Physical aspects of single-facer operation

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ABSTRACT: On its brief passage through the singlefacer, the fluting medium undergoes a rapid series of physical processes. This article is a theoretical examination of how these processes affect the papers and glue in the singlefacer. The postulated effects have implications for the starch pick-up and gelation process and provide an explanation for edge effects (fluff out, delamination). The speed of green-bond formation is found to be highly dependent on both the temperature and the pressure of impact in the nip where the liner is pressed against the glued flute tips.

KEYWORDS: Corrugating machines, corrugating medium, flutes, models, nip, operations, parameters, physical properties, processes, single facers, theories.

When developing a theoretical model of a process, the usual procedure is to consider all the parameters in universal terms and then substitute actual values to test the model. For this discussion of singlefacer operation, we decided instead to select a set of typical operating parameters to provide a basis for a theoretical discussion of the corrugating process. The chosen "typical" parameters are listed in **Table I.**

Corrugator operation

A modern singlefacer corrugator running at 240 m/min under the conditions listed in Table I can experience problems with forming a green bond between the fluting medium and the liner. The fluting medium experiences short, sharp pulses of temperature and pressure in the corrugator-roll nip and in the pressure-roll nip. These pulses can have a major effect on the penetration of the glue into the paper, the condition of the glue, and the formation of the green bond. However, there is limited published information about the condition of the fluting medium at the flute tips when the glue is applied. This report presents a theoretical discussion of the conditions in the fluting medium as it progresses through the singlefacer.

The singlefacer operation has eight zones, as illustrated in **Fig. 1** and described in **Table II.** Each of these zones will be considered in turn and the effect upon the fluting medium postulated.

On-corrugator conditions and effects

Preconditioning before the corrugator-roll nip

The fluting medium has a variable wrap on the preconditioner, which can raise the temperature to 80°C before the fluting medium enters the proportional steam shower. The application of steam is necessary to soften the fluting medium and make it sufficiently pliable to form flutes at very high speeds. A machine with 164 flutes/m operating at 4 m/s forms 656 flutes each second. (Referring to the lower portion of Fig. 4, a flute starts to form at pockets D and 5 and is fully formed at pocket 11, about 5 ms later.)

If the temperature of the fluting medium is raised from 80°C to 97°C, the energy needed from the steam to heat the 112-g/m² sheet (i.e., 104.2 g/m² of moisture-free fiber and 7.8 g/m² of moisture, as defined in Table I) is

$$(104.2\ \text{g/m}^2 \times 1.25\ \text{J/g°C} \times 17.0\text{°C}) + (7.8\ \text{g/m}^2 \times 4.18\ \text{J/g°C} \times 17.0\text{°C}) = 2768\ \text{J/m}^2$$

The moisture condensed to produce this energy is

$$2768\ \text{J·m}^{-2}/2257\ \text{J·g}^{-1} = 1.23\ \text{g/m}^2$$

The moisture in the web is now 7.8 g/m² + 1.23 g/m² = 9.03 g/m². The moisture-free fiber remains at 104.2 g/m², giving a total grammage of 113.23 g/m² at 97°C. Consequently, the moisture content of the paper is now 9.03/113.23 = 8.0%.

Labyrinth entering the corrugator-roll nip

There are two distinct air flows entering the labyrinth:

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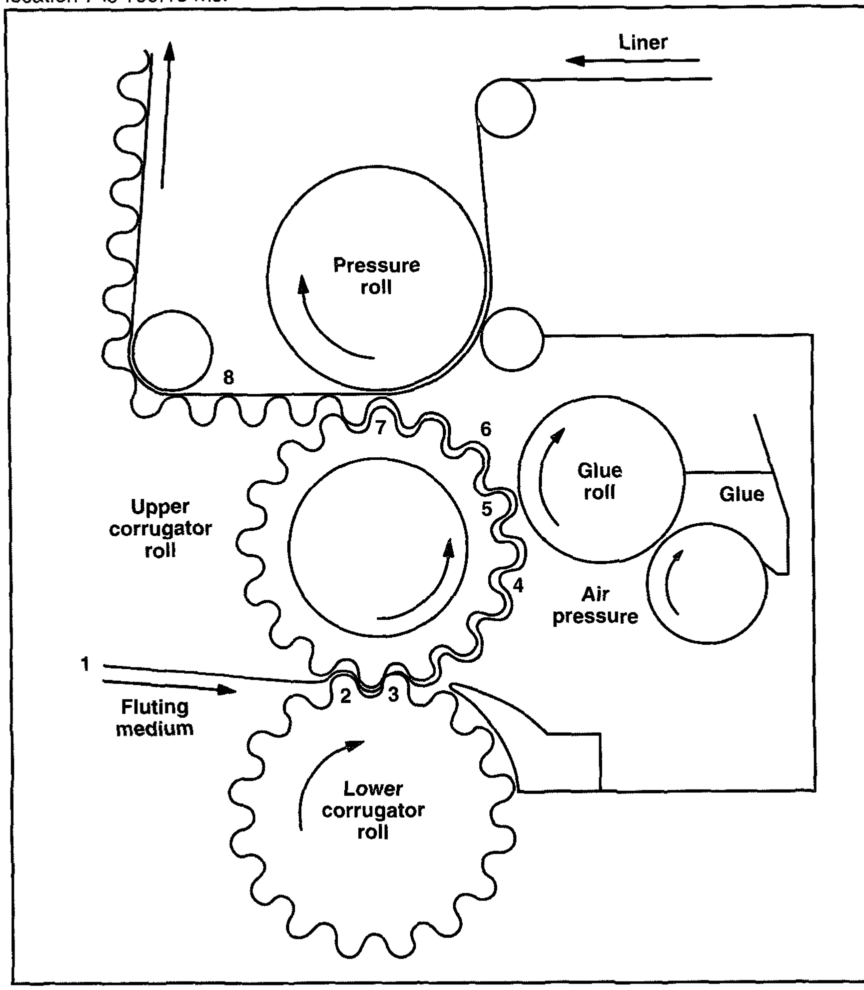
I. Single-facer parameters*

Machine conditions	
Speed, m/s	
Corrugator	4
Fluting medium	5.3
Temperature,°C	
Corrugator rolls	180
Pressure roll	180
Flute	
Density, flutes/m	164
Pitch, mm	6.1
Height, mm	2.5
Take-up ratio	1.33
Fluting medium	
Grammage, g/m²	112.0
Moisture-free fiber, g/m²	104.2
Moisture in the reel, g/m²	7.8
Bound moisture	2.8
Free moisture	5.0
Thickness, µm	230
Tension, N/lineal m	175–350
Temperature in the reel, °C	20
Specific heat, J/g °C	
Fiber	1.25
Water	4.18
Specific enthalpy of water, J/g	
at 165°C	2065
at 100°C	2257

*B-flute pressurized single facer

1. Singlefacer, with eight zones as described in Table II. Cumulative time (t) from location 2 to location 7 is 166.15 ms.



II. Description of locations depicted in Fig. 1

Location in Fig. 1	*Description*	*Residence time,ms*	*Cumulative time,ms*
1	Preconditioning before the corrugator-roll nip	...	...
2	Labyrinth entering the corrugator-roll nip	6.0	0–6
3	Labyrinth leaving the corrugator-roll nip	1.5	6–7.5
4	Pressure compartment before the glue roll	94.5	7.5–102
5	Glue application	3.0	102–105
6	Pressure compartment before the pressure roll	60.0	105–165
7	Pressing the liner against the glued flute tips	1.15	165–166.15
8	Formation of the green bond after the pressure roll	...	...

1. A boundary layer of moist air at 93–97°C traveling at 5.3 m/s on both sides of the fluting medium.
2. Pockets of air trapped in the valleys between the flute tips on each corrugator roll. These air pockets are travelling at 4 m/s at a temperature in the region of 160°C.

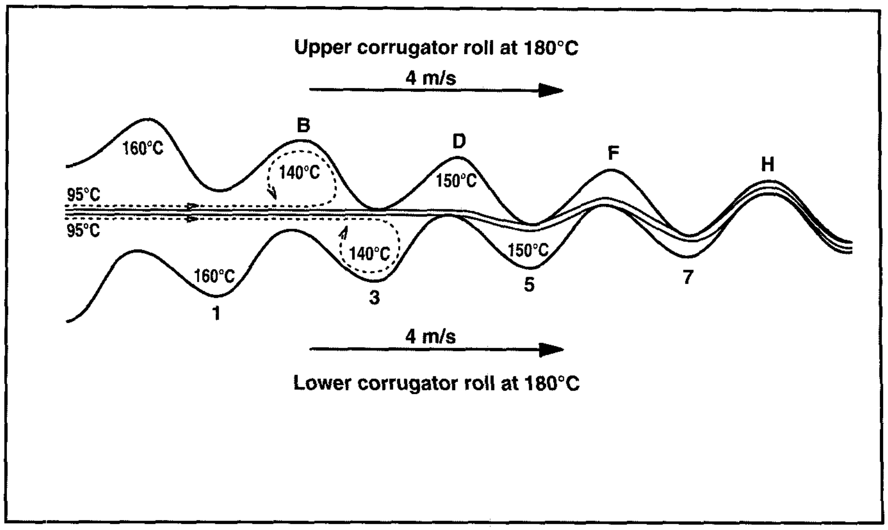
Both air flows are illustrated in **Fig. 2.** In pocket B on the upper corrugator roll and in pockets 1 and 3 on the lower corrugator roll, the boundary layers of air will mix, helped by the turbulence created by the speed differential between the paper and the corrugator rolls. By the time the mixed air is trapped in pocket D on the upper corrugator roll and in pocket 5 on the lower corrugator roll, the temperature of the air will be 150–160°C.

Assuming that no air escapes, the pressures in the pockets can be calculated from the cross-sectional areas of the pockets. Pressures and times are listed in **Table III.** Pressures and temperatures in pockets D, 5, F, and 7 are illustrated in **Fig. 3.** The final pressure achieved in pocket 11 at the centerline of the nip will vary with the flute profile and the clearance on the flanks, the density of the fluting medium, the nip pressure of the corrugator rolls, and the compressibility of the fluting medium.

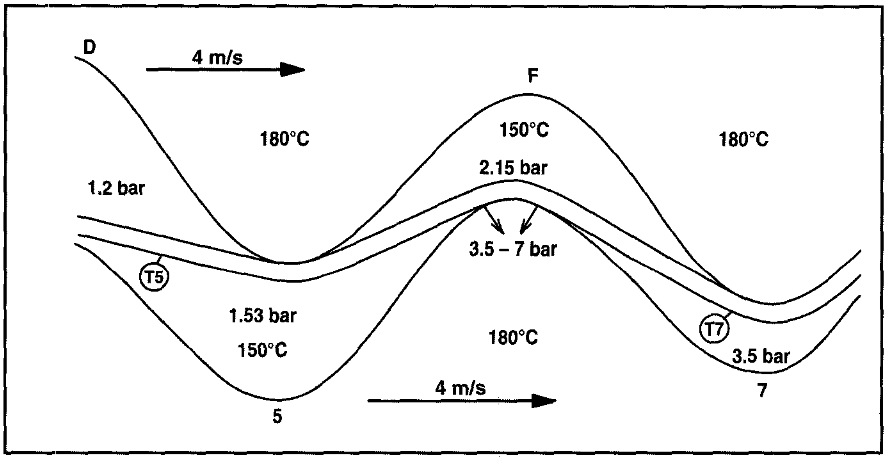
There are four paths by which the air could escape:

1. Along the flutes, toward the ends of the corrugator rolls. The pockets of air are trapped within a very narrow space—a few mm wide and 1–2-mm deep—and very long on a 2500-mm-wide corrugator. There is no time for the air to escape toward the ends of the corrugator rolls. The exception is in the 100 mm or so at each edge of the corrugator, where the air can escape.
2. Back over the flute tips, forcing a gap between the paper and the flute tip. The tension of the fluting medium over the flute tips in the range 175–350 N/m produces a pressure on the flute tips of $2T/r$ (where T is tension and r is radius) or 3.5–7.0 bar. The pressure differential between pockets 7 and 5 is 1.5 bar and between pockets H and F is 5.6 bar and between pockets J and H is 7.0 bar. With such pressure differentials, air is unlikely to escape between the paper and the flute tips.
3. Through the paper from one pocket to the next. The pressure differential across the paper between pockets is small in the early stages, and there is unlikely to be any appreciable air flow through the paper web in the time available.
4. On most singlefacers, one of the corrugator rolls has circumferential slots spaced at 50-mm intervals. The slots will allow some lateral air flow on one side of the fluting medium, which might reduce pressure on that side of the paper.

2. Boundary layers of air entering the labyrinth



3. Absolute pressures in pockets D and F and in pockets 5 and 7. Point T5 is the location of the future glue-application site as the fluting medium passes through pocket 5. Point T7 is the corresponding location in pocket 7.



III. Calculated pressures and times in corrugator-roll pockets

Corrugator pocket[a]	*Pressure, bar*	*Time, ms*[b]
B	1.00	...
3	1.00	0.00
D	1.20	0.75
5	1.53	1.50
F	2.15	2.25
7	3.50	3.00
H	7.84	3.75
9	12.02	4.50
J	14.86	5.25
11	14.86	6.00

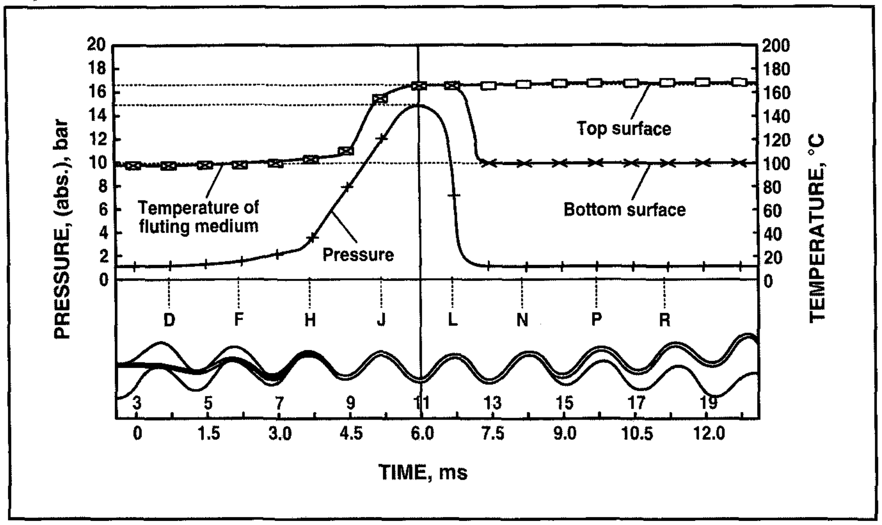
[a]Positions illustrated in Fig. 2
[b]Times represent duration from the point of first contact between the fluting medium and corrugator roll

IV. Assumptions for glue application

Adhesive	Stein Hall
Solids content*, %	24
Temperature, °C	
In glue pan	38
Gel temperature	62
Viscosity at 38°C, Stein Hall s	35
Glue thickness on applicator roll, µm	300

*20% cooked carrier starch, 80% uncooked starch

4. Temperature and pressure profiles for the fluting medium as it passes through the corrugator labyrinth. Pocket 11 is the nip centerline.



At pockets J and 11, the volume of the air is very small, as seen in the lower portion of **Fig. 4**. At these points, the paper is compressed by the mechanical pressure of the hot corrugator-roll nip. Most of the air and water vapor that was in the pockets is now compressed within the body of the fluting medium. The temperature achieved within the body of the paper is expected to be determined by the temperature of the air that was trapped in pockets 5, 7, and 9 on one side of the sheet and pockets D, F, and H on the other side, since this air is compressed into the paper. To this can be added the heat generated by the kinetic energy of the nip pressure and the heat conducted into the paper from the hot corrugator rolls.

From the viewpoint of bond formation, we are only interested in the condition of the fluting medium at the flute tip where the glue will be applied. This is point T5 in pocket 5, which becomes T7 in pocket 7 (Fig. 3). From position T7 onwards, the upper side of the paper is in contact with the upper corrugator roll. In pocket 11, the centerline of the nip, both sides of the paper are in contact with the hot corrugator rolls.

At the nip centerline, surface temperatures on both sides of the fluting medium approach the 180°C temperature of the corrugator rolls, as seen in the upper section of Fig. 4. The body of the fluting medium approaches the temperature of the air in the pockets, about 160°C. This would give an average paper temperature of 165°C, which exceeds the glass-transition temperature for lignin, enabling the fluting medium to soften and deform to the flute profile *(1)*.

As the pressure in the pockets increases, the moisture in the paper does not evaporate, since the boiling point of water increases with pressure. For instance, at 15.5 bar, water does not evaporate to form steam until the temperature reaches 200°C. At 165°C, the pressure for water to boil is 7.0 bar, well below the pressure in the pockets at the centerline of the corrugator-roll nip. **Figure 5** illustrates the relationship between temperature and pressure for the fluting medium as it enters and exits the labyrinth.

Labyrinth leaving the corrugator-roll nip

From pocket 13 onward, the fluting medium is in contact with the upper corrugator roll, as seen in the lower portion of Fig. 4. The fluting medium's bottom surface is open to the air in the pressure compartment. This air is at a low pressure, in the region of 1.1 bar, at about 30°C.

The sudden release of pressure from pocket 11 (15 bar) to pocket 13 (1.1 bar) a mere 1.5 ms later will apply to the body of the paper as well as the surrounding air. As soon as the pressure drops to 7.0 bar, most of the moisture in the paper evaporates, with the exception of the 2.8 g/m^2 of bound water in the fibers. The free moisture amounts to 6.23 g/m^2 (9.03 g/m^2 total moisture less 2.8 g/m^2 of bound moisture).

To evaporate the free moisture in the paper requires supplying the latent heat of evaporation. As the free water evaporates, it extracts heat from the fiber and the bound water in the fibers, causing web temperature to drop from 165°C to 100°C. If the temperature of the fluting medium drops 65°C, the heat energy released by 1 m^2 of dry fiber is

$$104.2 \text{ g/m}^2 \times 1.25 \text{ J/g°C} \times 65\text{°C} = 8466 \text{ J/m}^2$$

Similarly, the heat released by 1 m^2 of bound water is

$$2.8 \text{ g/m}^2 \times 4.18 \text{ J/g°C} \times 65\text{°C} = 760 \text{ J/m}^2$$

Thus the total heat released is 9226 J/m^2, and the free water evaporated by this heat is

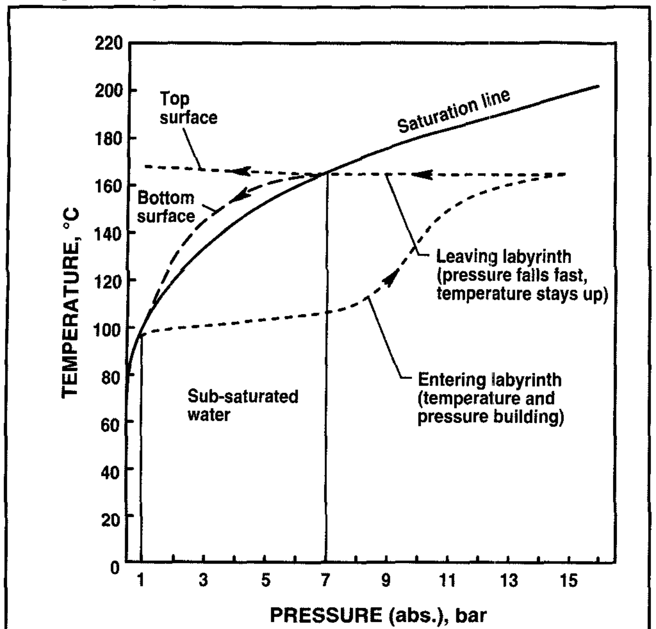
$$9226 \text{ J·m}^{-2}/2065 \text{ J·g}^{-1} = 4.47 \text{ g/m}^2$$

This sudden pressure drop from within the body of the paper will cause the hot air that was compressed within the body of the sheet to escape through the open underside of the sheet, carrying the water vapor with it. The temperature of the paper, both the interior and the outer surface, will still be about 100°C, so no condensation should occur in the web.

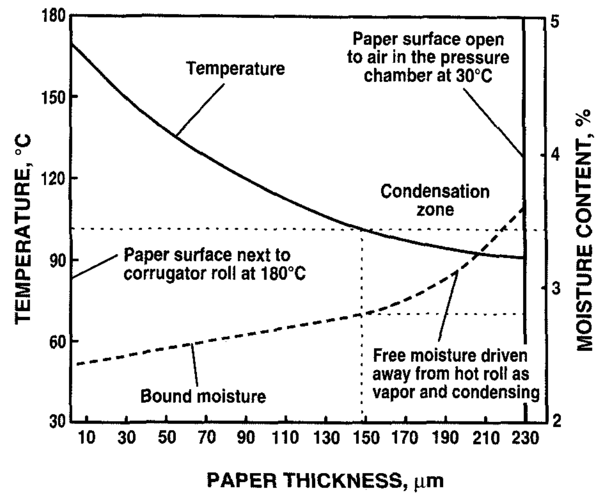
As the fluting medium enters pockets 15, 17, and 19, the upper side remains in contact with the upper corrugator roll at 180°C, and the lower side is still very close to the lower corrugator roll, which will be radiating heat onto the lower surface of the paper. It is possible that the temperature of the fluting medium starts rising slightly in this region of leaving the labyrinth.

The quality of the glue bond is affected by the surface roughness on

5. Temperature and pressure within the fluting medium as it passes through the labyrinth



6. Temperature and moisture profiles through the fluting medium as it approaches the glue roll



the underside of the fluting medium at the flute tip, where the glue will be applied. At the centerline of the corrugator-roll nip, the flute tip was at a temperature of 165°C and under the nip line pressure. The line pressure can reduce the thickness of the paper by 30%, which is similar to a hot calender and possibly imparts a surface smoothness to the paper.

As the flute tip leaves pocket 11 and enters pocket 13, the compressed air inside the paper web expands rapidly. In addition, the moisture that flashes off increases in volume by a factor of 1600. The combined effect is likely to produce an almost explosive exit of air and water vapor through the lower surface of the web. This may disrupt the lower surface. The degree of disruption, if any, may depend on the density and permeability of the paper. The roughness of the flute tip may now bear little relationship to the roughness measured in the fluting-medium sample taken from the reel.

Pressure compartment before the glue roll

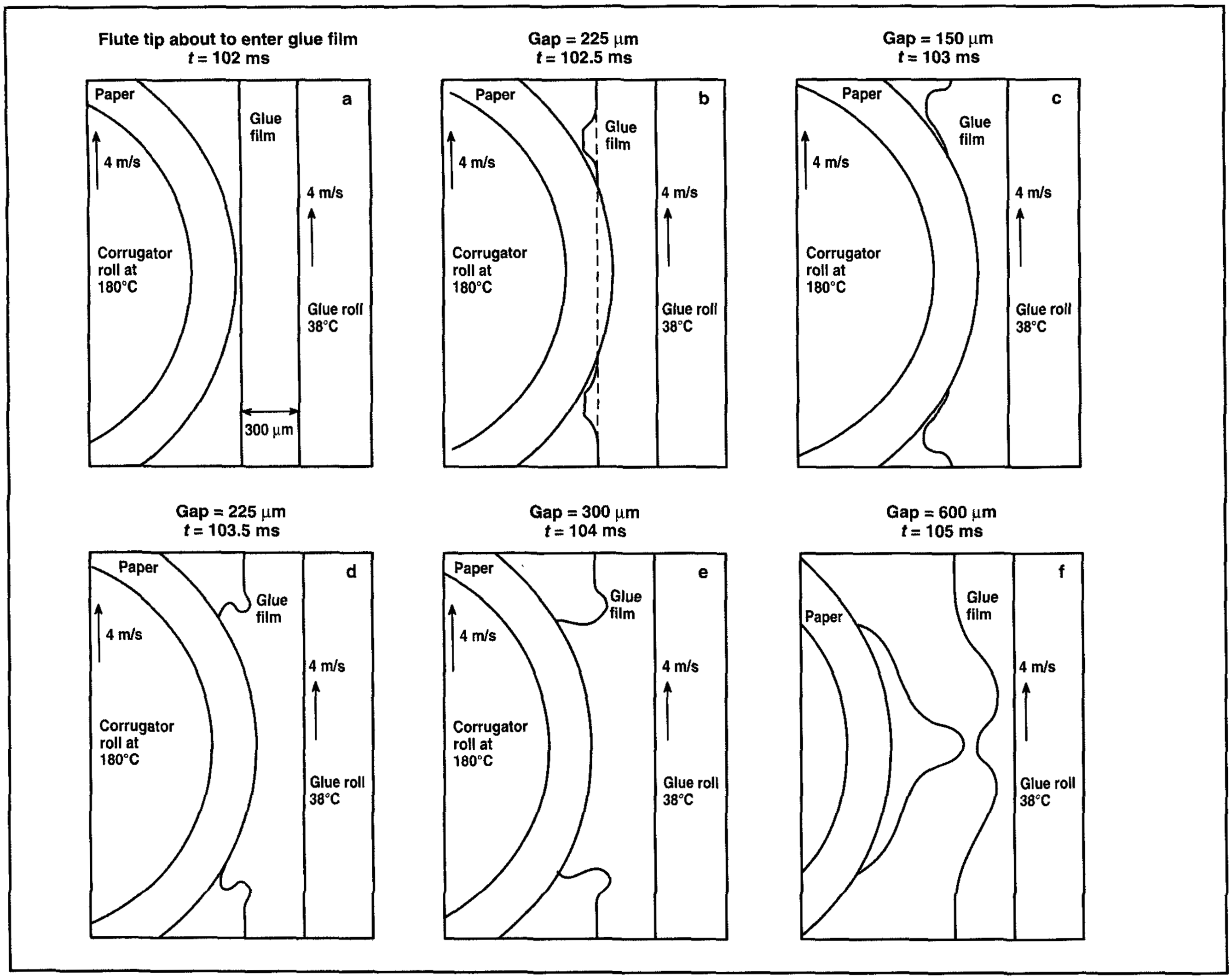
The fluting medium is now traveling in contact with the hot corrugator roll on the upper surface and exposed to the air at about 30°C in the pressure compartment on the lower surface. The body of the paper is initially at 100°C, and heat is radiated from the open surface at a rate determined by the thermal resistivity and surface emissivity of the fluting medium.

The heat loss will be partially replaced by heat conducted from the hot corrugator roll. The rate of replenishment of the heat loss will be controlled by the thermal resistance of the boundary layer of air between the roll and the closed paper surface and the thermal conductivity of the fluting medium, which is very dependent on the sheet structure and moisture content *(2)*.

It is difficult to estimate the temperature drop that occurs at the open surface of the fluting medium during the 94.5 ms it takes to travel from the corrugator nip to the glue roll. However, the surface temperature of the paper is unlikely to fall below 90°C.

The physical conditions of the fluting medium as it arrives at the glue roll can be postulated as follows:

7. Glue application to flute tip



- There will be a temperature gradient from the closed surface next to the corrugator roll at 165°C, falling to 90°C at the open surface, as illustrated in **Fig. 6**.
- The moisture in the fluting medium is 2.8 g/m² of bound moisture plus about 1.76 g/m² of free moisture. The free moisture next to the hot corrugator roll will have evaporated, creating a pressure gradient from the closed paper surface toward the open surface. The water vapor will be driven down the pressure gradient toward the open surface but will condense near the open surface, where the temperature falls below 100°C, as illustrated in Fig. 6
- The roughness of the open paper surface could have increased when the air and water vapor inside the web exploded through the outer layers.

Glue application

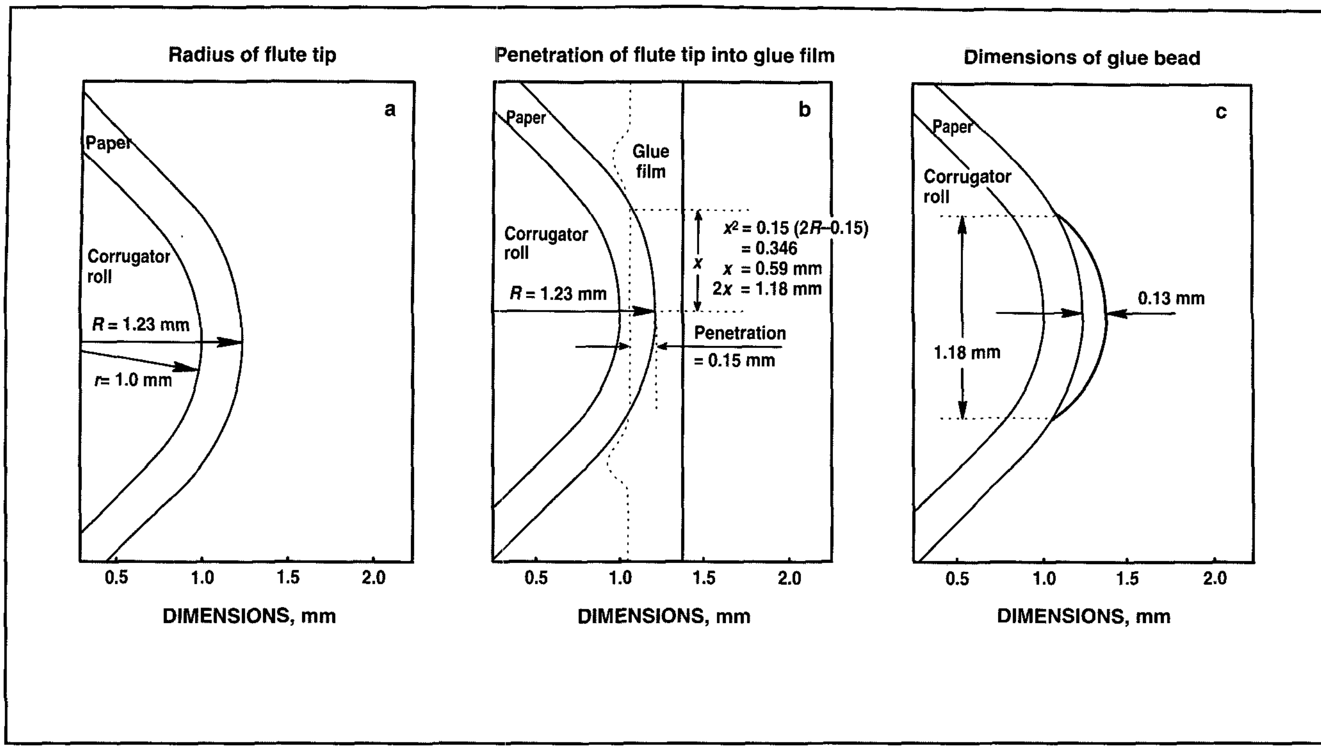
The assumptions for analysis of glue application are listed in **Table IV**.

The gap between the flute tips and the applicator roll will help to define the width of the glue line applied to the flute tips, as illustrated in **Figs. 7A–7F**. The time taken to apply the glue is very short. From the fluted paper tip first touching the glue film surface (Fig. 7A) to the point of deepest penetration of 150 μm (Fig. 7C) takes just 1.1 ms. Complete separation of the glued flute tip from the glue film (Fig. 7F) probably takes another 2 ms.

There is no pressure of the glue applicator roll against the flute tips. The amount of glue transferred depends on the glue penetration by capillary action combined with physical contact with the roughness of the paper surface *(3)*.

Since the total time that the flute tip is immersed in the glue film is in the order of 3 ms, the capillary action must be very limited. It will be affected by the moisture of the paper surface, which is estimated to be 3.5% (Fig. 6). This will depend on the initial moisture content of the fluting medium and the amount of moisture added by the steam shower before en-

8. Geometry of glue bead at flute tip



tering the labyrinth, which is dependent on the wrap on the preconditioner.

The mechanical transfer due to surface roughness can be assisted by a small speed differential between the glue film and the flute tips. A typical speed for the applicator roll is 97% of the speed of the corrugator roll.

If the radius of the flute tip of the corrugator roll is 1.0 mm, then the radius of the fluting medium surface penetrating the glue film is 1.23 mm, as seen in **Fig. 8A**.

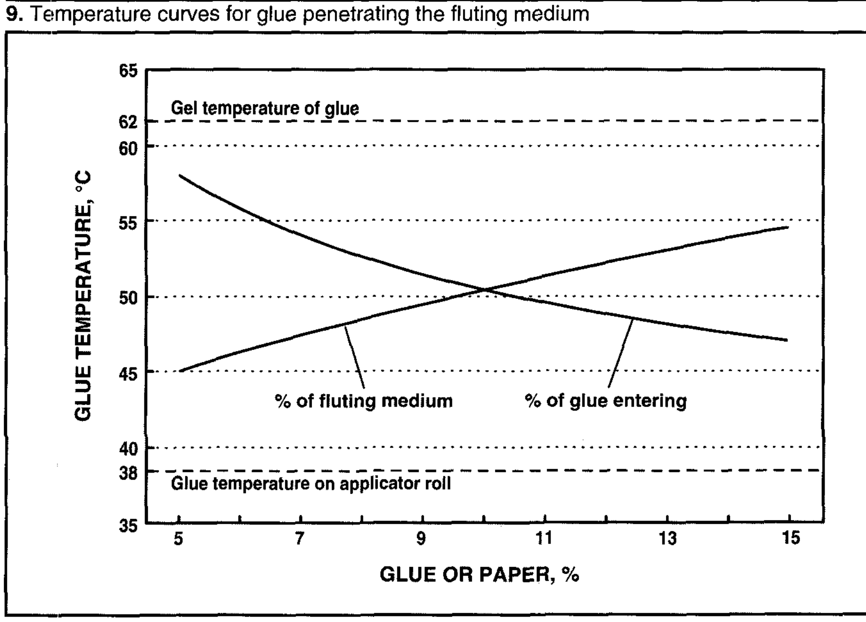
If the flute tip penetrates 0.15 mm into the glue film, as seen in Fig. 8B, then the width of the wetted area is 1.18 mm, as seen in Fig. 8C. With 164 flutes per meter, the wetted area in 1 m^2 of fluted medium is

$$164 \times 1.18 \text{ mm} = 0.194 \text{ m}^2 \text{ or } 1940 \text{ cm}^2$$

At 24% solids, typical glue spread is 5 g/m^2 of dry starch *(4, 5)* or 20.8 g/m^2 of wet starch. If the density is approximately 1 g/mL, the volume of wet starch transferred to the paper is 20.8 mL. The average thickness of the film transferred to the flute tip is

$$20.8/1940 \times 10 \text{ mm} = 0.107 \text{ mm}$$

9. Temperature curves for glue penetrating the fluting medium



Hence the cross-sectional area of the glue bead is

$$1.18 \text{ mm} \times 0.107 \text{ mm} = 0.126 \text{ mm}^2$$

This glue bead is expected to have a curved shape with a central thickness of about 0.13 mm, as seen in Fig. 8C. For a single flute 1m long, the volume of the glue bead is 126 mm^3, which has a mass of 126 mg (assuming a density of 1 g/mL).

Pressure compartment before the pressure roll

The time from the flute tip parting

from the glue film to its contact with the liner at the pressure roll is 60 ms. During this time, the closed side of the fluting medium is in contact with the hot corrugator roll, and the open side is exposed to the air in the pressure compartment at 30°C. The cycle of evaporation near the roll and condensation near the open surface will continue, so that the paper becomes very dry next to the roll. Most of the moisture evaporated will condense near the open surface, which could raise the moisture content to around 4.0%.

The flute tip itself is covered with the glue bead, which was initially at 38°C and which will increase in temperature with the heat transferred from the hot roll. The increase will be quite small, since the part of the paper next to the corrugator roll is very dry and, consequently, is a poor conductor, with a thermal conductivity of 0.88 W/m°C.

The glue that penetrates the paper by capillary action will increase in temperature by absorbing heat from the hotter paper fibers into which it has penetrated. Most of this glue will be carrier starch, while the uncooked starch granules will remain on the paper surface.

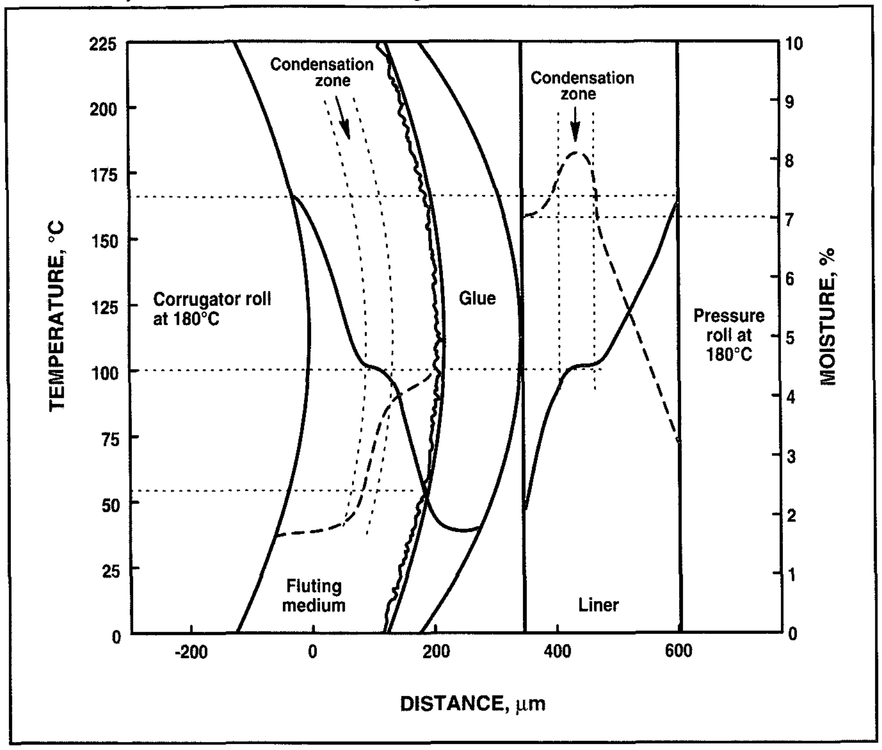
The depth of penetration of the capillary action will depend on the pore sizes of the paper surface at the flute tip. The pore sizes, in turn, will depend on several items:

- The density and pore size of the fluting medium in the reel
- The nip action of the corrugator rolls in closing the surface
- The explosive release of compressed air and water vapor, which may have disrupted the paper surface.

Assume that 8% or 10 mg of the glue penetrates the fluting medium to a depth of 23 µm, or 10% of the thickness. The paper fiber is at 90°C and the glue at 38°C. The mass of fiber penetrated by the glue is

$$0.00118 \text{ m}^2 \times 11.2 \text{ g/m}^2 = 0.0132 \text{ g}$$

10. Temperature (solid lines) and moisture (dashed lines) profiles across the fluting medium and the liner just before the liner meets the glue bead



Combining the temperature of the fiber (0.0132 g of fiber at 90°C and specific heat 1.25 J/g°C) and the water (0.01 g of water at 38°C and specific heat 4.18 J/g°C), we find that the temperature of the mixture is 52.6°C, which is 9.4°C below the gel temperature of the starch.

The quantity of glue that penetrates the fluting medium and the depth of penetration will vary with paper properties and glue characteristics. The temperature of various glue/fiber mixtures is shown in **Fig. 9**.

When the glued flute tip arrives at the pressure roll, the condition of the fluting medium is postulated to be as shown in **Fig. 10**, with the majority of the thickness of the paper next to the corrugator roll very dry, ranging from 1% to 2% moisture and with temperatures from 165°C to 100°C. The temperature of the outer part of the fluting medium will fall from 100°C to 50°C while the moisture rises quickly to 3.5% before jumping to 50%+ where the starch has infiltrated.

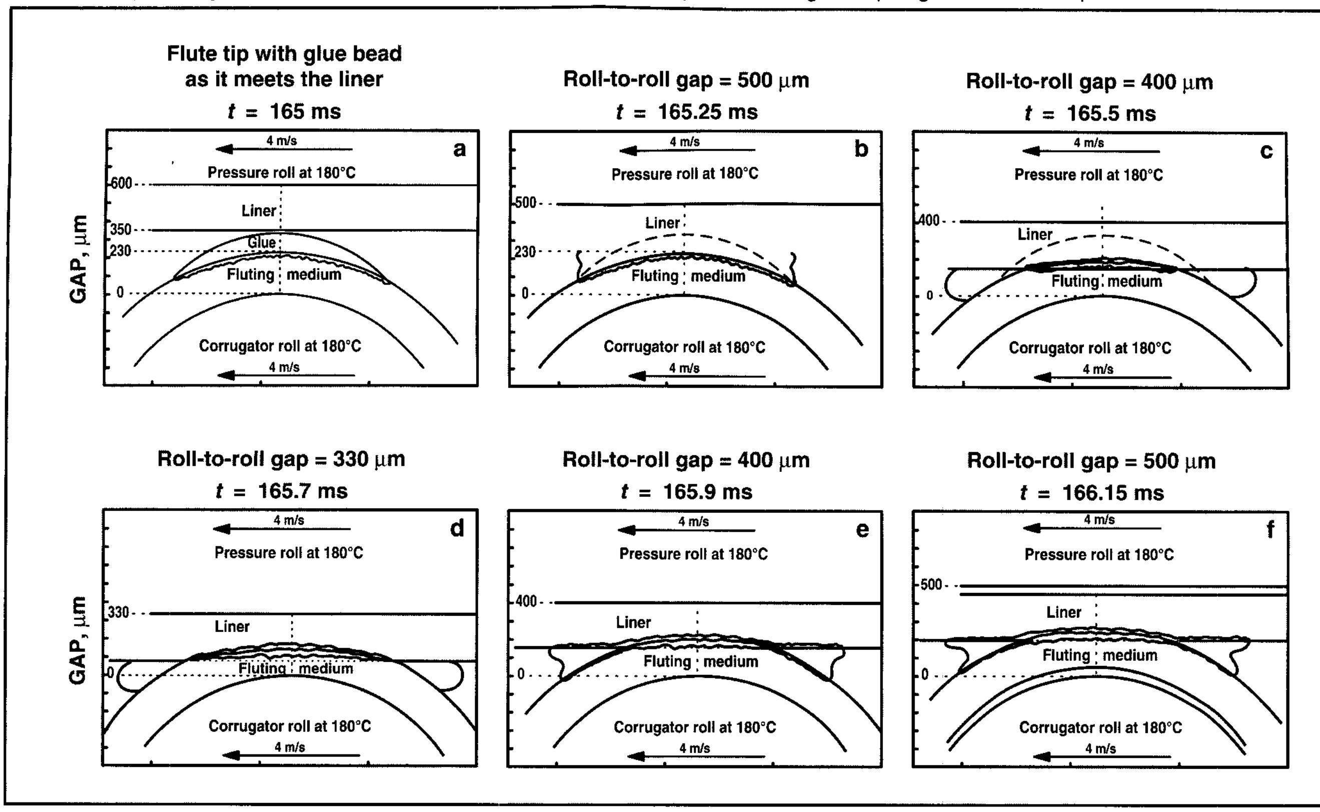
Pressing the liner against the glued flute tips

The liner approaching the pressure roll will have been heated on the preheater, which will raise the temperature but not reduce the moisture content appreciably from its original 7%. The distribution of the moisture through the sheet will depend on which side contacted the preheater.

As the liner wraps the pressure roll, the cycle of evaporation, transportation of vapor and heat toward the open surface, condensation, and migration of moisture back toward the hot roll will be in progress. The liner contacts the pressure roll for about 90° of arc, which takes 78 ms, so the cycling process does not have much time to operate. The condition of the liner and the fluting immediately before the liner meets the glue bead is postulated in Fig. 10.

Pressing the liner against the glued flute tips is a very rapid, high-energy event. **Figure 11** illustrates the sequence of events that occurs from the time the liner first contacts the glue

11. Geometry of the glue bead as the liner is pressed against the flute tip in the corrugator nip. Figure 11d is the nip centerline.



bead on the flute tip to the exit of the combined papers from the nip of the pressure roll and corrugator roll. The time frame for the events in Fig. 11 is 1.15 ms. The 230-µm fluting medium and 250-µm liner together have a thickness of 480 µm, and this may be reduced to 330 µm in the nip.

There is no time for capillary action to carry the glue into the liner. The physical impact is what drives the glue into the surface of the liner. In the 0.45-ms interval from Fig. 11B to Fig. 11D, the hydraulic pressure on the glue bead drives it into the surfaces of the liner and the fluting medium while forcing most of the glue outward onto the shoulders of the flute *(5)*.

It is speculated that the proportion of glue entering the liner surface—as opposed to being squeezed out onto the shoulder of the flute—is controlled by the permeability of the liner. A very compact, close, and incompressible liner is likely to resist the entry of the glue more than an open, permeable sheet.

Immediately after the nip centerline (Figs. 11E and 11F), the compression of the papers is released, taking less than 0.5 ms. The papers will recover some of their original thickness but not all of it. The fillets of glue squeezed out onto the shoulders have hardly had time to wet the surfaces of the papers before the separating surfaces cause them to contract and neck toward the join.

As drawn in Fig. 11F, about 30% (38 mg) of the glue has entered the papers, while 70% has been squeezed into the fillets on the flute shoulders. Most of the glue that has entered the paper surfaces is likely to be the cooked carrier starch *(6, 7)*, although some of the uncooked starch granules will have been trapped between the two paper surfaces.

Formation of the green bond after the pressure roll

The green bond is thought to be formed by the 38 mg of glue that has entered the paper surfaces. The glue that was squeezed onto the shoulders of the flute ultimately assists with the final bond after it has gelled on the bridge or in the double-backer's heater section *(4)*.

The green bond partly forms when the carrier portion loses enough moisture to become very tacky. This moisture loss occurs by diffusion and evaporation. Batelka demonstrates that the porosity and water absorption of the fluting medium are two controlling factors, in conjunction with the degree of preconditioning of the fluting medium *(8)*.

The average temperature of the glue trapped between the fluting medium and liner is about 52.6°C, and the gel temperature is 62°C. There must be enough heat available from the two paper webs to achieve this rise in temperature. To raise 38 mg of water from 52.6°C to 62°C requires

$$0.038 \text{ g} \times 4.18 \text{ J/g°C} \times 9.4\text{°C} = 1.5 \text{ J}$$

From the paper conditions shown in Fig. 10, taking the specific heat of fiber as 1.25 J/g°C, the heat available from a strip of paper 1.18 mm wide and 1 m long is about 1.4 J from the liner and 1.0 J from the fluting medium. To this must be added the heat conducted into the join from the hot corrugator roll and pressure roll during the compression experienced at the nip centerline (Fig. 11D). In addition, the kinetic energy from the compression is converted into heat.

Not all the heat available within the paper is transferred into the glue bond, since the outer surface of the liner has been measured in excess of 100°C some distance after leaving the pressure roll. This implies that the strength of the green bond is very sensitive to operating parameters and paper characteristics.

The heat transferred from the hot pressure roll and hot corrugator roll is controlled by the nip loading and both the density and dynamic compressibility of the fluting medium and liner. Kartovaara points out the importance of heat transfer by the gaseous phase in various air spaces between the fibrous solids *(2)*.

Conclusion

A theoretical examination of the physical processes taking place in the singlefacer leads to several speculative conclusions.

The first is that the fluting medium is subjected to four impulses during its brief (<200 ms) passage through the singlefacer. The impulses occur as the fluting medium enters and exits the two high-pressure nips on either side of the upper corrugator roll.

Hot air is trapped in the pockets of high-speed corrugator rolls entering the labyrinth. This air is compressed to pressures up to 15 bar and temperatures in excess of 160°C, which is above the glass-transition temperature of lignin. This does not apply at the edges of the corrugator, where air can escape. This may explain poor gluing and other edge effects experienced on corrugators.

At the outgoing side of the nip between the upper and lower corrugator rolls, the high-pressure air and moisture trapped in the fluting medium are released with almost explosive force, and most of the free moisture in the fluting medium flashes off. This sudden release of pressure may affect the surface texture of the fluting medium and, subsequently, the glue pickup and penetration.

The surface of the fluting medium at the flute tip just prior to the glue roll has a temperature of 90°C or more and a moisture content of about 3.5%. This low moisture content implies very little capillary action before the pressure roll. The high temperature of the flute tip raises the temperature of the carrier starch that does penetrate the fluting medium to within 10°C of its gel temperature prior to meeting the liner.

The critical part of the singlefacer process is the impact of the pressure roll forcing the liner against the glued flute tip of the fluting medium. The openness, density, and compressibility of the two papers determines how far the glue is forced into the fluting medium and liner and how much of the glue is squeezed out onto the shoulders of the flute. The density and compression of the papers also control how the heat from the corrugator roll and pressure roll is conducted into the glue zone of the join.

As the pressure pulse is released, the amount and rate of recovery or spring-back will partly determine whether the glue in the fillets on the flute shoulders is absorbed like a sponge or left on the surface as it necks inward. This spring-back also affects how the moisture from the glue is absorbed and how quickly the starch gels to form the green bond.

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The author acknowledges the sponsors of the PIRA international multi-client project (M206 "Gluability of densified corrugated case materials") for permission to publish this paper, which was part of the project's work program.

Received for review July 9, 1992.

Accepted Nov. 23, 1992.