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V. FRIEDRICH, JR.
PROCESS AND APPARATUS FOR AVOIDING
CURL IN MACHINE MADE PAPER
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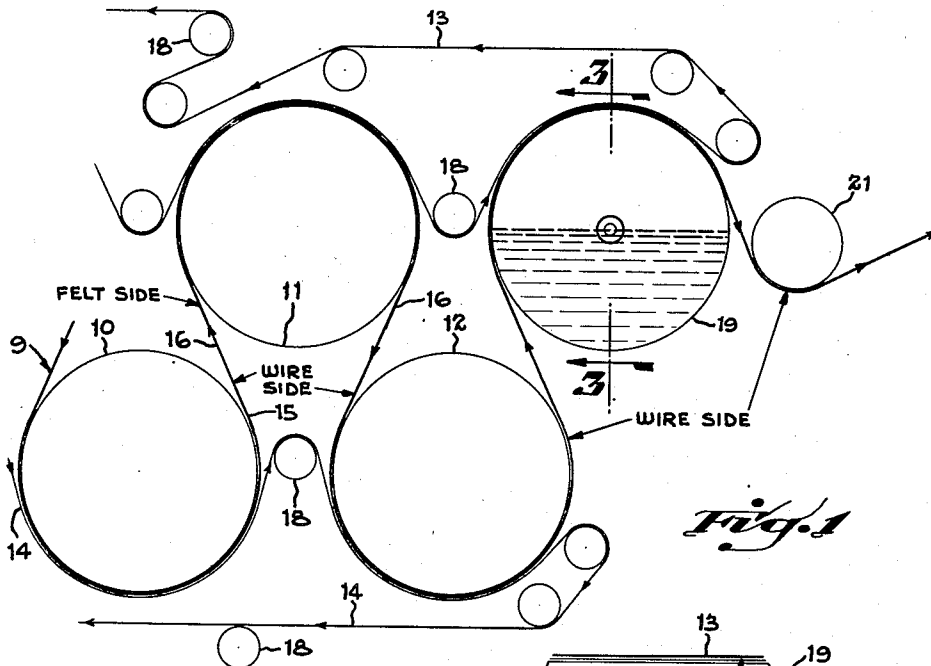


Fig. 1

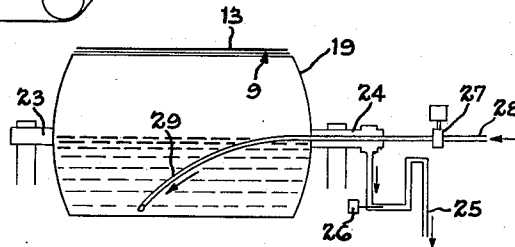


Fig. 3

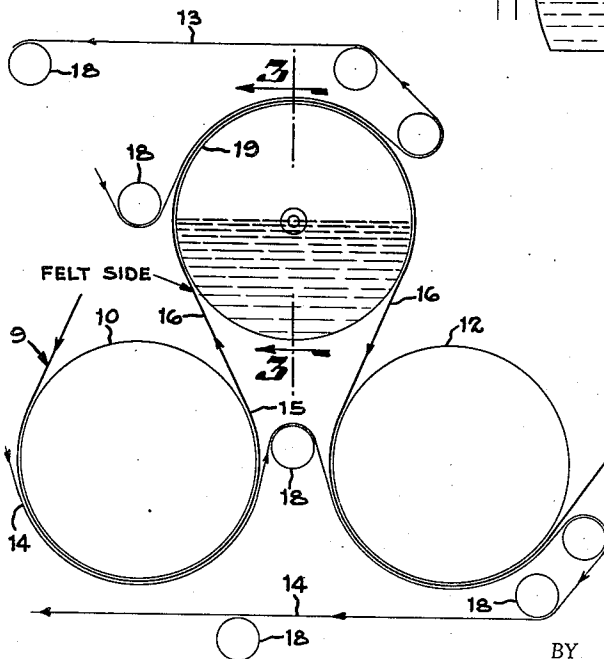


Fig. 2

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PROCESS AND APPARATUS FOR AVOIDING
CURL IN MACHINE-MADE PAPERValentine Friedrich, Jr., Hamilton, Ohio, assignor
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This invention relates to the art of paper making and is particularly concerned with a process and apparatus for overcoming the natural tendency to curl displayed by machine made paper.

Paper manufactured on conventional Fourdrinier machines displays a marked tendency to curl, invariably in the direction of the Fourdrinier wire upon which it was supported during processing. Particularly in multi-color printing processes such curl prevents the superposition of one color directly over another in exactly the right registration, for the curled, misshapen paper is always distorted, even though slightly, by the rollers of the first color printing. Such distortion is impossible to duplicate exactly at the second impression and therefore one cannot obtain the effect desired from the complementing of colors one printed on top of the other. Also, paper which curls when free to do so is difficult to handle by mechanical means.

In the past, there have been attempts, at printing establishments themselves, to overcome this objectionable tendency of paper to curl. These have been directed to maintaining the atmosphere of the press room at a fixed relative humidity, for example, 50%, at which paper generally has been found to display a lesser curling tendency. This has not been found to be the complete answer to press room problems because of the elaborate expensive equipment necessary to maintain the proper humidity, because of the fallibility of such equipment even when installed, and because of the fact that commercial papers do not always respond satisfactorily to such controls.

The primary objective of this invention is to attack the problem of curl at its source and to manufacture a paper which is free of the curl now exhibited by commercial papers.

The invention is predicated upon the concept of selectively re-introducing small, controlled amounts of moisture to one side only of a paper web, immediately after the web has been dried to a relatively standard water content.

It has been an object and accomplishment of this invention to utilize the basic processes and apparatus of existing paper machines to produce a paper which exhibits virtually no tendency to curl. The invention will thus be disclosed in the particular environment of a Fourdrinier paper machine, since such machines are in almost universal use, and since the invention can be practiced there with only small alterations in structure and in process steps, but with pronounced improvements in results.

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All Fourdrinier machines have in common four sections, (1) a wet end, (2) a pressing section (3) a drier section and (4) a calender section, although in some instances calendering may be omitted in the processing itself. As introduced at the wet end, the paper stock is a suspension of pulp in water. At the wet end of the machine the stock is deposited on a moving endless belt of wire cloth, called the Fourdrinier wire, over which the paper constituents travel toward the pressing section. As it passes over the supporting wire, water is drained from the paper web, first by gravity, and later by suction. During this travel, the fibers of the stock align themselves in characteristic pattern. At the end of the wire the paper web has become self-sustaining sufficient to be introduced into the pressing section. This portion of the machine is normally constituted by a succession of pairs of rollers between which the paper web travels, while excess water is squeezed out of it. Beyond the bank of pressing rollers are a succession of single-drum, heated drier rollers about which the paper is made to pass successively in a circuitous path. In this portion of the machine endless belts of papermakers' felt help absorb water and maintain an intimate contact between the paper and the surfaces of the respective drier drums, thus facilitating the transfer of heat from the drum to the paper and causing the maximum evaporation of water from the paper web. A final set of rollers are called calenders and impart the final desired surface finish to the dried web.

This invention arises from the recognition that the condition of the paper web as it passes from the bank of driers to the calender rolls is such that it is extremely receptive and reactive to only slight moisture introduction. I have discovered that the tendency of a paper to curl can be overcome, and a paper which will remain flat under widely varying humidity conditions can be produced, by purposefully introducing a small quantity of water in the felt side of the paper after it has been dried. An introduction of small, almost imperceptible amounts of water, immediately following upon deliberate removal of water from the web, paradoxically greatly affects the properties of the finished product.

It has been determined that the utility of water reintroduced to the travelling web of paper resides in making it available to the "felt" side of the paper only, i. e., to the side opposite that at which the pulp was supported on the wire in the first section of the Fourdrinier machine. The over-all moisture content of a paper web at its emergence from the drying section of a Four-

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drinier is customarily between 5½% and 6½%. This moisture content is sometimes referred to as the equilibrium moisture content of the paper at a given relative humidity, or merely as the atmospheric equilibrium moisture content. The water addition over and above such amount, as contemplated by this invention, is almost immeasurable. Its effect apparently lies not necessarily in its magnitude, but rather in its being applied to one side of the web only, during travel, and at the almost instantaneous interval between the steps of drying and calendering.

I have, in the course of extensive observation of the behavior of paper under controlled conditions of moisture, developed a theory which explains the significant results of my process. Machine-made papers normally contain unrelieved or "frozen" stresses as a result of having been dried under tension. This increases the directional effect created as the cellulose fibers, carried on the Fourdrinier wire in a water-suspension, tend to align themselves in the direction of travel. Due to the dragging effect of the moving wire, most of the longer fibers in the bottom layer, or wire side of the sheet, align themselves in the direction of travel, and this effect is accentuated by the loss of shorter fibers from the bottom layer of the sheet through the drainage of water by gravity and by suction. On the upper layer, or felt side, the shorter fibers remain in the web, and the longer fibers, being less affected by the dragging action of the wire, are distributed more nearly at random than are those in the wire side layer. Thus, the upper, or felt side, layer is less unidirectional in character than the wire side.

When the sheet is dried under tension, drying shrinkage is restricted to the cross direction. Since the loss of moisture causes cellulose fibers to shrink greatly in thickness but only slightly in length, the difference in alignment between the fibers in the wire side layer and those in the felt side layer results in different forces exerting themselves along and across the sheet as the web proceeds through the drying process. The wire side layer tends to shrink strongly in the cross direction but very little along the length of the web, while the felt side tends to shrink, as it dries, more evenly in both directions.

Although a sheet of paper dried as described above may lie flat when cut off from the web and maintained at the same moisture it contained when released from tension at the end of the paper machine, the different fiber alignment between the fibers of the wire side layer and the felt side layer causes curl toward the wire side if the sheet is dried out in an atmosphere of low relative humidity. The predominant force in this case is the force of contraction of the fibers of the wire side layer, and this force asserts itself most strongly across the web, pulling the upper layer into a curve, toward the wire side.

If one adds moisture to the felt side of the moving web at the end of the drying process, as I have described, the fibers become temporarily limp and flexible, and rearrange themselves so the unequal stresses are relieved. Within a short time the additional moisture briefly present in the felt side is partly absorbed into the other layers of the sheet and partly evaporated to the atmosphere, causing the fibers that had been moistened to shrink slightly, thus counteracting the force caused by the shrinkage of the fibers in the wire side layer. This equalization of strain prevents the accumulation of curling tendencies which inhere in paper processed customarily, and

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this condition maintains throughout a much wider range of moisture content than if the sheet had not been so moistened.

In practice, I find that I can substitute, for the last or second-last of the drying rolls of a conventional Fourdrinier, a special chilling roll which contacts the "wire" side of the web, drawing heat from it and making the web sufficiently cooler than a moisture-containing surroundings to result in introduction of water to the felt side of the web.

When I employ a chilling roller, or independently thereof, I find it expedient to utilize an already present source of water, i. e., one of the travelling moisture-laden belts of felt which is used to absorb water from the web during earlier stages of the process. As the felt arrives in the vicinity of the chilling roller, it is both hot and humid as a result of its functions in the drying zone. Its passage over the chilling roll not only causes transfer of moisture from it to the paper web, but also condensation of water from the moisture-laden air entrained between the parallel travelling paper and felt. Bearing thus-precipitated water, the web travels on to the calender rolls for further processing before the added moisture has a chance to undesirably "set."

A further determination of this invention is that the control of temperature of the chilling roll additionally contributes to an exact counterbalancing of the inherent tendency of the paper to curl toward its wire side. For given combinations of paper composition, web speed and machine dimensions (notably roller size and area of contact between felt and roll), an optimum temperature range exists. Such range usually spans 10 degrees Fahrenheit or more, within which curl is neutralized so that a paper is produced which will lie flat under normal conditions of use. Attempts to cool the roll, and the web passing over it, to lower temperatures than the experimentally determined optimum ranges have resulted in a curl of significant magnitude in the opposite direction, that is, a curl toward the felt side of the paper web.

Thus, by this invention a paper can be produced which has curl characteristics more than normally tolerant or independent of wide variations of conditions of transportation, storage and use.

Other objects and advantages of this invention will be apparent from the following description of the drawings in which one typical arrangement for controlled introduction of moisture is employed.

Figure 1 is a diagrammatic view of a portion of the drying section of a Fourdrinier paper machine equipped for the practice of the invention.

Figure 2 is a diagrammatic view similar to that of Figure 1 and discloses a variation in the practice of the invention in a modified type of dryer.

Figure 3 is a diagrammatic sectional view of the chilling roller of Figures 1 or 2, on line 3—3 of either, showing an arrangement by which the drum may be maintained within a definite temperature range.

The conventional mechanism for producing a self-sustaining web from paper pulp and water, forming no part of the present invention, is not shown in the drawings, but it will be understood that paper web 9, prior to reaching the stage shown in Figures 1 and 2, has been subjected to the usual processes of a Fourdrinier machine. Generally, the drying section of a Fourdrinier ma-

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chine will contain more than the rolls which are shown, and Figures 1 and 2 represent only the terminal portion of the drying section. Thus, by the time the web reaches the drying station, much of the excess water in the web will have been already removed, and successive steam heated rolls, 10, 11 and 12, rotating in the direction of web travel, continue the extraction of moisture from the web in cooperation with belts 13 and 14 of papermakers' felt.

As indicated, the rolls are disposed at two levels, or tiers, and are staggered with respect to each other. The paper web is made to travel a tortuous path over successive rolls, alternating from the top to the bottom tier, and progressing from left to right in the figures. The path thus defined results in an appreciable contact, with the steam heated rolls, of first the wire side, then the felt side, etc., of the paper. For purposes of illustration, it is assumed that wire side 15 of the paper web 9 lies adjacent the warm roller surface of roller 11 of the upper tier.

As the web travels through the drying zone, alternating faces of the web are intermittently contacted with an endless belt of papermakers' felt. This contact is simultaneous, or nearly so, with the winding about of the paper on drying rolls. One such belt 13 is disposed above the upper tier of rolls and in the drawings it will be seen that as the paper embraces portions of the circumference of roll 11 of the upper tier, the felt side of the paper, 16, opposite the wire side 15, is contacted by the felt belt 13. An additional belt 14 of papermakers' felt is disposed beneath the lower tier of drying rolls, of which rolls 10 and 12 are shown. As to rolls 10 and 12, the "felt" side 16 of the web 9 lies next adjacent the drying roll surface and wire side 15 is exposed to a felt surface.

Belts 13 and 14, of course, travel in the same direction as the web of paper and at the same speed. The belts themselves are mounted on rollers 18 which are disposed to festoon the respective belts in such a way that the traveling felt engages the web of paper over substantial circumferential portions as the paper web passes over corresponding drying rolls.

Rolls 10, 11 and 12 are each steam heated, as is conventional in a Fourdrinier machine. After leaving roll 12, in Figure 1, the web of paper next passes between roll 19 and the moving surface of belt 13. In the conventional machine, a roll in the position of roll 19 would be steam heated but in accordance with the present invention roll 19 is water chilled to induce introduction of water from moisture-laden belt 13, onto felt side 16, as by condensation. Water is thus deposited from belt 13 onto the felt side 16 of paper web 9, in, as will be seen, controlled amounts.

The web proceeds from the drying station of a Fourdrinier machine to a calendering portion after which it is reeled for shipment or storage. To maintain proper tension between the last web-processing roller, e. g., roll 19, as shown in Figure 1, and the calender, a roll 21 of lesser diameter than rolls 10, 11, 12 and 19 engages the web of paper and helps hold it taut after leaving chilling roll 19.

I have found that it is generally desirable to apply cooling water to the interior of this roll to avoid any abrupt change in temperature.

Some Fourdrinier machines are of such construction that the felt side of the paper resides in contact with the last roller of the dryer section rather than the wire side in the arrangement

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shown in Figure 1. In such event the construction shown in Figure 2 may be used.

In Figure 2 the construction is similar to that of Figure 1 except that water-chilled roll 19 is second from last roll in the drying section proper, in order to induce water introduction on felt side 16 of paper web 9. In such event the last roll of the dryer section may be decommissioned, or may be allowed to run at room temperature.

Figure 3 discloses the details for the temperature control of chilling roll 19, of either Figure 1 or 2. As shown, roll 19 has trunnions 23 and 24. Paper web passes over the top of roll 19; above it is endless belt 13 of papermakers' felt exposing its moist surface to web 9.

Roll 19 is hollow and has a hollow trunnion 24 which is connected to a water outlet 25 for accumulating overflow from the interior of roll 19. In typical practice, the roll 19 will be about half full of water, the level rising no higher than the overflow provided by trunnion 24 and its outlet conduit. There is disposed in conduit 25 a temperature responsive member 26 which is connected to water valve 27 in inlet 28, in any suitable manner.

Inlet line 28 passes through hollow trunnion 24 into the interior of roll 19. Water normally passes into the roll continuously, or at periodic intervals, so as to result in corresponding overflow and discharge of water into the vicinity of thermo-controller 26. The thermo-controller 26 responds to the temperature conditions inside roll 19 but is mounted externally thereof so as not to interfere with its rotation, and is free of the turbulence of the water produced by such rotation. Water passes through inlet line 28 to a spout 29 disposed at a point adjacent the inside wall of the roll 19 and near its lowest point. Valve 27 however, responds to temperature measurements of thermo-controller 26 to admit greater quantities of cooling water to the interior of roll 19 as the temperature measurements indicate that the overflow is too hot.

As the drying rollers are usually maintained at a temperature of from 220° to 230° F. by means of steam passed through them, roll 19 will have a chilling effect at any effective temperature below 220° F. However, in order to remove or neutralize the characteristic curl toward the wire side of the paper, it has been found desirable to maintain the temperature of the chilling roll appreciably below the boiling point of water.

The exact optimum temperature of the chilling roller varies from one paper to another, but preferably is between 80° F. and 200° F. For purposes of illustrating typical practices of the invention the following detailed examples are given.

On a given machine, having a web travelling at 400 ft. per minute, a ream of 25 x 38 inch lithographic paper weighing fifty pounds, exhibited the following characteristics at the indicated conditions:

Temperature of Chilling Roller	Curl Characteristic
200°-220° F.	Pronounced curl with the grain, toward the wire side.
160° F.	Virtually flat.
150° F.	Slight curl toward the felt side.
140° F.	Pronounced curl toward the felt side.

A ream of the same size sheet weighing sixty pounds, with a speed of travel in the machine of 390 ft. per minute, gave the following results.

Temperature of Chilling Roller	Curl Characteristic
200°-220° F.-----	Pronounced curl toward wire side.
150° F.-----	Virtually flat.
140° F.-----	Slight curl toward felt side.
130° F.-----	Pronounced curl toward felt side.

As indicated previously, the exact temperature at which it is desirable to maintain the chilling roller depends upon the weight and composition of the paper, the speed of travel of the web, and the diameter of the rollers and the amount of felt wrapped around the chilling rollers of each particular machine.

But generally speaking, chilling to the temperature of substantially 150° to 170° F. tends to minimize the tendency to curl of almost any ordinary paper, and the tendency may be eliminated entirely by testing samples of paper produced by the machine and adjusting the exact temperature of the chilling roller in conformity with the principles which have been disclosed and discussed.

Having described my invention, I claim:

1. The method of manufacturing, on a Fourdrinier paper making machine, a web of paper which does not display a tendency to curl, the said method comprising, forming a web of paper on a wire of a Fourdrinier machine, progressively drying the paper in the Fourdrinier machine by contacting alternate sides of the paper with drying rolls heated to a temperature higher than approximately 200° F., while respectively opposite sides of the paper are simultaneously engaged by a moisture absorptive papermakers' felt, and continuing the drying operation until the web of paper contains less than about 6½% of moisture, then passing that side of the paper web which was initially laid upon the wire of the Fourdrinier machine over a substantially dry surface of a roll which is maintained at a temperature in the range of approximately 150° to 170° F., and simultaneously contacting the opposite side of the portion of the paper engaging the said roll with the said papermakers' felt of the Fourdrinier machine while the said papermakers' felt is in a hot and humid condition, the specific temperature within the said range being so selected that a paper which is substantially free from the tendency to curl is produced.

2. In the process of manufacturing paper wherein a Fourdrinier wire and a moisture absorptive felt are employed to produce a paper web having a "wire" underside and a "felt" top-side, the successive steps of forming a paper web upon a Fourdrinier wire, passing the said web over a series of drying rolls heated to a temperature above the boiling point of water and in intermittent contact with a belt of the said papermakers' felt under such conditions as to reduce the moisture content of the paper web to not more than about 6½%, and then selectively introducing a small quantity of moisture

into the felt side of the said paper web by passing the said web over a substantially dry surface of a chilling roll which is maintained at a temperature within the range of approximately 80° to 200° F., with the "wire" underside of the paper web in direct contact with the surface of the said chilling roll, and simultaneously engaging the felt side of the paper directly opposite the portion of the paper contacting the said roll with the said belt of papermakers' felt while the papermakers' felt is hot and humid, the specific temperature within the said range being so related to the moisture conditions of the said papermakers' felt that a paper which is substantially free from the tendency to curl is produced.

3. In a Fourdrinier paper making machine, a wire for forming a web of paper, a succession of drying rolls about which a moisture-laden travelling web of paper formed on said wire is festooned, the rolls of the succession being so arranged that some of them engage the underside of the said paper web which was initially in contact with said wire, and the remainder of said rolls engage the topside of said web, means for maintaining the temperature of said drying rolls above approximately 200° F., a pair of endless papermakers' felts having portions travelling with the web for respectively engaging those portions of the web which are in engagement with said drying rolls, and means at the end of said succession of drying rolls for reducing the tendency to curl which the paper would otherwise display, comprising, a chilling roll positioned to engage the wire side of the paper, means for maintaining the temperature of the said chilling roll substantially below 200° F. but above substantially 80° F., and means constituting a portion of one of said papermakers' felts for engaging the web of paper as it passes over the said roll to selectively impart a small quantity of moisture from the felt to the felt side of said web.

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