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FIBROUS SHEET FORMER WHEREIN CONCENTRATED STOCK IS PASSED THROUGH SEPARATE CHANNELS INTO A DEFLECTION CHAMBER AND OUT THROUGH AN OUTLET CHANNEL

Filed April 19, 1973 2 Sheets-Sheet 1

Fig. 2

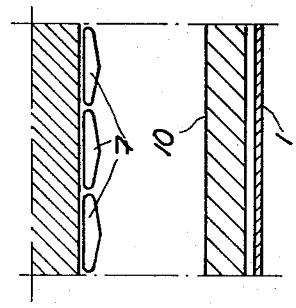

Fig. 1

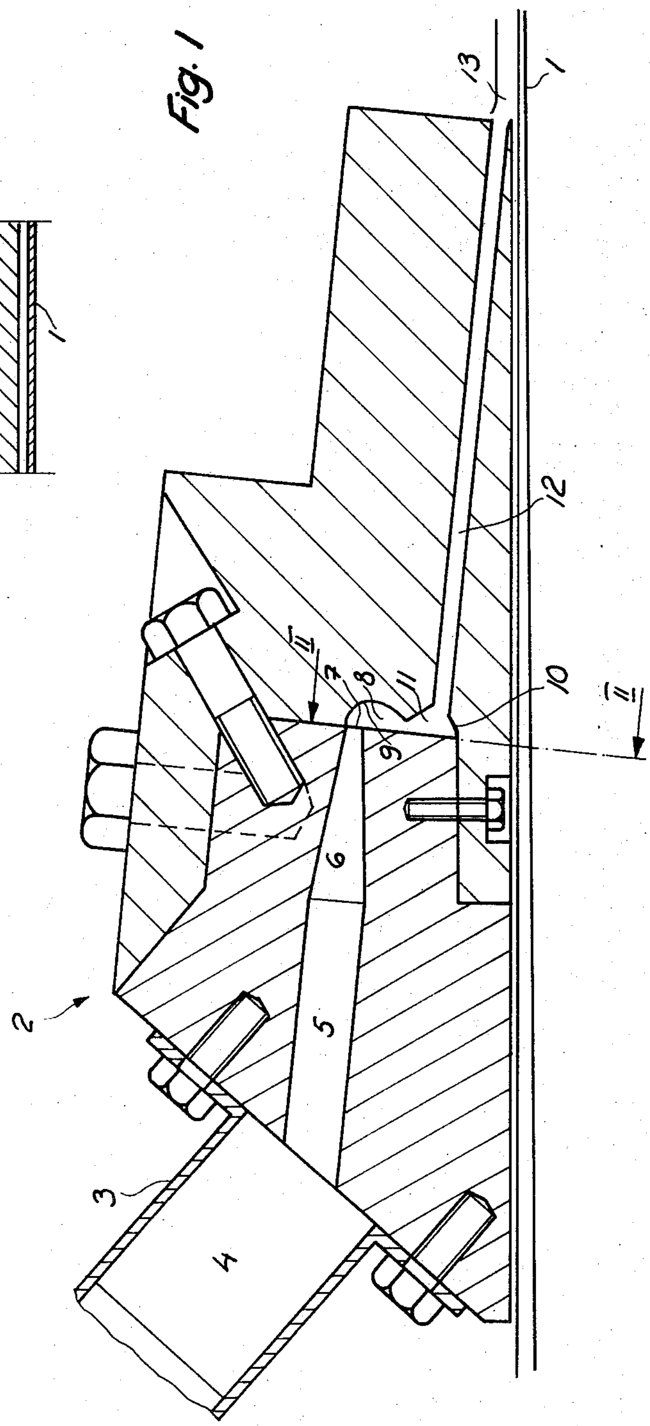

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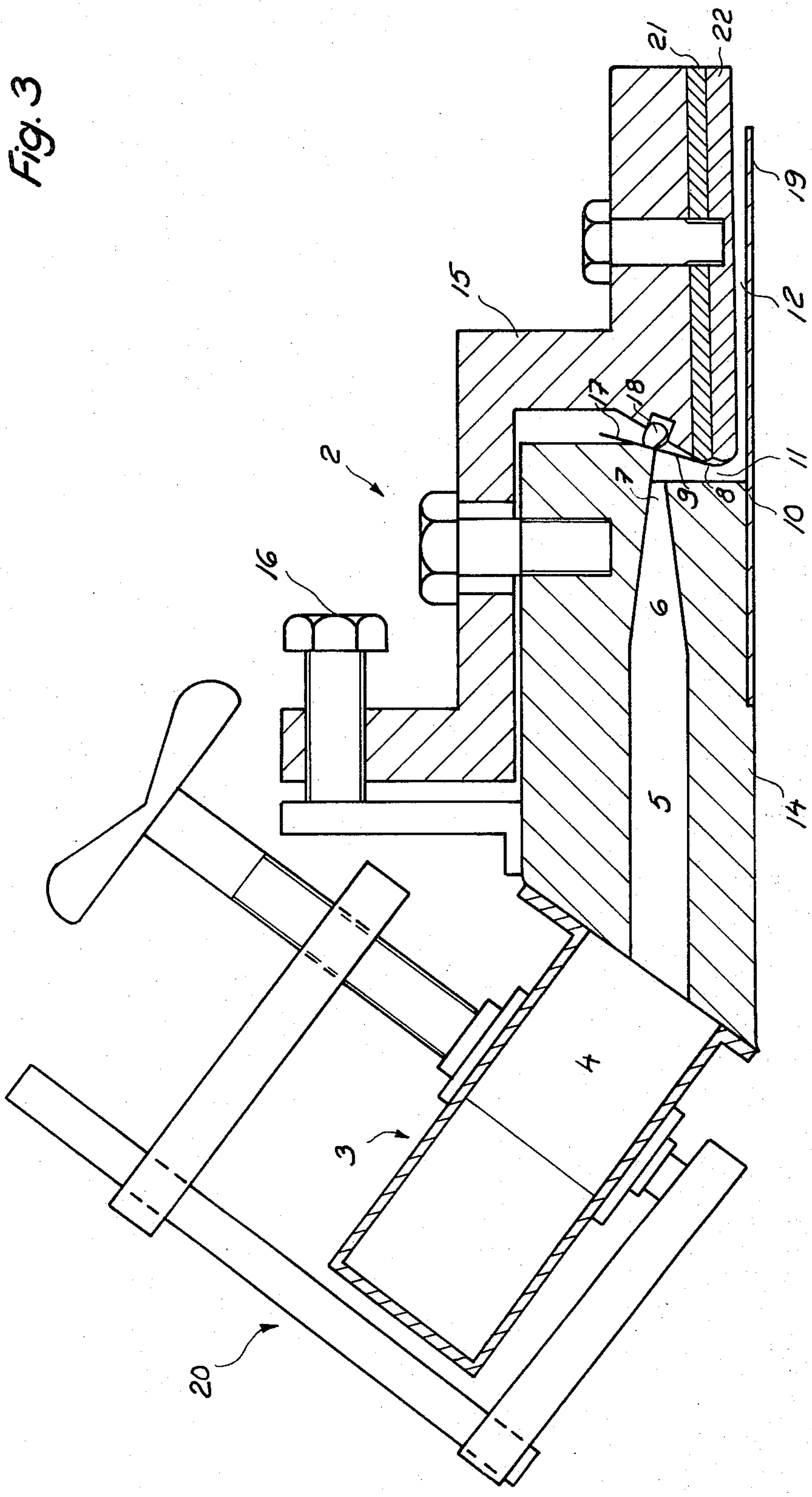
Fig. 3



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FIBROUS SHEET FORMER WHEREIN CONCENTRATED STOCK IS PASSED THROUGH SEPARATE CHANNELS INTO A DEFLECTION CHAMBER AND OUT THROUGH AN OUTLET CHANNEL

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ABSTRACT OF THE DISCLOSURE

Apparatus and method for forming a continuous material web of fibrous particles starting from a suspension of fibrous particles having a concentration of about 1 to 6% by weight, wherein the highly concentrated suspension is fed from a transverse distributor and divided up and sprayed through several parallel channels. The suspension jets are then sprayed through the channel outlets into a chamber where the jets are reunited and then deflected against an opposite wall of the chamber. The suspension flow is then accelerated through a chamber constriction and deflected again prior to passing through the outlet channel of the former and onto a forming wire.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to the field of web forming from a suspension of fibrous particles having a relatively high concentration.

Description of the Prior Art

The industrial manufacture of paper has on the whole been going on in the same manner as in the beginning of the 19th century. Only the size of the machines and the operational speed have increased. The increased widths and speeds of machines have required a greater and greater accuracy at the manufacturing of the machine parts. Accordingly the costs have increased heavily and it may be mentioned that the investment cost for a modern newsprint machine with appurtenant equipment and buildings approaches 40 million dollars. A considerable part of the cost for the machine resides in the "wet end," i.e. the distribution system of the suspension, the head box and the wire part.

In principle the following takes place at the wet end of the machine in conventional sheet forming: Fibre suspension, i.e. (more or less freely flowing) pulp fibres in water, distributed roughly over the width of the machine by a distribution system, for instance, a transverse distributor. In the head box the aim is that the fibres shall divide themselves evenly even in micro scale with the aid of irregular movements (turbulence) in the transporting medium. In order to eliminate some incompletenesses in the distributing system (e.g. comprising an oblique speed profile in the head box, which in addition to giving directly an uneven surface weight profile across the paper web even indirectly is the cause of unstable flow with rough-scale turbulence which becomes evident in the wire section

and disturbs the sheet forming) most often a number (2 to 5) perforated rolls are placed in the path of the flow. The fibres in suspension have a tendency to become conglomerated owing to mechanogeometric reasons. The task of the perforated rolls includes also generating of turblent shear fields which break up the appearing fibre flocks. Because of the tendency of the fibres to form flocks, which is accentuated at increased concentration, a higher fibre concentration than aprox. 0.5 percent cannot be kept if acceptable paper is to be made. (0.5% includes 5 g. fibre per litre, kg., water).

The suspension is portioned from the head box, in the best case with fibres evenly distributed, through a small slot, in a horizontal jet which lands on the wire (a more or less gauzy screen of metal or plastic), which moves at the same speed as the jet. The thickness of the jet may vary from 10 mm. up to and over 50 mm. On the wire most of the water has to be removed. Before all fibres are fixed in a fibre bed the concentration has to be increased from 0.5 to approx. 10%. With a jet height of 40 mm. and with an initial fibre concentration of 0.5% this means thus that about 40 litres of water is removed per square metre of wire and with the present machine speeds on a high-speed machine, this takes place within a space of time of about one second. Water removal takes place with the aid of different types of dewatering devices which, depending on the circumstances can both improve or worsen the sheet formation. Anyhow, this process is very hard to control.

Thus, when the jet lands on the wire the bed has the same speed as the jet itself. The actual sheet formation may therefore be compared to a sedimentation process, although it may be a forced one because of the dewatering elements. The sheet will be built up from below in such a manner that the remaining water has to be drained, practically through the entire sheet. The arriving fibres have a certain dispersion according to size and there occurs always a bigger or smaller part of fine fraction where the fibres or rather the fibre fragments are so small that they go with the water in the draining. The retention, i.e. the part of the fibre material which remains on the wire, is often only 50% or even less. Because of this mechanism a certain two-sidedness is also obtained in the sheet, i.e. in the bottom of the sheet an impoverishment of fine material is obtained as the substance of such material rises simultaneously against the uper side of the sheet. This two-sidedness becomes particularly marked when addition of some filler to the grist takes place, e.g. clay in certain newsprint qualities. This two-sidedness is even marked in paper containing wood pulp, e.g. newsprint, where a high percentage of fine fraction is included in the fibre material which causes different printing characteristics for both sides of the sheet. The above related sheet-forming mechanism compared to sedimentation gives the sheet a special two-dimensional structure. Because of the geometric form of the fibres (length 1–5 mm., diametre 30–50 μm.) all fibres sediment so that they lay down parallel with the sheet. Thus it may be said that the sheet is built up of a number of parallel layers, which—quite naturally—will affect the different characteristics of the paper such as the strength, stiffness etc.

What has just been described is, roughly simplified, the sheet-forming procedure of today's paper making. It is true, there are also other variations of it but they do not differ fundamentally to a larger degree from the above.

The pulp fibres are deposited on a wire cloth in one way or another and when the dewatering has been going on for so long that the strength of the sheet formed permits it to be lifted from the wire, it is transported further to the press part where further water is removed. The final dry content of the paper is obtained when the paper has been dried against a number of heated cylinders.

Thanks to the U.S. Patent application Ser. No. 157,120, and now abandoned hereby incorporated by reference, a method and equipment is known for forming of a continuous pulp web starting from a highly concentrated suspension of slim particles, at which the suspension is distributed and spouted through several openings arranged in series with deviation after every opening whereby the flow is distributed from one opening over a number of successive openings with a smaller diametre after which the turbulent flow is converted at the decay to a flow of consolidated three-dimensional net structure of the fibrous particles.

In one embodiment of this known arrangement the suspension is first divided into several series and parallel coupled units, comprising a tubular chamber with a constriction and an impact face after the constriction as well as several radial outlets with smaller diameters around the impact face. In this arrangement each outlet of the last units is coupled each to its respective inlet of a transverse row of inlets in the sheet forming equipment. In order to obtain a satisfactory sheet forming without stripes in the completed sheet with that kind of apparatus a two-sided feeding of suspension flows should, however, be used, i.e. with two rows of holes arranged on diametrically opposed sides of the sheet forming equipment, so that the flows meet and mix together right before the inlet channel. Such a bilaterally fed apparatus should not be placed right above a wire or felt as the inlet pipes to the lower row of holes takes the space required by the wire which will be placed parallel with and right below the outlet channel.

In another embodiment of the afore-mentioned known apparatus the distribution arrangement and the sheet-forming arrangement are built together to one compact unit, in which the distribution apparatus comprises a transverse distributor having a row of openings alongside its one long wall, wherein each opening of the row opens into a disc-formed hollow space with a number of peripherically arranged openings with a smaller diametre at regular distances from each other. These perpherically arranged openings form two parallel rows of holes arranged one on top of the other, which rows lead to a chamber divided into two zones one on top of the other by means of a partition which extends a bit into the outlet channel in which the flows from both rows of holes become reunited. This arrangement operates also with a two-sided feeding of the suspension even if the form is more compact than in the preceding case. Further, this arrangement is relatively sensitive for blocking due to the fact that the pulp is forced through smaller and smaller holes, the number of which, however, increases to a corresponding degree. The blocking results in a striped and thus inacceptable paper quality.

The object of the present invention is to create a method to form a continuous material web of fibrous particles, by which the blocking tendency of the highly-concentrated pulp is eliminated and at which the suspension can be fed one-sidedly to the chamber as well as an apparatus with which the web may be deposited on wire or felt and which arrangement is considerably more safe in operation and simpler as to its construction than hitherto.

SUMMARY OF THE INVENTION

The highly concentrated suspension is divided over and sprayed through several parallel-coupled apertures, after which the suspension jets are accelerated and sprayed at high velocity into at least one chamber in which the jets are reunited and deflected, then the suspension flow is accelerated and deflected anew, and finally the turbulence is allowed to decay in order to form a consolidated three-dimensional net structure of fibrous particles before they are deposited.

According to the invention there is provided a method comprising a combination of the following stages:

the highly concentrated suspension is distributed over and sprayed through many parallel-coupled outlets or channels in which the velocity of the suspension jets increases;

after this the suspension jets are sprayed at high speed into at least one chamber in which the jets are united and deflected;

then the suspension flow is accelerated and deflected anew; and

finally the turbulence is allowed to decay in order to form a consolidated three-dimensional web structure of fibrous particles before they are deposited.

According to the invention the highly concentrated pulp is fed by a transverse distributor of conventional type through a row of parallel-coupled channels whose outlets narrow down to a row of slots through which the pulp is fed at high speed into a chamber common for the channels, into which the accelerated flow is lead again by a throttling for acceleration of the flow before it is again deflected and fed in an outlet channel for decaying of the flow before the three-dimensional web structure, consolidated in it, is deposited. The method according to the invention comprises thus in turn two increases in velocity as well as two changes of direction of the suspension before it is allowed to decay, whereat the second throttlng may be adjusted according to the concentration of the pulp, velocity and type of fibre.

This is one example of implementation. The essential thing is to attain a sufficiently high fall of presure, ΔP, over a sufficiently small volume, V, in order to obtain herewith the required power density, ϵ. The following ratio is valid: $\epsilon = \Delta PQ/V$, where Q is the volume flow.

In order to decrease the possibility that the inlet openings of the channels become clogged by the fibres, the transverse distributor is conveniently diagonal in relation to the channels, so that the channels are connected to the transverse distributor in a diagonal angle, whereat the area of the inlet openings grow in a corresponding degree.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cross-section of a high-concentrate sheet former in accordance with the invention. FIG. 2 is a partial section alongside the line II—II on FIG. 1 and FIG. 3 shows a cross-section of an alternate mode of arrangement of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 the wire or the felt is marked with the reference number **1** and the high-concentration sheet former arranged on the wire or felt with reference number **2**. As clearly evident from FIG. 1, the inlet side of the sheet former **2** has been beveled so that the transverse distributor **3** fastened on its forms an oblique angle with the longitudinal axis of channels **5**. Because the inlet side of sheet former **2** has been beveled even the inlets of channels **5** become titled and have a bigger inlet area which decreases the danger of flock formation at the inlets. The channels **5** are cylindrical but change in section **6** into a more and more flattened form and at outlet **7** they are in the horizontal plane very elongated with a small bulge in the lower centre part (FIG. 2). The purpose for the flattening of channel **5, 6** is to divide it evenly laterally in chamber **11**. In practice, the form shown on FIG. 2 has proved to be the most advantageous. All channels **5, 6** alongside of each other and arranged in the same plane end in the same transverse chamber **11** which has a particular form.

At the entrance to chamber **11** the accelerated jets from channel sections **6** hit a wall surface **9**, which deflects the suspension flow approx. 90° downwards into chamber **11.** Then the deflected suspension flow is forced through a constriction **8** into chamber **11**, whereat the velocity of the flow is quickly accelerated and after this the flow is deflected anew 90°, so that it meets the bottom surface **10** of chamber **11.** After this the turbulent flow is led into an outlet channel **12**, in which the turbulence is allowed to decay so that a consolidated three-dimensional web structure is formed by the fibrous particles. The pulp web **13** is finally deposited on the wire or felt **1.**

Thus the suspension flow **4** is first distributed over a number of channel **5**, in which the velocity of the suspension jets is increased in sections **6**, after which the jets are sprayed at high velocity into a common chamber **11**, in which the jets reunite and deflect, the velocity of the suspension flow is increased and deflected anew in order to increase the intensity of the turbulence and decrease its graduation so that the fibres may arrange themselves freely into a three-dimensional web structure in outlet channel **12** at the decay of the turbulence. The length of the outlet channel is selected or adjusted in a convenient manner so that the web structure has time to consolidate before web **13** is deposited on the wire or felt **1.**

Fibres suspended in water have the tendency to cluster together and to form flocks, local web structures. This tendency is due to several factors. Above all the high ratio length-radius of the fibre as well as the fact that the fibre has a certain rigidity which makes it possible for the fibres to tighten themselves against each other and remain in clamped positions. This circumstance, which causes much trouble in conventional paper making, is made use of for sheet forming in the present invention. Instead of trying to hinder flock forming, it is facilitated to the utmost extent and in such a manner that a continuous web structure comes about. In order to create such a thing on the whole, it is required that the amount of fibres per volume unit is sufficiently big, i.e. the concentration must be high. In order to get a continuous web structure, it is required that web structures with high density are broken down so that the individual fibres get an opportunity to take up new places in the continuous web structure. This means that relatively high shearing forces must occur at the formation of the web structure. Once the web structure is formed, i.e. when all fibres are in their places, all the breaking forces shall cease to exist as soon as possible. It is this web structure which shall form a sheet of paper when compressed. The initial thickness of the web structure will be determined by the surface weight of the paper desired as well as of the fibre concentration used. With, for instance, a surface weight of 50 g./m.^{2} (newsprint) and with a fibre concentration of 5%, the thickness will be 1 mm.

Thus, in accordance with the invention, a very concentrated suspension is used, whereat the fibre concentration is at least equal to twice the sedimentation concentration defined by the formula:

$$C_S = 108\pi(r/h)^2$$

in which C_S represents the sedimentation concentration, r is the fibre radius and h is the fibre length. As an example may be mentioned that C_S is 0.2–0.4% for pine sulphate and 0.6–0.9% for mechanical pulp. 1–6% is a suitable concentration interval which is up to ten times more than what is usually used in the prior art. This means that considerably less water has to be removed from the pulp web which again results in smaller losses in material.

The most advantageous fibre length is 1–5 mm. and the thickness most suitably is 30–50 μm. The fibre type used may vary within wide limits from natural fibres to artificial fibres, etc.

Compared to sheet forming according to earlier methods and to earlier known arrangements the three-dimensional sheet, made according to this invention, shows improved strength qualities in a direction perpendicular to the plane of the sheet. Further, it should be noted that the apparatus according to the invention is remarkably smaller than the earlier known apparatuses and considerably cheaper, too.

The graduation and intensity required in the turbulent flow, so that all fibre flocks will disperse, depend on the concentration of the suspension, the fibre type, etc. However, it is clear that the special adjustment required by the formation of the consolidated web structure can easily be determined by an expert without extensive experiments.

As the pulp web **13** already at the start has a high dry content and a relatively good strength, it can be deposited directly on the press felt, between two felts or on a corresponding device for handling of the pulp web, for further transportation to a press or other water removal body.

In an apparatus according to the invention a transverse distributor **3** of conventional type may be used, which, however, was not possible with the arrangement in accordance with the U.S. Patent application Ser. No. 157,120, now abandoned, according to which specially formed and expensive distributing units were required.

It would particularly be emphasized that FIGS. 1 and 3 are on the whole designed to natural scale. If the sizes of the head boxes according to FIGS. 1 and 3 are compared with those of conventional head boxes, it can clearly be observed that a revolutionary decrease of all dimensions has been achieved. Of course, this decrease extends also to all auxiliary units which the head box requires for its operation according to the invention. The reason for this depends on the fact that far more concentrated pulp is being treated than up to now, i.e. far smaller volume flows of water. Thus even the pumping energy for the suspension is reduced, as well as the work required by water removal from the formed pulp web.

In order to obtain an even product of good quality, the suspension should obtain at the sheet forming a sufficient amount of energy per suspension volume unit. Thus there may arise difficulties at a sheet form with fixed dimensions and constructed for high surface weights and speeds when driven at low surface weights and/or low speeds. A low surface weight may be compensated with high speed but only to a certain limit. However, speeds of 6–14 m./s. can be well-controlled with an apparatus according to the invention.

For practical purposes and for the producing of pulp webs with different surface weights it is thus necessary to make the energy density adjustable so that it suits the desired driving requirements as far as the speed, surface weight and concentration are concerned. This can be achieved in several ways and a particularly convenient design is shown on FIG. 3.

The apparatus in accordance with FIG. 3 differs from the head box according to FIG. 1 in that in the former the constriction **8** in chamber **11** is adjustable for the regulation of energy density per suspension volume unit. This has been possible as the head box has been divided into a lower part **14**, comprising the channels **5, 6** and into an upper part **15**, horizontally movable on the lower part. This upper part and the mating lower part **14** define between themselves the chamber **11** and also the outlet channel **12**. The outlet channel **12** is enclosed by the upper part **15** and the lower lip **19** made of thin plate connected to the underside of the lower part **14.**

The upper part **15** rests on the horizontal upper side of the lower part **15** and extends downwards opposite the lower lip **19** and thereafter parallel to it. The moving is achieved by turning the screw **16** which is arranged horizontally between the upper part **15** and a counterpiece on the lower part **14.**

In order to achieve good sealing in chamber **11** and to give it a well-defined form, one wall in the chamber is formed by a springy plate **17** which has a thickness of approx. 0.5–1 mm. and which is mounted between the plates **21** and **22** on the underside of the upper part **15.** Plate **17** is tightened against the lower part **14** with the aid of a transverse hose **18** fitted in between plate

17 and the upper part 15 and filled with compressed air or the like. At the moving the pressure is released in air hose 18, the upper part 15 is moved and pressure is again fed.

In order to be able to change the surface weight at constant concentration, it is required that the height of the outlet channel 12 may be varied. This is achieved with suitable inserts 21 of different thicknesses. In a large head box, this adjustment can, of course, be arranged for continuous operation.

In a head box according to FIG. 1 the pulp web 13 is deposited at a certain angle on the wire or felt 1. In certain cases this disturbs the sheet structure in an unfavourable manner. In addition, the length of outlet channel 12 may be unnecessarily long for certain fibre types at which the web structure force will form especially quickly.

Both these drawbacks can be eliminated by replacing the quite stiff and formed bottom plate shown in FIG. 1 by a relatively thin plate like the plate forming the lip 19 in the embodiment of FIG. 3 and accordingly not illustrated. This functions both as channel bottom and breast plate. Its function is primarily to take up the vertical forces from chamber 11 and redirect these in direction of the wire or felt. After this the structure is in principle clear to be put down on the wire or felt. In order not to damage the structure unnecessarily, channel 12 should be as short as possible. However, for certain fibre types, etc., the web structure force may develop relatively slowly. Then the bottom plate can be pushed forward so that channel 12 is given the desired length for enabling the web structure to become fully formed before it is put down on the wire or felt. The putting-down takes place without stages if bottom plate is beveled a little on the underside and the angle against the wire or felt becomes minimal.

By putting a high fall of pressure over the last slot 8 the surface weight profile as a matter of fact, will be determined there to a great extent. This means that the function of outlet channel 12 is mainly limited to keeping the suspension together until a web structure is formed. Therefore the upper part of outlet channel 12 may be made rather soft in the outermost part. By making the outlet channel 12 soft in the outer section, it can follow the form of the sheet even during putting down on the wire or felt and during the first water removal. The length of the upper part of the outlet channel 12 should be made as short as possible; however the turbulence must have had time to decay and a web structure time to form before putting down.

As the surface weight profile is mainly determined in the last slot 8 the final correction of the profile takes place at this point. This correction in the case of precise manufacturing of the apparatus, need not be big—perhaps non-existent. In any case it may be limited to a few tenths of mm. For this reason an elastic deformation of one of the two walls in the last slot 8 could be considered.

In case the transverse distributor 3 is sufficiently narrow, one is able to alter the area of the transverse distributor 3 with clamps 20 or similar devices and with it the velocity of flow and the pressure of the grist and as a result of this the flow in the equipment and then also to a certain extent the profile of surface weight and velocity in the actual sheet former 2. This is possible only at high-concentration sheet forming, in accordance with the invention, wherein relatively small volume amounts of water are treated.

The head box according to the invention can also be simply modified for the production of a pulp web having several layers, conveniently so that two or several head boxes with appurtenant rows of channels and chambers are arranged on top of each other, so that the different suspension flows are united only when their turbulence has decayed sufficiently so that a mixture of the layers takes place only at their border layer in order to bind the layers to each other.

The method, according to the invention, has particularly proved to be suitable for the production of multi-layer cardboard in conventional manner, i.e., so that the lowest layer is deposited and dewatered first, after which the following layers are deposited and dewatered in turn on the underlaying layers. As the head boxes, according to the invention, work with a considerably higher consistency than before, the dewatering zones laying in between can be made shorter in a corresponding degree and the dewatering devices smaller and cheaper, as considerably smaller amounts of water are removed from the pulp web.

What is claimed is:

1. Method for forming a continuous material web of fibrous particles starting from a suspension of fibrous particles with a fibre concentration of about 1% to about 6% by weight, comprising in combination the following steps: the highly concentrated suspension is divided over and sprayed through several parallel-coupled apertures; after which the suspension jets are accelerated and sprayed at high velocity into at least one chamber in which the jets are reunited and deflected; then the suspension flow is accelerated and deflected anew; and finally the turbulence is allowed to decay in order to form a consolidated three-dimensional net structure of fibrous particles before they are deposited.

2. Method as claimed in claim **1**, wherein the suspension is deflected both times approximately 90° and the second time into a direction opposite that of the first time.

3. Method as claimed in claim **1**, wherein the suspension is prepared of fibres having a length of 1–5 mm. and a thickness of approximately 30–50 μm.

4. Apparatus for forming a continuous material web of fibrous particles starting from a suspension of fibrous particles having a concentration of at least twice the sedimentation concentration of fibrous particles comprising at least one means forming a transverse distributor, means forming several parallel-coupled channels, means forming a chamber, one end of each channel opening onto one sidewall of said transverse distributor and an opposite end of each channel opening through a wall of said chamber, the opposite wall of which chamber forms an impact face for the jets from channels for deflection and mixing of the jets in the chamber, the outlet opening of the channels being flattened in a direction which is at right angles to the extension of the outlet opening row in order to achieve an even distribution, the chamber further comprising a constriction as well as an impact face downstream of the constriction for renewed deflection of the turbulent suspension, and finally means forming an outlet channel with sufficient length to give the fibrous particles time to form a consolidated three-dimensional net structure before the pulp web is deposited.

5. Apparatus as claimed in claim **4**, in which the channels arranged alongside each other form an oblique angle with the wall surface in which their inlet openings are formed for enlargement of the inlet area and thereby reducing the risk for blocking.

6. Apparatus as claimed in claim **4**, in which the outlet openings of the parallel channels, arranged alongside each other, show a bulge in one side of their middle part in order to further an even distribution of the suspension jets.

7. Apparatus as claimed in claim **4**, in which the sheet former is divided into two parts which together define the chamber and the outlet channel, and which are also displaceable in relation to each other for the regulation of the constriction so that the sheet former is adjustable for the adaption of energy density to the concentration, velocity and fibre type of the suspension.

8. Apparatus as claimed in claim **4** and including means for adjusting the length of the outlet channel.

9. Apparatus as claimed in claim 4, in which the impact faces stand essentially at right angles to the flow.

10. Apparatus as claimed in claim 4, in which at least two transverse distributors for feeding of identical or unidentical pulp each through its channel set and chamber which are united in a place in the outlet channel, at which the turbulence of the suspension flows is decayed sufficiently so that a mixture of the consolidated web structures takes place at the most at their border layers for binding the different pulp layers together.

11. Apparatus according to claim 4 and including means for adjusting the height of the outlet channel.

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