A finishing alternative for offset LWC

Jeffery M. Groshek

ABSTRACT: Lightweight coated offset grades are not commercially using hot, soft nip calendering in part because of the high speeds compared to wood-free coated grades and the scarce print quality information available. This paper reports results of a pilot calendering experiment with a commercial heat-set web offset print trial. Results show that soft nip calendering is an alternative to traditional supercalender finishing even at high speeds.

KEYWORDS: Calendering, coated papers, finishing, lightweight papers, machine speed, offset papers, paper properties, performance evaluation, pilot plants, print quality, soft nip calenders.

Soft nip calendering (SNC) is a finishing process that is finding more frequent commercial applications. Practically all grades of paper and board that use finishing have exposure to SNC. In the coated wood-containing market, however, lightweight coated (LWC) is generally absent from the use of SNC. Supercalendering still remains the dominant finishing technique used for commercial production of grades with gloss above 50%. Various papers have discussed the differences between SNC and supercalendering from the viewpoint of equipment, process, and operations *(1, 2)*. The primary operational advantage SNC offers over traditional supercalendering is the ability to finish on-line at machine speed. This reduces capital and production costs.

Following are the usual descriptive terms for LWC:

- Basis weight: 50–68 g/m^2 (34–46 lb/3300 ft^2)
- Coat weight: 7.5–9.0 g/m^2 (5–6 lb/3300 ft^2) per side
- Furnish: 45–75% mechanical and 55–25% kraft pulps.

In the North American system, LWC falls in the No. 5 coated grade category with sheet gloss in the 50–55% range and brightness in the 68–72% range. Production speeds vary from 750–1350 m/min (2460–4429 ft/min) with recent installations operating at the higher end and even pushing 1525 m/min (5003 ft/min). Other wood-containing grades—primarily MFC (machine finished coated)—are using SNC due to lower gloss and smoothness requirements coupled with slower operating speeds.

The heat-set web offset method prints most LWC production. The forecast is for offset (lithography) printing to remain the dominant process in the publication grade sector for many years. Choosing offset printing for a trial study therefore seems appropriate.

Experimental procedure

The investigation consisted of two parts. First, pilot calendering equipment generated sample rolls with similar smoothness and paper gloss to that of commercially supercalendered LWC. Additionally, there were a few rolls of lower gloss or matte finished paper produced for comparison. Second, a commercial offset press printed these rolls for evaluation of print quality.

The commercial LWC and coated, unsupercalendered paper came from a U.S. mill. Furnish consisted of 100% southern pine with equal parts of mechanical and kraft pulps. The base sheet was 43 g/m^2 (29 lb/3300 ft^2) with approximately 8 g/m^2 (5.5 lb/3300 ft^2) of coating per side or a 59 g/m^2 (40 lb/3300 ft^2) coated offset grade. This paper exhibited smoothness two-sidedness with a 1.0 μm Parker Print Surf differential. To compensate, the rougher side underwent calendering first. Before calendering the basestock, moisture was 4.5–5.0%, and temperature was 26°C (79°F).

Groshek is manager, coating and finishing, for Beloit Corp., 1165 Prairie Hill Rd., Rockton, IL 61072.

Calendering

The pilot calendering experiment consisted of both supercalendering and SNC, but the emphasis was on SNC. There was an initial matrix experiment during the SNC portion to determine the process conditions necessary for producing print rolls. The conditions explored included the following:

- Speed: 762–1372 m/min (2500–4500 ft/min)
- Nip loading: 263–525 kN/m (1500–3000 lb/linear in.) per nip
- One or two nips per side
- Metal roll surface temperature: 149–204°C (300–400°F).

A total of nine SNC conditions produced print trial rolls with minimal sidedness. Additionally, a pilot supercalender run used two passes through a four nip arrangement at 305 m/min (1000 ft/min) and 263 kN/m (1500 lb/linear in.) per nip to produce a single print roll. **Table I** summarizes these ten pilot calender print roll conditions.

Figures 1 and 2 show the pilot SNC and supercalendering equipment, respectively. Of the two lines, the SNC equipment most closely duplicates a commercial arrangement for two reasons. First, the roll sizes of 1168 mm and 965 mm (46 in. and 38 in.) for the metal and soft covered rolls, respectively, represent commercial diameters. Second, the line treats both sides of the sheet in a single pass. The SNC data is therefore representative of commercially achievable results.

The pilot supercalendering used a six roll fixed queen stack. The queen roll is 559 mm (22 in.) diameter while all other rolls are 381 mm (15 in.) diameter. Each side of the web underwent treatment in separate passes.

I. Calender print roll conditions

Ident. no.	*Temp., °C bottom side*	*Temp., °C top side*	*Load, kN/m, bottom side*	*Load, kN/m top side*	*No.nips per side*	*Speed, m/min*
1	149	149	263	263	1	762
2	149	149	263	263	1	1372
3	204	204	263	263	1	1372
4	163	177	394	525	2	1372
5	177	191	263	394	2	1372
6	177	177	525	525	1	1372
7	204	204	525	525	1	1372
8	177	191	394	525	2	1372
9	177	204	263	394	2	762
10	82	82	263	263	4	305

II. Summary of print trial sequence

Print roll no.	*Calender ident. no.*	*Comment*
1	**n.a.**	Gloss, commercial supercalender
2	**1**	Semi-gloss, SNC
3	**2**	Matte, SNC
4	**3**	Semi-gloss, SNC
5	**4**	Gloss, SNC
6	**5**	Gloss, SNC
7	**6**	Gloss, SNC
8	**7**	Gloss, SNC
9	**8**	High gloss, SNC
10	**9**	High gloss, SNC
11	**10**	Gloss, pilot supercalender
12	**n.a.**	Gloss, commercial supercalender

Printing

The print trial used a commercial heat-set web offset press. It had a five station arrangement on a commercial printing press. As is typical, color application was in the order black, cyan, magenta, and yellow. The fifth station applied a small amount of water only. The ink and fountain solution (alcohol-free) were the printer's typical production mode products. Speed of the press remained constant at 200 m/min (656 ft/min) or 17,500 impressions/h. All print rolls ran through the press without problems such as breaks, picking, blistering, etc.

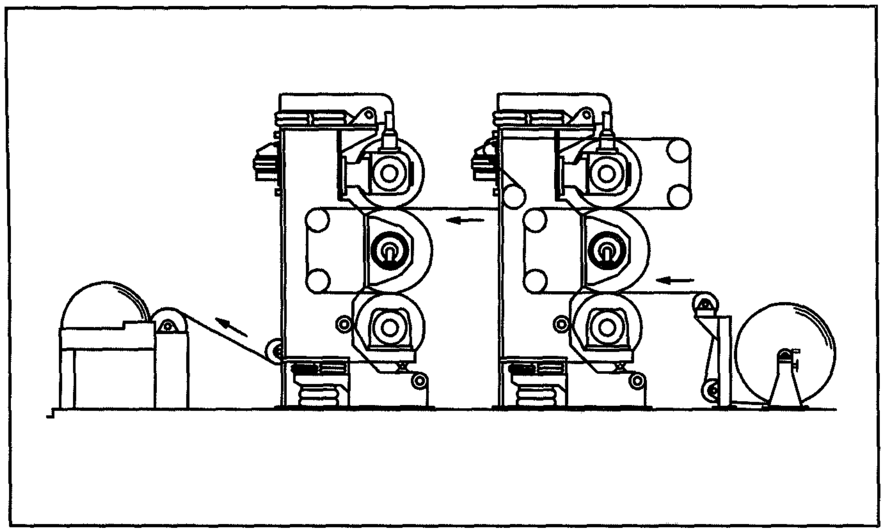
The print trial had minimal changes during the entire run. **Table II** summarizes the sequence of the runs. The commercially supercalendered LWC started and ended the trial. In between, the pilot calendered paper generally progressed from the "less" finished (<50% gloss) toward the "most" finished (>55% gloss) paper. The pilot supercalendered paper was the last of the pilot finished paper run during the print trial.

Results

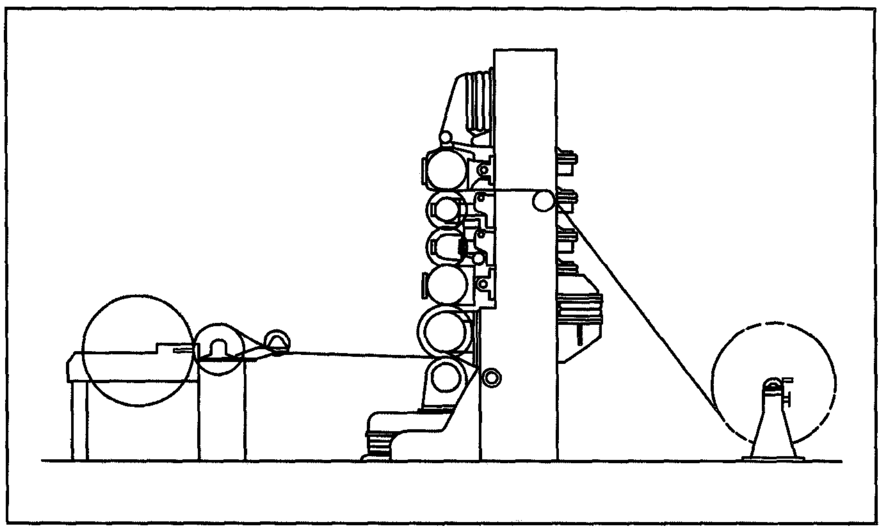
Following are the properties and tests evaluated on the samples generated:

- Sheet gloss
- Sheet smoothness

1. Pilot soft nip calender



2. Pilot supercalender



- Sheet strength
- Sheet brightness
- Sheet opacity
- Pick strength
- Print gloss
- Printed smoothness
- Print mottle

For ease of comparison, a single value shows the average of the combination of the commercial and pilot supercalender results. The pilot and commercial supercalendered paper test results agreed well. A graphic summary and discussion of the results follow. Although the values only indicate the bottom side, both sides showed similar trends.

Gloss

Testing used a 75° angle of incidence in the machine direction to evaluate gloss. SNC can produce equal or better gloss compared to supercalendering for both sheet,or unprinted, and printed samples and printed samples. This is true even at a speed of 1372 m/min (4500 ft/min). The supercalender control had 52% and 57% gloss for sheet and print samples, respectively. Sheet gloss as high as 58% and printed gloss up to 67% resulted with SNC as **Fig. 3** indicates.

Print gloss measurements used a single color, black area where print density averaged 1.55. Commercially equivalent gloss occurs at 1372 m/min (4500 ft/min) using only a single nip (metal roll contact) per side. Since gloss is mainly a surface property, it develops quickly and easily in the heated nip. This explains the ability to achieve the desired results even at high speeds. The matte samples, although lower in gloss level, exhibited similar trends to the standard, gloss samples for percentage gain after printing. Considering the elevated temperature and pressure used, this sheet exhibited no signs of coating pick—a potential concern during hot SNC.

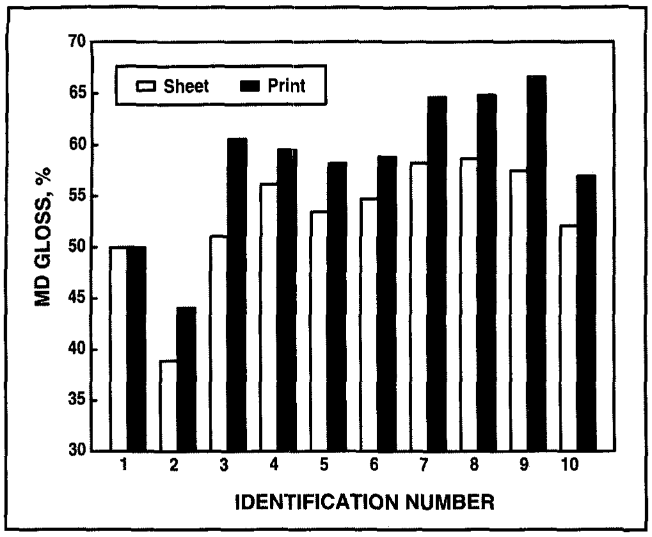
Smoothness

The Parker Print Surf test with a soft backing at 10 [kilogram force (kgf)]/cm^2 air pressure (PPS-S10) evaluated smoothness. As with gloss, SNC can produce equal or better smoothness compared to supercalendering. For the unprinted sheet, **Fig. 4** shows that SNC generated values in the range of 1.2–1.6 μm on the gloss grade and 1.8–2.1 μm for the matte grade.The supercalender control was at 1.4 μm.

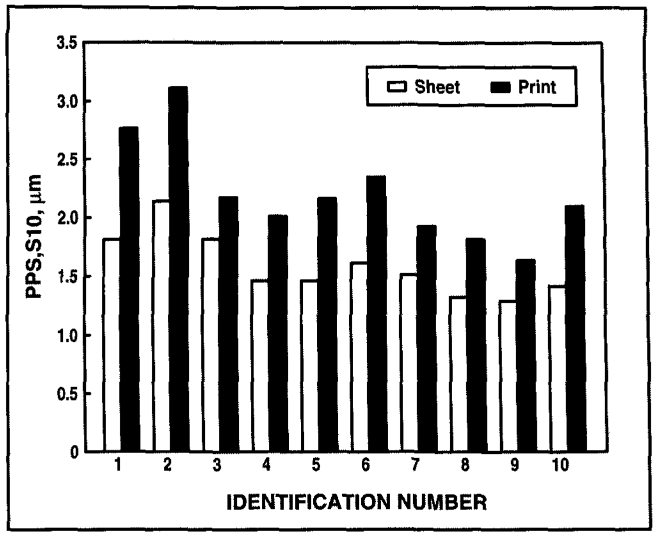
Unlike gloss, however, two nips per side are necessary at high speed to match supercalendering. Smoothness is a property requiring changes made not only to the surface but also within the web. Increasing dwell time for heat transfer into the web and using pressure to promote fiber collapse and replication of the very smooth metal roll accomplish this.

On average, gloss grade SNC samples roughen less (15%) than supercalendered samples after printing. Values in the range of 1.6–3.1 μm (gloss to matte spectrum) occurred with the SNC printed samples. The supercalender control was 2.15 μm. Printed smoothness was an average of measurements in three places. With SNC, highest tempera-

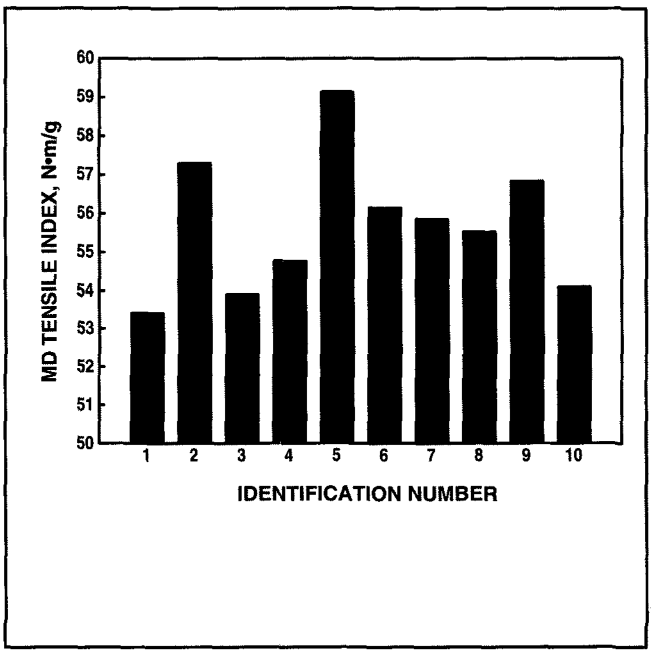
3. Gloss vs. calendering condition



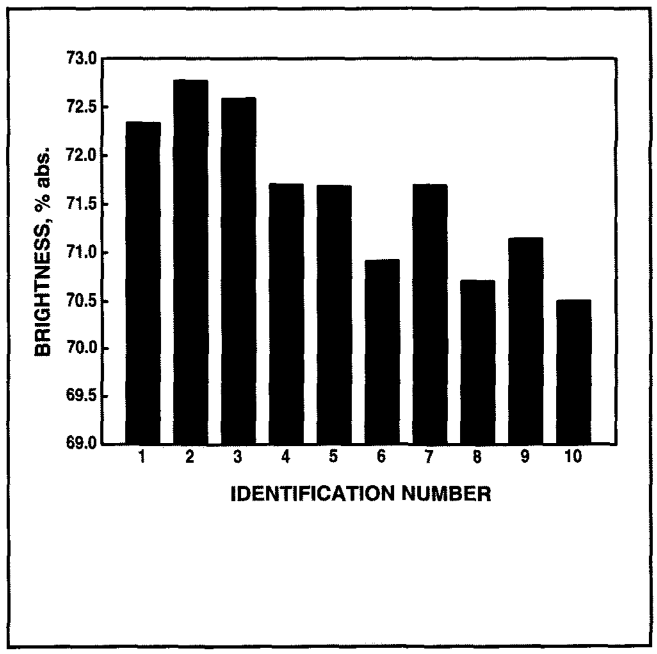
4. Smoothness vs. calendering condition



5. Tensile strength vs. calendering condition



6. Brightness vs. calendering condition



tures maintained smoothness best. There is a 0.3–0.5 μm advantage after printing for the 204°C samples vs. the 177°C or 149°C samples with everything else being constant.

Strength

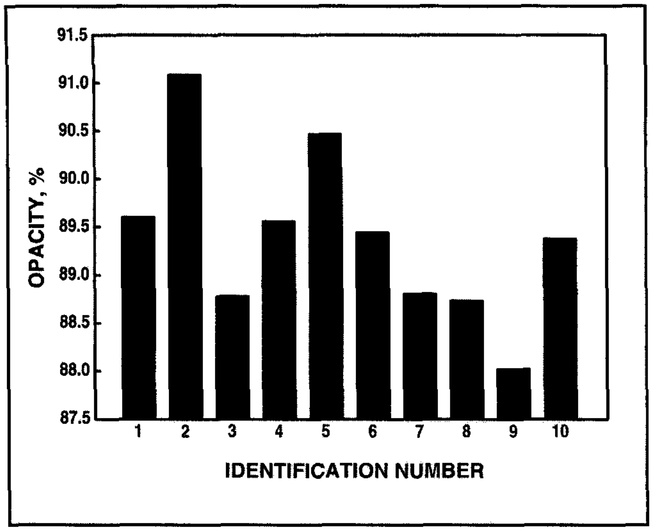
Sheet strength preservation during finishing is important for minimizing press room breaks. Again, SNC produced superior results compared to supercalendering. On average, **Fig. 5** shows that the MD tensile index was 1.8 N·m/g higher for SNC compared to supercalendering. There was no obvious trend relating strength to density. Density ranged from 0.92 g/cm^3 to 1.05 g/cm^3. The supercalendered sheets were at 1.04 density. SNC produced sheets with generally lower density especially for the matte samples.

Minimizing densification improves the perception of the user that he is receiving more "substantial" product. MD stiffness values for SNC quantitatively support this, since they were 4% greater than the supercalendering results.

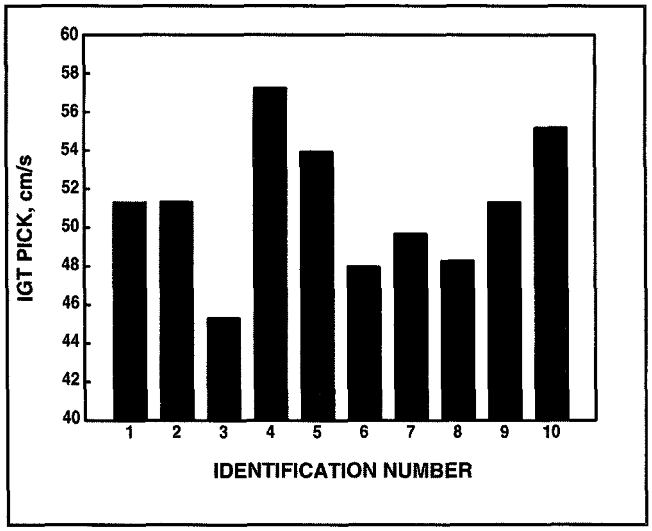
Brightness

The optical property of sheet brightness is important from an aesthetic viewpoint and from economic and environmental considerations. Brightness development achieved by fiber bleaching or expensive coating ingredients is costly. Reducing brightness loss during finishing is

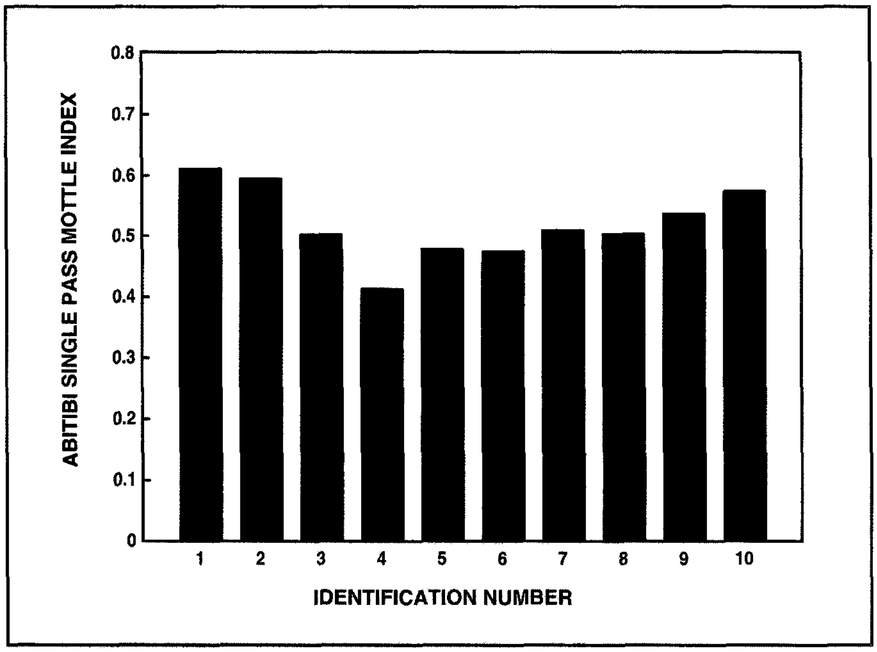
7. Opacity vs. calendering condition



8. Pick strength vs. calendering condition



9. Print mottle vs. calendering condition



therefore desirable. Brightness dropped 1–2 points due to finishing. This generally related to the severity of the calendering conditions. **Figure 6** shows that brightness for SNC was well within acceptable levels for LWC at 70–72% and compared favorably to supercalendering.

Opacity

Sheet opacity is important for print quality because it reduces "show-through." In other words, higher opacity enhances the ability to separate the image being viewed from the one printed on the opposite side. The same comments made for brightness apply to opacity. Opacity ranged from 88% to 91%. **Figure 7** indicates, however, that supercalendering was marginally better than SNC.

Surface strength

A major concern for a printer is the amount of picking that occurs during a press run. Excessive picking requires expensive downtime for cleaning. With this in mind, an IGT dry pick test evaluated surface strength using a medium viscosity oil (500 P @ 23°C) at a velocity of 1 m/s. **Figure** 8 shows that there was no trend in the test results for various finishing methods. SNC and supercalendering were comparable. As positive substantiation of this, there were no problems during the print trial to indicate differences or insufficient surface strength.

Print mottle

Image analysis evaluated mottle in the 50% halftone areas of black, cyan, and magenta with a modified version of the Abitibi method *(3)*. This image processing technique appears most sensitive (higher output) for the black with decreasing sensitivity for cyan and magenta. Generally, the mottle values (larger number is worse) were random and did not indicate a particular trend for any calendering type or condition. Cyan, which is most likely to exhibit backtrap mottle *(4)*, was an exception. It had a minimum mottle condition with peaks on either side compared to the severity of calendering as **Fig. 9** shows. The lightest and hardest calendered samples produced the most mottle with an optimum condition between. SNC tended to produce equal or lower mottle values than supercalendering.

Even with the most sophisticated image analysis techniques, the human eye is still the most demanding critic. Although it was a subjective evaluation, all the printers and papermakers who viewed the printed samples have rated the SNC conditions that had similar sheet properties to commercial LWC at least equal to the supercalendering control samples.

Conclusion

SNC can produce sheet properties and offset print quality equal to that of supercalendering for LWC. This is the case even at operating speeds up to 1372 m/min (4500 ft/min). The necessary SNC conditions are the following:

- Nip load above 350 kN/m (2000 lb/linear in.)
- Metal roll surface temperature above 177°C (350°F)
- Two metal roll contacts per side.

For the base paper used during this study, the properties most difficult to attain were PPS-S10 values below 1.2 μm and maintaining brightness and opacity. Hot SNC is better than supercalendering for developing gloss and preserving strength.

This study indicates SNC is a viable finishing method for high speed production of LWC offset grades. Future work of interest includes the capability of SNC to produce rotogravure grades. Also of interest are the potential improvements from optimization of temperature and moisture levels and distributions in the web especially as they apply to controlling two–sidedness.

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