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An agency of Industry Canada

CA 2678879 C 2015/11/24

(11)(21) 2 678 879

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2008/02/20
(87) Date publication PCT/PCT Publication Date: 2008/09/04
(45) Date de délivrance/Issue Date: 2015/11/24
(85) Entrée phase nationale/National Entry: 2009/08/18
(86) N° demande PCT/PCT Application No.: US 2008/054350
(87) N° publication PCT/PCT Publication No.: 2008/106344
(30) Priorités/Priorities: 2007/02/27 (US60/903,789); 2008/02/19 (US12/033,207)

(51) Cl.Int./Int.Cl. *D21F 11/00* (2006.01), *D21F 11/14* (2006.01)

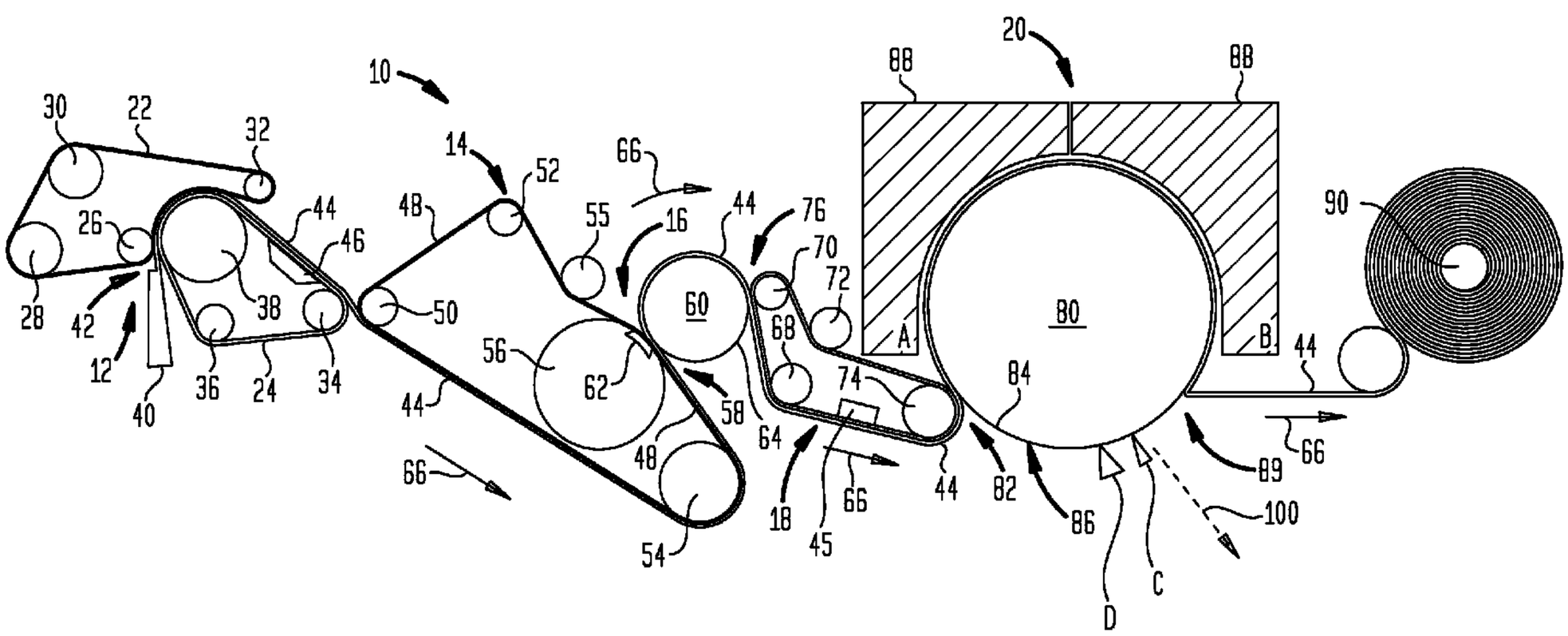
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(54) Titre : PROCEDE DE CREPAGE DE TISSU AVEC CYCLE DE PRODUCTION PROLONGE ET SECHAGE AMELIORE

(54) Title: FABRIC-CREPE PROCESS WITH PROLONGED PRODUCTION CYCLE AND IMPROVED DRYING



(57) Abrégé/Abstract:
A method of manufacturing absorbent sheet is directed to a wet-press/fabric-crepe process wherein add-on of adhesive to the Yankee surface is at relatively low levels, yet sheet transfer is maintained and production increased. Materials are selected and process parameters are controlled such that a paper machine can be operated for at least 4 hours before the Yankee coating needs to be stripped. Preferably, average increase in Yankee hood temperature is less than 1°F/minute (0.55°C/minute) during a production interval.

ABSTRACT

A method of manufacturing absorbent sheet is directed to a wet-press/fabric-crepe process wherein add-on of adhesive to the Yankee surface is at relatively low levels, yet sheet transfer is maintained and production increased. Materials are selected and process parameters are controlled such that a paper machine can be operated for at least 4 hours before the Yankee coating needs to be stripped. Preferably, average increase in Yankee hood temperature is less than 1°F/minute (0.55°C/minute) during a production interval.

FABRIC-CREPE PROCESS WITH PROLONGED PRODUCTION CYCLE AND IMPROVED DRYING

Technical Field

The present invention relates to an improved fabric-crepe process for making absorbent sheet such as paper tissue or towel. Adhesive add-on to a Yankee drying cylinder is at relatively low levels, providing prolonged production cycles between stripping of excess coating from a Yankee drying cylinder. A heated backing cylinder dries the web prior to transfer to the Yankee dryer, reducing the load on the Yankee hood.

Background Art

Fabric-creping has been employed in connection with papermaking processes which include mechanical or compactive dewatering of the paper web as a means to influence product properties. *See* United States Patent Nos. 4,689,119 and 4,551,199 of *Weldon*; 4,849,054 and 4,834,838 of *Klowak*; and 6,287,426 of *Edwards et al.* While in many respects, these processes have more potential than conventional papermaking processes in terms of energy consumption and the ability to use recycle fiber, operation of fabric-creping processes has been has hampered by the difficulty of effectively transferring a web of high or intermediate consistency to a dryer. *Note also* United States Patent No. 6,350,349 to *Hermans et al.* which discloses wet transfer of a web from a rotating transfer surface to a fabric. Further United States Patents relating to

fabric-creping more generally include the following: 4,834,838; 4,482,429; 4,445,638 as well as 4,440,597 to *Wells et al.*

More recently, high-speed fabric-crepe processes have been developed as is seen in United States Application Serial No. 10/679,862, filed October 6, 2003, entitled "Fabric-crepe Process for Making Absorbent Sheet" (Attorney Docket. 12389; GP-02-12). The level of adhesion of the papermaking web to a Yankee dryer cylinder is of importance as it relates to transfer of the web from a creping fabric to the drying cylinder as well as control of the web in-between the dryer and the reel upon which a roll of the paper is being wound. Webs which are insufficiently adhered may blister or, even worse, become disengaged from a drying cylinder and cause a hood fire.

Moreover, wet-tack is critical in fabric-crepe processes where insufficient wet-tack may lead to a transfer failure wherein the web fails to transfer from a creping fabric to a drying cylinder and remains imbedded in a fabric causing shutdowns and waste of material and energy.

Further, the level of adhesion of the papermaking web to the dryer is of importance as it relates to the drying of the web. Higher levels of adhesion reduce the impedance to heat transfer and cause the web to dry faster, enabling more energy efficient, higher speed operation; provided excessive build-up of adhesive is avoided. Note, however that some build-up is desirable inasmuch as adhesion of the sheet to the dryer occurs largely by means of creping adhesive deposited in previous passes. Thickness of a coating layer on a Yankee drying cylinder tends to increase with time, insulating a wet web from the Yankee surface to the web. In other words, the adhesive coating build-up on the Yankee reduces heat transfer from the Yankee surface. To maintain the same moisture level in the finished product, the Yankee hood temperature (and energy input to the web) is increased accordingly. After a production interval of two hours or so, the hood temperature reaches its upper ceiling and the coating layer needs to be stripped off to reduce

the hood temperature to a normal operating window. A new cleaning doctor is typically used to strip off the old coating build-up.

Stripping of the coating, however, results in sheet transfer problems at the pressure roll due to blistering and edge floating. Further details are seen in copending United States Provisional Patent Application Serial No. 60/779,614, entitled "Method of Controlling Adhesive Build-Up on a Yankee Dryer", filed March 6, 2006 (Attorney Docket No. 20140; GP-06-1).

Even if the stripping operation is accomplished efficiently, downtime reduces production significantly.

Initially, operation of high-speed fabric-crepe processes was based, in part, on the belief that the wet-tack required for effective transfer from a creping fabric to a Yankee drying cylinder was best achieved with relatively wet sheet and relatively high levels of creping adhesive, especially a hygroscopic re-wettable adhesive such as polyvinyl alcohol resin.

It has been unexpectedly found in accordance with the present invention that low levels of creping adhesive on a Yankee drying cylinder are advantageously employed in a production process with a heated cylinder upstream of the Yankee.

Summary of the Invention

In accordance with the present invention, adhesive add-on to a Yankee drying cylinder is at relatively low levels and Yankee hood temperature increase is kept below about 1°F/minute (0.55°C/minute) during a production campaign for making fabric-creped sheet. Substantial increases in productivity, 20% and more in a commercial paper machine, are realized by keeping adhesive add-on low while maintaining sheet-transfer to a Yankee dryer.

In accordance with the present invention, there is provided a method of making a fabric-creped absorbent cellulosic sheet, the method comprising: (a) compactively dewatering a papermaking furnish to form a cellulosic web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed; (b) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric; (c) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee dryer also having a dryer hood with a characteristic operating temperature limit; (d) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating; (e) drying the web on the surface of the heated drying cylinder of the Yankee dryer to form a dried web; (f) removing the dried web from the surface of the heated drying cylinder of the Yankee dryer; and (g) periodically stripping at least a portion of

the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the dryer hood of the Yankee dryer is approached,-wherein a production interval between successive strippings of resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a predetermined target production rate of dried web is met.

In accordance with the present invention, there is provided a method of making a fabric-creped absorbent cellulosic sheet, the method comprising: (a) compactively dewatering a papermaking furnish to form a web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed; (b) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric; (c) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee

dryer also having a dryer hood configured to provide drying energy to the web on the heated drying cylinder of the Yankee dryer in the form of a heated air stream, the dryer hood having a characteristic operating temperature and a characteristic operating temperature limit; (d) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating; (e) drying the web to a predetermined dryness on the surface of the heated drying cylinder of the Yankee dryer to form a dried web; (f) removing the dried web from the surface of the heated drying cylinder of the Yankee dryer; and (g) periodically stripping at least a portion of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the dryer hood of the Yankee dryer is approached,-wherein a production interval between successive strippings of resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a predetermined target production rate of dried web is met, the production interval further characterized in that an average rate of increase of the characteristic operating temperature of the dryer hood over the production interval is less than 1°F/minute (0.55°C/min).

In accordance with the present invention, there is provided a method of making a fabric-creped absorbent cellulosic sheet, the method comprising: (a) preparing an aqueous papermaking furnish, the aqueous papermaking including pulp

comprising pre-dried papermaking fibers that have been air dried to at least 80% prior to preparing the aqueous papermaking furnish; (b) depositing the aqueous papermaking furnish on a formaninous support; (c) compactively dewatering the aqueous papermaking furnish to form a nascent web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed; (d) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric; (e) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee dryer also having a drying hood with a characteristic operating temperature limit; (f) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating; (g) drying the web to a predetermined dryness on the surface of the heated drying cylinder of the Yankee dryer to form a dried web; (h) removing the dried web from the surface of

the heated drying cylinder of the Yankee dryer; and (i) periodically stripping at least a portion of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the drying hood of the Yankee dryer is approached, wherein a production interval between successive strippings of adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a target production rate of dried web is met.

The process of the present invention provides a pre-dried sheet to a transfer nip between a creping fabric and a Yankee drying cylinder by way of wet-pressing and heating the web prior to transfer to the Yankee for further drying. The inventive process includes compactively dewatering a papermaking furnish to form a cellulosic web and concurrently applying the web to a heated rotated backing cylinder. The web is then fabric-creped from the backing cylinder at a consistency of from about 30 to about 60% with a patterned creping fabric such that the web is creped from the backing cylinder surface and transferred into the creping fabric. A resinous adhesive coating composition is supplied to the surface of a heated drying cylinder of a Yankee dryer; advantageously at add-on rates of less than 20 mg/m^2 of drying cylinder surface such that a resinous adhesive coating is formed. The Yankee dryer may have a dryer hood with a characteristic operating temperature limit of about 850°F (454°C) or so. The web is transferred from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer and adhered to the drying cylinder by the resinous adhesive coating, whereupon the web is dried on the surface of the drying cylinder. The dried web is removed from the drying cylinder surface, by peeling or creping, for example. Inasmuch as adhesive tends to build up on the Yankee drying cylinder, it is periodically stripped as the characteristic operating temperature limit of the drying hood of the Yankee dryer is approached. The furnish and adhesive composition are selected and process parameters are controlled such that a production interval between successive strippings of adhesive coatings from the Yankee cylinder has duration of at least four hours, and preferably for 5 hours or more.

The advantages of the present invention thus include both increased drying capacity and prolonged production cycles, the combination of which significantly increases the amount of production available from a paper machine.

More sheet dryness is achieved prior to transfer to the Yankee, for example, by heating the backing roll and increasing the pressure in the transfer nip

to the backing roll. When the sheet has a higher % solids it carries less water to the Yankee dryer. Without intending to be bound by any theory, it is believed adhesion to the Yankee improves because the coating remains more concentrated, i.e., less diluted by water than under conventional conditions. This provides the opportunity to reduce the adhesive add-on during processing and provides for extending production cycles. Shoe-press loading during compactive dewatering can also be used to increase sheet dryness prior to the Yankee dryer. For example, shoe press loading at transfer to the backing cylinder may be set at 725 PLI (129.5 kglcm) and backing roll steam pressure may be set at about 95 - 100 psig. This produces relatively high dryness in the sheet prior to transfer to the Yankee in a pressure nip. Yankee cylinder coating add-on may be reduced to about 15 mg/m^2 of drying cylinder surface or less and a coating stripping cycle is readily extended to 5 hours or more by making the foregoing modifications to the process. A production interval between successive stripping of coating of 8-10 hours is desirable.

In another aspect of the invention, it is was found that pre-dried papermaking fibers provide for increased processing rates and still further extending the production interval between required stripping operations. Without intending to be bound by theory, possible explanations include less ionic trash and lower fines which may interfere with adhesion to the Yankee cylinder. It is also believed that pre-drying the pulp produces drying hysteresis in the pulp allowing for more efficient drying of the furnish, further reducing processing times. That is, "slush" pulps, those less than about 80% air-dry, are believed to contain relatively large amounts of tightly-bound water in the fiber that requires more heat to remove than is the case with commercial pre-dried pulp.

Proper selection of a coating package also facilitates practice of the inventive process. A preferred coating package includes PVOH resin, polyamidoamine adhesive resin, and a creping modifier. Preferred coating compositions provide for good sheet transfer with fast coating recovery after a

blade change, and allows for reducing the coating to 15 mg/m^2 of dryer surface or less during production at continuous operation of the paper machine. Preferably, the coating package is stable to a temperature of at least about 300°F (148.9°C) such that this temperature can be maintained during a production campaign.

A synergestic effect was realized as the above aspects of the invention were employed during testing. A machine was sped up by 14.2 % for towel manufacture and the total production was increased 20% due to the shorter coating recovery time and longer coating/stripping cycle. Such advantages of the present invention are appreciated by reference to **Figures 1-5**, which present operating data on the same paper machine operated under different conditions as noted on the **Figures**. **Figure 1** is a plot of Yankee hood temperature versus time for a commercial paper machine operated with a hood temperature limit of 850°F (454.4°C). It is seen that operation of the machine is maintained below the hood temperature limit for 5-6 hours when employing an adhesive add-on rate of 10 mg/m^2. When the operating temperature limit is reached, the Yankee coating is stripped and operation resumed. When operating the same paper machine under similar conditions with twice the adhesive add-on rate, it is seen in **Figure 2** that the Yankee coating must be stripped every 3 hours or so.

Energy usage in the Yankee hood is likewise reduced in accordance with the invention as seen in **Figures 3-5**. **Figure 3** is a plot of Yankee hood gas usage versus time for the same paper machine and production runs discussed above in connection with **Figure 1**. It is seen in **Figure 3** that Yankee hood energy consumption starts at about 2 MMBtu/ton (2110 MJ/ton) after stripping a coating from the Yankee and increases to about 4 MMBtu/ton (4220 MJ/ton) over a 5-6 hour period. *Note also*, that hood energy usage is kept below 3 MMBtu/ton (3165 MJ/ton) of sheet produced for 1-2 hours.

Figure 4 is a plot of Yankee hood energy consumption versus time for the same paper machine operated with higher adhesive add-on and a wetter sheet

provided to the Yankee. Here it is seen that Yankee hood energy consumption begins at between 2.5-3 MMBtu/ton (2638-3165 MJ/ton) and increases to about 4 MMBtu/ton (4220 MJ/ton) in 2½ hours or so. *Note* in **Figure 4**, that hood energy usage exceeds 3 MMBt/ton (3165 MJ/ton) of sheet produced almost immediately as the production interval begins. Inasmuch as the Yankee hood requires a relatively high grade energy source, natural gas, the process of the present invention is much preferred since steam made with any fuel, including recycle fuels and is readily available in production facilities to heat the web prior to transfer to a Yankee dryer.

Figure 5 is a similar plot for the same paper machine operated with an adhesive add-on of 20 mg/m^2 with a drier sheet than that used in the trials of **Figure 4** (having a sheet dryness at transfer to the Yankee similar to **Figure 1**). Here it is seen that while there is benefit to drying the sheet prior to transfer to the Yankee, the results are not nearly as good as cases where lower adhesive add-on is used.

Details, including with respect to **Figures 1-5**, are further described hereinafter.

Brief Description of Drawings

The invention is described in detail with reference to the drawings wherein like numbers designate similar parts and wherein:

Figure 1 is a plot of Yankee hood inlet jet temperatures versus time during operation of a high-speed, fabric-crepe paper machine, wherein the sheet was dried with high pressure stream at the creping cylinder and the Yankee was operated with low adhesive add-on in accordance with the present invention;

Figure 2 is a plot of Yankee hood inlet jet temperatures versus time during operation of a high-speed, fabric-crepe paper machine, wherein the sheet was

dried with high pressure stream at the creping cylinder and the Yankee was operated with twice the adhesive add-on as compared with the process of **Figure 1**;

Figure 3 is a plot of Yankee hood gas usage versus time for the process of **Figure 1**;

Figure 4 is a plot of Yankee hood gas usage versus time for a process utilizing twice as much creping adhesive as compared with the process of **Figure 1** and wherein the backing cylinder was provided with steam at lower pressure;

Figure 5 is a plot of Yankee hood gas usage versus time for a process utilizing twice as much creping adhesive as compared with the process of **Figure 1** and wherein the backing cylinder was provided with high pressure steam as in **Figure 1**;

Figure 6 is a schematic diagram of a first paper machine suitable for practicing the process of the present invention; and

Figure 7 is a schematic diagram of a second paper machine suitable for practicing the present invention.

Detailed Description

The invention is described in detail below with reference to several embodiments and numerous examples. Such discussion is for purposes of illustration only.

Terminology used herein is given its ordinary meaning consistent with the exemplary definitions set forth immediately below; mg refers to milligrams and

m^2 refers to square meters, MM refers to million, Btu refers to British thermal units, psig refers to gauge pressure and so forth.

The creping adhesive "add-on" rate is calculated by dividing the rate of application of adhesive (mg/min) by surface area of the drying cylinder passing under a spray applicator boom (m^2/min). The resinous adhesive composition most preferably includes a polyvinyl alcohol resin, a polyamidoamine-epichlorohydrin resin, and a creping modifier. The add-on rate of Yankee adhesive is calculated based on solids or active ingredient content; that is, irrespective of water content. Commercial components may be purchased dry or in aqueous form and diluted with water to the desired concentration. The weight % of the various components in the adhesive resin or coating composition is likewise calculated on a dry basis.

Throughout this specification and claims, when we refer to a nascent web having an apparently random distribution of fiber orientation (or use like terminology), we are referring to the distribution of fiber orientation that results when known forming techniques are used for depositing a furnish on the forming fabric. When examined microscopically, the fibers give the appearance of being randomly oriented even though, depending on the jet to wire speed, there may be a significant bias toward machine direction orientation making the machine direction tensile strength of the web exceed the cross-direction tensile strength.

Unless otherwise specified, "basis weight", BWT, bwt and so forth refers to the weight of a 3000 square foot (278.7 square meter) ream of product. Consistency refers to % solids of a nascent web, for example, calculated on a bone dry basis. "Air dry" means including residual moisture, by convention up to about 10% moisture for pulp and up to about 6% for paper. A nascent web having 50% water and 50% bone dry pulp has a consistency of 50%. 95% air-dry pulp has a consistency of 85% or more.

A characteristic operating temperature limit of a drying hood refers to the maximum inlet jet temperature of a Yankee hood, measured at the wet-end of the hood unless otherwise indicated. This may be an equipment limit or be imposed by operating considerations at the wet-end of the hood such that the product will not scorch, for example. Yankee hood temperature and characteristic operating temperature are likewise on the jet temperature at the wet-end of the hood.

As used herein, the term compactively dewatering the web or furnish refers to mechanical dewatering by wet-pressing on a dewatering felt, for example, in some embodiments by use of mechanical pressure applied continuously over the web surface as in a nip between a press roll and a press shoe wherein the web is in contact with a papermaking felt. The terminology "compactively dewatering" is used to distinguish processes wherein the initial dewatering of the web is carried out largely by thermal means as is the case, for example, in United States Patent No. 4,529,480 to *Trokhan* and United States Patent No. 5,607,551 to *Farrington et al.*. Compactively dewatering a web thus refers, for example, to removing water from a nascent web having a consistency of less than 30% or so by application of pressure thereto and/or increasing the consistency of the web by about 15% or more by application of pressure thereto.

The term "cellulosic", "cellulosic sheet" and the like is meant to include any product incorporating papermaking fiber having cellulose as a major constituent. "Papermaking fibers" include virgin pulps or recycle (secondary) cellulosic fibers or fiber mixes comprising cellulosic fibers. Fibers suitable for making the webs of this invention include: nonwood fibers, such as cotton fibers or cotton derivatives, abaca, kenaf, sabai grass, flax, esparto grass, straw, jute hemp, bagasse, milkweed floss fibers, and pineapple leaf fibers; and wood fibers such as those obtained from deciduous and coniferous trees, including softwood fibers, such as northern and southern softwood Kraft fibers; hardwood fibers, such as eucalyptus, maple, birch, aspen, or the like. Papermaking fibers can be liberated from their source material by any one of a number of chemical pulping

processes familiar to one experienced in the art including sulfate, sulfite, polysulfide, soda pulping, etc. The pulp can be bleached if desired by chemical means including the use of chlorine, chlorine dioxide, oxygen, alkaline peroxide and so forth. The products of the present invention may comprise a blend of conventional fibers (whether derived from virgin pulp or recycle sources) and high coarseness lignin-rich tubular fibers, such as bleached chemical thermomechanical pulp (BCTMP). "Furnishes" and like terminology refers to aqueous compositions including papermaking fibers, optionally wet strength resins, debonders and the like for making paper products.

It has been found in accordance with the present invention that pre-dried pulps are preferred over "slush" pulps. When we refer to pre-dried pulps, we refer to pulps that are at least 80% air-dry, that is, those that have been dried to a consistency of at least 72% prior to use in the furnish supplied to the process. For present purposes, "Air-Dry" is calculated as: consistency ÷ 90 X 100%. Commercial pulps which are at least 90% or 95% air-dry are preferred and may be hardwood Kraft pulps, softwood Kraft pulps, and so forth, such as Southern Softwood Kraft fiber. Suitable commercial pre-dried pulps may have a GE Brightness of at least 80, 85 or 90; in many cases, suitable pulps will have a GE Brightness between about 85 and 95. In some preferred cases, at least 60% pre-dried pulp is used while, in still others, at least 75% pre-dried pulp and more is employed. Recycle pulp may be used as desired.

Creping fabric and like terminology refers to a fabric or belt which bears a pattern suitable for practicing the process of the present invention and preferably is permeable enough such that the web may be dried while it is held in the creping fabric. In cases where the web is transferred to another fabric or surface (other than the creping fabric) for drying, the creping fabric may have lower permeability.

When referring to an adhesive coating or composition as "durable" to a specific temperature we mean that the coating or composition will not harden and remains re-wettable after being heated to that temperature.

Fpm refers to feet per minute; while fps refers to feet per second.

GE brightness is measured in accordance with TAPPI T 452 om-02. TAPPI 452 incorporates 45° illumination and 0° observation geometry.

MD means machine direction and CD means cross-machine direction.

Nip parameters include, without limitation, nip pressure, nip length, backing roll hardness, fabric approach angle, fabric takeaway angle, uniformity, and velocity delta between surfaces of the nip.

Nip width means the length over which the nip surfaces are in contact.

"Wet-tack" refers generally to the ability of an adhesive coating on a drying cylinder to adhere a wet web to the cylinder for purposes of drying the web.

"Fabric-crepe ratio" is an expression of the speed differential between the creping fabric and the forming wire and typically calculated as the ratio of the web speed immediately before fabric-creping and the web speed immediately following fabric-creping, the forming wire and transfer surface being typically, but not necessarily, operated at the same speed:

Fabric-crepe ratio = transfer cylinder speed ÷ creping fabric speed

Fabric-crepe can also be expressed as a percentage calculated as:

Fabric-crepe, %, = [Fabric-crepe ratio – 1] x 100%

A web creped from a transfer cylinder with a surface speed of 750 fpm (228.6 mpm) to a fabric with a velocity of 500 fpm (152.4 mpm) has a fabric-crepe ratio of 1.5 and a fabric-crepe of 50%. For reel crepe, the reel crepe ratio is calculated as the Yankee speed divided by reel speed. To express reel crepe as a percentage, 1 is subtracted from the reel crepe ratio and the result multiplied by 100%.

The total crepe ratio is calculated as the ratio of the forming wire speed to the reel speed and a % total crepe is:

$$\text{Total Crepe \%} = \left[\text{Total Crepe Ratio} - 1\right] \times 100\%$$

A process with a forming wire speed of 2000 fpm (609.6 mpm) and a reel speed of 1000 fpm (304.8 mpm) has a line or total crepe ratio of 2 and a total crepe of 100%.

A product is considered "peeled" from a Yankee drying cylinder when removed without substantial reel crepe, under tension. Typically, a peeled product has less than 1% reel crepe.

A "production interval" refers to a period of operation, that is, steady state or quasi-steady state, during which absorbent sheet is being produced for consumption between successive cleaning or stripping operations, for example, where material is typically recycled to the process. Preferably, the production of paper product is maintained at a substantially constant rate, +/- 20% of a target during a production interval.

PLI or pli means pounds force per linear inch.

Pusey and Jones (P&J) hardness (indentation) is measured in accordance with ASTM D 531, and refers to the indentation number (standard specimen and conditions).

Velocity delta means a difference in linear speed.

The resinous adhesive coating composition used to secure the web to the Yankee drying cylinder is preferably a hygroscopic, re-wettable, substantially non-crosslinking composition. Typically, the resinous adhesive coating composition includes one or more adhesive resins, a modifier and one or more additives. Examples of adhesive compositions are those which include poly(vinyl alcohol) and PAE resins of the general class described in United States Patent No. 4,528,316 to *Soerens et al.*. *See also,* United States Patent Nos. 5,660,687 and 5,833,806, both to *Allen et al.*.

Polyamide adhesive resins for use in the present invention may include polyamide-epihalohydrin resins such as polyamidoamine-epichlorohydrin (PAE) resins of the same general type employed as wet strength resins. PAE resins are described, for example, in "Wet-Strength Resins and Their Applications," Ch. 2, H. Epsy entitled Alkaline-Curing Polymeric Amine-Epichlorohydrin Resins. Suitable PAE resins for use according to the present invention include a water-soluble polymeric reaction product of an epihalohydrin, preferably epichlorohydrin, and a water-soluble polyamide having secondary amine groups derived from a polyalkylene polyamine and a saturated aliphatic dibasic carboxylic acid containing from about 3 to about 10 carbon atoms. A suitable PAE resin may be based on diethylene triamine (DETA), glutaric and/or adipic acid, and epichlorohydrin.

PAE resin compositions for use according to the present invention can be obtained from Process Applications, Ltd of Washington Crossing, PA and

Hercules Corporation, based in Wilmington, Delaware. A particularly suitable PAE creping adhesive resin composition which is useful in connection with the present invention is Ultracrepe™ HT. Commercial PAE resin compositions may include other components, such as cross-linkers, additives, by-products and so forth.

The creping adhesive also preferably includes a film-forming semi-crystalline polymer. Film-forming semi-crystalline polymers for use in the present invention can be selected from, for example, hemicellulose, carboxymethyl cellulose, and most preferably includes polyvinyl alcohol (PVOH). Polyvinyl alcohols used in the creping adhesive can have an average molecular weight of about 13,000 to about 124,000 daltons.

The polyvinyl alcohol (PVOH) resins may be based on vinyl acetate homopolymer or copolymers of vinyl acetate with any suitable comonomer and/or blends thereof. PVOH resins employed in the present invention are predominately (more than 75 mole %) based on vinyl acetate monomer which is polymerized and subsequently hydrolyzed to polyvinyl alcohol. Generally, the resins are 99 mole % or more vinyl acetate derived. If used, comonomers may be present from about 0.1 to 25 mole % with vinyl acetate and include acrylic comonomers such as AMPS or salts thereof. Other suitable comonomers include glycol comonomers, versatate comonomers, maleic or lactic acid comonomers, itaconic acid comonomers and so forth. Vinyl versatate including alkyl groups (veova) comonomers may likewise be useful. *See* Finch et al., Ed. Polyvinyl Alcohol Developments (Wiley 1992), pp. 84 and following. The comonomers may be grafted or co-polymerized with vinyl acetate as part of the backbone. Likewise, homopolymers may be blended with copolymers, if so desired.

In general, polyvinyl acetate in an alcohol solution can be converted to polyvinyl alcohol, i.e. $-OCOCH_3$ groups are replaced by -OH groups through "hydrolysis", also referred to as "alcoholysis." The degree of hydrolysis refers to

the mole % of the resin's vinyl acetate monomer content that has been hydrolyzed. Methods of producing polyvinyl acetate-polyvinyl alcohol polymers and copolymers are known to those skilled in the art. United States Patent Nos. : 1,971,951; and 2,109,883, as well as various literature references describe these types of polymers and their preparation. Among the literature references are "Vinyl Polymerization", Vol. 1, Part 1, by Ham, published by Marcel Dekker, Inc., (1967) and "Preparative Methods of Polymer Chemistry", by Sorenson and Campbell, published by Interscience Publishers, Inc., New York (1961).

Polyvinyl alcohols, for use according to the present invention, include those obtainable from Monsanto Chemical Co. and Celanese Chemical. Appropriate polyvinyl alcohols from Monsanto Chemical Co. include Gelvatols, including, but not limited to, GELVATOL 1-90, GELVATOL 3-60, GELVATOL 20-30, GELVATOL 1-30, GELVATOL 20-90, and GELVATOL 20-60. Regarding the Gelvatols, the first number indicates the percentage residual polyvinyl acetate and the next series of digits when multiplied by 1,000 gives the number corresponding to the average molecular weight. Generally, polyvinyl alcohol or PVOH resins consist mostly of hydrolyzed polyvinyl acetate repeat units (more than 50 mole %), but may include monomers other than polyvinyl acetate in amounts up to about 10 mole % or so in typical commercial resins.

Celanese Chemical polyvinyl alcohol products for use in the creping adhesive (previously named Airvol products from Air Products until October 2000) are listed below:

Table 1 – Polyvinyl Alcohol for Creping Adhesive

Grade	% Hydrolysis,	Viscosity, cps[1]	pH	Volatiles, % Max.	Ash, % Max.[3]
Super Hydrolyzed					
Celvol® 125	99.3+	28-32	5.5-7.5	5	1.2
Celvol® 165	99.3+	62-72	5.5-7.5	5	1.2
Fully Hydrolyzed					
Celvol® 103	98.0-98.8	3.5-4.5	5.0-7.0	5	1.2
Celvol® 305	98.0-98.8	4.5-5.5	5.0-7.0	5	1.2
Celvol® 107	98.0-98.8	5.5-6.6	5.0-7.0	5	1.2
Celvol® 310	98.0-98.8	9.0-11.0	5.0-7.0	5	1.2
Celvol® 325	98.0-98.8	28.0-32.0	5.0-7.0	5	1.2
Celvol® 350	98.0-98.8	62-72	5.0-7.0	5	1.2
Intermediate Hydrolyzed					
Celvol® 418	91.0-93.0	14.5-19.5	4.5-7.0	5	0.9
Celvol® 425	95.5-96.5	27-31	4.5-6.5	5	0.9
Partially Hydrolyzed					
Celvol® 502	87.0-89.0	3.0-3.7	4.5-6.5	5	0.9
Celvol® 203	87.0-89.0	3.5-4.5	4.5-6.5	5	0.9
Celvol® 205	87.0-89.0	5.2-6.2	4.5-6.5	5	0.7
Celvol® 513	86.0-89.0	13-15	4.5-6.5	5	0.7
Celvol® 523	87.0-89.0	23-27	4.0-6.0	5	0.5
Celvol® 540	87.0-89.0	45-55	4.0-6.0	5	0.5

[1] 4% aqueous solution, 20°C

Creping modifiers which may be used include quaternary ammonium complexes, polyethylene glycols and so forth. Modifiers include those obtainable from Goldschmidt Corporation of Essen/Germany or Process Applications, Ltd., based in Washington Crossing, PA. Creping modifiers from Goldschmidt Corporation include, but are not limited to, VARISOFT® 222LM, VARISOFT® 222, VARISOFT® 110, VARISOFT® 222LT, VARISOFT® 110 DEG, and VARISOFT® 238. A particularly suitable modifier is Ultra FDA GB available from Process Applications, Ltd.

Preferred resinous adhesive coating compositions used in connection with the present invention include a polyvinyl alcohol resin, a PAE resin and a modifier. A suitable PAE resin may be based on glutaric acid and DETA having a weight average molecular weight (GPC) of 150,000 or more, while the creping modifier may include imidazolinium salts and polyethylene glycols as major components. The resinous adhesive resin composition may suitably include less than 75% by weight of a polyvinyl alcohol resin, suitably between about 40% by weight and 80% by weight of the resinous adhesive coating composition. In some preferred embodiments, the resinous adhesive coating composition includes less than 60% by weight polyvinyl alcohol resin and in some embodiments, less than 50% by weight of a polyvinyl alcohol resin. Partially hydrolyzed, relatively high viscosity PVOH may be used.

The resinous adhesive coating composition also suitably includes a major portion PVOH, from about 5% by weight to about 35% by weight of a polyamidoamine composition, such as the commercially available compositions noted above. Suitable adhesive resinous compositions thus include at least 10-30% by weight of a polyamidoamine resin composition such as Ultracrepe™ HT as well as from about 2.5 weight % to about 20 weight % or 30 weight % of a modifier such as Ultra FDA GB, the balance Celvol® 523 PVOH.

In connection with the present invention, an absorbent paper web is made by dispersing papermaking fibers into aqueous furnish (slurry) and depositing the aqueous furnish onto the forming wire of a papermaking machine. Any suitable forming scheme might be used. For example, an extensive but non-exhaustive list in addition to Fourdrinier formers includes a crescent former, a C-wrap twin wire former, an S-wrap twin wire former, or a suction breast roll former. The forming fabric can be any suitable foraminous member including single layer fabrics, double layer fabrics, triple layer fabrics, photopolymer fabrics, and the like. Non-exhaustive background art in the forming fabric area includes United States Patent Nos. 4,157,276; 4,605,585; 4,161,195; 3,545,705; 3,549,742; 3,858,623;

4,041,989; 4,071,050; 4,112,982; 4,149,571; 4,182,381; 4,184,519; 4,314,589; 4,359,069; 4,376,455; 4,379,735; 4,453,573; 4,564,052; 4,592,395; 4,611,639; 4,640,741; 4,709,732; 4,759,391; 4,759,976; 4,942,077; 4,967,085; 4,998,568; 5,016,678; 5,054,525; 5,066,532; 5,098,519; 5,103,874; 5,114,777; 5,167,261; 5,199,261; 5,199,467; 5,211,815; 5,219,004; 5,245,025; 5,277,761; 5,328,565; and 5,379,808. One forming fabric particularly useful with the present invention is Voith Fabrics Forming Fabric 2164 made by Voith Fabrics Corporation, Shreveport, LA.

The furnish may contain chemical additives to alter the physical properties of the paper produced. These chemistries are well understood by the skilled artisan and may be used in any known combination. Such additives may be surface modifiers, softeners, debonders, strength aids, latexes, opacifiers, optical brighteners, dyes, pigments, sizing agents, barrier chemicals, retention aids, insolubilizers, organic or inorganic crosslinkers, or combinations thereof; said chemicals optionally comprising polyols, starches, PPG esters, PEG esters, phospholipids, surfactants, polyamines, HMCP (Hydrophobically Modified Cationic Polymers), HMAP (Hydrophobically Modified Anionic Polymers) or the like.

The pulp can be mixed with strength adjusting agents such as wet strength agents, dry strength agents and debonders/softeners and so forth. Suitable wet strength agents are known to the skilled artisan. A comprehensive but non-exhaustive list of useful strength aids includes urea-formaldehyde resins, melamine formaldehyde resins, glyoxylated polyacrylamide resins, polyamide-epichlorohydrin resins and the like. Thermosetting polyacrylamides are produced by reacting acrylamide with diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic polyacrylamide copolymer which is ultimately reacted with glyoxal to produce a cationic cross-linking wet strength resin, glyoxylated polyacrylamide. These materials are generally described in United States Patent Nos. 3,556,932 to *Coscia et al.* and 3,556,933 to *Williams et al.*. Resins of this

type are commercially available under the trade name of PAREZ 631NC by Bayer Corporation. Different mole ratios of acrylamide/-DADMAC/glyoxal can be used to produce cross-linking resins, which are useful as wet strength agents. Furthermore, other dialdehydes can be substituted for glyoxal to produce thermosetting wet strength characteristics. Of particular utility are the polyamide-epichlorohydrin wet strength resins, an example of which is sold under the trade names Kymene 557LX and Kymene 557H by Hercules Incorporated of Wilmington, Delaware and Amres® from Georgia-Pacific Resins, Inc. These resins and the process for making the resins are described in United States Patent No. 3,700,623 and United States Patent No. 3,772,076. An extensive description of polymeric-epihalohydrin resins is given in Chapter 2: Alkaline-Curing Polymeric Amine-Epichlorohydrin by Espy in *Wet Strength Resins and Their Application* (L. Chan, Editor, 1994). A reasonably comprehensive list of wet strength resins is described by Westfelt in *Cellulose Chemistry and Technology* Volume 13, p. 813, 1979.

Suitable temporary wet strength agents may likewise be included, particularly in special applications where disposable towel with permanent wet strength resin is to be avoided. A comprehensive but non-exhaustive list of useful temporary wet strength agents includes aliphatic and aromatic aldehydes including glyoxal, malonic dialdehyde, succinic dialdehyde, glutaraldehyde and dialdehyde starches, as well as substituted or reacted starches, disaccharides, polysaccharides, chitosan, or other reacted polymeric reaction products of monomers or polymers having aldehyde groups, and optionally, nitrogen groups. Representative nitrogen containing polymers, which can suitably be reacted with the aldehyde containing monomers or polymers, includes vinyl-amides, acrylamides and related nitrogen containing polymers. These polymers impart a positive charge to the aldehyde containing reaction product. In addition, other commercially available temporary wet strength agents, such as, PAREZ 745, manufactured by Bayer can be used, along with those disclosed, for example in United States Patent No. 4,605,702.

The temporary wet strength resin may be any one of a variety of water-soluble organic polymers comprising aldehydic units and cationic units used to increase dry and wet tensile strength of a paper product. Such resins are described in United States Patent Nos. 4,675,394; 5,240,562; 5,138,002; 5,085,736; 4,981,557; 5,008,344; 4,603,176; 4,983,748; 4,866,151; 4,804,769 and 5,217,576. Modified starches sold under the trademarks CO-BOND® 1000 and CO-BOND® 1000 Plus, by National Starch and Chemical Company of Bridgewater, N.J. may be used. Prior to use, the cationic aldehydic water soluble polymer can be prepared by preheating an aqueous slurry of approximately 5% solids maintained at a temperature of approximately 240 degrees Fahrenheit (115.6°C) and a pH of about 2.7 for approximately 3.5 minutes. Finally, the slurry can be quenched and diluted by adding water to produce a mixture of approximately 1.0% solids at less than about 130 degrees Fahrenheit (54.4°C).

Other temporary wet strength agents, also available from National Starch and Chemical Company are sold under the trademarks CO-BOND® 1600 and CO-BOND® 2300. These starches are supplied as aqueous colloidal dispersions and do not require preheating prior to use.

Temporary wet strength agents such as glyoxylated polyacrylamide can be used. Temporary wet strength agents such glyoxylated polyacrylamide resins are produced by reacting acrylamide with diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic polyacrylamide copolymer which is ultimately reacted with glyoxal to produce a cationic cross-linking temporary or semi-permanent wet strength resin, glyoxylated polyacrylamide. These materials are generally described in United States Patent No. 3,556,932 to *Coscia et al.* and United States Patent No. 3,556,933 to *Williams et al.*. Resins of this type are commercially available under the trade name of PAREZ 631NC, by Bayer Industries. Different mole ratios of acrylamide/DADMAC/glyoxal can be used to produce cross-linking resins, which are useful as wet strength agents.

Furthermore, other dialdehydes can be substituted for glyoxal to produce wet strength characteristics.

Suitable dry strength agents include starch, guar gum, polyacrylamides, carboxymethyl cellulose and the like. Of particular utility is carboxymethyl cellulose, an example of which is sold under the trade name Hercules CMC, by Hercules Incorporated of Wilmington, Delaware. According to one embodiment, the pulp may contain from about 0 to about 15 lb/ton (0 to about 7.5 kg/mton) of dry strength agent. According to another embodiment, the pulp may contain from about 1 to about 5 lbs/ton (0.5 to about 2.5 kg/mton) of dry strength agent.

Suitable debonders are likewise known to the skilled artisan. Debonders or softeners may also be incorporated into the pulp or sprayed upon the web after its formation. The present invention may also be used with softener materials including but not limited to the class of amido amine salts derived from partially acid neutralized amines. Such materials are disclosed in United States Patent No. 4,720,383. Evans, *Chemistry and Industry*, 5 July 1969, pp. 893-903; Egan, *J.Am. Oil Chemist's Soc.*, Vol. 55 (1978), pp. 118-121; and Trivedi et al., *J.Am.Oil Chemist's Soc.,* June 1981, pp. 754-756, indicate that softeners are often available commercially only as complex mixtures rather than as single compounds. While the following discussion will focus on the predominant species, it should be understood that commercially available mixtures would generally be used in practice.

Quasoft 202-JR is a suitable softener material, which may be derived by alkylating a condensation product of oleic acid and diethylenetriamine. Synthesis conditions using a deficiency of alkylation agent (e.g., diethyl sulfate) and only one alkylating step, followed by pH adjustment to protonate the non-ethylated species, result in a mixture consisting of cationic ethylated and cationic non-ethylated species. A minor proportion (e.g., about 10%) of the resulting amido amine cyclize to imidazoline compounds. Since only the imidazoline portions of

these materials are quaternary ammonium compounds, the compositions as a whole are pH-sensitive. Therefore, in the practice of the present invention with this class of chemicals, the pH in the head box should be approximately 6 to 8, more preferably 6 to 7 and most preferably 6.5 to 7.

Quaternary ammonium compounds, such as dialkyl dimethyl quaternary ammonium salts are also suitable particularly when the alkyl groups contain from about 10 to 24 carbon atoms. These compounds have the advantage of being relatively insensitive to pH.

Biodegradable softeners can be utilized. Representative biodegradable cationic softeners/debonders are disclosed in United States Patent Nos. 5,312,522; 5,415,737; 5,262,007; 5,264,082; and 5,223,096. The compounds are biodegradable diesters of quaternary ammonia compounds, quaternized amine-esters, and biodegradable vegetable oil based esters functional with quaternary ammonium chloride and diester dierucyldimethyl ammonium chloride and are representative biodegradable softeners.

In some embodiments, a particularly preferred debonder composition includes a quaternary amine component as well as a nonionic surfactant.

The nascent web is typically dewatered on a papermaking felt. Any suitable felt may be used. For example, felts can have double-layer base weaves, triple-layer base weaves, or laminated base weaves. Preferred felts are those having the laminated base weave design. A wet-press-felt which may be particularly useful with the present invention is Vector 3 made by Voith Fabric. Background art in the press felt area includes United States Patent Nos. 5,657,797; 5,368,696; 4,973,512; 5,023,132; 5,225,269; 5,182,164; 5,372,876; and 5,618,612.

A differential pressing felt as is disclosed in United States Patent No. 4,533,437 to *Curran et al*. may likewise be utilized.

Suitable creping or textured fabrics include single layer or multi-layer, or composite preferably open meshed structures. Fabric construction *per se* is of less importance than the topography of the creping surface in the creping nip as discussed in more detail below. Long MD knuckles with slightly lowered CD knuckles are greatly preferred for some products. Fabrics may have at least one of the following characteristics: (1) on the side of the creping fabric that is in contact with the wet web (the "top" side), the number of machine direction (MD) strands per inch (mesh) is from 10 to 200 (25.4 to 508 strands per cm) and the number of cross-direction (CD) strands per inch (count) is also from 10 to 200 (25.4 to 508 cm); (2) the strand diameter is typically smaller than 0.050 inch (0.127 cm); (3) on the top side, the distance between the highest point of the MD knuckles and the highest point on the CD knuckles is from about 0.001 to about 0.02 or 0.03 inch (.0025 to about .051 or .076 cm); (4) in between these two levels there can be knuckles formed either by MD or CD strands that give the topography a three dimensional hill/valley appearance which is imparted to the sheet; (5) the fabric may be oriented in any suitable way so as to achieve the desired effect on processing and on properties in the product; the long warp knuckles may be on the top side to increase MD ridges in the product, or the long shute knuckles may be on the top side if more CD ridges are desired to influence creping characteristics as the web is transferred from the backing cylinder to the creping fabric; and (6) the fabric may be made to show certain geometric patterns that are pleasing to the eye, which is typically repeated between every two to 50 warp yarns. One preferred fabric is a W013 Albany International multilayer fabric. Such fabrics are formed from monofilament polymeric fibers having diameters typically ranging from about 0.25 mm to about 1 mm. Such fabrics are formed from monofilament polymeric fibers having diameters typically ranging from about 10 mm to about 100 mm. This fabric may be used to produce an absorbent cellulosic sheet having variable local basis weight comprising a papermaking fiber reticulum

provided with (i) a plurality of cross-machine direction (CD) extending, fiber-enriched pileated regions of relatively high local basis weight interconnected by (ii) a plurality of elongated densified regions of compressed papermaking fibers, the elongated densified regions having relatively low local basis weight and are generally oriented along the machine direction (MD) of the sheet. The elongated densified regions are further characterized by an MD/CD aspect ratio of at least 1.5. Typically, the MD/CD aspect ratios of the densified regions are greater than 2 or greater than 3; generally between about 2 and 10. In most cases the fiber-enriched, pileated regions have fiber orientation bias along the CD of the sheet and the densified regions of relatively low basis weight extend in the machine direction and also have fiber orientation bias along the CD of the sheet. This product is further described in copending application United States Application Serial No. 60/808,863, entitled "Fabric Creped Absorbent Sheet with Variable Local Basis Weight", filed May 26, 2006, (Attorney Docket No. 20179; GP-06-11).

The creping fabric may be of the class described in United States Patent No. 5,607,551 to *Farrington et al.*, Cols. 7-8 thereof, as well as the fabrics described in United States Patent No. 4,239,065 to *Trokhan* and United States Patent No. 3,974,025 to *Ayers*. Such fabrics may have about 20 to about 60 mesh per inch (50.1 to about 152.4 mesh per centimeter) and are formed from monofilament polymeric fibers having diameters typically ranging from about 0.008 to about 0.025 inches (0.020 to about 0.064 centimeters). Both warp and weft monofilaments may, but need not necessarily be of the same diameter.

In some cases the filaments are so woven and complimentarily serpentinely configured in at least the Z-direction (the thickness of the fabric) to provide a first grouping or array of coplanar top-surface-plane crossovers of both sets of filaments; and a predetermined second grouping or array of sub-top-surface crossovers. The arrays are interspersed so that portions of the top-surface-plane crossovers define an array of wicker-basket-like cavities in the top surface of the

fabric which cavities are disposed in staggered relation in both the machine direction (MD) and the cross-machine direction (CD), and so that each cavity spans at least one sub-top-surface crossover. The cavities are discretely perimetrically enclosed in the plan view by a picket-like-lineament comprising portions of a plurality of the top-surface plane crossovers. The loop of fabric may comprise heat set monofilaments of thermoplastic material; the top surfaces of the coplanar top-surface-plane crossovers may be monoplanar flat surfaces. Specific embodiments of the invention include satin weaves as well as hybrid weaves of three or greater sheds, and mesh counts of from about 10 X 10 to about 120 X 120 filaments per inch (4 X 4 to about 47 X 47 per centimeter). Although the preferred range of mesh counts is from about 18 by 16 to about 55 by 48 filaments per inch (9 X 8 to about 22 X 19 per centimeter).

Instead of an impression fabric, a dryer fabric may be used as the creping fabric if so desired. Suitable fabrics are described in United States Patent Nos. 5,449,026 (woven style) and 5,690,149 (stacked MD tape yarn style) to *Lee* as well as United States Patent No. 4,490,925 to *Smith* (spiral style).

If a Fourdrinier former or other gap former is used, the nascent web may be conditioned with suction boxes and a steam shroud until it reaches a solids content suitable for transferring to a dewatering felt. The nascent web may be transferred with suction assistance to the felt. In a crescent former, use of suction assist is unnecessary as the nascent web is formed between the forming fabric and the felt.

Figure 6 is a schematic diagram of a paper machine **10** having a conventional twin wire forming section **12**, a felt run **14**, a shoe press section **16** a creping fabric **18** and a Yankee dryer **20** suitable for practicing the present invention. Forming section **12** includes a pair of forming fabrics **22, 24** supported by a plurality of rolls **26, 28, 30, 32, 34, 36** and a forming roll **38**. A headbox **40** provides papermaking furnish issuing therefrom as a jet in the machine direction

to a nip **42** between forming roll **38** and roll **26** and the fabrics. The furnish forms a nascent web **44** which is dewatered on the fabrics with the assistance of suction, for example, by way of suction box **46**.

The nascent web is advanced to a papermaking felt **48** which is supported by a plurality of rolls **50, 52, 54, 55** and the felt is in contact with a shoe press roll **56** which has a shoe **62**. The web is of low consistency as it is transferred to the felt. Transfer may be assisted by suction; for example roll **50** may be a suction roll if so desired or a pickup or vacuum shoe as is known in the art. As the web reaches the shoe press roll it may have a consistency of 10-25%, preferably 20 to 25% or so as it enters nip **58** between shoe press roll **56** and transfer roll **60**. Transfer or backing roll **60** is heated with steam. It has been found that increasing steam pressure to roll **60** helps lengthen the time between required stripping of excess adhesive from the cylinder of Yankee dryer 20. Suitable steam pressure may be about 95 psig or so, bearing in mind that roll **60** is a crowned roll and roll **70** has a negative crown to match such that the contact area between the rolls is influenced by the pressure in roll **60**. Thus, care must be exercised to maintain matching contact between rolls **60, 70** when elevated pressure is employed.

Instead of a shoe press roll, roll **56** could be a conventional suction pressure roll. If a shoe press is employed, it is desirable and preferred that roll **54** is a vacuum roll effective to remove water from the felt prior to the felt entering the shoe press nip since water from the furnish will be pressed into the felt in the shoe press nip. In any case, using a vacuum roll at **54** is typically desirable to ensure the web remains in contact with the felt during the direction change as one of skill in the art will appreciate from the diagram.

Web **44** is wet-pressed on the felt in nip **58** with the assistance of pressure shoe **62**. The web is thus compactively dewatered at **58**, typically by increasing the consistency by 15 or more points at this stage of the process. The configuration shown at **58** is generally termed a shoe press; in connection with the

present invention, cylinder **60** is operative as a transfer cylinder which operates to convey web **44** at high speed, typically 1000 fpm-6000 fpm (304.8 mpm-1828.8 mpm), to the creping fabric.

Cylinder **60** has a smooth surface **64** which may be provided with adhesive (the same as the creping adhesive used on the Yankee cylinder) and/or release agents if needed. Web **44** is adhered to transfer surface **64** of cylinder **60** which is rotating at a high angular velocity as the web continues to advance in the machine-direction indicated by arrows **66**. On the cylinder, web **44** has a generally random apparent distribution of fiber.

Direction **66** is referred to as the machine-direction (MD) of the web as well as that of paper machine **10**; whereas the cross-machine-direction (CD) is the direction in the plane of the web perpendicular to the MD.

Web **44** enters nip **58** typically at consistencies of 10-25% or so and is dewatered and dried to consistencies of from about 25 to about 70 by the time it is transferred to creping fabric **18** as shown in the diagram.

Fabric **18** is supported on a plurality of rolls **68, 70, 72** and a press nip roll **74** and forms a fabric-crepe nip **76** with transfer cylinder **60** as shown.

The creping fabric defines a creping nip over the distance or width in which creping fabric **18** is adapted to contact roll **60**; that is, applies significant pressure to the web against the transfer cylinder. To this end, backing (or creping) roll **70** may be provided with a soft deformable surface which will increase the width of the creping nip and increase the fabric-creping angle between the fabric and the sheet and the point of contact or a shoe press roll could be used as roll **70** to increase effective contact with the web in high impact fabric-creping nip **76** where web **44** is transferred to fabric **18** and advanced in the machine-direction.

Creping nip **76** generally extends over a fabric-creping nip width of anywhere from about 1/8" to about 2" (0.3175 cm to about 5.08 cm), typically ½" to 2" (1.27 cm to 5.08 cm). For a creping fabric with 32 CD strands per inch, web **44** thus will encounter anywhere from about 4 to 64 weft filaments in the nip.

The nip pressure in nip **76**, that is, the loading between backing roll **70** and transfer roll **60** is suitably 20-200 (3.6-35.7 kglcm), preferably 40-70 pounds per linear inch (PLI) (7.1-12.5 kglcm).

After fabric-creping, the web continues to advance along MD **66** where it is wet-pressed onto Yankee cylinder **80** in transfer nip **82**. Optionally, suction is applied to the web by way of a suction box **45**.

Transfer at nip **82** occurs at a web consistency of generally from about 25 to about 70%. At these consistencies, it is difficult to adhere the web to surface **84** of cylinder **80** firmly enough to remove the web from the fabric thoroughly. This aspect of the process is important, particularly when it is desired to use a high velocity drying hood.

The use of particular adhesives cooperate with a moderately moist web (25-70% consistency) to adhere it to the Yankee sufficiently to allow for high velocity operation of the system and high jet velocity impingement air drying and subsequent peeling of the web from the Yankee. In this connection, a poly(vinyl alcohol)/polyamidoamine adhesive composition is applied at surface **86** as needed, preferably at a rate of less than about 20 mg/m^2 of sheet. One or more spray booms may be employed.

The web is dried on Yankee cylinder **80** which is a heated cylinder and by high jet velocity impingement air in Yankee hood **88**. Hood **88** is capable of variable temperature. During operation, temperature may be monitored at wet end **A o**f the Hood (at or near the point at which the wet web enters) and dry end **B** of

the hood(at or near the point at which the wet web exits) using an infra-red detector or any other suitable means if so desired. As the cylinder rotates, web **44** is peeled from the cylinder at **89** and wound on a take-up reel **90**. Reel **90** may be operated 5-30 fpm (preferably 10-20 fpm) [1.52-9.14 mpm (preferably 3.05-6.1 mpm)] faster than the Yankee cylinder at steady-state when the line speed is 2100 fpm (640.08 mpm), for example. A creping doctor **C** is normally used and a cleaning doctor **D** mounted for intermittent engagement is used to control build up. When adhesive build-up is being stripped from Yankee cylinder **80** the web is typically segregated from the product on reel **90**, preferably being fed to a broke chute at **100** for recycle to the production process.

Instead of being peeled from cylinder **80** at **89** during steady-state operation as shown, the web may be creped from dryer cylinder **80** using a creping doctor such as creping doctor **C**, if so desired.

There is shown schematically in **Figure 7** another paper machine **10** which may be used in connection with the present invention. Paper machine **10** is a three fabric loop machine having a forming section **12** generally referred to in the art as a crescent former. Forming section **12** includes a forming wire **22** supported by a plurality of rolls such as rolls **32**, **35**. The forming section also includes a forming roll **38** which supports paper making felt **48** such that web **44** is formed directly on felt **48**. Felt run **14** extends to a shoe press section **16** wherein the moist web is deposited on a transfer roll **60** as described above. Thereafter web **44** is creped onto fabric in fabric-crepe nip between rolls **60**, **70** before being deposited on Yankee dryer **20** in another press nip **82**. Suction is optionally applied by suction box **45** as the web is held in fabric in order to conform the web to the textured fabric. Headbox **40** and press shoe **62** operate as noted above in connection with **Figure 1**. The system includes a vacuum turning roll **54**, in some embodiments; however, the three loop system may be configured in a variety of ways wherein a turning roll is not necessary.

Between the Yankee dryer and reel **90** there is provided a Measurex® control instrument to measure consistency and basis weight in order to provide data for feedback control of the paper machine. Further details are also seen in the following co-pending applications: United States Patent Application Serial No. 11/151,761, filed June 14, 2005, entitled "High Solids Fabric-crepe Process for Producing Absorbent Sheet with In-Fabric Drying" (Attorney Docket 12633; GP-03-35); United States Patent Application Serial No. 11/402,609, filed April 12, 2006, entitled "Multi-Ply Paper Towel With Absorbent Core" (Attorney Docket No. 12601; GP-04-11); United States Patent Application Serial No. 11/451,112, filed June 12, 2006, entitled "Fabric-Creped Sheet for Dispensers" (Attorney Docket No. 20195; GP-06-12); United States Provisional Patent Application Serial No. 60/808,863, filed May 26, 2006, entitled "Fabric-creped Absorbent Sheet with Variable Local Basis Weight" (Attorney Docket No. 20179; GP-06-11); and United States Application Serial No. 10/679,862, filed October 6, 2003, entitled "Fabric-crepe Process for Making Absorbent Sheet" (Attorney Docket. 12389; GP-02-12), disclose particular paper machine details as well as creping techniques, equipment and properties; United States Application Serial No. 11/108,375, filed April 18, 2005, entitled "Fabric-crepe/Draw Process for Producing Absorbent Sheet" (Attorney Docket No. 12389P1; GP-02-12-1), provides still further processing and composition information; United States Application Serial No. 11/108,458, filed April 18, 2005, entitled "Fabric-crepe and In Fabric Drying Process for Producing Absorbent Sheet" (Attorney Docket 12611P1; GP-03-33-1) and United States Application Serial No. 11/104,014, filed April 12, 2005, entitled "Wet-Pressed Tissue and Towel Products With Elevated CD Stretch and Low Tensile Ratios Made With a High Solids Fabric-crepe Process" (Attorney Docket 12636; GP-04-5), provide some further variation as to selection of components and processing techniques. Another copending application, United States Serial No. 11/451,111, filed June 12, 2006, entitled "Method of Making Fabric-creped Sheet for Dispensers" (Attorney Docket No. 20079; GP-05-10), provides information on suitable drying and other manufacturing techniques.

Preferably, the methodology employed includes: a) compactively dewatering a papermaking furnish to form a nascent web having an apparently random distribution of papermaking fiber; b) applying the dewatered web having the apparently random fiber distribution to a translating transfer surface moving at a first speed; and c) fabric-creping the web from the transfer surface at a consistency of from about 30% to about 60%, the creping step occurring under pressure in a fabric creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling at a second speed slower than the speed of said transfer surface, the fabric pattern, nip parameters, velocity delta and web consistency being selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with an optionally drawable reticulum having a plurality of interconnected regions of different local basis weights including at least (i) a plurality of fiber-enriched regions of high local basis weight, interconnected by way of (ii) a plurality of optionally elongated densified regions of compressed papermaking fibers, the densified regions having relatively low local basis weight and preferably being generally oriented along the machine direction (MD) of the sheet. In one preferred embodiment, the elongated densified regions are further characterized by an MD/CD aspect ratio of at least 1.5.

Various features and operating parameters of the present invention are summarized in Table 2 below.

Table 2: Operating Features

Operating Feature	Typical Range(s)	Preferred Range(s)
Adhesive Composition Add-On to Yankee Cylinder (mg/m^2)	5-25; 5-50; <20	<15; <10; 5-15
Production Interval Between Successive Stripping of Coating From Yankee Cylinder (hours)	5-15	>8
Average Air Jet Inlet Temperature to Yankee Hood °F (°C)	<850 (<454.4)	600-800; (315.6-426.7) optionally up to 850 (454.4)
Durability Temperature Limit of Coating Composition °F (°C)	240-300 (115.6-148.9)	300 (148.9)
Final Sheet Dryness (%)	90-99	>95; >92.5
Fabric-Crepe (%)	2-50	2-20
Reel Crepe (%)	0-25	2-15; 2.5-20
Shoe-Press Pressure to Backing Roll PLI (kglcm)	500-800 (89.3-144)	>600 (>107.1); 675-775 (120.5-139.5); >650 (>116.1)
Backing Roll Saturated Steam Pressure (psig)	50-150; >60; 80-150	>75; >90; 90-110
Yankee Cylinder Saturated Steam Pressure (psig)	75-150	90-125
Production Rate FPM (mpm)	>2000 (609.6)	>2250 (685.8); ≥2500 (762)

Examples

Utilizing a paper machine of the class shown in **Figures 6** and **7**, a series of trials were performed manufacturing absorbent basesheet on a commercial paper machine. Typical conditions appear in Table 2, above. Creping adhesive compositions was used which included commercial polyamidoamine resin compositions, a commercial polyvinyl alcohol resin and commercial creping modifier compositions. Typical resinous creping compositions included 60-70% by weight PVOH, 25-35% by weight PAE resin composition and 5-20% by weight creping modifier. The resin composition selected must be effective to

transfer the web from the creping fabric to the Yankee cylinder at the add-on levels employed. The more salient features and results are presented in **Figures 1-5**.

Figure 1 is a plot of hood temperature versus time for three production intervals on a commercial paper machine. The machine was operated at 2,450 fpm (746.8 mpm) with an add-on rate of Yankee creping adhesive of 10 mg/m^2. The backing cylinder **60** was supplied with relatively high pressure steam (about 95 psig) during these trials to dry the sheet prior to Yankee transfer. During the various production campaigns shown in **Figure 1** it was seen that the rate of increase of hood temperature was kept relatively low, about <0.5°F/min (0.28°C/min). This enabled operation of the machine for six hours or so until the operating temperature limit of the Yankee dryer, about 850°F (454.C) was reached.

Figure 2 is a plot of hood temperature versus time for multiple production intervals on the same machine operated at a slightly lower speed and a higher add-on rate of Yankee adhesive coating – 20mg/m^2. In **Figure 2** it is seen that the rate of increase of temperature with time is much greater than is seen in **Figure 1**. The temperature increased in the various production runs about 1°F/min (0.55°C/min) and more during the various production intervals shown in **Figure 2**. In these trials, high pressure steam (95, psig) was supplied to backing cylinder **60** and it was possible to operate the machine for three hours or more when providing such additional heating to the upstream backing cylinder, that is, prior to transfer to the Yankee cylinder. However, it is seen by comparing **Figures 1** and **2** that much better results are achieved with a lower Yankee creping adhesive add-on rate.

This latter point is further illustrated in **Figure 3** is a plot of gas usage per ton (MMBtu) of the Yankee dryer hood versus time for the production runs discussed above in connection with **Figure 1**. It is seen in **Figure 3** that the gas

usage per ton is quite low at the beginning of a production interval, around 2 MMBtu/ton (2110 MJ/ton). Moreover, the gas usage per ton of the Yankee hood remains below 3 MMBtu/ton (3165 MJ/ton) for extended periods of time during a production interval, generally for more than one hour and up to an hour and a half or two hours in some cases.

Figure 4 is a plot similar to **Figure 3**, wherein the paper machine was operated at a slightly lower production speed with an add-on rate of Yankee creping adhesive coating of 20 mg/m^2. During the trials illustrated in **Figure 4**, lower pressure steam, about 55 psig, was supplied to backing cylinder **60**. It is seen in **Figure 4** that the Yankee hood energy usage is much higher at the beginning of a production run, typically close to 3 MMBtu/ton (3165 MJ/ton) and increases rather rapidly.

Figure 5 is a plot of Yankee hood gas usage per ton at a production rate similar to **Figure 4**, wherein the Yankee coating was also applied at 20 mg/m^2. The production runs of **Figure 5** differ from those of **Figure 4** in that a heated backing cylinder was provided with high pressure steam (about 95 psig) as opposed to low pressure steam, about 55 psig. It is seen in **Figure 5** that the elevated steam pressure or additional drying, prior to transfer the Yankee resulted in lower initial gas usage by the Yankee hood. Typically, the production runs in **Figure 5** initially used less than 2.5 MMBtu/ton (2638 MJ/ton) of energy by the hood at the start of a production run. While **Figure 5** shows substantially improved results as compared with **Figure 4**, a comparison of **Figure 3** with **Figure 5** reveals that lowering adhesive add-on to the Yankee and increasing drying prior to transfer of the web to the Yankee cylinder provides vastly improved results.

WHAT IS CLAIMED IS:

1 A method of making a fabric-creped absorbent cellulosic sheet, the method comprising:

(a) compactively dewatering a papermaking furnish to form a cellulosic web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed;

(b) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric;

(c) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee dryer also having a dryer hood with a characteristic operating temperature limit;

(d) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating;

(e) drying the web on the surface of the heated drying cylinder of the Yankee dryer to form a dried web;

(f) removing the dried web from the surface of the heated drying cylinder of the Yankee dryer; and

(g) periodically stripping at least a portion of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the dryer hood of the Yankee dryer is approached,

wherein a production interval between successive strippings of resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a predetermined target production rate of dried web is met.

2. The method according to Claim 1, wherein the add-on rate of the resinous adhesive coating composition to the surface of the heated drying cylinder is less than 15 mg/m^2 of drying cylinder surface.

3. The method according to Claim 1 or 2, wherein the add-on rate of the resinous adhesive coating composition to the surface of the heated drying cylinder is less than 10 mg/m^2 of drying cylinder surface.

4. The method according to Claim 1 or 2, wherein the add-on rate of the resinous adhesive coating composition to the surface of the heated drying cylinder is from about 5 mg/m^2 of drying cylinder surface to about 15 mg/m^2 of drying cylinder surface.

5. The method according to any one of Claims 1 to 4, wherein the production interval between successive strippings of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer is from about 5 hours to about 15 hours.

6. The method according to any one of Claims 1 to 4, wherein the production interval between successive strippings of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer is at least about 5 hours.

7. The method according to any one of Claims 1 to 4, wherein the production interval between successive strippings of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer is at least about 7 hours.

8. The method according to any one of Claims 1 to 4, wherein the production interval between successive strippings of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer is at least about 10 hours.

9. The method according to any one of Claims 1 to 8, wherein the characteristic operating temperature limit of the dryer hood is about 850°F (454°C) or less.

10. The method according to any one of Claims 1 to 9, wherein the dryer hood is operated at an average air jet inlet temperature of from about 600°F (315°C) to about 850°F (454°C) during the production interval.

11. The method according to any one of Claims 1 to 10, wherein the resinous adhesive coating composition is durable up to a temperature of at least 240°F (115°C).

12. The method according to any one of Claims 1 to 11, wherein the resinous adhesive coating composition is durable up to a temperature of at least 300°F (148°C).

13. The method according to any one of Claims 1 to 12, wherein the dried web is removed from the surface of the heated drying cylinder at a sheet temperature of from about 240°F (115°C) to about 300°F (148°C).

14. The method according to any one of Claims 1 to 13, wherein the web is dried to a consistency of at least 90% prior to removal from the surface of the heated drying cylinder.

15. The method according to any one of Claims 1 to 14, wherein the web is dried to a consistency of at least 92.5% prior to removal from the surface of the heated drying cylinder.

16. The method according to any one of Claims 1 to 15, wherein the dried web is peeled from the surface of the heated drying cylinder.

17. The method according to any one of Claims 1 to 15, wherein the dried web is creped from the surface of the heated drying cylinder at a Reel Crepe of from about 2.5% to about 20%.

18. The method according to any one of Claims 1 to 17, wherein the dewatered web is applied to the surface of the heated backing cylinder in a shoe press utilizing a pressure of more than 650 PLI (116.1 kg/cm).

19. The method according to any one of Claims 1 to 18, wherein the dewatered web is applied to the surface of the heated backing cylinder in a shoe press utilizing a pressure of more than 700 PLI (125 kg/cm).

20. The method according to any one of Claims 1 to 19, wherein the dewatered web is applied to the surface of the heated backing cylinder in a shoe press utilizing a pressure of from about 675 PLI (120.5 kg/cm) to about 775 PLI (139.5 kg/cm).

21. The method according to any one of Claims 1 to 20, wherein the backing cylinder is heated with steam at a pressure of more than 60 psig.

22. The method according to any one of Claims 1 to 21, wherein the backing cylinder is heated with steam at a pressure of more than 75 psig.

23. The method according to any one of Claims 1 to 22, wherein the backing cylinder is heated with steam at a pressure of more than 90 psig.

24. The method according to any one of Claims 1 to 23, wherein the backing cylinder is heated with steam at a pressure of from about 80 psig to about 150 psig.

25. The method according to any one of Claims 1 to 24, wherein the drying cylinder of the Yankee dryer is heated with steam at a pressure of from about 90 psig to about 110 psig.

26. The method according to any one of Claims 1 to 25, wherein production of the dried web is substantially constant during a production interval between successive strippings of the resinous adhesive coating from the surface of the heated drying cylinder.

27. The method according to any one of Claims 1 to 26, wherein the predetermined target production rate of the dried web is at least 2000 fpm (609.6 mpm).

28. The method according to any one of Claims 1 to 27, wherein the predetermined target production rate of the dried web is at least 2250 fpm (685.8 mpm).

29. The method according to any one of Claims 1 to 28, wherein the predetermined target production rate of the dried web is at least 2500 fpm (762 mpm).

30. A method of making a fabric-creped absorbent cellulosic sheet, the method comprising:

(a) compactively dewatering a papermaking furnish to form a web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed;

(b) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric;

(c) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee dryer also having a dryer hood configured to provide drying energy to the web on the heated drying cylinder of the Yankee dryer in

the form of a heated air stream, the dryer hood having a characteristic operating temperature and a characteristic operating temperature limit;

(d) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating;

(e) drying the web to a predetermined dryness on the surface of the heated drying cylinder of the Yankee dryer to form a dried web;

(f) removing the dried web from the surface of the heated drying cylinder of the Yankee dryer; and

(g) periodically stripping at least a portion of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the dryer hood of the Yankee dryer is approached,

wherein a production interval between successive strippings of resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a predetermined target production rate of dried web is met, the production interval further characterized in that an average rate of increase of the characteristic operating temperature of the dryer hood over the production interval is less than 1°F/minute (0.55°C/min).

31. The method according to Claim 30, wherein the average rate of increase of the characteristic operating temperature of the dryer hood over the production interval is less than 0.75°F/min (0.41°C/min).

32. The method according to Claim 30 or 31, wherein the average rate of increase of the characteristic operating temperature of the dryer hood over the production interval is less than 0.5°F/min (0.28°C/min).

33. The method according to any one of Claims 30 to 32, wherein the dryer hood is provided drying energy at a rate of less than 3 MMBtu/ton (3165 MJ/ton) for a duration of at least 30 minutes during the production interval.

34. The method according to any one of Claims 30 to 33, wherein the dryer hood is provided drying energy at a rate of less than 3 MMBtu/ton (3165 MJ/ton) for a duration of at least 60 minutes during the production interval.

35. The method according to any one of Claims 30 to 34, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes a polyvinyl alcohol resin and a polyamidoamine resin.

36. The method according to Claim 35, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes less than 75% by weight of polyvinyl alcohol resin.

37. The method according to Claim 35 or 36, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes less than 65% by weight of polyvinyl alcohol resin.

38. The method according to any one of Claims 35 to 37, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes less than 60% by weight of polyvinyl alcohol resin.

39. The method according to any one of Claims 35 to 38, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes less than 50% by weight of polyvinyl alcohol resin.

40. The method according to Claim 35, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes from about 40% by weight to about 80% by weight of polyvinyl alcohol resin.

41. The method according to any one of Claims 35 to 40, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes from about 5% by weight polyamidoamine resin to about 35% by weight polyamidoamine resin.

42. The method according to any one of Claims 35 to 40, wherein the resinous adhesive coating composition provided to the surface of the heated drying cylinder includes at least 10% by weight of a polyamidoamine resin.

43. The method according to any one of Claims 35 to 42, wherein the resinous adhesive coating composition includes from about 2.5% by weight of a modifier to about 30% by weight of a modifier.

44. The method according to any one of Claims 35 to 42, wherein the resinous adhesive coating composition contains up to about 20% by weight of a modifier.

45. The method according to any one of Claims 35 to 42, wherein the resinous adhesive coating composition contains up to about 30% by weight of a modifier.

46. A method of making a fabric-creped absorbent cellulosic sheet, the method comprising:

(a) preparing an aqueous papermaking furnish, the aqueous papermaking including pulp comprising pre-dried papermaking fibers that have been air dried to at least 80% prior to preparing the aqueous papermaking furnish;

(b) depositing the aqueous papermaking furnish on a formaninous support;

(c) compactively dewatering the aqueous papermaking furnish to form a nascent web and concurrently applying the web to a surface of a heated, rotating backing cylinder, the heated, rotating backing cylinder traveling at a first speed;

(d) fabric-creping the dewatered web from the surface of the heated backing cylinder at a consistency of from about 30% to about 60% utilizing a patterned creping fabric, the fabric-creping step occurring under pressure in a fabric-creping nip defined between the surface of the heated backing cylinder and the creping fabric, wherein the creping fabric is traveling at a second speed that is slower than the first speed of the heated backing cylinder, the fabric pattern, nip parameters, velocity delta, and web consistency being selected such that the web is creped from the surface of the heated backing cylinder and transferred to the creping fabric;

(e) providing a hygroscopic, re-wettable resinous adhesive coating composition to a surface of a heated drying cylinder of a Yankee dryer at an add-on rate of less than 20 mg/m^2 of drying cylinder surface, such that a resinous adhesive coating is formed, the Yankee dryer also having a drying hood with a characteristic operating temperature limit;

(f) transferring the web from the creping fabric to the surface of the heated drying cylinder of the Yankee dryer such that the web is adhered to the heated drying cylinder of the Yankee dryer by the resinous adhesive coating;

(g) drying the web to a predetermined dryness on the surface of the heated drying cylinder of the Yankee dryer to form a dried web;

(h) removing the dried web from the surface of the heated drying cylinder of the Yankee dryer; and

(i) periodically stripping at least a portion of the resinous adhesive coating from the surface of the heated drying cylinder of the Yankee dryer as the characteristic operating temperature limit of the drying hood of the Yankee dryer is approached,

wherein a production interval between successive strippings of adhesive coating from the surface of the heated drying cylinder of the Yankee dryer has a duration of at least 4 hours, and during which production interval, a target production rate of dried web is met.

47. The method according to Claim 46, wherein the pre-dried papermaking fibers are air dried to at least 90% prior to preparing the aqueous papermaking furnish.

48. The method according to Claim 46 or 47, wherein the pre-dried papermaking fibers are air dried to at least 95% prior to preparing the aqueous papermaking furnish.

49. The method according to any one of Claims 46 to 48, wherein the pre-dried papermaking fibers include southern softwood kraft fiber.

50. The method according to any one of Claims 46 to 49, wherein the pre-dried papermaking fibers have a GE brightness of at least 80.

51. The method according to any one of Claims 46 to 50, wherein the pre-dried papermaking fibers have a GE brightness of at least 85.

52. The method according to any one of Claims 46 to 51, wherein the pre-dried papermaking fibers have a GE brightness of at least 90.

53. The method according to any one of Claims 46 to 51, wherein the pre-dried papermaking fibers have a GE brightness of between about 85 and 95.

54. The method according to any one of Claims 46 to 53, wherein the pulp in the aqueous papermaking furnish comprises at least 60% by weight pre-dried papermaking fibers.

55. The method according to any one of Claims 46 to 54, wherein the pulp in the aqueous papermaking furnish comprises at least 75% by weight pre-dried papermaking fibers.

FIG. 1

YANKEE HOOD INLET JET TEMPERATURES VS. TIME
YANKEE SPEED-2450 FPM (745 mpm) & ADD-ON RATE OF YANKEE COATING-10mg/m^2
(INVENTION)

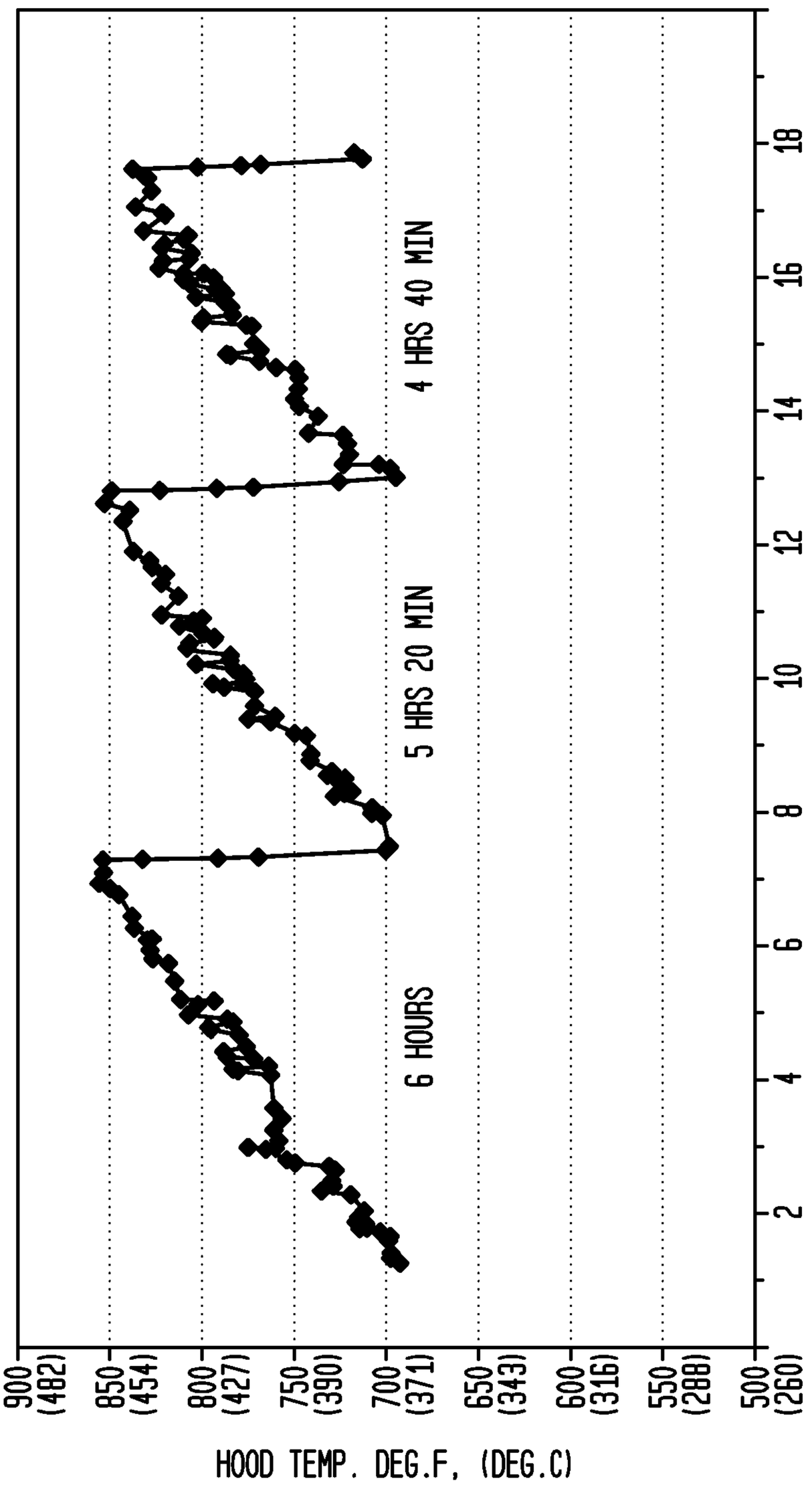


FIG. 2

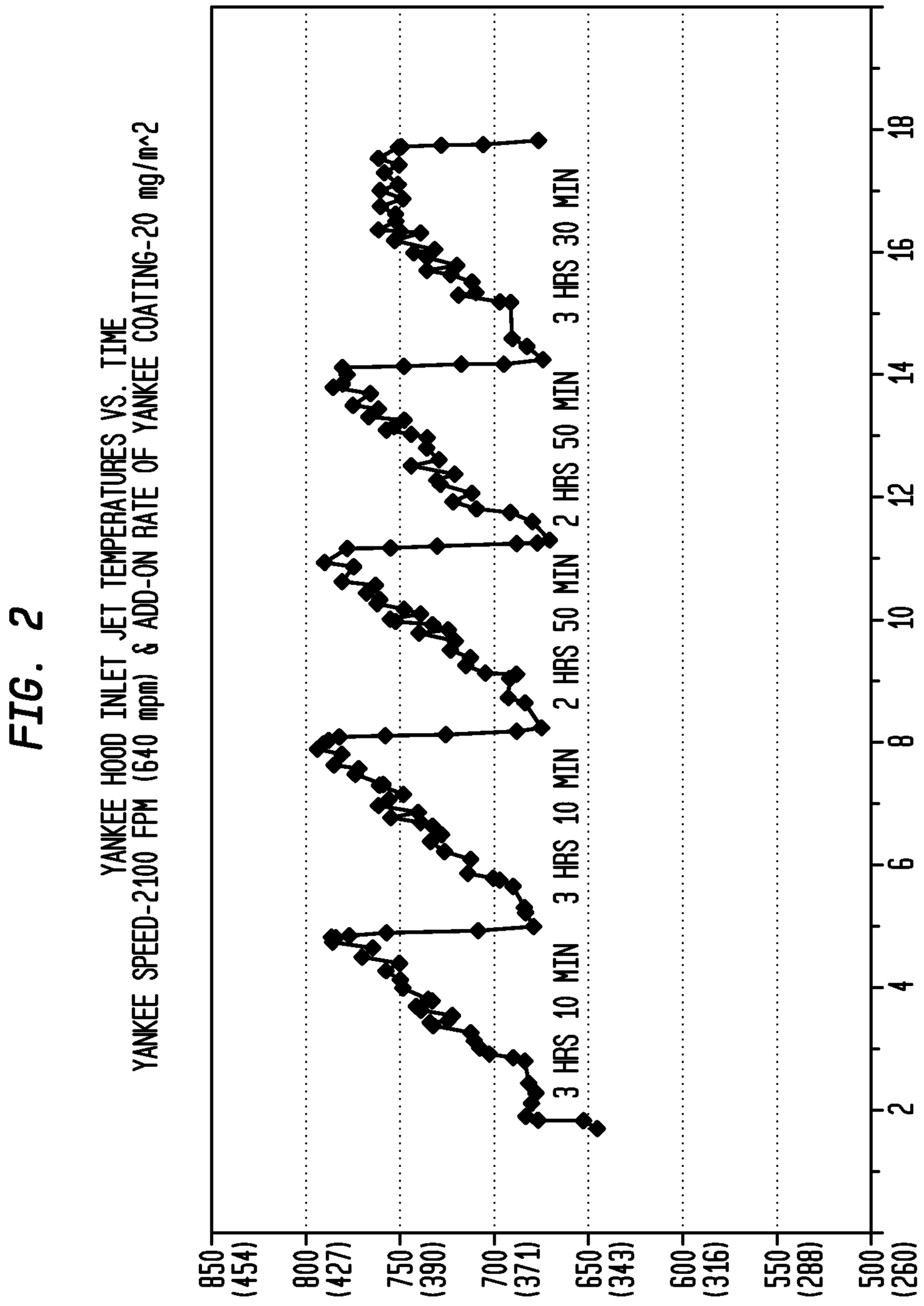

YANKEE HOOD INLET JET TEMPERATURES VS. TIME
YANKEE SPEED-2100 FPM (640 mpm) & ADD-ON RATE OF YANKEE COATING-20 mg/m^2
2 HRS 50 MIN
2 HRS 50 MIN
3 HRS 30 MIN
3 HRS 10 MIN
3 HRS 10 MIN
TIME (HOURS)
2
4
6
8
10
12
14
16
18
850 (454
800 (427
750 (390
700 (371
650 (343
600 (316
550 (288
500 (260
HOOD TEMP. DEG.F, (DEG.C)

FIG. 3

GAS USAGE PER TON VS. TIME
YANKEE SPEED-2450 FPM (745 mpm) & ADD-ON RATE OF YANKEE COATING- 10mg/m^2
(INVENTION)

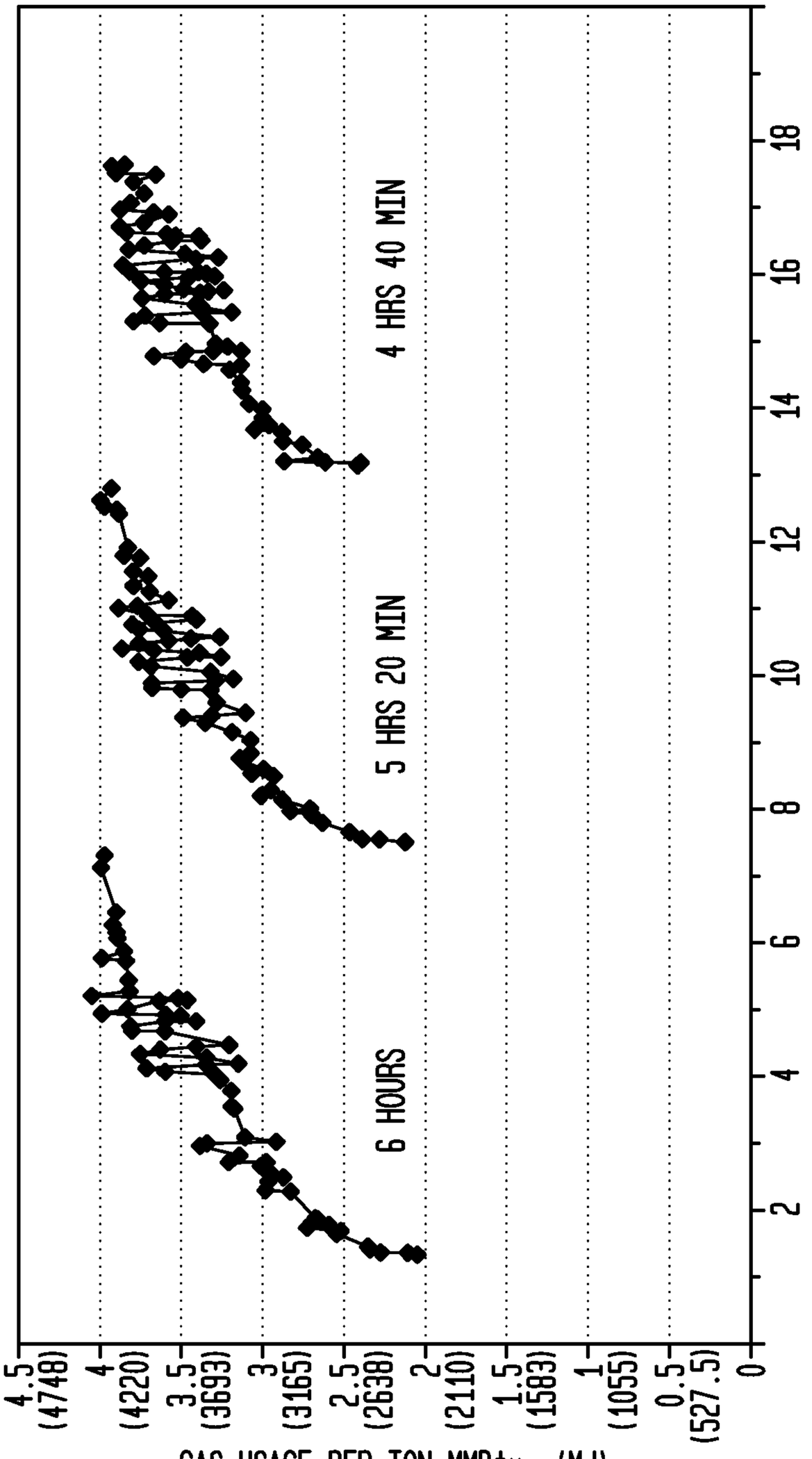


FIG. 4

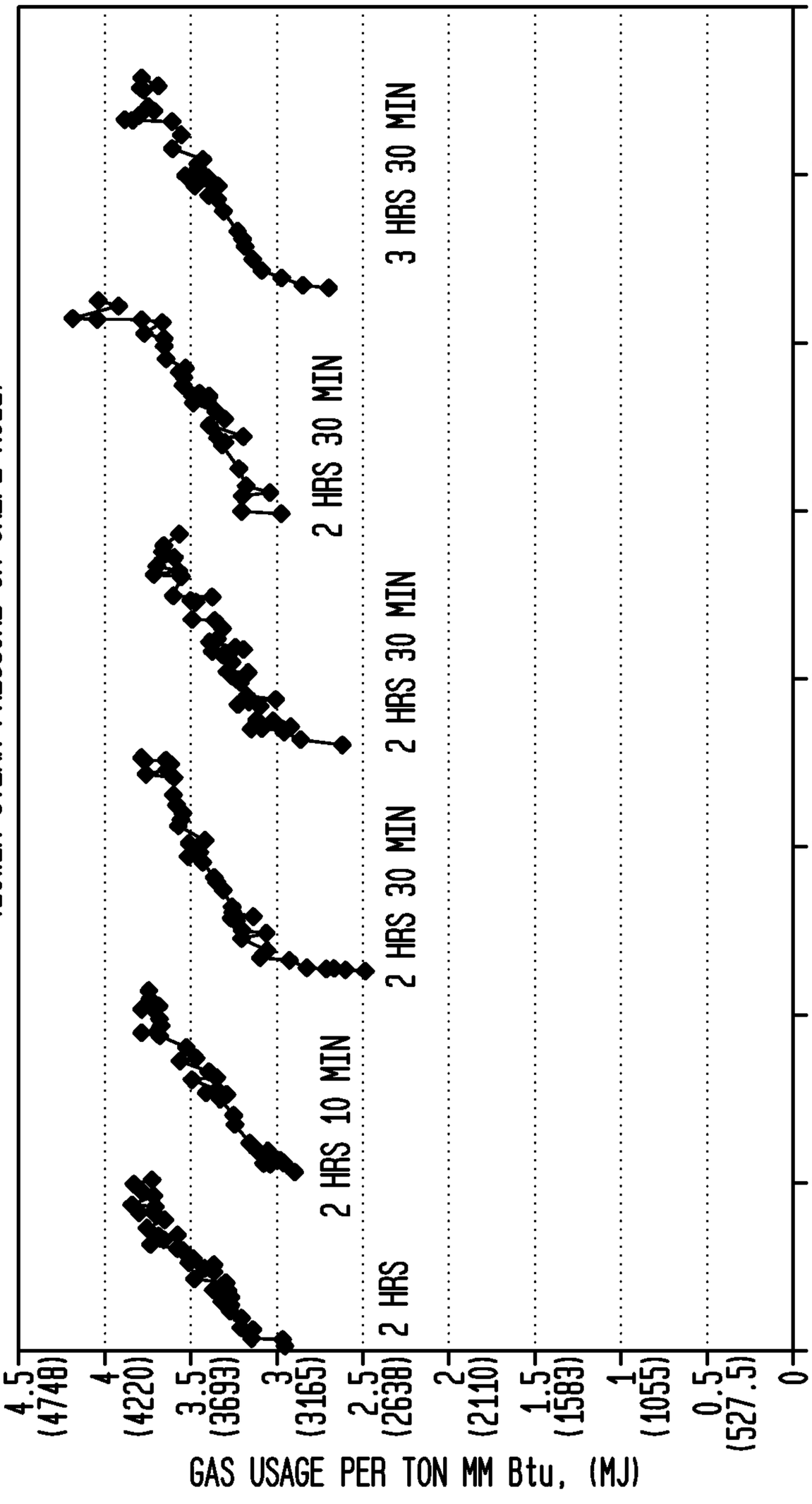
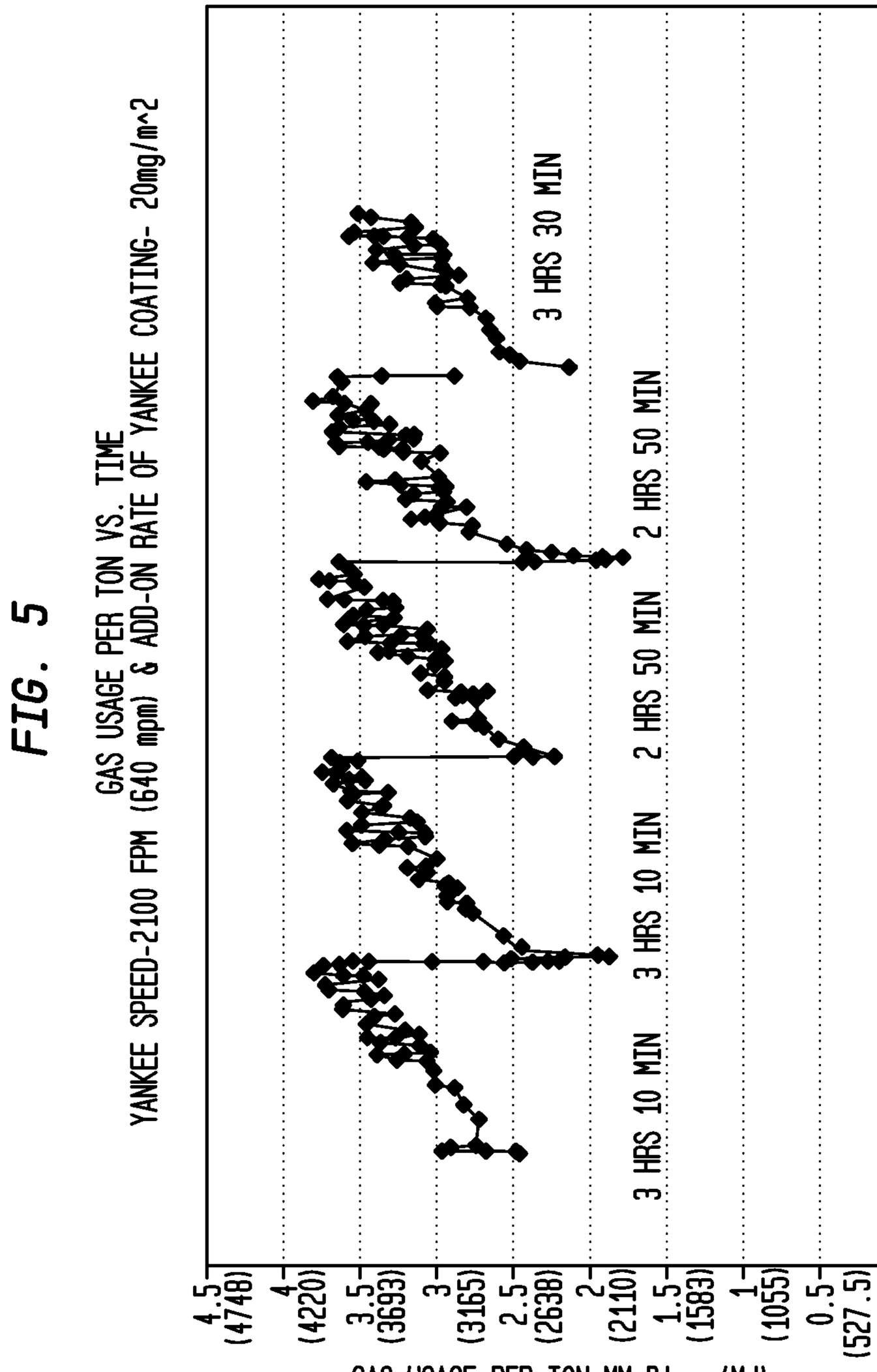

GAS USAGE PER TON VS. TIME
YANKEE SPEED-2100 FPM (640 mpm) & ADD-ON RATE OF YANKEE COATING- 20mg/m^2
(LOWER STEAM PRESSURE ON CREPE ROLL)
2 HRS
2 HRS 10 MIN
2 HRS 30 MIN
2 HRS 30 MIN
3 HRS 30 MIN
4.5 (4748)
4 (4220)
3.5 (3693)
3 (3165)
2.5 (2638)
2 (2110)
1.5 (1583)
1 (1055)
0.5 (527.5)
0
2
4
6
8
10
12
14
TIME (HOURS)
GAS USAGE PER TON MM Btu, (MJ)

FIG. 5


GAS USAGE PER TON VS. TIME
YANKEE SPEED-2100 FPM (640 mpm) & ADD-ON RATE OF YANKEE COATING- 20mg/m^2
3 HRS 30 MIN
2 HRS 50 MIN
3 HRS 10 MIN
2 HRS 50 MIN
3 HRS 10 MIN
TIME (HOURS)
GAS USAGE PER TON MM Btu, (MJ)

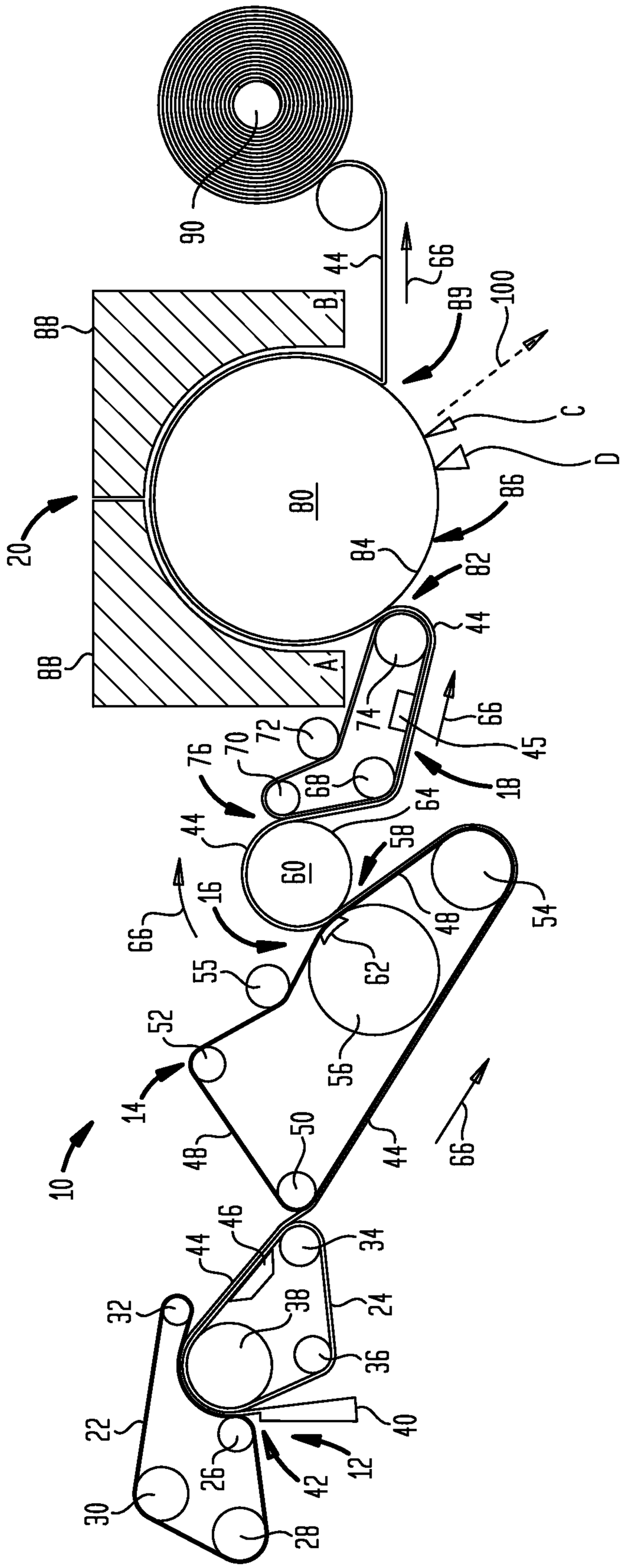
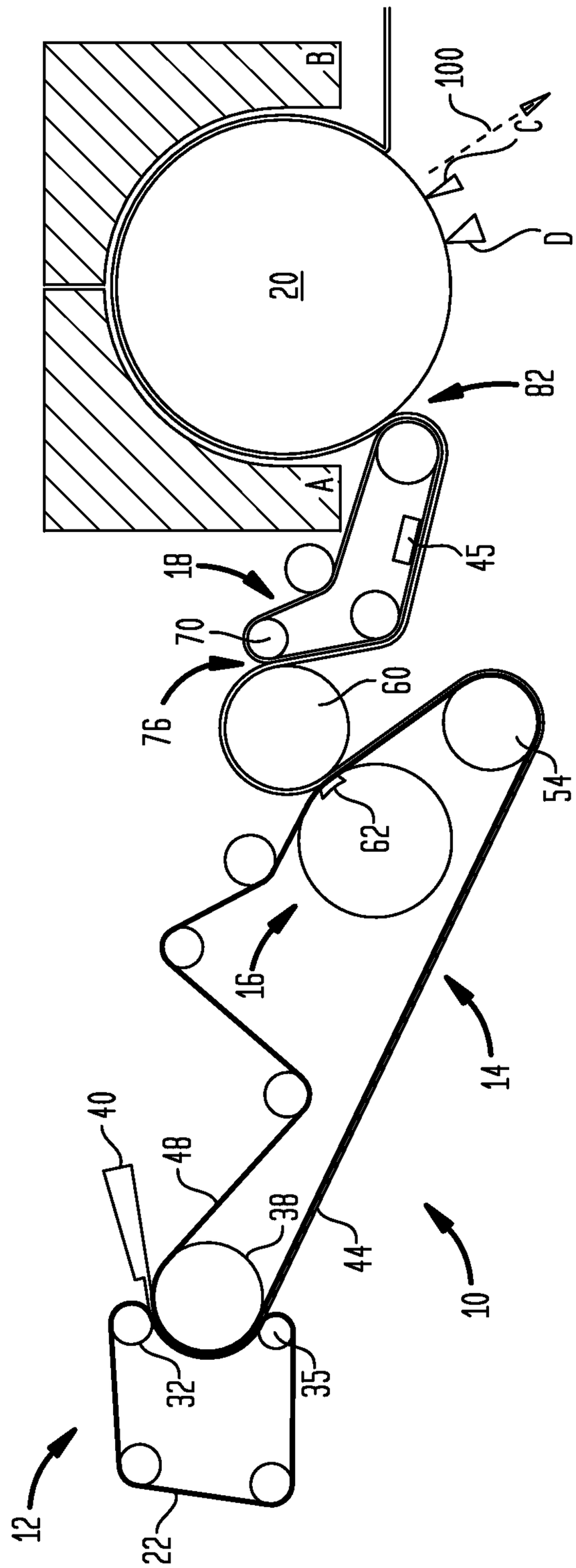
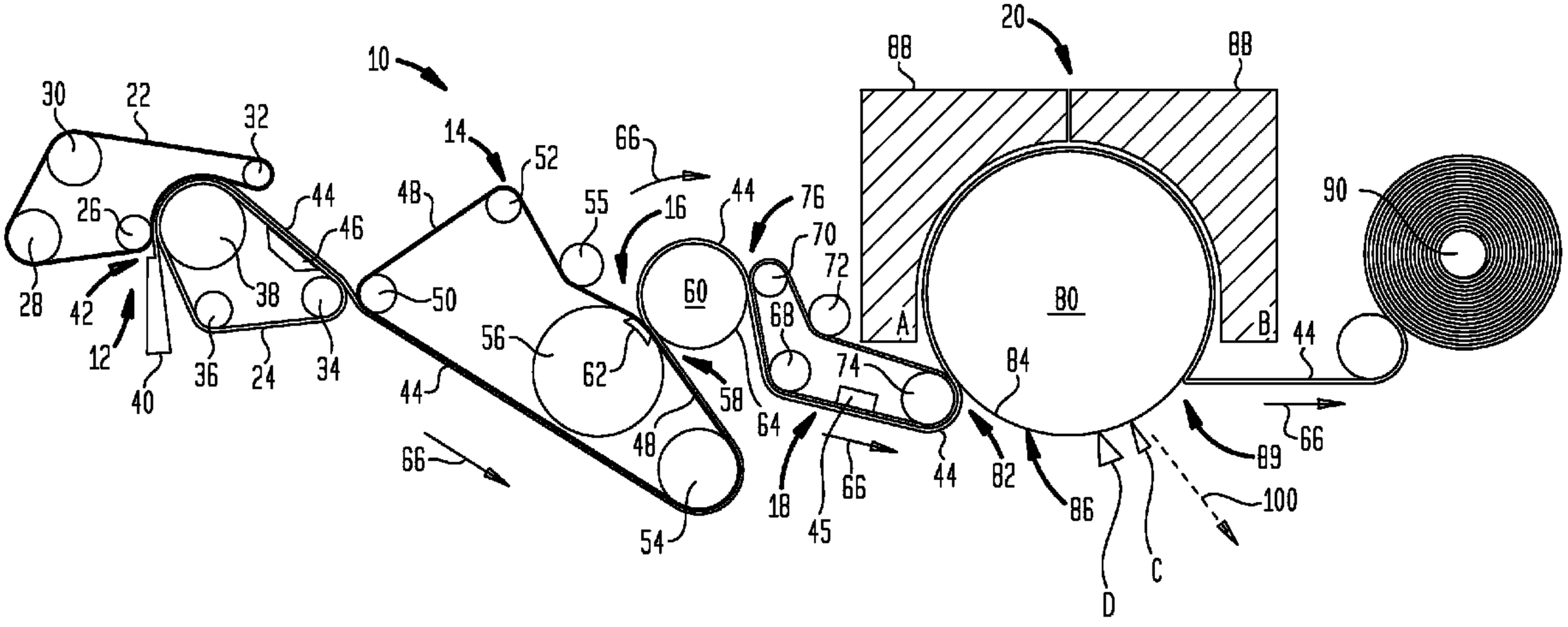

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89
100
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C
D
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FIG. 6

FIG. 7




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C
D