

Dispersion barrier coating of high-density base papers

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HIGH-DENSITY PAPERS ARE MADE of extensively refined chemical pulp. With their sealed pores and layered structure, they offer interesting possibilities as a packaging material. High-density papers can be coated with aqueous barrier dispersions and polymer melts to produce a material with very low gas transmission rates. This study examines the effects of dispersion coating and calendering on the sheet's barrier properties.

The high-density papers studied were greaseproof papers made of extensively refined chemical pulp. Refining can be performed by Hollander beaters or in refiners. Fibers are fibrillated, swelled, and collapsed, which increases the contact area between the fibers (1). The structure of the resultant paper is layered and tortuous. Calendering and surface sizing improve the barrier properties by densifying the paper and closing the surface (2). Paper machines producing high-density papers must run at low speeds to accommodate the slow drainage from the web.

The grease barrier is achieved because the sheet has a relatively small number of pores. However, because cellulose is hydrophilic, greaseproof paper has poor resistance against water vapor. Water resistance can be obtained by coating the paper with a barrier layer such as polyethylene. Extrusion coating of high-density papers with polyethylene gives a structure with low oxygen and water vapor transmission rates (2, 3). However, polyethylene is not particularly effective as a gas barrier, and the

paper has pinholes and pores that allow gases to pass through. The decrease in oxygen transmission rate for polyethylene-coated papers is thought to be due to the sealing of the pores in the paper surface (3, 4).

It is also possible to achieve good oxygen barrier by coating high-density papers with aqueous barrier dispersions (3, 5). The base paper plays an essential role in the formation of a good gas barrier, although the barrier properties are very dependent on the drying conditions for the applied film. Water-based polymer dispersions are used to provide paper/paperboard with barrier properties to resist penetration by water, water vapor, and grease. The two largest groups of nonchlorine polymer dispersions are styrene-butadiene and various acrylates. However, dispersions made of biodegradable polymers are emerging. Dispersion coatings are often modified with fillers and/or waxes to improve barrier, friction, gluability, economics, etc. Although most coatings are applied off-machine on various coating and converting lines, the trend is toward on-machine coaters in the case of high-volume products.

Pre- and postcalenders have been used in barrier coating lines. Hard-nip calendering is performed to even the caliper and improve smoothness. Soft-nip calendering evens the density and absorption properties (6).

The aim of this study was to discover the effects of calendering on base paper properties such as barrier, smoothness, and coating result. The use of a metering blade to coat

COATING

ABSTRACT

High-density papers are made of extensively refined chemical pulp. With their sealed pores and layered structure, they offer interesting possibilities as a packaging material. High-density papers can be coated with aqueous barrier dispersions and polymer melts to produce a material with very low gas transmission rates. Refining and calendering affect the sheet structure, principally by changing the pore size distribution (as measured by the mercury intrusion method) and increasing the barrier properties. Dispersion coating can be applied with various techniques commonly used in pigment coating and converting. The results of this study demonstrate that the properties of these coated papers can be affected both by pre- and postcalendering. The precise effects depend on the basestock properties, coating composition, and coating method.

Application:

Shows how coating and calendering variables can affect the barrier properties of high-density papers.

high-density papers with barrier-enhancing dispersion coatings was also tested. Finally, the effects of calendering on the barrier properties of these dispersion-coated materials were also evaluated. The results presented in this paper have been published earlier in an author's Ph.D. thesis (3).

PROCEDURES

Materials

The high-density papers used in this study are identified in **Table I**. Gasella grades are made of more highly refined pulp and surface-sized with carboxymethyl cellulose (CMC), while Serlapack grades are surface-sized with starch. The dispersion coating was a styrene-butadiene

Paper No.	Description	Level of refining	Sizing	Basis weight, g/m ²
Serlapack				
710	conventional	standard	starch	50
742	totally chlorine free	standard	starch	50
Gasella				
826	wet strength	very high	CMC	40
828	wet strength	very high	CMC	50
831	wet strength, opaque	very high	CMC	50

I. High-density paper grades used as basestock

Sample	Air resistance, ^a s	Grease resistance, ^b s	PPS roughness (S10), μm
Paper 826			
Noncalendered	126	291	7.8
Precalendered			
Soft calendered ^c	309	879	5.0
Supercalendered ^d	437	1329	3.9
Paper 710			
Noncalendered	59	407	8.1
Precalendered			
Soft calendered ^c	111	986	5.6
Supercalendered ^d	150	1180	4.5

^a As measured by the Lindén method
^b As measured using TAPPI T 454 om-44
^c Soft calendering performed with a laboratory sheet calender at a line load of 80 kN/m
^d Supercalendering performed with a laboratory sheet calender at 85°C and a line load of 200 kN/m

II. Effect of precalendering on barrier properties and smoothness of high-density Papers 826 and 710

base ($T_g = 20^\circ\text{C}$) filled with various amounts of platey filler and/or paraffin wax. Filler content ranged from zero to 65% of the solids.

Process equipment

Coating was applied using one of three methods:

1. Manual application in the laboratory using Mayer bars
2. On a pilot coating line (roll applicator, blade metering) at the university's Paper Converting Institute
3. On a pilot coating line (jet applicator, blade metering) at Coating Technology Center (CTC), Finland.

Similarly, calendering was carried out using one of three methods:

1. Laboratory sheet calender
2. On-line soft calender
3. Pilot supercalender.

The effect of precalendering was first demonstrated with a laboratory sheet calender. In this "supercalendering" operation, the temperature of the steel roll was 85°C and the line load 200 kN/m. One side was pressed against the steel roll five times and the filled roll four times. Soft calendering was performed with a polymer roll (Shore-D 92) using two nips. Both sides of the paper faced the polymer roll once. Line load was 80 kN/m. Precalendering was also performed with a pilot-scale supercalender. Only five nips were used because of runnability problems with the more highly refined grade. The maximum temperature settings of the supercalender (120°C on the top rolls, 90°C on the bottom rolls) were used. Line load is expressed as kN/m in the bottom nip.

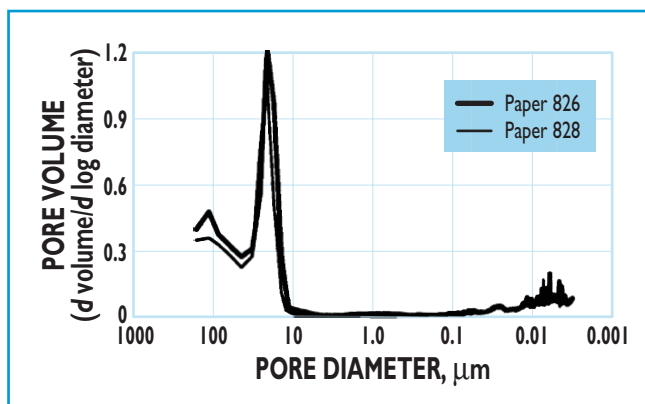
Postcalendering of dispersion-coated substrates was performed using the same facilities, i.e., a laboratory sheet calender, a pilot-scale soft calender, and a pilot-scale supercalender.

Tests

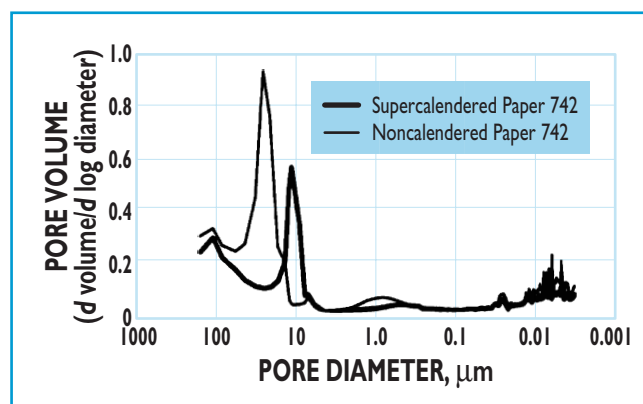
Water vapor transmission rate (WVTR) was measured from flat samples according to SCAN P22:68. (Other similar standards are ASTM E-96 and DIN 53122.) This is a gravimetric cup method using anhydrous calcium chloride as desiccant. The desiccant is placed on the bottom of an aluminum dish, and the sample is then sealed tightly against the dish with wax. As the water vapor penetrates the sample, the weight of the dish increases. After stabilization, the constant rate of weight increase is given as the WVTR. The WVTR of uncoated paper samples was measured within 6 hours of stabilization to prevent excessive saturation of the desiccant. Results are expressed as g/m²/day. Test conditions are reported with the results.

Oxygen transmission rate (OTR) was measured from flat samples with OxTran (Mocon) using ASTM D-3985. Oxygen is led to one side of the sample, and the molecules that penetrate through the sample are conveyed to a sensor by a carrier gas. A measurable voltage is created in the sensor. The working pressure of the sensor is slightly higher than atmospheric pressure. The driving force for gas transmission is partial pressure difference. Dry test gases were used. The coated side was toward the sensor to avoid possible leakages. Lower values indicate better performance as an oxygen barrier. A value of 1 cm³/m²/day/bar is regarded as a very good oxygen barrier. The OTR of uncoated papers cannot usually be measured.

Water absorption tests were performed with a Cobb tester based on standards SCAN P12:64, ISO 535, and DIN 53132. The method measures



1. Pore size distribution for noncalendered Papers 826 and 828



2. Pore size distribution for noncalendered and supercalendered Paper 742

the amount of water that penetrates into the sample over a given period of time. The measurement time is reported with the results (in this case as seconds). Thus Cobb 600 s refers to a test where water is allowed to penetrate into the sample for approximately 10 minutes. Results are expressed as g/m².

Grease resistance was measured using TAPPIT 454 om-44, which measures the time for a colored turpentine to penetrate the sample from a saturated pile of sand placed over the sample.

The Lindén method indicates the time required for an air volume of 0.318 cm³ to penetrate a paper sample with a surface area of 37 cm². The gauge pressure is 100 mm Hg at 20 °C and a relative humidity (RH) of 65%.

The effect of calendering was also measured using an STFI method that determines local density by measuring local thickness and basis weight (7). Thickness is measured as a distance between two spherical probes. The diameter of the spheres is 1 mm, and the load from the weight of the probe is 3.5 g. Probes are moved in steps of 150 μm, and the total scanning area is a square of 900 mm². Local basis weight is determined with β-radiography using C¹⁴ as the radiation source. The radiation passing through the sample creates an image on the X-ray film. Differences in basis weight are detected as different gray tones. The resultant radiogram is read using a video camera coupled with an image-analysis sys-

tem. The resolution is the same as in the thickness measurement, i.e., 150×150 μm. Both maps are finally combined to determine local density.

Pinhole density was determined with dyed water (containing a detergent to reduce surface tension). Test liquid was spread over the coating, and the pinholes were detected as darker stains. The number of pinholes was counted from an area of 300 cm² and expressed as pinholes per m².

Roughness (smoothness) was measured using a Parker Print-Surf (PPS) device at a clamping pressure of 10 kg/cm² (S10). The mercury intrusion method (Micromeritics Inc.) was used to study the porosity of the high-density papers, and water-paper interactions were measured by the DPM (dynamic penetration measurement) equipment based on ultrasound technique. Photographs presented in this report were obtained with an atomic force microscope (AFM). The AFM scans the surface topography of the sheet using a cantilever probe in very soft contact with the surface. The bending of the cantilever is monitored by a laser beam reflecting to the detector. (The equipment used was a NanoScope II, Digital Instruments.)

RESULTS

Impact of precalendering on paper properties

Table II shows the positive effects of precalendering on the grease barrier

Sample	Total porosity, %	Surface porosity, %
Paper 742		
Noncalendered	33	30
Supercalendered	22	19
Paper 826		
Noncalendered	34	34
Paper 828		
Noncalendered	30	29

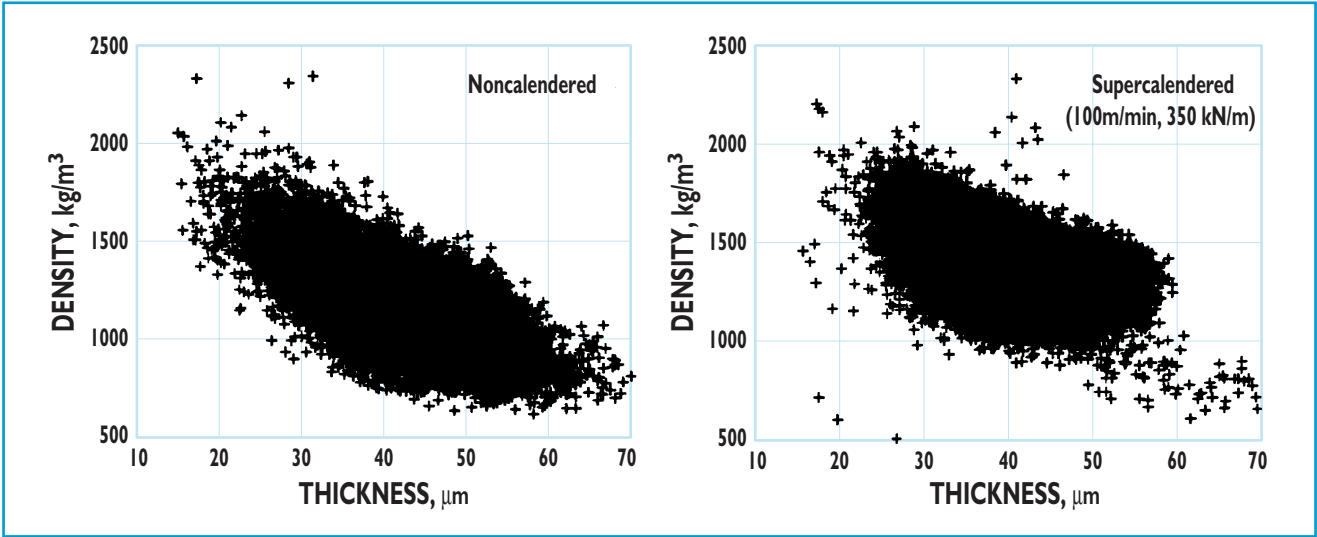
*Pores measuring 0.1–40 μm

III. Porosity of high-density Papers 742, 826, and 828*

and smoothness of high-density papers. Precalendering was performed with a laboratory sheet calender.

Figure 1 presents the differential mercury intrusion volume as a function of pore diameter for the more highly refined grades. As can be observed, there are virtually no pores in the 0.1–10 μm region, which is defined in the literature as “internal porosity” (8). Only large pores are present. The difference in the grease barrier was small for Papers 826 and 828.

Figure 2 shows the porosity of a less refined sheet, Paper 742, before and after supercalendering. In this case, there is evidence of some small pores. Calendering had a clear effect on the large surface pores, which decrease in size as the surrounding fibers are pressed. Calendering also had a slight effect on the internal porosity (0.1–10 μm).



3. Effect of calendering on local thickness–density distribution of Paper 742

Sample	Air resistance, ^a s	Grease resistance, ^b s	PPS roughness (S10), μm
Paper 831			
Noncalendered	>600	660	8.13
Supercalendered ^c			
100 m/min at 250 kN/m	>600	1340	5.41
100 m/min at 350 kN/m	>600	1345	4.85
150 m/min at 350 kN/m	>600	1315	5.14
Paper 742			
Noncalendered	22	165	8.30
Supercalendered ^c			
100 m/min at 350 kN/m	130	420	4.51

^a As measured by the Lindén method
^b As measured using TAPPI T 454 om-44
^c Supercalendering was carried out through five nips on a pilot-scale machine running at 100 m/min and 350 kN/m, with maximum temperature settings of 120°C, 110°C, and 90°C for the top, middle, and bottom heated rolls, respectively.

IV. Effect of supercalendering on barrier properties and smoothness of high-density Papers 831 and 742

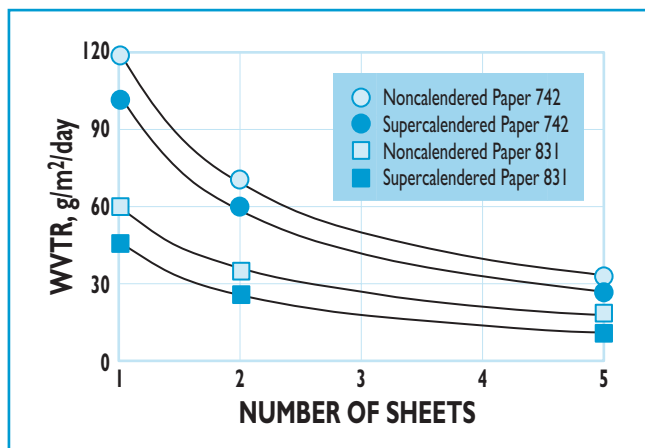
If we neglect the porosities above 40 μm and below 0.1 μm and use the common density of cellulose, then supercalendering decreases porosity from 33% to 22%. If the concept of Silvy *et al.* (8) is utilized—modified in such a way that the surface porosity includes pores in the range 7–44 μm and internal pores are 0.1–7 μm—then the total and surface porosities are as presented in Table III. From these results, it can be concluded that all of the void volume seems to be accessible to the mercury. The major contributor to poros-

ity is the surface porosity and large dead-end pores. This is also the porosity that is reduced by the calendering process, along with the small pores at the very surface. Pore size distribution and tortuosity are more important than total porosity as far as grease barrier is concerned. Table IV presents the results from the trial performed with a pilot-scale supercalender. These are in agreement with the previous results obtained with a laboratory sheet calender (Table II).

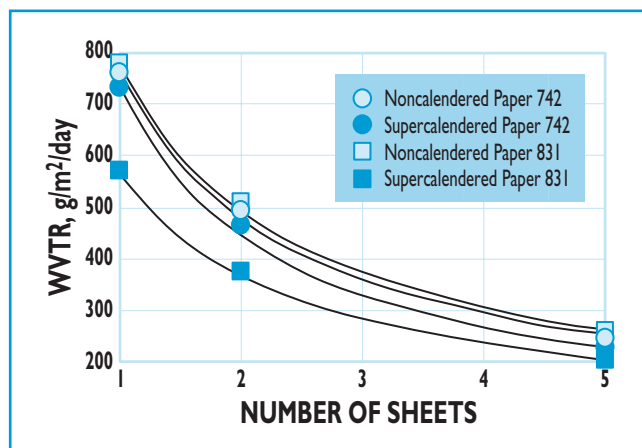
Figure 3 shows the effects of calendering on the local thickness vs. density distribution of high-density Paper 742. Surprisingly, the thicker the paper, the lower is the local density. This can be partly explained by the location of pores near the thick fiber crossings. The effect of calendering is especially obvious at the thicker parts of the paper. In addition, it was observed that supercalendering reduced the WVTR of high-density papers under moderate conditions of temperature and humidity (20°C, 50% RH), as indicated in Fig. 4 for a single paper sheet and piles consisting of up to five sheets. At a slightly higher relative humidity gradient (25°C, 75% RH), the difference between noncalendered and supercalendered Paper 742 was much smaller than that between noncalendered and calendered Paper 831, as seen in Fig. 5. The difference between the noncalendered samples was negligible because of increased interactions between the paper and water molecules at the higher relative humidity. The nonlinear decrease in WVTR as a function of the number of stacked sheets is due to the increased volume of densified surface layers (9).

Barrier dispersion coating

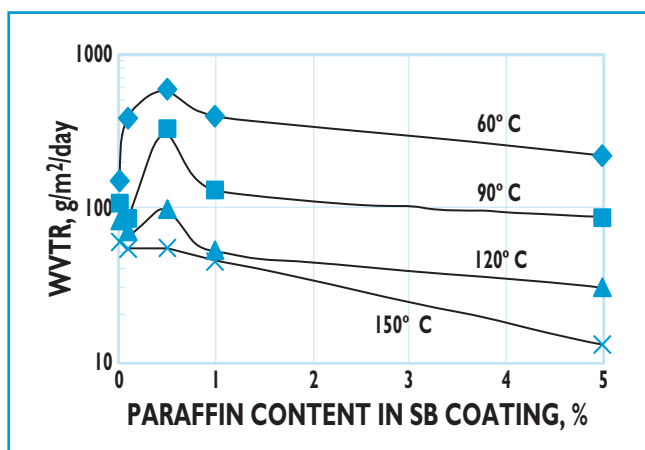
The initial coating trials were performed manually with Mayer bars.



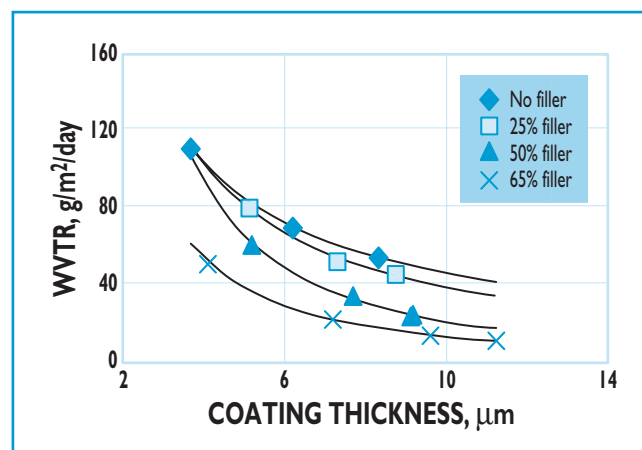
4. WVTR (20°C, 50% RH) for single and piled sheets of Papers 831 and 742 before and after supercalendering



5. WVTR (25°C, 75% RH) for single and piled sheets of Papers 831 and 742 before and after supercalendering



6. WVTR (25°C, 75% RH) as a function of paraffin wax addition at four levels of oven temperature



7. WVTR (25°C, 75% RH) as a function of apparent coating thickness at various levels of filler content for Paper 828

These indicated the strong importance of drying conditions (20 s) on the film formation and barrier properties, as pointed out also by Passier (10). Figure 6 shows the influence of oven temperature on the WVTR of a styrene-butadiene dispersion containing varying amounts of paraffin wax.

A coating trial was performed using Paper 828 on a pilot line with a roll applicator and a metering blade. Coater speed was approximately 50 m/min. Coating weight was controlled by applying multiple coats. WVTR decreased with increasing filler content, as shown in Fig. 7. There was no difference in OTR of high-density papers coated with the two most highly filled coatings. The apparent coating thickness was cal-

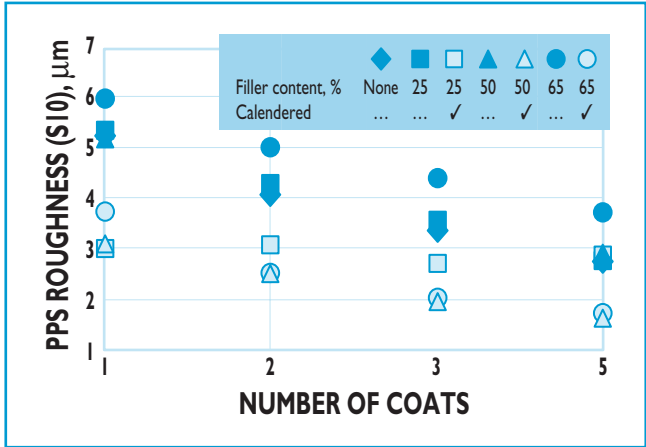
culated from coating weight and solids density. As far as barrier properties are concerned, coating thickness is more important than coating weight for dispersions with different amounts of fillers.

Another coating trial was also performed with a pilot coater using a jet applicator and a metering blade. The reverse side of the paper was treated with starch to minimize the strong curling tendency. The positive effect of precalendering on the coating result can be observed in Table V. The main reason for the improved WVTR is probably better surface coverage. Coated precalendered paper is smoother and has fewer coating defects than plain coated paper. The water absorption properties of the

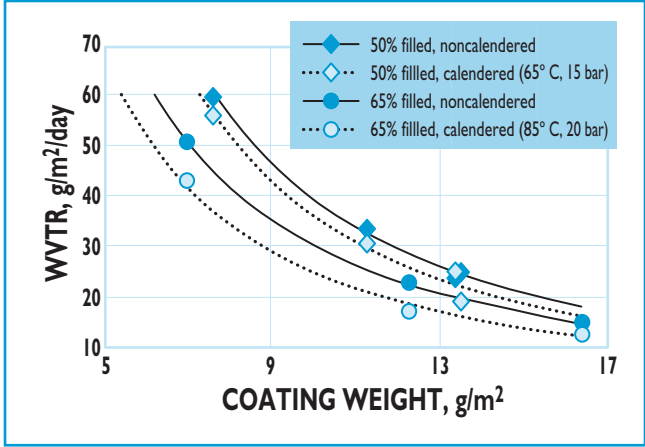
wet-strength and more highly refined paper (Paper 831) are quite different from those of a nonwet-strength, less refined paper (Paper 742). Wetting for the highly refined wet-strength paper is slower and swelling is more moderate. The smoothness of precalendered and coated Paper 742 is only slightly better than the noncalendered sample, indicating possible reroughening during the coating. It is also interesting to note that the relative improvement in WVTR for the precalendered and coated papers was similar to that observed for the precalendered papers before coating was applied.

Postcalendering

Calendering of dispersion-coated high-density papers was first studied



8. Roughness as a function of the number of coats applied at various levels of filler content before and after calendering (laboratory sheet calender) for Paper 828



9. WVTR (25°C, 75% RH) as a function of coating weight at two levels of filler content before and after calendering (laboratory sheet calender) for Paper 828

Sample	Coat weight, g/m^2	WVTR (25°C, 75% RH), $\text{g/m}^2/\text{day}$	Water absorption (Cobb 600 s), g/m^2	PPS roughness (S10), μm	Pinholes per m^2
Paper 742					
Noncalendered	11	95.9	14.1	4.88	133
Precalendered*	15	80.9	5.6	4.68	0
Paper 831					
Noncalendered	17	69.5	2.7	4.52	100
Precalendered*	16	52.0	1.8	3.49	0

* Precalendering was carried out through five nips on a pilot-scale supercalender running at 100 m/min and 350 kN/m, with maximum temperature settings of 120°C, 110°C, and 90°C for the top, middle, and bottom heated rolls, respectively.

V. Effect of precalendering on the properties of dispersion-coated Papers 831 and 742

	OTR (23°C, 0% RH), $\text{cm}^3/\text{m}^2/\text{day}/\text{bar}$		
	Measurement 1	Measurement 2	Average
Noncalendered			
7 g/m^2 coat weight ^a	5.8	14.0	9.9
16 g/m^2 coat weight ^b	0.01	0.02	0.02
Calendered ^c			
7 g/m^2 coat weight ^a	0.02	0.02	0.02

^a Coating (65% filler content) applied with a single pass through pilot coater with roll applicator.
^b Coating (65% filler content) applied with four passes through pilot coater with roll applicator.
^c Coated side of sheet faced heated steel roll five times (85°C, 20 bar).

VI. Effect of coating weight and calendering (laboratory sheet calender) on OTR for coated Paper 828

with a laboratory sheet calender. Only filled dispersions were calendered, since sheets coated with the unfilled dispersion faced blocking problems even during rewinding. Filler content was 0–65% of the solids. Coating was performed on

the pilot line with a roll applicator (see Fig. 7). The coating containing 65% filler was easiest to calender. However, as the number of nips and coating weight increased, calendering (85°C, 20 bar) became difficult because of

the sticking tendency. The coated side faced the steel roll five times. The coating containing 50% filler was difficult to calender, since the coated paper tended to stick to the steel roll. Lower temperature (65°C) and lower pressure (15 bar), and thus lower line load, cured the problem. In the case of 25% filler, paper tended to stick to the roll even at 65°C without external pressure. Clearly, these results demonstrate that when calendering dispersion-coated substrates, the coating composition, temperature, and line load must be chosen carefully.

Figure 8 shows the smoothness of noncalendered and calendered samples after successive applications of coating. As coating weight (and coating times) increases, the coverage of the coating is better and the surface becomes smoother. The relatively poor performance for the 25%-filled dispersion can partly be attributed to the conditions and partly to the damage caused when the coating was sticking to the steel roll during calendering.

Calendering has a positive effect on barrier values if the heat treatment closes the surface of the coating and the applied pressure flattens the filler particles. Some changes, such as densification, could also occur in the paper. A small but clear improvement in the water vapor

transmission values after calendering can be seen in **Fig. 9**. However, the effect of calendering on OTR was dramatic, as seen in **Table VI**. OTR was approximately 9 cm³/m²/day/bar for the lower coating weight. In contrast, OTR was <1 cm³/m²/day/bar for the higher coating weight. Calendering and multiple coating clearly have a positive effect on barrier properties.

Table VII shows the results from the trial with the jet applicator and blade metering. Soft calendering was done on-line with the coating. Paper 742 was coated with 15 g/m² of the dispersion with the highest filler content (65%) at a speed of 500 m/min. Temperature of the steel roll was 60°C. **Table VII** shows the positive effect of soft calendering in the case of Paper 742. However, calendering the precalendered and coated paper decreased the barrier properties.

The effect of supercalendering on the dispersion-coated, high-density paper was positive, as seen in **Table VIII**. However, both pre- and postcalendering are again slightly problematic with Paper 742 as far as barrier values are concerned. Precalendered paper is generally more susceptible to coating defects. In addition, it has been found that the water-paper interactions for the more highly refined wet-strength Gasella are quite different than those for the less-refined Serlapack. Precalendered, less-refined paper tends to reroughen during coating. There are also differences in the surface sizing between the two. Five nips of the supercalender were used, and speed was 100 m/min. For some of the supercalendered samples, the coated side faced the steel rolls three times, while the coated side faced the steel rolls four times for the remainder of the samples. It was observed that OTR decreased with one sample almost to 10% of the value prior to supercalendering. Low calendering temperature should be used.

Sample	WVTR (25°C, 75% RH), g/m ² /day	Water absorption (Cobb 600 s), g/m ²	PPS roughness (S10), μm
Noncalendered	122	6.7	4.84
Soft calendered ^b			
50 kN/m	107	5.3	4.21
100 kN/m	86.2	5.2	3.96
150 kN/m	97.2	5.9	3.81
Precalendered ^c	80.9	5.6	4.68
Soft calendered ^b			
50 kN/m	134	11	3.51
100 kN/m	128	13	3.35

^a Coated with 15-g/m² dispersion (65% filler content) applied with a jet applicator at 500 m/min.

^b Temperature of steel roll in soft calendering was 60°C.

^c Precalendering was carried out through five nips on a pilot-scale supercalender running at 100 m/min and 350 kN/m, with maximum temperature settings of 120°C, 110°C, and 90°C for the top, middle, and bottom heated rolls, respectively.

VII. Effect of soft calendering on barrier properties and smoothness of dispersion-coated Paper 742 ^a

Sample	WVTR (25°C, 75% RH), g/m ² /day	Water absorption (Cobb 600 s), g/m ²	PPS roughness (S10), μm	Pinholes per m ²
Paper 742				
Noncalendered	95.9	14.1	4.88	133
Supercalendered ^b				
220 kN/m at 80°C ^c	56.2	5.4	2.75	66.7
300 kN/m at 80°C ^c	74.2	5.6	2.74	33.3
350 kN/m at 80°C ^c	75.9	5.4	...	33.3
350 kN/m at 70°C	63.4	5.1	2.59	0
Precalendered ^d	80.9	5.6	4.68	0
Supercalendered ^b				
350 kN/m at 70°C	85.9	7.5	...	0
Paper 831				
Noncalendered	69.5	2.7	4.52	100
Supercalendered ^b				
350 kN/m at 70°C	50.7	1.8	2.32	0
Precalendered ^d	52.0	1.8	3.49	0
Supercalendered ^b				
350 kN/m at 70°C	43.0	1.7	...	0

^a Coated with 15-g/m² dispersion (65% filler content) applied with a jet applicator at 500 m/min.

^b Supercalendering was carried out through five nips on a pilot-scale machine running at 100 m/min

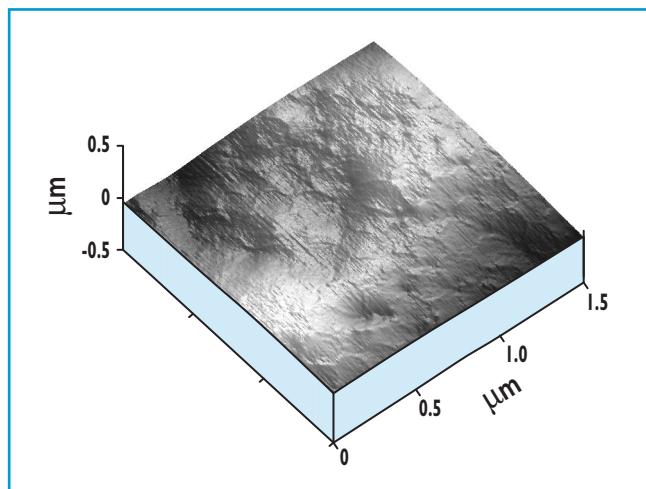
^c Coated side was toward steel roll three times. For all other samples, the coated side was toward the steel roll four times.

^d Precalendering was carried out through five nips on a pilot-scale supercalender running at 100 m/min and 350 kN/m, with maximum temperature settings of 120°C, 110°C, and 90°C for the top, middle, and bottom heated rolls, respectively.

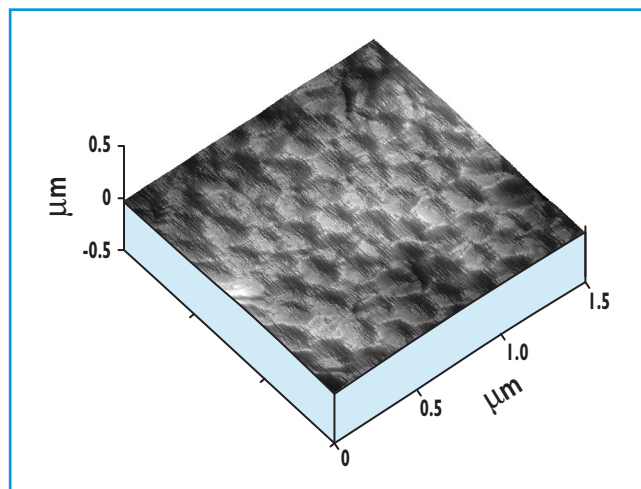
VIII. Effect of supercalendering on barrier properties and smoothness of dispersion-coated Papers 742 and 831 ^a

Surfaces of noncalendered and calendered coated papers were studied with the AFM (atomic force microscope) to detect changes in the film surfaces after calendering. **Figure 10** presents the surface of

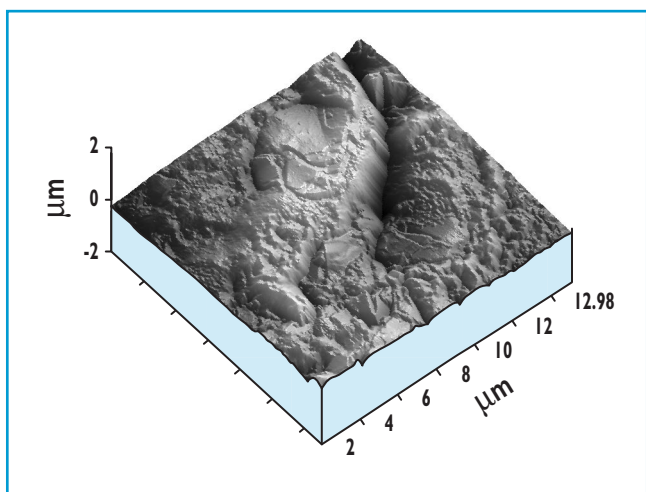
coated, reverse-side treated, noncalendered Paper 742. The film formation is good, and the "honeycomb" structure with individual latex particles can be observed weakly. Reverse-side treatment had no effect on



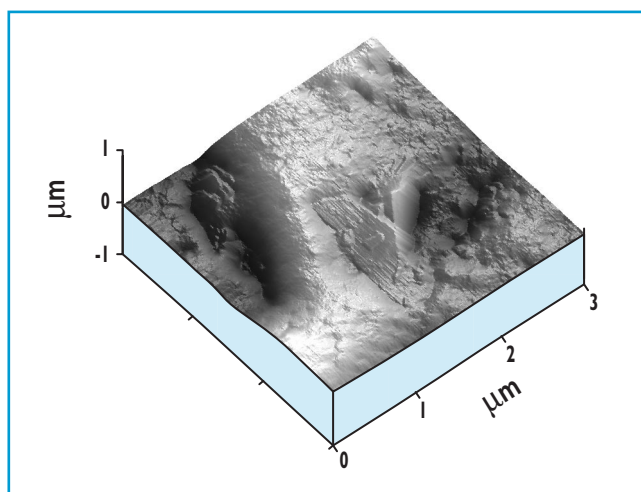
10. AFM picture of dispersion-coated Paper 742 before calendering



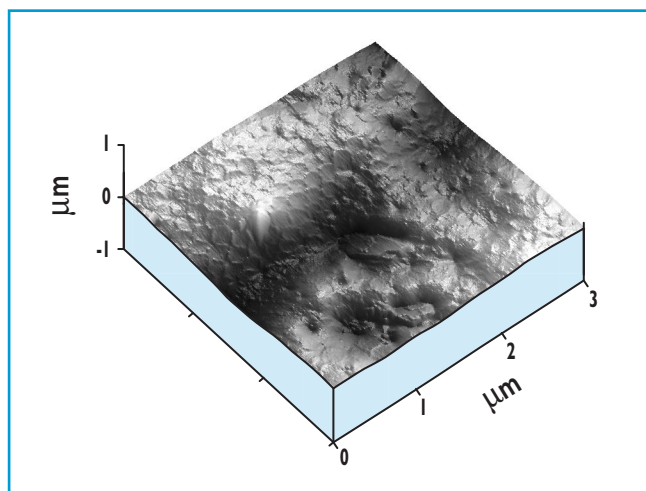
11. AFM picture of dispersion-coated Paper 742 after supercalendering



12. AFM picture of dispersion-coated Paper 742 after supercalendering (same as Fig. 11, but larger scale)



13. AFM picture of dispersion-coated Paper 742 before calendering



14. AFM picture of dispersion-coated Paper 742 after soft calendering

the WVTR of the coated papers. **Figure 11** shows that after supercalendering, the interior of the latex particles has collapsed, but the strong interfacial adhesion between the particles keeps them together. The density of the coating must have increased, and the obvious decrease in the overall coating thickness cannot be observed as a decrease in the barrier values. In addition, the filler particles are aligned parallel to the coating. All these factors, together with the densification of the base paper, improve the barrier properties. The complicated nature of filled dispersion coatings can be observed in **Fig. 12**, which is a larger-scale photograph of the sample depicted in **Fig. 11**.

Figures 13 and 14 show the surfaces of dispersion-coated Paper 742 before and after soft calendering. The photos show a similar collapse of latex particles as a result of the thermal treatment during soft calendering.

OTR was measured for some of these samples. The results in **Table IX** demonstrate the importance of the base paper and the presence of coating defects such as those presented in **Fig. 15** in the case of a further converted sample. It became obvious that if blade metering is to be used for barrier coating, it is better to apply two thinner coats instead of a single thick coating layer. With the second layer, it is possible to block the coating defects such as pinholes in the first layer and thus improve the barrier properties.

CONCLUSIONS

High-density papers are made of extensively refined chemical pulp. Intensive refining of the furnish decreases the number of internal pores with a diameter of 0.1–10 μm . Most of the pores in high-density papers are larger surface pores that do not extend through the sheet. Calendering presses fibers into the sheet, thus decreasing the diameter of these large surface pores and improving barrier properties such as grease and water-vapor resistance. In supercalendering of high-density papers, mainly the thickest parts of the paper are affected, but overall sheet density also increases.

The barrier properties of dispersion coatings depend largely on the drying process and on filler type and content. Barrier coatings can be applied to high-density papers with a roll applicator or a jet applicator and metered with a blade.

Precalendering improves the properties of coated papers, since base papers with high smoothness contribute to the overall smoothness of the coated sheet. Calendering of the coated sheet generally improves the properties of the coated material. However, the extent of improvement depends on the dispersion coating and its composition. In some cases, postcalendering of a precalendered and coated substrate can lead to deterioration of barrier properties. **TJ**

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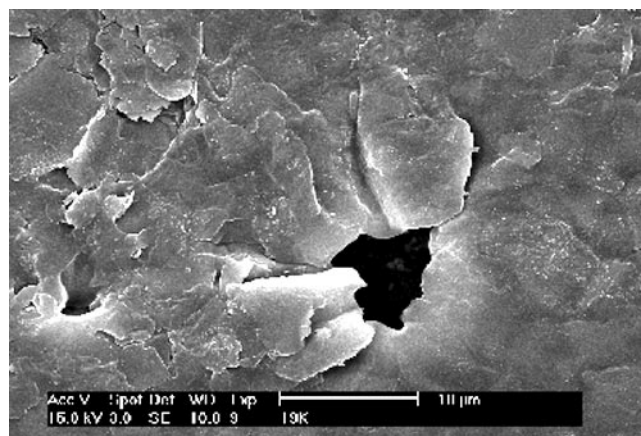
Presented at the TAPPI 1998 Coating and Papermaking Conference.

Sample	OTR (23°C, 65% RH), cm ³ /m ² /day/bar
Paper 742	
Soft calendered at 150 kN/m and 60°C	23,900
Precalendered; soft calendered at 150 kN/m and 60°C ^a	23,400
Precalendered; supercalendered at 350 kN/m and 70°C ^a	16,400
Paper 831	
Supercalendered at 350 kN/m and 70°C ^a	694
Supercalendered at 350 kN/m and 70°C ^b	295
Precalendered; supercalendered at 350 kN/m and 70°C ^b	1,728

^a Reverse-side treatment with a sizing unit

^b Reverse-side starch treatment with blade

IX. Oxygen transmission rate of various samples



15. Coating defect in dispersion-coated and further-converted sample

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