This invention relates to paper pulp screens; and it comprises a screen for screening paper pulp and the like, provided with a plurality of parallel slots with a plurality of undulations running substantially perpendicular with respect to said slots, said undulations being of such shape as to cause liquids passed across said plates to impinge against said slots by cascading and/or rippling in passing over said undulations, said screen plates being adapted to be placed in the usual pulp screens at or above the average levels of the liquid in the discharge chambers with streams of pulp passing across their surfaces in a direction substantially parallel to said slots; all as more fully hereinafter set forth and as claimed.

Early in the history of paper making it was discovered that it was necessary to screen the stock in order to remove dirt, knots and other impurities as well as oversize fibers. Since that time a large number of different methods of screening have been devised. In one of the early methods a slotted or perforated pulp screen was totally submerged within the liquid in the screening vat, the screen being reciprocated in the liquid in order to assist in the screening action. When submerged screens of this type are used, a forward and backward motion of the stock is produced but there is no continuous motion of the stock along the surface of the screen. In this method various forms of screens were employed, in some of which flat plates were placed in a saw-tooth arrangement in order to work the unscreened stock forward when subjected to the shaking movement. In such “submerged screens” such saw-tooth arrangements were necessarily of large dimension. For example, the depressions would have a depth of 4 inches to 12 inches, in order to accomplish the above described action when submerged in a stationary liquid of considerable depth. The base line, or general direction of the screen arrangement, sloped upwardly to the end of the screen where unscreened material was discharged.

A later development involved the use of slotted screen plates which were mounted above the surface of the screened liquid in discharge chambers that contained air except for the screened stock that passed out sidewise, transversely to the direction of flow of stock above the plates, diaphragms being provided at the bottoms of the discharge chambers, which diaphragms were vibrated in order to produce alternate suction and pressure beneath the screens. The resultant intermittent forcing of air and water through the slots tended to prevent the slots from being clogged. In both of these types of screens slots were sometimes placed cross-wise and sometimes length-wise of the screen. In more recent practice, flat pulp screens have become more or less standardized, being of this latter “non-submerged” type. In this type, the surface of the plate is not submerged below the average level of the liquid in the screening vat. The flash boards, which control the levels of the stock in the discharge chambers, are set with their upper edges either at or just below the level of the screen. The slope of the base line of the screen is downward to the end where unscreened material is discharged.

This modern pulp screen, which is conventionally used in large scale production, has a flat screening surface and is composed of from about 12 to 70 screen plates provided with slots usually running parallel to the flow of stock. The general plane of the screen is inclined to the horizontal about 3 to 10 degrees in such direction as to assist in the flow of stock across its surface. Diaphragms are operated under each pair of screen plates so as to force a mixture of air and water up through the slots to clean them, and to draw stock down through the slots during the suction action. The stock screened in this manner usually consists of from about 0.5 to 1 per cent of dry paper fiber suspended in water. This stock is passed over the screen in a layer which varies in thickness from about 4 inches at the upper end down to zero at the lower end. It will be noted that, with this type of screen, there is a continuous flow of stock along the surface of the screen in the direction of its base line. The relative motion of stock and screen is uni-directional.

The conventional screen plate is approximately 11 inches to 12 inches wide, 43 inches long and ¾ inch thick. Fine slots about 2 inches to 4 inches in length are sawed into the plate, these slots being usually arranged in from two to four rows which run from one end of the plate to the other, leaving uncut longitudinal sections in between which serve as strengthening bars. To make a pulp screen a number of these screen plates are placed transversely in an elongated, sloping screening vat having a width corresponding to the length of the plates. Holding members are provided between the plates, forming a flat but sloping screening surface across which the stock flows smoothly toward the lower end of the screen. Screening vats are usually adapted to hold from five to seven pairs of screen plates, but several of these vats are usually placed in series so as to constitute a practically continuous
The screen plates of the present invention are particularly adapted for use in screening vats of the type just described in which the plates are supported at or above the level of the screened stock in the discharge chambers under each pair of plates, and the stock is passed in a stream across the plates, the slots in the plates being usually parallel to the line of flow of the stock.

We have found that, if the usual paper stock is forced to impinge repeatedly against a slotted screening surface by being cascaded on to these surfaces or by being forced to change its direction of flow as it passes over the surfaces in such manner that the momentum of the stock tends to force it through the slots, a much more efficient screening action is secured. This result is produced by undulating the surface of the screen plate in a direction perpendicular to the flow of stock. Of course, such undulations must be of suitable size in order to produce this action without blocking the flow of stock. This may be accomplished by providing steps in the plate over which the stream of pulp is forced to cascade upon a row of slots or at least to provide undulation screen plates with a single step in the stream of stock to ripple in passing over the undulations, the plate being slotted at the points where its surface is concave or where the surface rises into the stream of flow.

We have found that, when a stock stream is caused to cascade or to ripple in the manner described, a two-fold effect is produced. First, the stock is forced to change its direction of flow in such manner that a force, usually a centrifugal force, is developed tending to make it pass through the slots, this force being added to the usual force of gravity as well as to the suction produced by the diaphragms. The total force tending to make the stock pass through the slots is substantially increased. The second effect is that the cascades or ripples, caused by passing over the undulations in our screen plates effectively mix the pulp with the water. When the stock passes over a conventional flat plate the layer of pulp collects adjacent the surface of the plate which impedes the passage of both the water and the fibers through the slots. This layer further tends to clog the slots. But if the stock is caused to ripple or to cascade this layer of pulp is mixed with the thinner stock above and a substantially increased rate of screening results.

Surprisingly, we have found that a considerable increase in screening capacity can be produced in the manner described above. Further, we have found that a better screening is produced owing to the fact that less dirt and coarse fibers pass through our screens. The exact cause for this latter effect is not known but it is probably due to the repeated mixing of the stock when passing over the undulations of our screen plates; this action preventing particles of dirt from being forced through the slots by the pressure of the fibers above them. It may also be explained by the fact that satisfactory production can be obtained with less forcing of the diaphragms in the flat screens, or of the agitating mechanism in the rotary screens.

Owing to the increased screening capacity of our screen plates we have found that it is usually possible to produce adequate screening by the use of fewer screens. The number of our plates, required to produce the same quality of screening produced by up to 70 of the flat plates of the prior art, may sometimes be as low as 28. The total number of screen plates required in a given case may therefore be reduced by about one-half to one-third by the use of the present invention. When our screen plates are introduced into the conventional screening vat it is possible to reduce the vat which is available for this purpose when necessarily, or these may be left in service in order to collect a larger percentage of the screenable stock.

We have discovered another surprising result which is caused by the use of our undulating screen plates. We have found that the pulsating air pressure produced by the diaphragms tends to concentrate at the highest points of the under surfaces of the screen plates. But if the slots of the screen plate extend up the undulating slope to or just beyond the high point of the undulations, as in our preferred embodiment, particles of stock which are just too large to pass through the slots also tend to collect on the screen surface at these downstream ends of the slots. We find as a result of this circumstance that the clogging stock fibers are expelled much more completely than is the case with flat plates where no such localized suction zone is available. This is possible. This effect cannot be produced, of course, in the obsolete type of screen, the plate of which was submerged in the stock in the screening vat.

In making our plates the sections of the screening surface which are concave or which rise in the direction of the flow of stock should be slotted. The convex or downwardly sloping portions are not necessarily slotted. These unslotted portions form reinforcing ribs, providing stiffness in the direction of the length of the plate. Where these unslotted portions are substantially vertical, or have a large vertical dimension as compared with their horizontal dimension, the stiffening effect is increased. An additional advantage accruing from this disposition of the stiffening portion of the screen plate is that less of the width of the plate is required to produce stiffness, and hence much of the plate is available in a direction of flow.

In this way, the screening capacity is increased. Moreover, the slots, being set at an inclination to the horizontal, are longer than if they had been set in the horizontal surface of the conventional flat screen plate.

In view of the above, it is clear that the material of which the screen plate is to be made, or the manner in which it is to be formed, are secondary in importance. It has, however, been found that, because of the shape of the new plate, it is considerably stiffer lengthwise than the conventional plate for equal thicknesses of material and thickness of fibers, and may therefore be materially decreased without loss in rigidity. Not only is a saving in material so obtained but substantial economies in construction are made possible. For example, in conventional plates, it is necessary to mill grooves into the under side of a cast, machined plate, and then to saw slots from these grooves into the upper face. By using a thin material, the milling of the grooves can be eliminated. Moreover, because of the decreased thickness of the material, rolled sheet can be used, instead of a cast plate, and surface machining can be omitted. If flat sheet is used, it can be bent into shape or stamped or rolled. If desired, the required blanks can be made by extrusion, during which operation reinforcing ribs can be formed on the
plates. Extruded sections can also be formed with the desired contour from the start. While the conventional flat plates are fabricated from cast bronze having a thickness of from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch, we have found that the additional strength resulting from the undulations in our new plate, enables the use of plates ranging from about $\frac{1}{8}$ inch to $\frac{1}{4}$ inch in thickness and which, as mentioned, can be made by less expensive methods than casting and from less expensive materials than bronze.

There are a variety of forming methods suitable for the making of our plates, enabling us to choose the material most suitable, either for easy construction, or for resistance to wear or corrosive action of the stock, or for the deposition thereon of resistant coatings, such as, for example, chromium. Suitable materials may include stainless steel, Monel metal, bronze, brass or steel among others.

The longitudinal stiffness of our plates effectively maintains the slot size and there is no danger of "breathing" to be feared. The lateral stiffness is generally less than the longitudinal stiffness of our plates, but there is a degree of flexibility, with the result that in case of shock, as for example by water hammer, they will flex rather than break. If a greater lateral rigidity is desired, this can be obtained by fastening braces to the underside of the plate by any convenient means, as, for example, by riveting, bolting, welding, brazing or soldering.

Our invention can be described in more detail by reference to the accompanying drawings which show, more or less diagrammatically, several embodiments of our screen plates which may be used in our process. The stock is assumed to be flowing from left to right in the several figures. In this showing,

Fig. 1 is a transverse vertical section through a screen plate, showing slotted and unslotted sections, as well as the contour of the screening surface.

Fig. 2 is a similar showing of a modification provided with strips of felt to collect dirt.

Fig. 3 is a similar showing of a modification having a wave-like contour.

Fig. 4 is a similar showing of a plate having a screening surface with sinuous contour.

Fig. 5 is a similar showing of a plate having reinforcing ribs.

Fig. 6 is a similar showing of a plate built in sections.

Fig. 7 is a diagrammatic sectional view showing, on an enlarged scale, the action of a stream of stock passing over a plate having a contour similar to that shown in Fig. 1, and

Fig. 8 is a partial, longitudinal, vertical section through a screening vat, showing the mounting of our novel plates, as well as the mechanism for producing suction and pressure beneath the plate.

In the various figures like parts are designated by like reference numerals. It should be noted that all figures in the drawings are section taken through the screening slots and transversely through the plates. The base lines 20 of the plates are shown on the figures, as well as horizontal and vertical lines. These lengths of the plates are approximately four times their widths. The slots of the plates are shown at 1 while the unslotted sections are indicated at 2. Some of the plates shown are provided with bevelled edges 3 which are adapted to be secured in the screening vat by means of bevelled cleats, not shown. Others are provided with flat and squared edges 4 which may be secured by means of countersunk screws, not shown, to the screening vat.

The function of the various structures shown in the figures is believed to be more or less self evident. In Fig. 2 felt strips 16 are shown in the depressions between the undulations of the plate. These felt strips are placed along the non-slotted sections in such position that the stock passes over these felt strips just after passing over the undulations. The felt strips collect dirt, sand and other heavy particles, and help to prevent clogging of the slots.

In Fig. 5 a modification is shown which is provided with reinforcing bars 16 between the slotted sections. These reinforcing bars may be cast, extruded, or rolled integrally with the plate. The edges of this plate can be made in the same fashion.

In Fig. 6 the plate shown is made in sections, the ends of these sections being welded or brazed or otherwise secured together. The exposed edges of the plate sections should be bevelled as shown, in order to reduce the resistance to the flow of stock. It is evident that a plate of any desired size can be made by the use of the required number of sections.

The slots in the various embodiments shown can be sawed in the plates after they have received their final shapes but it is obvious that, in the case of some of the modifications, the slots may be sawed in a flat sheet which then can be bent into the required undulatory form.

It is evident from the showing of Figs. 1 to 6 that the contour of the undulating screening surface used in our invention may be varied widely. It is only necessary to provide a plurality of undulations and screening sections in each of these being of such proportions and shape as to cause the stock to impinge against and/or cascade onto the slots without stopping the onward flow of the unscreened stock. The momentum of the flowing stock then tends to force the stock through the slots. This effect is illustrated in Fig. 7.

Fig. 7 shows diagrammatically the different actions which are involved in our invention. In the figure a stream of stock 6 is shown rising into ripples 11 as it passes over the undulations 7 of the plate. The continuous arrowed lines 8 indicate the course of flow of the various strata of liquid within the stream 6. It will be observed that the strata adjacent the surface of the plate have components of motion directed toward the slotted sections of the plate as indicated by the discontinuous arrowed lines 8. Obviously there is a tendency for the stock to pass directly through the slots rather than to continue up and over the succeeding undulations. In this drawing the stream of stock 6 is shown as being of considerable thickness, so that the undulations cause the formation only of ripples 11 upon the surface of the stream. It is evident that, if the stream were of considerably lessened thickness or if the undulations were of the shape shown in Fig. 6, it would pass over the plate in a series of cascades and impinge directly upon the ends of the slots 1.

As the stock passes up the rising slotted sections of the plates, the water passes through the slots somewhat more readily than the pulp, which causes a thin layer of pulp 10 (Fig. 7) to form adjacent the screening surface. When the stock passes over the undulations 7, these layers of pulp become uniformly mixed with the liquid as indicated diagrammatically in the figure which means...
that the flow of the stock through the slots is no longer impeded by the layers of pulp. In Fig. 8 our plates are shown mounted in a conventional screening vat. The screen plate are shown generally in this figure at 22. The ends 5 of these plates are secured to supporting cross members 27, usually of wood. Flexible diaphragms 24 are fastened beneath these cross members. These diaphragms are supported in their centers between wooden blocks 25 and plates 15, the diaphragms being operated by means shown diagrammatically at 26. Each diaphragm extends between two screen plates, the latter being supported beneath the center of each diaphragm by means of the intermediate supporting members 31. The diaphragms produce alternating pressure and suction beneath the screen plates and serve to draw stock through these plates. The stock to be screened is supplied by the launder or trough 27, formed by the boards 35 which are joined to the head board 34. The stock passes from the launder over the head-board falling on a board 29, these boards serving to distribute the stock uniformly over the screen. The screenings leave by way of the launder 30 while the screened stock which collects beneath the screen plate is withdrawn from the sides of the screening vat.

Our tests show that excellent results are obtained in our invention when the slotted sections of our screen plate against which the flowing stock is forced to impulse rise, with respect to the base line of the screen plate, at an angle of at least 5 degrees. A 10 degree rise produces better results. The maximum angle of rise for good results is about 45 to 55 degrees. We have also found that it is advantageous to shape the screenings in such manner that no deep pockets are formed in which dirt and other impurities may collect and which may tend to block the forward motion of the stream of pulp. In general, the pockets formed between undulations should not have a depth greater than would form a dam equal in height to the average thickness of the freely flowing stock above the plates. Satisfactory results can be obtained for example, with pockets having a depth ranging from about 1/4 inch to 1 1/4 inches. Constructions tending to produce the formation of eddies in which dirt might become trapped should be avoided. The plates should, of course, be streamlined, without sharp ridges or depressions which might tend to block the flow of stock.

While we have described what we consider to be the more important embodiments of our screen plate and process, it is obvious that various modifications can be made in the specific structures and procedures which have been set forth without departing from the purview of this invention. Our invention is particularly adaptable for use in connection with screening vats in which the screens are rigidly secured above the liquid level in the discharge chamber, the stock flowing in a continuous stream across these screens. The structure of our screen plate may be varied widely both as to the contour of its screen surfaces as well as in its physical structure. It is possible, for example, to produce a complete screen from a single, longitudinally-slotted, rolled sheet having a length corresponding to the width of two of the usual screen plates, or even to the length of the usual screening vat, this screen being provided with transverse undulations and supporting bars. The lengths and disposition of the slots in our plates may be varied in accordance with the usual practice. It is possible, for example, to incline the slots to as much as 45 degrees to the direction of the stream of stock, the undulations remaining substantially transverse to the course of the stream. With this construction the slots will have a component of their length equal to at least about 70% of their length parallel to the course of the stream, and perpendicular to the undulations. The thickness of the screen plate may be varied. And, as indicated previously, a wide range of different methods of manufacturing these plates is available.

With respect to the process of our invention it is only necessary that a continuous stream of stock be passed across an undulated, slotted screening surface in such manner that its line of motion, if extended in the direction of the motion, passes through said slots at a plurality of points. This causes impingement of the stream of stock against the undulations of said screening surface and rippling or cascading where the stream crosses the undulations. The surface must be slotted at these points of impingement, the slots running in a direction substantially parallel with, or having a substantial component of their length parallel with said relative motion, whereby said impingement causes the stock to pass through said slots.

If desired, water may be sprayed on the stock as it passes over the screening surface in order to dilute and agitate the stock, and add to its momentum.

Further modifications of this invention, which fall within the scope of the following claim will be immediately evident to those skilled in this art.

In the ensuring claim, by a screen plate of the "nonsubmerged" type we mean the type of plate adapted to be mounted above a discharge chamber, the chamber containing air and screened stock, the plate being mounted either at or above the average level of the screened stock in the discharge chamber.

What is claimed is:

A screen for screening thin aqueous suspensions of paper pulp in combination with a screening vat, said screen being mounted stationary in said vat above the average level of the liquid in said vat in such manner that its base line slopes downwardly towards one end of said vat, means for introducing a continuous stream of stock to be screened on the top surface of the high end of said screen, said screen being provided with slotted undulations running perpendicular to said stream of stock, said slots running parallel with the flow of stock and being sufficiently fine to screen out knots and dirt while permitting paper fibers to pass therethrough, the undulations being of sufficient height to form depressions therebetween having depths ranging from about 1/4 to 1 1/4 inches, the upstream portion of said undulations being slotted and rising at an angle of from about 5° to 45° with respect to said base line, whereby the said stream of stock is caused to repeatedly impinge against said slots in passing across said plate thereby developing a force tending to make said stock pass through said plate, and means for intermittently producing suction and pressure beneath said screen to clean the same and to draw stock through said screen.

ERICH A. BECK
RALPH E. CLEVELAND.