

July 17, 1962

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3,044,925

METHOD AND APPARATUS FOR THE MANUFACTURE OF PAPER

Filed Nov. 20, 1958

2 Sheets-Sheet 1

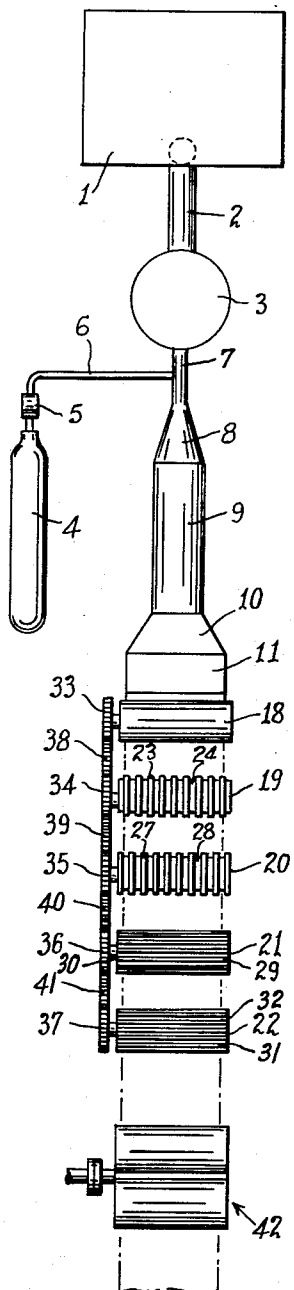


Fig 1

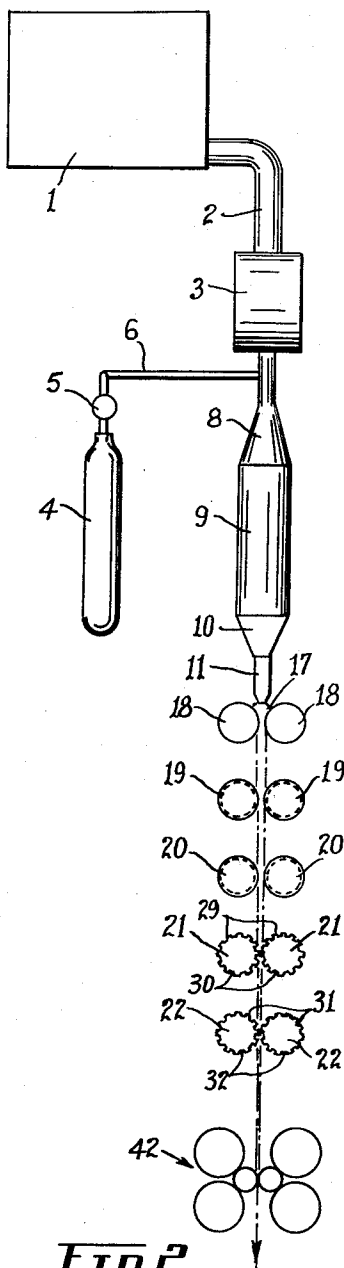


Fig 2

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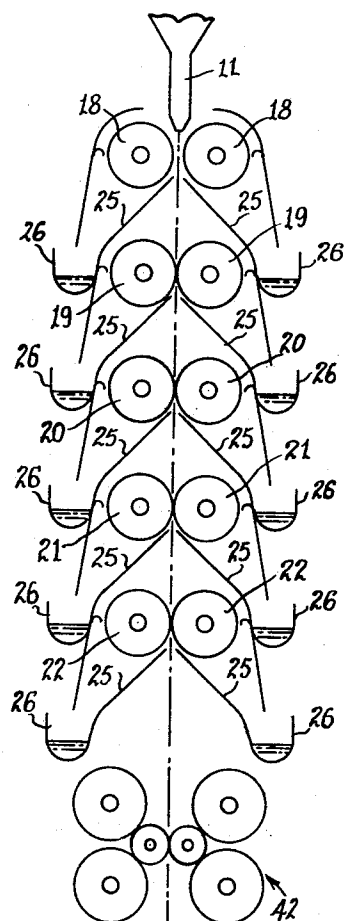


Fig. 4

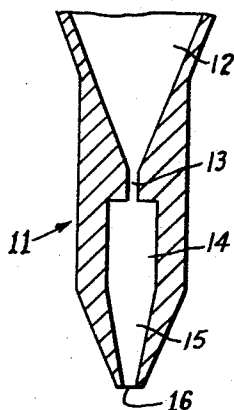


Fig. 6

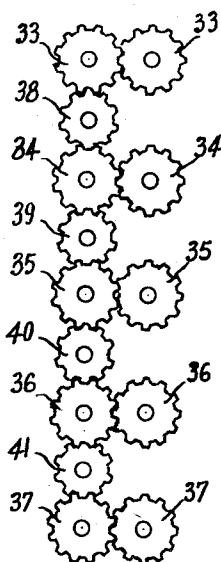


Fig. 5

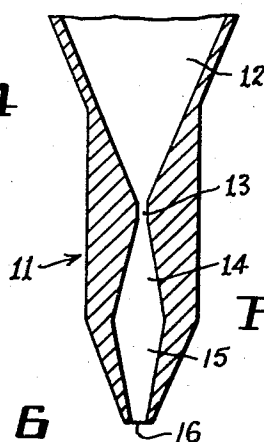


Fig. 3

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METHOD AND APPARATUS FOR THE MANUFACTURE OF PAPER

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Filed Nov. 20, 1958, Ser. No. 775,236
13 Claims. (Cl. 162—202)

This invention relates to improvements in the manufacture of paper and, while applicable to the manufacture of paper at conventional speeds, is especially useful for the manufacture of paper at speeds greatly in excess of conventional speeds. More particularly, the invention is concerned with that phase of paper-making which consists in forming an aqueous suspension of paper-making fibres into a wet web or sheet.

In the manufacture of paper at high speed in a continuous sheet, according to contemporary practice, a suspension of fibres in water, known in the industry as "the stock," is flowed onto the substantially horizontal upper run of a moving endless belt of wire cloth, known in the industry as "the wire."

Water drains from the stock through the wire as the wire carries it from the region of the breast roll towards the couch roll. As it is flowed onto the wire, the stock usually has a "consistency" of (parts by weight) one part of fibre to two hundred of water; such would be described as "0.5% stock."

Supporting the upper run of the wire are a number of rolls, known as "table rolls" whose function is to accelerate the drainage of water from the stock through the wire. A given element of stock, deposited on the moving wire near the breast roll, loses water progressively as the wire passes over the table rolls in its travel towards the couch roll; the consistency of this element of stock therefore increases progressively as it travels away from the breast roll.

At a point in its ride on the wire where the consistency of this element of stock has risen to about 2.5%, or (parts by weight) one part of fibre to forty of water, table rolls are no longer effective in accelerating the drainage of water from it.

Just beyond the last table roll, in the direction of travel of the wire, a series of suction boxes, sometimes known as "flat boxes," is employed to accelerate drainage of water from the (now) "high-consistency" stock on the wire.

The wire slides over the upper faces of the flat boxes; these upper faces are provided with openings which are in communication with vacuum pumps.

Before the wet web of fibre is removed from the wire, the wire wraps onto a perforated "suction couch roll" which is provided with an internal suction box connected with a vacuum pump.

The web, as it finally leaves the wire, is about "20% dry," which is to say, that it consists of (parts by weight) one part of fibre to four of water.

A disadvantage of this method of forming a web is the enormous volume of material which must be handled because the consistency of the stock, as flowed onto the wire, must be kept in the neighbourhood of 0.5% in order to achieve acceptably uniform dispersion of the fibres in the water. Unless this uniformity of dispersion is achieved, the "formation of the sheet" is unacceptable. This is due to the phenomenon of "floccing" of the fibres, which insist on congregating into bundles unless dispersed in a dilute suspension.

Another disadvantage of this method is that the cost of Fourdrinier wires is high while their life-expectancy is low; also the time taken to change wires represents loss of

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production and, in effect, reduces the efficiency of the machine.

With further reference to the phenomenon of floccing of the fibres in high-consistency stock, when the consistency is above 2% floccing is so marked that the appearance of a free surface of such stock is reminiscent of a pebbled surface. The size of the individual bundles of fibres varies only slightly; furthermore, the average size of the bundles does not change significantly over a 2% to 12% range of consistencies.

A major contributory factor to design stagnation in the field of web-forming devices has been the difficulty of achieving the deflocculation of high-consistency stock.

The conventional low-consistency stock, however, is not without its problems also; and is, in one respect, a victim of its own diluteness. It suffers from a tendency to reflocculation in the interval between admission to the headbox and discharge from the slice because, in the presence of much water, the individual fibres are free to swim to each other and satisfy their disposition to congregate into bundles.

High-consistency stock, on the other hand, having a tenth, say, of the amount of water, does not provide individual fibres with the freedom of movement that they require for reflocculation. For this reason 5% stock, once it has been deflocculated, is more stable than deflocculated 0.5% stock.

This invention covers a method of deflocculating high-consistency stock and a method of forming a web without the use of a wire; it is more particularly dedicated to the manufacture of paper at speeds in the order of 100 feet per second, and higher, though not excluded from use at lower and more conventional speeds.

In the method of forming a web according to this invention the consistency of stock fed to the web-forming device is about ten times that employed in contemporary paper-making machinery, or in the order of 5% fibre by weight.

Deflocculation of the fibres is effected by dissolving a gas under pressure into the stock and forcing this gas-impregnated stock through an orifice at high velocity into a diffuser or expansion chamber.

There is a substantial and rapid pressure drop in the stock as it passes from the upstream side to the downstream side of the orifice. As a consequence of this pressure drop, dissolved gas comes out of solution in the form of bubbles which, growing between adjacent fibres, force them apart and break up the bundles or flocs.

The sudden increase of volume which takes place as a result of the formation of gas bubbles within the stock creates turbulence.

Simultaneous forced turbulence and separation of adjacent fibres results in deflocculation of the stock.

The expansion chamber is provided with a slice outlet proportioned to give the desired stock exit velocity.

The stream of deflocculated stock issuing from the slice is received by the web-forming device which compacts it and forms it into a web by passing it through a series of pairs of rolls.

The first stages of compacting consists chiefly of bursting the bubbles in the stock; the last stage of compacting consists entirely of squeezing out water.

In this web-forming device all rolls, with the exception of the first pair, are provided with surface grooves which form paths for escape of water from the web without forcing it back in to areas which have been wrung.

An object of this invention is to reduce the volume of material to be handled in the manufacture of paper.

Another object is to reduce the cost of the equipment used in the manufacture of paper.

Another object is to reduce the physical size of the equipment used in the manufacture of paper.

Another object is to eliminate the use of costly, short-life, expandable components from web-forming devices used in the manufacture of paper, as for example Fourdrinier wires.

Another object is to provide paper-manufacturing means which do not demand periodic down-time for renewal of expendable components such as Fourdrinier wires.

FIG. 1 is a vertical schematic elevation in a plane parallel with the plane of the web.

FIG. 2 is a vertical schematic elevation in a plane normal to the plane of the web.

FIG. 3 is a section, on an enlarged scale, in a plane normal to the plane of the web, through the deflocculator device.

FIG. 4 is an enlarged partial schematic vertical section, in a plane normal to the plane of the web, showing the means for catching water removed from the web.

FIG. 5 is an enlarged partial schematic vertical elevation, in a plane normal to the plane of the web, indicating the arrangement of driving gears for the rolls shown in FIGS. 1, 2, and 4.

FIG. 6 is a view, similar to FIG. 3, but showing a modified design of deflocculator device.

With reference to FIGS 1, 2 and 3, high-consistency stock from a stock tank 1 passes through stock feed duct 2 to stock pump 3.

A source of compressed gas 4 is ducted to a gas flow control device 5 from which gas duct 6 leads gas to the stock pump discharge duct 7.

Stock pump discharge duct 7 is connected to the inlet end 8 of plenum chamber 9.

Plenum chamber 9, at its discharge end 10 feeds deflocculator 11.

Deflocculator 11 is shown in section, to an enlarged scale, in FIG. 3 from which it will be seen that stock flows into it through a contracting passage 12 to a constriction 13 which opens into a diffuser or expansion chamber 14.

From diffuser 14 the stock passes into an accelerating chamber 15 which is provided with a slice outlet 16.

It is to be noted that the stock path throughout the length of the deflocculator 11, as shown in FIG. 3, is the full width of the web to be formed.

It is also to be noted that the gas from the source of compressed gas 4 is of a nature having the characteristic of solubility in water as, for example, air.

From the slice outlet 16 the stock issues in a stream 17 which passes between rolls 18.

The diameter of these rolls is such that, at the linear speed of operation of the web-former or given angular velocity of the roll, the centrifugal effect at the periphery of the rolls is of the order of 10^3 times gravity.

This diameter is chosen in order to prevent adhesion of fibres to the roll surfaces and to provide that the stock leaves the roll nip in a compact stream instead of a diffused spray.

Due to the action of rolls 18 in bursting gas bubbles, the stream of stock is reduced in thickness in its pass through the nip.

Passing from rolls 18 in a somewhat compacted stream, the stock passes through the nips of pairs of rolls 19, 20, 21 and 22 in succession and is further compacted in its passage through each pass.

Rolls 19 are provided with circumferential lands 23 somewhat wider than the grooves 24 between the lands 23. The lands 23 on each of the two rolls 19 are mutually registered in planes normal to the roll axes. Stock passing through the nip of rolls 19 is therefore wrung in longitudinal stripes which coincide with the registered pairs of peripheral lands 23 on the roll surfaces.

Water removed from the stock, where it is squeezed between pairs of roll lands 23, escapes into the spaces formed by registered pairs of roll grooves 24 whence it

is centrifuged off rolls 19 and deflected by strippers 25 (FIG. 4) into troughs 26.

Rolls 20 are provided with circumferential lands 27 of the same width as the lands 23 on rolls 19 and therefore somewhat wider than the grooves 28 between the lands 27 on rolls 20. Lands 27 on each of the two rolls 20 are mutually registered in planes normal to the roll axes. Stock passing through the nip of rolls 20 is therefore wrung in longitudinal lands 27.

Water removed from the stock, where it is squeezed between pairs of roll lands 27 into the spaces formed by registered pairs of roll grooves 28 whence it is centrifuged off rolls 20 and deflected by strippers 25 into troughs 26.

It is to be noted that the longitudinal stripes wrung by the lands 27 of rolls 20 are in staggered relationship to the longitudinal stripes wrung by the lands 23 of rolls 19 and, since the lands 23 and 27 are wider than the grooves 24 and 28, the wrung longitudinal stripes due to lands 27 on rolls 20 overlap the wrung longitudinal stripes due to the lands 23 on rolls 19.

Rolls 21 are provided with uniformly spaced longitudinal lands 29 parallel with the roll axes; lands 29 are somewhat wider than grooves 30 between lands 29. Rolls 21 are mutually phased so that lands 29 register with lands 29 and grooves 30 with grooves 30, at the nip between the two rolls 21.

It will be seen that, in passing through the nip of rolls 21, the stock, is wrung in transverse stripes.

Water removed from the stock, where it is squeezed between pairs of roll lands 29 escapes into the spaces formed by registered pairs of roll grooves 30 whence it is centrifuged off rolls 21 and deflected by strippers 25 into troughs 26.

Rolls 22 are provided with uniformly spaced longitudinal lands 31 parallel with the roll axes; lands 31 are somewhat wider than grooves 32 between lands 31.

Rolls 22 are mutually phased so that lands 31 register with lands 31, and grooves 32 with grooves 32, at the nip between the two rolls 22.

It will be seen that, in passing through the nip of rolls 22 the stock is wrung in transverse stripes.

Water removed from the stock, where it is squeezed between pairs of roll lands 31, escapes into the spaces formed by the registered pairs of roll grooves 32 whence it is centrifuged off rolls 22 and deflected by strippers 25 into troughs 26.

The pair of rolls 22 is so phased with relation to the pair of rolls 21 that the transverse stripes wrung by rolls 22 are in staggered relation to the transverse stripes wrung by rolls 21. Since lands 29 are wider than grooves 30 and lands 31 are wider than grooves 32, the transverse stripes wrung by rolls 22 overlap the transverse stripes wrung by rolls 21.

It will therefore be seen that the entire stream of stock, in passing successively through five roll nips, has been subjected first to preliminary compacting, then to wringing in overlapping longitudinal stripes and, finally, to wringing in overlapping transverse stripes.

Pairs of rolls 18, 19, 20, 21 and 22 (see FIGS. 1 and 5) are driven by pairs of synchronizing gears 33, 34, 35, 36, and 37 respectively.

Synchronizing gears 33 and 34 are phased by pinion 38; synchronizing gears 34 and 35 are phased by pinion 39; synchronizing gears 35 and 36 are phased by pinion 40 and synchronizing gears 36 and 37 are phased by pinion 41.

After leaving the nip of rolls 22 the web is passed through a press, or presses, 42 of the type disclosed in our U.S. co-pending application Serial No. 699,255, filed November 27, 1957, now Patent No. 2,885,954.

In the modification shown in FIG. 6 the inside configuration of the deflocculator 11 is such as to give a more sudden expansion as compared with the configuration shown in FIG. 3. In this connection, it will be noted that the diffuser section 14 shown in FIG. 6 has, through-

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out its length, a substantially uniform inside diameter considerably greater than that of the communicating constriction 13.

It may also be noted, at this point, that the invention is not restricted to the use of the particular design of web-forming rolls shown in the present drawings. On the contrary, it is feasible to provide the rolls 19, 20, 21 and 22 or, in fact, all of the rolls with either circumferential grooves and lands or helical grooves and lands.

When helical grooves and lands are employed, the helical grooves and lands on each of a pair of cooperating rolls may be of the same hand or may be of opposite hands; in the former case, the wringing would be in a diamond-shaped pattern while, in the latter case, the wringing would be in diagonal stripes.

It may be also pointed out that the term "high consistency" paper stock, as used in the preceding description and in the appended claims, is intended to designate a stock having a consistency within the range of from approximately 2% to 12% higher.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of forming a high consistency aqueous suspension of fibres in the order of five percent consistency into a sheet which comprises effecting pressure impregnation of the stock with a water-soluble gas, forcing the gas-impregnated stock through an orifice at high velocity into an expansion zone in which dissolved gas comes out of solution in the form of bubbles which serve to deflocculate the stock by forcing adjacent fibres apart and which also breaks up flocs and creates turbulence, delivering the deflocculated stock from the expansion zone in a downwardly flowing stream, and subjecting the downwardly flowing deflocculated stream of stock to compacting pressure applied thereto at different points along the length of the downward path of travel of said stream to thereby force water and gas from the downwardly flowing stream of stock and compact the fibrous components of the stream into a sheet.

2. A method of forming a high consistency aqueous suspension of fibres in the order of five percent consistency into a sheet which comprises effecting pressure impregnation of the stock with a water-soluble gas, forcing the gas-impregnated stock through an orifice at high velocity into an expansion zone in which dissolved gas comes out of solution in the form of bubbles which serve to deflocculate the stock by forcing adjacent fibres apart and which also breaks up flocs and creates turbulence, delivering the deflocculated stock from the expansion zone in a downwardly flowing stream, and subjecting the downwardly flowing deflocculated stream of stock to compacting pressure to force water and gas from the downwardly flowing stream of stock and compact the fibrous components of the stream into a sheet.

3. Apparatus for forming a high consistency aqueous suspension of fibres into a sheet which comprises a deflocculator including an expansion zone having a restricted stock inlet orifice, means for first impregnating the stock with a water-soluble gas under pressure and then forcing the gas-impregnated stock through said orifice and into said expansion zone and compacting means through which a stream of deflocculated stock is passed from the deflocculator to compact the fibrous components of the stream into a sheet.

4. Apparatus as set forth in claim 3 in which the stock is passed from the deflocculator in a downwardly flowing stream and in which the compacting means comprises a vertical series of pairs of compacting elements arranged so that the downwardly flowing stream of stock passes between and is subjected to compacting pressure by the compacting elements of each pair.

5. Apparatus as set forth in claim 3 in which the stock is passed from the deflocculator in a downwardly flowing

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stream and in which the compacting means comprises a vertical series of pairs of compacting rolls arranged so that the downwardly flowing stream of stock passes between and is compacted by the rolls of each pair.

6. Apparatus as set forth in claim 3 in which the stock is passed from the deflocculator in a downwardly flowing stream and in which the compacting means comprises a vertical series of pairs of compacting rolls arranged so that the downwardly flowing stream of stock passes between and is compacted by the rolls of each pair, said compacting means being further characterized in that the component rolls of at least certain of said pairs of rolls are provided with grooves and lands.

7. Apparatus as set forth in claim 3 in which the stock is passed from the deflocculator in a downwardly flowing stream and in which the compacting means comprises a vertical series of pairs of driven rolls arranged so that the downwardly flowing stream of stock passes between and is subjected to pressure by the rolls of each pair, said compacting means being further characterized in that the diameter at a given angular velocity of the rolls is such that the centrifugal effect at the periphery of the rolls is of the order of 10^3 times gravity.

8. Apparatus for forming a high consistency aqueous suspension of fibres into a web or sheet which comprises a tank containing the high consistency stock, a plenum chamber, a pump through which the stock is pumped from the tank to the plenum chamber, a source of water-soluble gas under pressure, a duct through which gas from said source is introduced into the stock at the discharge side of the pump, a deflocculator to which the gas-impregnated stock is delivered from the plenum chamber, and compacting means through which a stream of deflocculated stock is passed from the deflocculator.

9. Apparatus as set forth in claim 8 in which the deflocculator includes an expansion zone in which dissolved gas comes out of solution in the form of bubbles which serve to force adjacent fibres apart to break up flocs and to create turbulence which causes random orientation of the fibres.

10. Apparatus as set forth in claim 8 in which the deflocculator includes an expansion zone in communication with the plenum chamber via a restricted orifice through which stock is delivered from the plenum chamber to the expansion zone, said apparatus being characterized in that the gas comes out of solution in the expansion zone in the form of bubbles which serve to deflocculate the stock by forcing adjacent fibres apart and to arrange the fibres in random orientation.

11. Apparatus as set forth in claim 8 in which the deflocculator includes an expansion zone, a restricted orifice through which stock is delivered from the plenum chamber to the expansion zone and an accelerating zone through which the stream of stock is delivered from the expansion zone to the compacting means.

12. Apparatus as set forth in claim 8 in which the stock is passed from the deflocculator in a downwardly flowing stream and in which the compacting means include a plurality of pairs of rolls arranged in vertical series so that the downwardly flowing stream of stock passes between and is subjected to pressure by the rolls of each pair.

13. Apparatus for forming a high consistency aqueous suspension of fibres into a sheet or web, comprising a deflocculator including an expansion zone having a restricted stock inlet orifice, means for impregnating the stock with a water-soluble gas under pressure and forcing the gas-impregnated stock through said orifice and into said expansion zone and compacting means through which a downwardly flowing stream of deflocculated stock is passed from the deflocculator, said compacting means including a plurality of pairs of rolls arranged in vertical series so that the downwardly flowing stream of stock passes between and is subjected to pressure by the rolls of each pair, deflectors positioned below each pair of rolls

and troughs into which water centrifuged from the rolls is deflected by the deflectors.

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