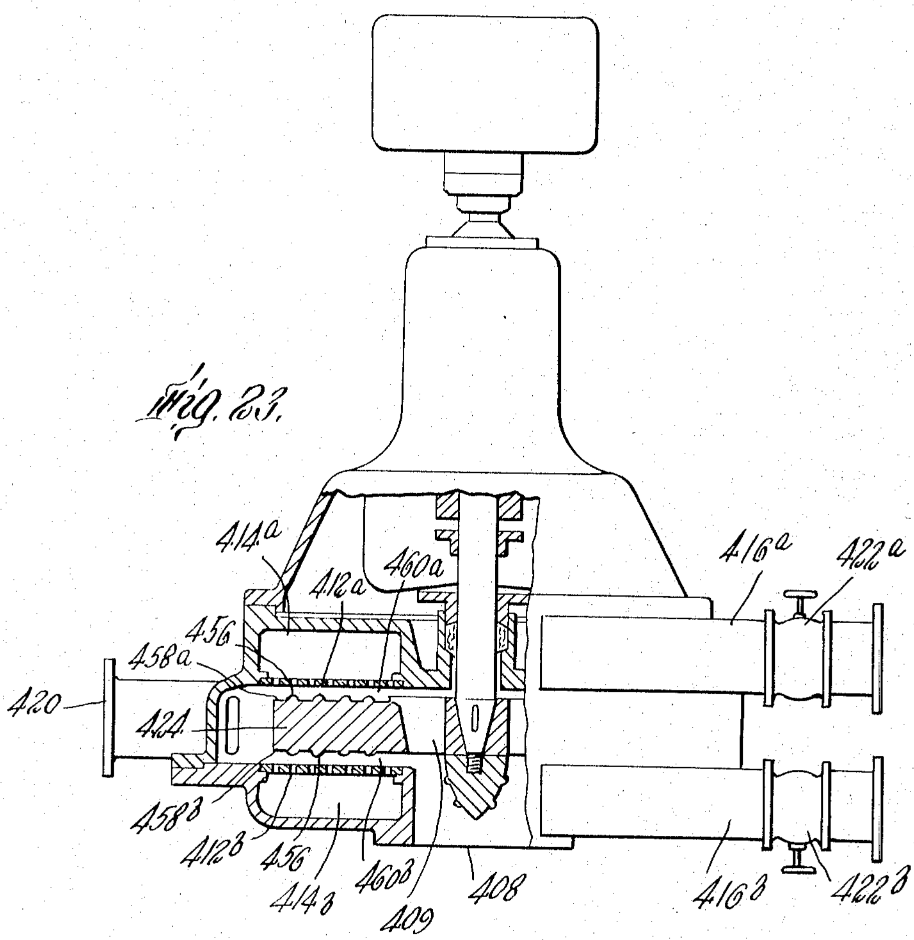
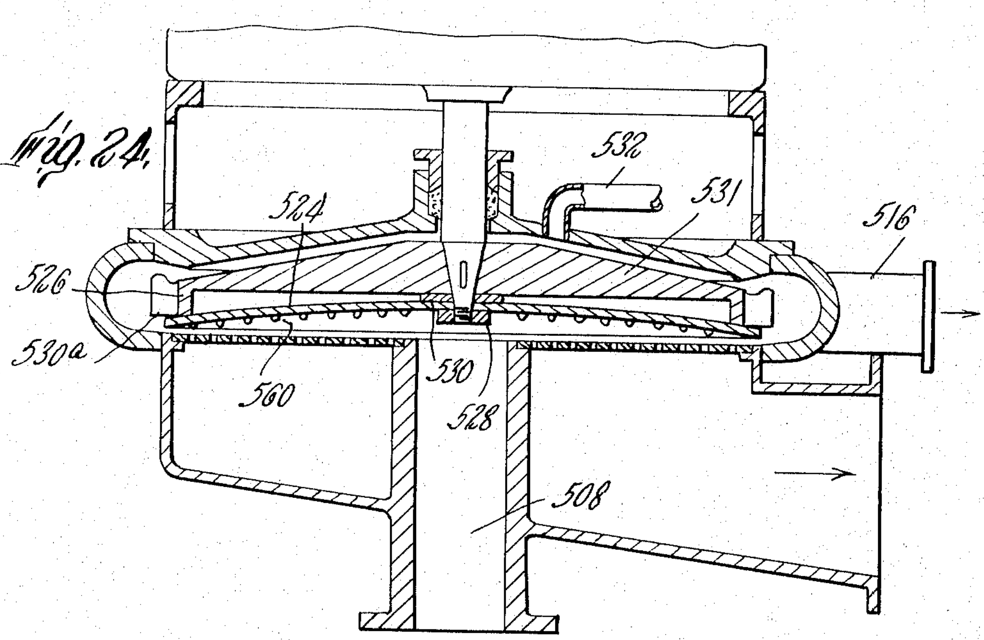


Fig. 24.



3,363,759
Patented Jan. 16, 1968

3,363,759

SCREENING APPARATUS WITH ROTARY PULSING MEMBER

Ian J. Clarke-Pounder, Pierrefonds, Quebec, Canada, assignor to Bird Machine Company, South Walpole, Mass., a corporation of Massachusetts

Filed Apr. 29, 1964, Ser. No. 363,438
20 Claims. (Cl. 209—273)

This invention relates to the screening of fluids comprising mixtures of fibrous material and liquid and in particular to paper pulp fluids and the like.

Prior art screening devices for accomplishing fine screening, e.g. to remove slivers, shives and foreign matter from pulp, have suffered from a number of serious limitations. One such limitation is the inability to process a wide range of pulp consistencies, and particularly high consistencies ranging to 2 percent solids and above, and another limitation is the need for substantial dilution liquid to be added to the pulp during screening. With either low consistency pulps, or when substantial dilution liquid is added during screening, it is necessary after screening, for the purpose of achieving a thick or dry pulp, to remove the excess liquid at substantial expense through the use of thickener devices.

Another limitation has been the inability of prior art devices to achieve desired levels of cleanliness of the screened fluid i.e. removal of objectionable material, under pressurized conditions, it having been found necessary under pressurized conditions to use fine screening devices in series, or to maintain very large reject flows from the inlet side of the screen in order to achieve satisfactory cleanliness levels, either of which adversely affects the cost of producing the pulp. As is well known, it is desirable to operate under pressurized conditions in order to avoid addition of air and impurities to the pulp and to enable location of the screening device at any level in the building.

Another limitation is that prior art fine screening apparatus have been large, having large screen plate areas to be maintained and being expensive to fabricate.

Accordingly, one principal object of the present invention is to enable the efficient fine screening of high consistency pulp without dilution, another principal object is to achieve an acceptably clean output under pressurized conditions without the need of series screening or unduly large reject flow, and another principal object is to achieve a smaller screen apparatus requiring a smaller screen area per unit volume flow through the screen as well as per unit weight of output pulp through the screen.

Still further objects of the present invention are to provide a basic screening apparatus which, by minor alterations, is capable of handling a wide variety of pulps for the purpose of achieving a wide variety of effects. A further object is to produce a screening apparatus which is simple and economical to manufacture and maintain.

According to the present invention the pulp at the inlet side of an apertured screen member is exposed to a rotary wall member that has an irregular surface characterized by having a multiplicity of discrete surface portions offset from the remaining base surface of the wall member, for the purpose of producing localized changes in volume in the screening zone defined between the rotary wall member and the screen member. The offset surface portions are distributed over the surface of the wall member and can be generally described as being quite small relative to both the length and width of the screen member or corresponding wall member, and are shaped to move with the wall member relative to the fluid. The projected surface area of each offset surface portion upon a plane parallel to the base can be characterized both as having a length to width ratio less than about 5 to 1, preferably

substantially less in many instances, and as being at least substantially equal to, preferably greater than, the projected area of the impelling surface of the offset surface portion upon a plane perpendicular to the direction of movement.

The offset surface portions may project toward the screen member from the general base surface of the wall member forming "bumps," or the offset surface portions may extend away from the screen member forming "dents," or combinations of the two may be employed, alone or with other devices. In the case of bumps it will be appreciated that localized reductions of volume are produced as the bumps move with the wall member, the bumps displacing the fluid both away from the wall member in the direction of the screen member and parallel to the wall and screen members, and in the case of dents similar localized additions of volume are produced.

What is meant by the "impelling" surface of a bump is the entire forwardly directed surface of the bump. With respect to dents, the "impelling" surface is limited to so much of the inward extent of the dent as is in relatively movable contact with the fluid.

In the case of bumps it is preferable that each should have a width and length not substantially less than its height, preferably both greater than its height; should preferably decrease in cross-sectional area parallel to the base, from the base outwardly; and should preferably have rounded leading sides.

In the case of dents it is preferable that each should have a width and length not substantially less than its depth, preferably both greater than its depth. The dents may have decreasing cross-sectional area parallel to the base, from the base inwardly, as well as rounded sides.

With movement of the wall member the multiplicity of offset surface portions produce a very high number of small localized turbulences in the fluid in the screening zone, this being particularly effective when the distance between the closest part of the wall member and the screen member is less than 2 inches, in many cases preferably substantially less. These small turbulences condition the fluid in a manner to produce a fluidizing effect, that is to say that the fluid is kept in a more or less homogenized state, i.e. preventing the fibers from forming clusters, and also preventing the blinding of the screen member.

Two characteristics are preferable for maximizing the fluidizing effect of the offset surface portions, one being that the offset surface portions adjacent to each other be shaped and spaced to produce conflicting, radiating disturbances in the fluid. In other words, in the case of either bumps or dents, the pressure pulses generated by the offset surface portions should radiate into each other before they have become substantially attenuated. Bumps which are adjacent each other in the direction transverse to the direction of movement are shaped to displace fluid toward each other, the spacing between the bumps providing a path through which at least part of the displaced fluid can pass, with relative localized increase in speed.

The second characteristic is that at least some of the offset surface portions should be adapted to produce similar disturbances in opposite directions parallel to the wall member, transverse to its direction of movement, a feature that is best achieved by each offset surface portion having parts lying on both sides of a line projected along the direction of movement through the middle of the forward-most part of the offset surface portion.

Certain preferable shapes for the offset surface portions achieve effective combinations of high degree of fluidization, freedom from accumulation or hangup of fibers thereupon and simplicity of manufacture. Among these are globular segments with the maximum dimension at the wall member, desirable for bumps, and generally cylindrical shapes, with the cylinder axis normal to the direction of travel, which are suitable for dents. It is preferable to have the ratio of base width to length of the offset surface portions substantially equal to one, but it is also possible to employ offset surface portions having elongated bases.

Another feature which lends effectiveness to the bumps and dents is their being spaced apart generally over the surface of the wall member, and preferably at least some of the are located transversely to the direction of movement in a pattern by which their paths of movement overlap, this overlapped relation existing over the entire transverse extent of the screen member so that every point of the screen member lies along the path of movement of at least one of the offset surface portions.

Furthermore, it appears advantageous that there be at least on the order of 5 offset surface portions or more per square foot of area of the wall member.

A particularly important feature of the invention is that an extremely high consistency pulp can be screened by use of high frequency pulses produced by unusually rapid movement of the wall member. Similarly, even with lower consistency stocks, the unusually rapid movement and high frequency produce a marked increase in the output while still maintaining high levels of cleanliness and satisfatcory reject flow rates.

While the speed of the wall member and the frequency of the disturbances can be varied over a considerable range, even the slowest speeds and frequencies are above those produced by prior art blades and foils. Thus, generally the wall member should be driven at a surface speed in excess of 3,000 feet per minute, establishing a basic pulse frequency in excess of 3,000 cycles per minute at a given point on the screen, assuming, as is preferred, the successive bumps or dents which produce pulses at any given point are not more than 1 foot apart in the direction of movement. But beyond that, when the screening apparatus is considered for high consistency output paper pulps, i.e. pulps above 1.5 percent consistency, then the drive means preferably should move the wall member at a predetermined speed in relation to the spacing of the surface portions along the direction of movement sufficient to produce pulses in the fluid at every given point in the screening zone in excess of 6,000 cycles per minute.

In the present most preferred form the screen member takes the form of a surface of revolution and the irregular surfaced wall member is also in the general form of a surface of revolution and is disposed within the screen member, defining therebetween an annular screening zone. Advantageously, for pressurized operation, all the fluid conduits into and out of the screening apparatus, and the casing thereof, are adapted to withstand substantial fluid pressures, e.g. in excess of 50 p.s.i., and the reject conduit is provided with a means to regulate the reject flow, which can regulate the cleanliness of the accepted stock. In such an embodiment in some cases it is advantageous that the spacing between the wall member and the screen member, or at least between the base surface of the wall member and the screen member, decrease with increased distance from the point of entry of the fluid being screened. Also, it is advantageous that substantially all of the surface of the wall member be closed to the entry of diluting liquid, for reasons indicated above.

In a presently preferred form the offset surface portions are defined as integral portions of the general wall member. In the case of a cylindrical wall member, for instance a plate could be first dented or bumped with a die while the plate is in a planar shape, and thereafter the plate can be bent into the general form of a surface of revolution.

In the figures:

FIG. 1 is a side view, partially in vertical cross-section, of a preferred screening apparatus according to the present invention:

FIG. 2. is a horizontal cross-sectional view of the screening apparatus of FIG. 1, taken on line 2—2 thereof;

FIG. 3 is a perspective view of the exterior of the screening apparatus of FIG. 1;

FIG. 4 is a perspective view of the particular rotary drum shown in FIG. 1;

FIG. 5 is a partial development of the outer surface of the rotary drum of FIG. 4;

FIG. 6 is a horizontal cross-sectional view of a portion of the rotary drum taken on line 6—6 of FIG. 5 showing its relationship to the adjacent part of the screen member;

FIG. 6*a* is a vertical cross-sectional view taken on line 6*a*—6*a* of FIG. 6;

FIGS. 7 and 8 are side views, partially in cross-section, of alternative relationships of rotary drums and hollow screen members;

FIG. 9 is a partial development of the surface of the rotary drum of FIG. 8;

FIG. 10 is a horizontal cross-sectional view similar to FIG. 6 of the rotary drum of FIG. 9 taken on lines 10—10 of FIG. 9;

FIG. 10*a* is a vertical cross-sectional view taken on line 10*a*—10*a* of FIG. 10;

FIG. 11 is a diagram of the pressure pulses obtainable with the rotary drums of FIGS. 4, 7 and 8;

FIG. 12 is a partial development of an alternative surface for a rotary drum;

FIG. 13 is a diagram of the pressure pulses obtainable with the rotary drum of FIG. 12;

FIGS. 14 and 15 are partial perspective views of rotary drums having alternative forms of bumps;

FIGS. 16 and 17 are each horizontal cross-sectional views of alternative bump forms;

FIGS. 18 and 19 are side and cross-sectional views of still another rotary drum employing dents of the present invention in combination with bar members;

FIG. 20 is a vertical cross-sectional view of an alternative form of screening apparatus which is capable of double action;

FIG. 21 is a vertical cross-sectional view of another alternative form of the screening apparatus;

FIG. 22 is a side view, partially in vertical cross-section, of an alternative form of screening apparatus employing concentric inner and outer screen members between which is mounted a rotary wall member having bumps;

FIG. 23 is a side view, partially in vertical cross-section, of another alternative form of screening apparatus employing axially spaced-apart disc-form screening members between which is mounted a disc-form rotary wall member having bumps; and

FIG. 24 is a vertical cross-sectional view of still another alternative form of screening apparatus employing a disc-form screening member and a variable contour, disc-form rotary wall member having bumps.

Referring now to the screening apparatus shown in FIGS. 1 and 3, the apparatus includes a vertically arranged pressure casing **2** including a removable pressure dome **4**. An annular inlet gutter **6** is defined in the upper region of the casing **2** and an inlet conduit **8** is arranged to introduce pulp to be screened into the inlet gutter **6**. A gutter trap **9** communicates with the inlet gutter **6** for removing heavy debris thrown to the periphery by centrifugal force.

The inlet gutter **6** communicates radially over a baffle **10** with the central part of the screening apparatus. Below the baffle **10** is located a circumferential, apertured screen member **12** whose walls are spaced inwardly relative to the casing **2**, so as to define an annular accepts chamber **14** outside of the screen member **12**. A tangential accepts conduit **16** adapted to remove fluid under substantial pressure is connected to the accepts chamber **14**, having its initial portion extending the full height of the screen member **12**.

Below the screen member **12** is arranged an annular rejects gutter **18** in communication with the inside of the cylindrical screen member **12**. A rejects conduit **20** communicates with this rejects gutter **18**, this conduit being capable of removing fluid under substantial pressure and being provided with a valve **22** which serves to regulate the flow therethrough. While this valve is shown regulatable by hand, it can also be automatically regulated e.g. to respond to changes in the inlet flow rate or changes in the pressure differential between inlet and accepts conduits or by changes in the reject consistency. Also, while the rejects conduit **20**, shown tangential to the rejects gutter **18**, extends in the direction opposite from the movement of inlet pulp, in some instances it may extend in the same direction, or be not tangential at all.

Referring to FIG. 2, it will be observed that the pressure casing **2** is slightly scroll-shaped in horizontal cross-section, and the screen member **12** is arranged therein so that the accepts chamber **14** increases in radial width gradually about its circumference, all the way along its extent until it discharges to the accepts conduit **16**.

Referring to FIGS. 1 and 2, in this embodiment the irregular surfaced wall member of the invention comprises a rotary drum **24** of circular cross-section mounted inside and concentric with the cylindrical screen member **12**. As shown, preferably the rotary drum **24** is of frustro conical shape, has a length equal to that of the screen member **12**, a diameter substantially the same as the screen member, though with clearance, and is continuous circumferentially. Regarding the details of mounting in this preferred embodiment, the rotary drum **24** is mounted from the bottom end only upon a rotary shaft **28** which extends through a stationary bearing pedestal **26**. For this purpose two vertically spaced-apart sets of ball bearings (not shown) are employed in the pedestal, one or both of which can take the axial thrust.

The lower end of the rotary shaft **28** extends below the bearing pedestal **26** and carries a pulley **30**. This pulley is driven by a belt **32**, or a series of belts, by an electric motor **34** capable of turning the drum **24** to develop a surface speed of at least 3,000 f.p.m. when the casing is full of fluid.

Referring still to FIG. 1, preferably the drum member **24** has a central web **36**, located substantially mid-way between its ends, at least near its center of gravity, joined to a hub **38** which is removably mounted upon rotary shaft **28** by means of a mounting nut **40** which may extend through the end cover **42** of the drum down to the threaded end **44** of the rotary shaft **28**.

In this embodiment provision is made for introducing clear liquid to the reject gutter **18** for the purpose of maintaining the thick rejected material in a sufficiently fluid state to flow through the reject conduit **20**. For this purpose it is advantageous to leave the lower end of the drum unsealed, and provide an upward flow passage **46** for the clear liquid into the drum **24**, the fluid proceeding from passage **46** down through a slot **48** defined between the lower end of the rotary drum **24** and the stationary pedestal structure **27**. In this embodiment it is also preferred to employ a stuffing box **50** on shaft **28** to prevent leakage.

The stationary screen member **12** may be of the usual form for fine screening, e.g. it can have 23 percent open area provided by circular holes of 1/16 inch diameter spaced in a staggered pattern on 1/8 inch centers.

The rotary drum **24** in this embodiment is of tapered form, increasing in diameter towards the reject gutter **18**, and is defined by an outer plate **52** mounted upon an inner support plate **54**.

Referring to FIGS. 4–6, the rotary drum shown in FIG. 1 has an irregular surface with surface portions offset from the base surface **58** of outer plate **52**, projecting toward the screen member, forming bumps **56**, these having heights *h* (FIG. 6), from the base surface **58**, less than their lengths and widths *l* and *w* (FIG. 5), having

decreasing cross-sectional area parallel to the base surface **58**, from the base outwardly (FIG. 6), and having rounded, leading sides as can be seen in FIGS. 5 and 6. More particularly, in this specific preferred embodiment, the bumps are in the form of globular segments protruding outwardly from the base surface **58** of the outer plate **52**, and as can be seen in FIG. 6, each bump **56** protrudes into the space defined between the base surface **58** and the screen member **12**, this space hereafter being referred to as the screening zone **60**. It will be appreciated that with movement of the rotary drum **24** in the direction of the arrow A, each bump **56** produces a localized reduction of volume to the screening zone **60** as it travels with the rotary drum **24**. Each bump **56** therefore produces localized radial displacement, arrow *r*, of the fluid and turbulence arrow *t*, FIG. 6; similarly, the bumps displace fluid sideways, parallel to the axis, arrows *p*, the fluid flowing in paths *s* circumferentially at increased speed through the openings O between the discrete bumps as relative movement between the rotary drum and the fluid progresses. A great many of these disturbances occur due to the multiplicity of bumps **56** present on the rotary drum **24** and as a result the fluid in the screening zone is homogenized and fluidized. The ability of the displaced fluid to flow between bumps in paths *s* close to the base surface **58** achieves the fluidization without detrimentally affecting the screening action of the apertures, while the thus moderated localized radial displacements *r* help propel the liquid through the apertures.

Preferably the clearance *c* (FIG. 6) between the nearest parth of the outer plate **52**, i.e. the tops of the bumps **56**, and the screen member **12** is maintained less than 2 inches, preferably substantially less, to ensure that the action of the various bumps is propagated to the screen member before being substantially attenuated.

As will be discussed in more detail later, the bumps can take various forms, but preferably have their leading parts of rounded shape, at least in one of the two transverse directions, to prevent accumulation of fibers thereon as well as achieving better movement relative to the fluid, and avoiding degradation of the pulp. Moreover, referring to FIG. 5, in which the direction of movement is indicated by arrow A, it is advantageous that the bumps have two particular characteristics. The first is that they be shaped and spaced so that bumps that are generally adjacent to each other in the direction transverse to the direction of movement A produce conflicting, intersecting disturbances, as indicated by the fragment of disturbance wave **56'** created by bumps **56** and disturbance wave **56a'** produced by transversely adjacent bump **56a**. The intersection of these disturbance waves promotes the homogenization and fluidization of the pump.

With regard to the second characteristic it has already been explained that each bump produces a radial effect *r* and a transverse effect *p* in at least one direction. Referring to FIG. 5, the second characteristic is that each bump is shaped to produce disturbance in opposite transverse directions so that in combination with other bumps, it produces intersecting axial disturbances at both its sides, or at least can produce a substantially greater disturbance effect than can a bump acting in a single transverse direction. The structure that achieves this double action most effectively is defined by parts **56b** and *c* extending to opposite transverse sides of a line M projected along the direction of movement, through the middle of the forward-most point of the bump. With relative movement between rotary drum **24** and the fluid each such bump **56** splits the fluid flow, and displaces it axially in opposite directions transverse of direction of movement A, in effect reducing the circumferential flow cross-section at any given point of the screening zone **60** that is aligned with the moving bump.

Referring still to FIG. 5, it will be obvious that the discrete bumps have only very localized pulse effects but every point along the axial length of the screen member

12 and the fluid in the screening zone 69 (FIG. 6) preferably lies along the path of travel of at least one of the bumps, such being assured by the arrangement of the bumps as shown in FIG. 5 wherein the bumps are staggered so that the bumps 56 and 56*a* which are closest transversely to the path of travel of an intermediate bump 56*e* are out of transverse alignment with that bump 56*e*, and have paths that overlap with its path, such overlapping being desirable throughout the swept axial length of the screen member.

Comparing FIG. 6*a* with FIG. 5 it can be seen that the impelling surface area 56*p* of the bump 56 projected upon a plane perpendicular to the direction of travel, (FIG. 6*a*) is less than the projected area of the bump upon a plane parallel to the base (FIG. 5). In FIG. 6*a* openings O are also seen.

Referring again to FIG. 1, it is seen that the screening zone 60 has a tapering form, decreasing in radial depth in the direction of the rejects gutter 18, due to the fact that the screen member 12 is cylindrical and the rotary member 24 is tapered.

Referring to the alternative embodiment of FIG. 7, the screening zone 60′ tapers in the same direction, but due to the taper of the screen member 12′ rather than of the rotary drum 24′. Another preferable feature of FIG. 7 is that the bumps 56*i* at the inlet end of the rotary drum 24′ are substantially higher than the bumps 56*r* at the reject end, preferably the bumps decreasing in height progressively from inlet to reject end, and also in base width and length.

While in these present embodiments the screening zone 60 tapers to smaller radial depth in the direction of the rejects outlet, it is possible in some instances for the tapering to be provided in the opposite sense, to larger radial depth in the direction of the rejects outlet.

Referring to the alternative embodiment of FIG. 8, the inlet zone 60″ is of constant radial depth, the screen member 12″ and the rotary drum 24″ both being cylindrical.

Referring to FIGS. 9 and 10 as well as to FIG. 8, this embodiment differs from those previously shown in that the offset surface portions are dents 62 extending inwardly from base surface 58′ rather than bumps, except that bumps 56*t* (FIG. 8) may be provided on the top of the drum as shown, the dents adapted to produce localized additions of volume to the inlet zone 60″ as they move with the rotary drum 24″. Referring to FIG. 9, it will be seen that the disturbance waves 62′ and 62*a*′ of transversely adjacent dents 62 and 62*a* intersect, just as with the bumps described above, and that the dents are adapted to produce pulses in opposite directions transverse to the direction of movement of the rotary drum 24″ due to the parts 62*b* and 62*c* extending to either side of a line M projected along the direction of movement through the forward-most part of the dent. It will also be seen from a comparison of FIGS. 9 and 5 that those dents, e.g. dents 62 and 62*a*, which are closest to the path of travel of a given dent transversely thereto, e.g. 62*e*, are out of transverse alignment with that given dent. These have paths that overlap for the purpose of ensuring that every part of the screening zone 60″ exposed to the wall member lies along the path of travel of at least one dent.

Referring to FIG. 10, the dented rotor is of particularly simple construction, since it can comprise only a smooth drum-like inner support plate 54′ upon the outer surface of which is mounted outer plate 52′ which can comprise a perforated plate. This simple construction is possible because it is found that dents whose depths d are less than their base lengths l and widths w (FIG. 9) are particularly effective. Under some circumstances, however, deeper dents could be provided. The extra deepness of the dents would not affect the operation of the wall member in any particular way since the impelling surface of the dents is limited essentially to the part of the trailing wall of the dent that is in relative movable contact with fluid, the deeper part of the dent, which is not contacted by moving fluid from the screening zone, having no effect. The effective depth d of the dent is generally no more than the maximum height h of an operable bump having the same base dimension, this effective depth d being generally less than ¾ the base dimension of the dent in the direction of movement A.

One distinguishing feature between dents and bumps is that the bumps preferably have rounded, preferably streamlined, leading parts for the purpose of preventing the accumulation of fibers thereon, it being a well-known fact that if fibers accumulate upon a rotary drum, eventually a string will form trailing behind the member a substantial distance. For this reason, the globular form of the bumps such as shown in FIG. 5 is particularly preferred, since the leading parts are rounded in both the radial and transverse directions. On the other hand, with dents the moving liquid within their effective volume is turbulent and prevents the accumulation of fibers therein. Therefore, it becomes possible to have relatively sharp changes in the surface between base wall member and dent, which makes the cylindrical perforations shown in FIG. 10 useful. Such a form causes a sharp volumetric change, due to the sudden drop-off from the base surface which is believed to help the fluidizing action, but globular form may require less power.

Referring to the diagram of FIG. 11, pulses are depicted which any of the irregular surfaced rotary drums described above can produce at a point on the surface of the apertured screen member aligned with the center of a circumferential row of offset surface portions, see FIGS. 5 and 9.

The value of the intensity of the pulses varies with different rotor configurations, governing factors being the size and shape of the offset surface portions, the speed of rotation and the radial distance between the drum and screen members. In a total revolution the number of pulses that occur corresponds exactly to the number of offset surface portions to be counted in a circumferential band of the rotary drum embracing all of the offset surface portions in adjacent circumferential rows, counting in zig-zag fashion e.g. bumps 56*g*, 56*e*, 56 and 56*f*, etc. (FIG. 5).

In FIG. 12 is shown an alternative arrangement for the offset surface portions 65, arranged in a stair-stepped pattern, the offset surface portion in each successive axial row V being stepped down about one half diameter, so that half of the paths of movement of surface portions in successive rows overlap. The axial spacing of adjacent portions in the same vertical row is greater than the diameter of a single portion, and can be substantially greater than that shown. The pattern can be arranged to repeat over the developed area of the rotary wall member, as indicated by the alignment of surface portions 65*a* and 65*b*.

In FIG. 13 is shown a diagram of pulses acting upon a given point on the screen member. Every vertical row of offset portions is represented by a pulse, the largest pulses corresponding to offset surface portions whose paths of movement correspond with the given point, e.g. portions 65*a* and 65*b*, the progressively decreasing pulse intensities corresponding to progressively greater spacing from the given point of the paths of movement of portions in successive rows, it being observable that the pulses radiate to points transversely beyond their paths of movement.

One of the advantages of the present invention is that an optimum rotary drum can be made for the specific type of pulp being processed, and if it is desired to process two or more different types of pulp through the same screening apparatus, it is necessary only to remove the rotary drum and replace it and the screen with appropriate ones for the new type of pulp to be processed.

There follows a table of experimental results obtained with rotary drums of different configurations. All of these tests were conducted with the screening apparatus generally as shown in FIG. 1, but with different rotary drums as indicated in the table. The screen plate cylinder for all of these tests was 18 inches in diameter and had an effective length of 19½ inches, substantially the same length as the rotary drum. It had 23 percent open area with 1/16 inch diameter holes formed in a staggered pattern on 1/8 inch centers.

The reject flow, R_w, through reject conduit 20, is given in terms of percent by weight of the total flow introduced to the screening apparatus.

The results of the table can be best understood by keeping in mind that it is usually desired to minimize K_{sa}, the cleanliness ratio, and R_w, percent rejects by weight, and maximize the rejects and accepts consistencies and the output tons per day.

From this table and from other data it has been observed that the output of the screening apparatus gener-

TABLE

	Test Run					
	A	B	C	D	E	F
Shape of Offset Portions	([1])	([2])	([3])	([4])	([4])	([5])
Number of Offset Portions Axially	12	11	11	24	24	[6] 8
Number of Offset Portions Circumferentially	34	24	11	[7] 70	68	[7] 6
Clearance Wall Member to screen member (in.)	7/16	5/16	5/16	9/16–3/16	13/16–7/16	¾
Speed, r.p.m.	1,500	1,195	1,195	1,750	1,750	1,195
Frequency, c.p.m., at given point	51,000	28,700	13,000	122,500	119,000	7,200
Power	140	53	67	169	156	64
Inlet Consistency, percent	1.29	1.09	0.84	1.91	2.04	1.16
Accept Consistency, percent	1.11	1.00	0.79	1.64	1.75	1.12
Output tons per day	154	95	114	107	115	138
Reject Consistency, percent	2.47	3.71	2.52	5.14	4.00	2.6
Reject Flow, R_{20}, percent	14.4	11.5	14.9	17.4	20.4	11.4
Cleanliness Ratio, K_{sa}	.066	.094	.107	.124	.080	.190

[1] B, 1" diam., 5/16" high.
[2] D, 5/8" diam., 1/8" deep.
[3] D, 1¼" diam., 1/8" deep.
[4] B, ½" diam., 3/16" high.
[5] B, 2" diam., ¾" high.
[6] Avge., spiral pattern.
[7] Average.

With regard to the table, tests A, D, E and F were conducted with a drum having only globular shaped bumps, as indicated by the letter B in the row entitled "Shape," while tests B and C were conducted with an entirely dented drum, indicated by letter D. In each case the general distribution of the bumps or dents is shown in FIGS. 5 and 9 respectively. For tests A, B, C and F both the rotary drum member 24 and the screen member 12 were cylindrical, thus forming a constant radial depth screening zone throughout the axial length of the screening apparatus. For test D the rotary drum alone was tapered, as shown in FIG. 1, and in test E the screen member was tapered, as shown in FIG. 7.

The clearance given in the table specifies the wall member to screen member clearance, which in the case of dents (FIGS. 9, 10 and 10*a*) would be the distance *c'* between the base surface 58' and the screen member, but in the case of bumps (FIGS. 6 and 6*a*) would be the distance *c* from the outer apex of the bump 56 to the screen member. In the case of bumps, the distance between the base surface and the screen member is computed by the addition of the clearance with the height of the bumps given in the row entitled "Shape."

All test runs above were conducted with groundwood pulp to which no dilution liquid was added in the screening operation. In these test runs the apparatus never plugged due to the consistency of the pulp which indicates that the screen member can operate at substantially higher consistencies, and indeed successful operation has already been accomplished at consistencies as high as 2.8% with groundwood pulp.

In the table, the term K_{sa} is the cleanliness ratio, representing the weight of objectionable particles remaining in the screened pulp per unit weight in accepts conduit 16, relative to the weight of objectionable particles in the original pulp, per unit weight in inlet conduit 8. This ratio is established by the passing of a predetermined weight of pulp through a flat laboratory screen member, having slotted apertures of .005 inch in width in the case of test runs A, B, C and F and .007 inch in width in the case of runs D and E.

ally increases with speed of rotation of the drum member and with decrease in clearance between the rotary drum and the screen plate. The cleanliness ratio, however, is improved with increase in the clearance between the rotary drum and the screen member and also with increase in the reject flow.

Excepting run A, all of the runs in the table were conducted with the rotary drum 24 rotating clockwise as seen in FIG. 2, in the same direction as the inlet flow in gutter 6. However, it is entirely possible to employ counter-clockwise rotation, which increases the output, but requires somewhat more horsepower relative to rotating the drum clockwise at the same speed.

One of the striking facts to be observed from the table is that extremely high inlet consistencies, i.e. around 2% consistency for groundwood, are efficiently screened under very high frequency pulse conditions.

Another fact to be observed is that excellent cleanliness is obtained under pressurized conditions, i.e. the screen member is totally submerged and under substantial pressure.

It is desired to make clear that this table is presented only for the purpose of showing some of the results obtainable, and is not by any means exhaustive of the types of results that can be obtained with various modifications and with operation on different pulps.

The screen member is applicable to chemical pulps such as produced in kraft mills, and to waste paper pulps as well as to the groundwood pulps, and is believed to have uses outside of the paper pulp field as well.

In the paper industry, the use of the screening apparatus is not restricted to the pulp mill, but may also be used as a tailing screen to take the rejects of the head box screen and remove therefrom good fibers while producing a high consistency reject output that can be directed, without a further thickening step, to a refiner, or indeed, the screen can be used at the head box, in advance of the slice, the high frequency of the pulsations being too high to adversely affect the flow conditions of the paper stock as it proceeds from the slice to the Fourdrinier wire.

As has already been discussed, one of the aspects of the present invention is the production of localized expansions and contractions of the pulp at high frequency, in excess of 3,000 cycles per minute, and for high consistency pulps preferably at a minimum of 6,000 cycles per minute. Another aspect of the invention which is complementary to the first is that the pulses are generated by discrete offset surface portions which are spaced apart transversely as well as in the direction of movement and are omni-directional in effect, and which are capable of the high speeds relative to the pulp which are necessary to obtain the desirable frequencies, fluidization, etc. In the case of bumps, their discrete nature, and the flow paths provided between them allow part of the liquid always to flow adjacent the base surface rather than all to be pulsed towards the screen, an important feature with respect to fine screening, because fluidization is thereby achieved in combination with a desirable amount, but not too great an amount, of radial force so that flow through the apertures is promoted, while still the objectionable material is prevented from passing through the apertures.

For finest screening, it is highly preferred that, as shown, the base surface **58** or **58'** be a surface of revolution coaxially arranged with the axis of rotation so that no radial displacements are obtained except those produced by offset surface portions, bumps or dents. Each bump or dent produces transverse displacement simultaneously with a radial displacement (and always with flow paths *s* (FIG. 5) present in the case of bumps), so that the radial effect is not too intense, nor too extensive in the direction transverse to movement.

As was stated, a wide choice is available of the form of the offset surface portions. Referring to the alternative embodiment of FIG. 14 the bumps comprise discrete, integral surface portions **56***s* formed by being struck from the base wall member **52***s*, so that the trailing parts are completely separated therefrom. The supporting member **54***s* is preferably continuous, preventing flow through the openings beneath the bumps.

Referring to FIG. 15 there is shown a view of alternative offset surface portions **64**. These are elongated. As shown these projections are in the form of bumps, with semi-circular cross section and rounded ends, however they could equally be dents and/or have flat sides or ends.

Referring to FIGS. 16 and 17 alternative cross sectional forms are shown, it being understood that the leading part of each can be rounded, at least in one of the transverse directions, in order to avoid the accumulation and stringing of fibers as discussed above, e.g. FIG. 16 can be the cross sectional shape of a cone **156** and FIG. 17 that of a cylinder **256**. Dents of these forms can also be employed.

With reference to FIGS. 18 and 19, it must be understood however that the discrete offset surface portions according to the invention can be employed in combination with other members to produce combined effects. In the particular embodiment of FIGS. 15 and 16 spaced apart helical bar members **81** are provided, and dents **62** are provided on the surface of the rotor **24***a*, preferably both on the bar members **81** and between them. These bar members decrease the cleanliness of the output pulp, but increase the flow through the screen plate, and may be useful for instance in the production of paper board. In connection with this embodiment, it must be understood that the dents, or alternatively bumps, must be employed if the advantages of this invention are to be achieved of fluidizing the stock in the screening zone to obtain the desirable effects already described.

Referring now to the alternative embodiment of FIG. 20 for the purpose of achieving a double action, the rotary drum **124**, provided with offset surface portions, either dents or bumps as described above preferably, tapers from the mid-portion outwardly in opposite directions to larger ends. This drum is disposed in coaxial relation with two cylindrical screen members **112**, one surrounding each end, and defining therewith two screening zones **160**. An inlet passage **108** is provided centrally of the rotary drum, between the screen members, discharging to an annular inlet gutter **106** surrounding the mid-portion of the rotary drum **124**.

Two pressure casing sections **102** are provided, one surrounding each of the screen members **112** in a spaced relation, defining therewith accepts compartments **114** from which accepts conduits **116** conduct the screened fluid. At opposite ends of the apparatus, communicating with the screening zones **160** are annular reject gutters **118** connected to reject conduits **120**, equipped with control valves **122**.

The operation of this screening apparatus is in principle the same as that of FIG. 1, however because it has a double accepts outlet, and a double reject conduit each provided with a separate valve member **122**, it can be used to feed two different pulp systems requiring different qualities from a single inlet flow, by virtue of the separate controls afforded by the two valve members **122** on the reject conduits.

Referring now to the embodiment of FIG. 21, the general construction of this preferred screening apparatus is similar to that of FIG. 1 except for the features to be described.

The inlet conduit **216** is axially aligned with the rotary drum **224**, and discharges against the free end thereof. A plurality of vanes **210** are provided on that end of the rotary drum, and due to its high speed the vanes fling the inlet stock outwardly to the guttertrap **206**, and also insuring even distribution of the pulp to the screening zone. Any heavy weight objectionable material can be intermittently removed through tangential outlet **209**.

At the opposite end of the rotary drum **224**, the lower part of the drum is preferably formed into a labyrinth seal **240** in cooperation with a stationary end casing member **241**, into which is introduced clear water or other liquid at **242** accomplishing two purposes. One, the liquid keeps the spacing between the rotary member and the end member free of the thick rejected pulp, so that the drum can rotate freely, and secondly, it dilutes to some degree the rejected pulp to enable it to flow freely.

Vanes **260** are also provided at the lower end of the drum member for propelling the high consistency rejects through the rejects conduit **220**.

This embodiment, just as the embodiments of FIGS. 1 and 20, is very well adapted for horizontal arrangement as well as vertical.

Referring to the embodiment of FIG. 22, two concentric, radially spaced-apart, cylindrical screen members **312***a* and **312***b* are provided between which moves a driven rotary wall member **324** having oppositely directed base surfaces **358***a* and **358***b*, from each of which bumps **356** project, to fluidize the pulp in screening zones **360***a* and **360***b*. Flow through the inlet conduit **308** enters gutter **306**, flows over baffle **310**, into the screening zones **360***a* and **360***b*. Accepted stock passes through the screen members **312***a* and **312***b* to accepts compartments **314***a* and **314***b*, defined by casing **302** surrounding the screen assembly, thence out through accepts conduit **316**. Rejects flow from the screening zones through rejects conduit **320**.

Referring to the embodiment of FIG. 23, two axially spaced-apart disc-shaped screen members **412***a* and **412***b* are provided between which moves a driven rotary wall member **424** of disc form having oppositely directed base surfaces **458***a* and **458***b*, from each of which bumps **456** project, to fluidize the pulp in screening zones **460***a* and **460***b*. Flow through the inlet conduit **408** enters axially to screening zone **460***b* and also passes axially through apertures **409** in the wall member to screening zone **460***a*. Accepted stock passes through the screen members **412***a* and **412***b* to accepts compartments **414***a* and **414***b*, thence out through accepts conduits **416***a* and **416***b* controllable by valves 422 and 422a. Rejects flow from the screening zones through rejects conduit 420.

Referring to the embodiment of FIG. 24, a single acting disc form screen apparatus is shown similar to the lower side of the screen apparatus shown in FIG. 23. The wall member 524, however, is mounted for variable contour, to taper the screening zone 560 radially to the degree required. This wall member 524 comprises a plate member capable of being dished. It is supported by rotor 531 only at its outer periphery by rotor ledge 526, and centrally by nut 528 and spacer washer 530. By adjusting the thickness of the spacer washer 530 the amount of taper can be varied or a nontapering zone can be provided.

Vanes 510 are provided at the periphery of the wall member for impelling the rejects, and clear liquid inlet 532 is provided to maintain the rotary member free to rotate and to dilute the rejects.

With the vanes omitted in some instances it is possible to reverse the flow through the screening zone employing rejects conduit 516 for inlet, and inlet conduit 508 for rejects.

While all of the wall members shown have had substantially the same working area as the screen members with which they are used (i.e. in the case of the drum they have substantially the same axial and circumferential dimension), and the bumps or dents have been uniformly distributed thereover, as is presently highly preferred, it must be understood that certain benefits of the invention are achievable when these conditions do not exist. For instance the distribution on the wall member may be irregular, even with substantial areas not covered, and/or the wall member itself may be discontinuous or have one or both dimensions substantially different from the dimensions of the screen member.

In conclusion, it must be observed that the present invention marks a substantial advance in the screening of pulps and in light of the teachings above, numerous modifications of the various details can be made within the spirit and scope of the invention.

What is claimed is:

1. In a screening apparatus for fluid mixtures of fibrous matter and liquid, adapted to separate the fibrous matter into an accepts portion and a rejects portion, the apparatus having a screen member with apertures sized to pass fibers acceptable for paper making, a pulse-generating rotary wall member spaced from the inlet side of said screen member, said screen member and said wall member providing a screening zone therebetween through which fluid can proceed while exposed to the screen member, an inlet for supplying said mixture to said screening zone, an accepts passage for receiving the portion of said mixture which passes through said screen member, and an outlet for removing the rejects portion of said mixture from said screening zone, the improvement comprising means for creating a high number of small localized displacements of the mixture to maintain the fibers fluidized and flowable within the liquid while the mixture is exposed to the inlet side of said screen member, whereby a large portion of the fibers and liquid can readily pass through said screen member while larger fibrous matter is rejected by said screen member, said means comprising a multiplicity of discrete surface portions offset from the base surface of said wall member, said offset surface portions being spaced from each other and distributed over the surface of said wall member in a predetermined pattern, the number, size, shape and location of said offset surface portions in said pattern and the speed of their rotation being such that they move relative to said mixture and cause localized changes of volume in said screening zone over the effective area of said screen member to thereby create said localized displacements, the projected area of each offset surface portion upon a plane parallel to said base surface having a length to width ratio less than about 5 to 1, and said projected area of each offset surface portion upon a plane parallel to said base surface being at least substantially equal to the projected area of the impelling surface of said offset surface portion upon a plane perpendicular to its direction of movement.

2. The screening apparatus of claim 1 wherein said apertures are round holes with diameters on the order of about $\frac{1}{16}$ inch.

3. The screening apparatus of claim 1 wherein said offset surface portions project toward said screen member to define bumps which have widths and lengths at least not substantially less than their heights of projection, and rounded sides.

4. The screening apparatus of claim 3 wherein said bumps are each shaped to displace fluid in opposite directions transverse to the direction of movement, each bump extending on both sides relative to a line projected along the direction of movement, through the forwardmost part of said bump.

5. The screening apparatus of claim 3 wherein there are bumps which are adjacent each other in the direction transverse to the direction of movement, said transversely adjacent bumps shaped to displace fluid transversely toward each other, said bumps spaced substantially from each other to define a flow path for the fluid as the bumps advance through the fluid.

6. The screening apparatus of claim 3 wherein said bumps decrease in cross-sectional area parallel to the base surface, from the base surface toward said screen member.

7. The screening apparatus of claim 3 wherein said bumps are in the general form of globular sections.

8. The screening apparatus of claim 1 wherein said offset surface portions extend away from said screen member to define dents.

9. The screening apparatus of claim 3 wherein said bumps have a width to length ratio substantially equal to 1.

10. The screening apparatus of claim 1 wherein said offset surface portions and said base surface comprise a continuous integral member.

11. The screening apparatus of claim 1 wherein the spacing between the nearest part of said wall member and the screen member is on the order of between 2 inches and $\frac{3}{16}$ inch.

12. The screening apparatus of claim 1 wherein a drive means is provided, said drive means adapted to move said wall member at a surface speed in excess of 3,000 feet per minute relative to said screen member.

13. The screening apparatus of claim 1 adapted to screen high consistency pulp wherein said drive means is adapted to move said wall member at a predetermined speed in relation to the spacing of said surface portions along the direction of movement, sufficient to produce disturbances in the fluid at every point in said screening zone at a frequency in excess of 6,000 cycles per minute.

14. The screening apparatus of claim 1 adapted for pressurized operation, said means for supplying fluid to said screening zone comprising a conduit adapted to introduce fluid under substantial pressure, said accepts passage defined by a pressure casing surrounding and spaced from said screen member to provide an accepts chamber and an accepts conduit adapted to remove fluid under substantial pressure connected thereto, and said means for removing rejected matter from said screening zone comprising a reject conduit adapted to remove fluid under substantial pressure and means associated with said reject conduit adapted to regulate the flow therethrough.

15. The screening apparatus of claim 1 wherein said screen member and wall member are elongated, said screen member is in generally cylindrical form, said wall member being in the form of a drum disposed within said screen member, said drum member having one end

closed, defining a closed volume, a single supporting shaft, said shaft extending from the opposite end of said drum to means for driving said shaft.

16. In a screening apparatus for fluid mixtures of fibrous matter and liquid, adapted to separate the fibrous matter into an accepts portion and a rejects portion, the apparatus having a screen member in the general form of a surface of revolution with apertures sized to pass fibers acceptable for paper making, an inlet for supplying said mixture to one side of said screen member to establish a screening zone, a pulse-generating rotary member spaced from the inlet side of said screen member adapted to move over the surface of said screen member in the region of said screening zone, an accepts passage for receiving the portion of said mixture which passes through said screen member, and an outlet for removing the rejects portion of said mixture from the inlet side of said screen member, the improvement wherein the rotary member comprises means for creating a high number of small localized displacements of the mixture to maintain the fibers fluidized and flowable within the liquid while the mixture is exposed to the inlet side of said screen member, whereby a large portion of the fibers and liquid can readily pass through said screen member while larger fibrous matter is rejected by said screen member, said rotary member in the region adjacent said screen member having a special impelling profile as projected upon a plane perpendicular to the direction of movement, said impelling profile defined by a plurality of projections spaced apart in that direction which is both transverse to the direction of movement and substantially parallel to the axis of rotation of said rotary member, the longest dimension of each of said projections being substantially less than the circumference and the axial length of said screen member, and openings located between transversely adjacent projections, at least some of said projections each shaped to displace said fluid mixture simultaneously in opposite directions substantially transverse to the direction of movement and parallel to said axis of rotation, and also toward said screen member, and said openings providing paths through which said mixture may pass relative to said rotary member as said projections advance, enabling a substantial portion of the mixture displaced in the vicinity of said screen member by said projections to be conditioned without being forced against said screen member, the number, size and shape of said projections and the speed of their rotation being such that they move relative to said mixture and cause localized changes of volume over the effective area of said screen member to thereby create said localized displacements.

17. The screening apparatus of claim **16** wherein transversely adjacent projections are adapted to displace fluid transversely toward each other causing localized increase in speed of flow through the opening therebetween.

18. The screening apparatus of claim **16** wherein transversely adjacent projections are substantially aligned on lines extending substantially transverse to the direction of movement, the shortest distance between said transversely adjacent projections in said transverse direction being at least equal to the dimension of either of said projections in the same transverse direction.

19. The screening apparatus of claim **16** wherein at least some of said projections are circumferentially spaced apart, said projections being staggered in the direction transverse to the direction of movement in the manner that the path of movement of leading projections are aligned with openings located at the sides of circumferentially spaced behind projections.

20. In a pressurized screening apparatus for fluid mixtures of fibrous matter and liquid adapted to separate the fibrous matter into an accepts portion and a rejects portion, the apparatus having a stationary screen member in the form of a surface of revolution with apertures sized to pass fibers acceptable for paper making, a pulse-generating rotary wall member in the general form of a drum mounted within said screen member and spaced therefrom, defining therewith an annular screening zone therebetween through which fluid can proceed while exposed to the screen member, an inlet pressure conduit for supplying fluid to said screening zone, an accepts pressure conduit for receiving the portion of fibers and liquid which passes through said screen member, and a rejects pressure conduit for removing rejected matter from said screening zone, said apparatus being so constructed and arranged as to maintain said conduits filled with said fluid, the improvement wherein said movable wall member has an irregular outer surface, there being a multiplicity of discrete bumps distributed over said wall member, each bump shaped to move relative to said fluid and cause a localized change in volume in said screening zone for conditioning said fluid, the projected area of each bump upon a plane parallel to said base surface having a length to width ratio less than about 5 to 1, and said projected area of each bump upon a plane parallel to said base surface being at least substantially equal to the projected area of the impelling surface of said bump upon a plane perpendicular to its direction of movement, said bumps being spaced apart from each other in the direction transverse to the direction of movement such that the spacing exceeds the width of said bumps, providing substantial spaces into which fibers and liquid can be displaced sideways by the bumps, thereby enabling a substantial portion of the mixture to be conditioned without being forced against said screen member, the number, size, shape and location of said bumps being such that they move relative to said mixture and cause localized changes in volume in said screening zone over the effective area of said screen member.

References Cited

UNITED STATES PATENTS

5,440	2/1848	Umholtz	241—84 X
341,417	5/1886	Howe	209—273
1,605,969	11/1926	Mitchell	241—84
1,921,750	8/1933	Heinrich	209—273
2,078,065	3/1937	Bethune	259—96
2,357,316	9/1944	Cowles	241—84
2,364,171	12/1944	Staege	210—415 X
3,029,951	3/1962	Cannon	209—273 X
3,188,942	6/1965	Wandel	210—415 X
3,203,457	8/1965	Minet	146—76
3,223,239	12/1965	Dick	209—270
3,245,535	11/1966	Cowan	209—273 X

FOREIGN PATENTS

79,843	3/1934	Sweden.

HARRY B. THORNTON, *Primary Examiner.*

R. HALPER, *Assistant Examiner.*