Effect of papermaking and coating variables on offset-print quality

Part 1—Papermaking variables

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ABSTRACT: Studies were carried out to explore the potential of improving offset-print quality on coated, wood-free, publication-grade papers. Part 1 of the study focuses on the effects of fiber source (northern, central, and southern United States) and press configuration (Tri-Nip, Tri-Nip with fourth press, Tri-Nip with smoothing press) on the physical properties and print quality of coated/calendered sheets. Part 2 (scheduled for publication in December) will examine the effects of coat weight, finishing technique (thermofinishing vs. supercalendering), and the practice of precoating/precalendering before top coating and calendering. Part 1 shows that the thin northern fibers gave a slightly better print quality. A fourth press enhanced print quality and surface smoothness on the felt side but diminished these properties on the wire side. A smoothing press improved surface smoothness and print quality on both sides.

KEYWORDS: Blade coating, coating, offset papers, paper stock, print quality, smoothness, two sidedness, wet pressing.

The demand for high-quality coated paper has grown in recent years because of the large expansion in the volume of multicolor printing *(1)*. Growth in demand is expected to continue through the 1990s.

Generally, an increase in production rates for printing and converting operations imposes higher demands on the coated paper. For example, a 50% increase in printing-press speed—from the current 600–700 m/min to 900–1000 m/min—will require a stronger paper web with a significantly higher blistering tolerance to withstand the higher oven temperatures dictated by the speed increase *(2)*. It is a great challenge for manufacturers of coated paper to meet the escalating quality requirements at these higher production rates. With new coating capacity emerging in North America, competition within the coated-paper market is pushing quality standards even higher.

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The print quality of coated paper is one of the most important factors to the customer. Paper is also differentiated based on optical properties, strength properties, and consistency in overall quality. An improvement in print quality without negative effects on other properties helps to strengthen the marketability of a given paper.

There is little information in the literature pertaining to the relationship between papermaking, coating, and calendering variables and the offset-print quality of coated paper. This report presents the results of a study that was undertaken in an effort to improve the offset-print quality of coated publication-grade papers by examining the effects of papermaking, coating, and calendering variables. Part 1 of this report focuses on papermaking variables, including fiber source and press configuration. Part 2 will examine the effects of coat weight, finishing (supercalendering vs. thermofinishing), and precoating/precalendering on offset-print quality. Machine runnability of the webs at various experimental conditions was evaluated by conducting large-scale trials with the coater, calender, and printing press running at production conditions.

Experimental

Basestock

The three coating basestocks were produced on commercial paper machines. The preparation of fiber furnishes and the operation of a fourth press and a smoothing press during the basestock trials were conducted under routine mill production conditions.

Coating

Preparation. A clay/$CaCO_3$-based formulation with 14% binder (7% starch and 7% styrene butadiene latex) designed for web offset publication grades was used in the studies. The coating color was prepared using a high-shear mixer to a solids target of 62%. The pH was adjusted to about 8.5 with ammonium hydroxide. Percent solids, pH, and both Brookfield and Hercules viscosities were measured.

Application. The coating was applied at a speed of 1000 m/min using a high-speed pilot coater with a rigid blade for metering (Jagenberg Combi-Blade) and a flooded-nip roll applicator. The coated web was dried to a moisture level of 4.5–5.0% using hot-air foils in combination with steam dryer cans. The wire side of the basestock was coated first. The coat weight for both the felt and wire sides was in the range of 10–15 g/m².

Calendering

The coated rolls were calendered using a high-speed pilot compact calender. The calender has two three-roll stacks, each with a steel roll at the center and plastic-covered rolls in the top and bottom positions. Supercalendering was simulated by running the web through both stacks with the surface temperature of the steel rolls at 80°C. Thermofinishing was simulated by operating at 160–170°C. The paper web passed through a total of four nips at a speed of 600 m/min. The individual nip load was increased from nip 1 to nip 4, and the nip loads were adjusted in a range of 70–350 kN/m. The paper was either calendered under equal nip loads or to a specific sheet-gloss target (usually 70° Hunter gloss) on both sides. The felt side was always calendered first against the steel roll in nips 1 and 2 to minimize two-sidedness in the roughness of the finished sheet.

I. Characteristics of furnishes used to produce coating basestocks

Furnish characteristics	*Furnish A (northern)*	*Furnish B (central)*	*Furnish C (southern)*
Softwood			
Furnish content, %	35	35	30
Viscosity, cP	19.1	21.6	23.0
Fiber length, mm	1.83	2.07	2.55
Fiber coarseness, mg/m	0.165	0.285	0.290
Hardwood			
Furnish content, %	45	45	70
Viscosity, cP	23.6	20.1	22.1
Fiber length, mm	0.77	0.88	1.24
Fiber coarseness, mg/m	0.079	0.108	0.165
Coated broke, %	20	20	0
Stuff-box freeness, mL CSF	390	360	...
Ash content (550°C), %	9	9	11

II. Properties of basestocks produced from three furnishes

Basestock properties	*Furnish A (northern)*	*Furnish B (central)*	*Furnish C (southern)*
Basis weight, g/m²	64.6	66.2	74.2
Ash content (550°C), %	7.0	6.7	9.2
Opacity, %	88.1	85.2	87.7
Gurley porosity[a], s/100 mL	21	17	12
Caliper, µm	94.0	94.0	99.1
Bulk, cm³/g	1.455	1.420	1.335
Scattering coefficient, cm²/g	45.48	41.85	45.62
Absorption coefficient, cm²/g	1.09	1.04	0.96
Tensile strength, kN/m			
Machine direction	12.80	12.35	11.25
Cross-machine direction	4.80	4.40	4.93
Tear resistance, mN			
Machine direction	51.5	54.5	60.4
Cross-machine direction	52.3	55.0	75.2
Roughness (PPS-10)[b], µm			
Wire side	9.75	9.49	7.35
Felt side	11.19	10.72	9.20
Smoothness (Sheffield), cm³/min			
Wire side	248	200	138
Felt side	303	258	158

[a]Gurley porosity measured at 1.22 kPa (low pressure)
[b]PPS-10: Parker print-surf roughness measured at 98kPa

Offset printing

The calendered rolls were printed using a commercial web offset press at production speeds. All papers were printed to the SWOP (Standard Web Offset Press) specifications for web offset printing (constant-ink-density printing). The paper was evaluated for printability—including picking, piling, and blistering—during the printing trial. A full-color test image was used to determine the print quality by a panel of judges using the all-pairs comparison technique *(3)*. Print gloss and ink density were measured on 100% or 400% ink coverage (black solid targets).

Paper testing

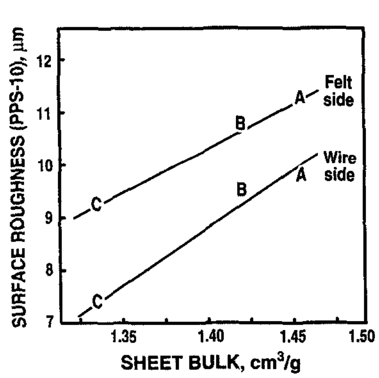
All samples (basestock, coated/uncalendered sheets, coated/calen-

III. Properties of coated/uncalendered webs produced from three furnishes

Properties of coated/uncalendered web	*Furnish A (northern)*	*Furnish B (central)*	*Furnish C (southern)*
Basis weight, g/m²	88.3	89.5	101.4
Opacity, %	95.8	96.1	95.6
Gurley porosity,[a] s/10 mL	48	41	46
Coat weight, g/m²			
Wire side	13.3	12.7	14.1
Felt side	12.1	12.1	12.6
Gloss			
Wire side	26.9	22.8	29.1
Felt side	28.2	23.4	30.1
Roughness (PPS-10)[b], µm			
Wire side	4.78	5.71	4.00
Felt side	5.38	7.80	4.73

[a]Gurley porosity measured at 3.084 kPa (high pressure)
[b]PPS-10: Parker print–surf roughness measured at 980 kPa

1. Parker print-surf roughness (PPS-10) as a function of sheet bulk for uncoated basestocks made from Furnishes A, B, and C



dered sheets, and printed sheets) were conditioned for at least 24 h at 23°C and 50% RH before testing. Values for caliper, gloss, opacity, brightness, and Parker print–surf roughness (at 980 kPa) were obtained by averaging 20 measurements (four measurements on five replicates). Values for basis weight, coat weight, and ash content were obtained by averaging five measurements on five replicates. All tests were conducted by following the appropriate TAPPI Test Methods.

Results and discussion

Effect of fiber sources

The basestocks used in this study were manufactured from three different fiber furnishes representative of fibers available in the northern, central, and southern regions of the United States. **Table I** provides data on the three furnishes and shows the range of fiber length and coarseness.

Furnish A, which consisted of 45% baled hardwood pulp, 35% slushed softwood pulp, and 20% coated broke, represents the fibers produced in the northern part of the United States. Both the softwood and hardwood fibers are relatively thin and short. Furnish C, which is estimated to contain 30% southern pine fibers and 70% hardwood fibers, represents the fiber source in the southern region of the United States. The southern fibers are significantly longer and thicker than the northern fibers. Furnish B contains the same percentages of baled softwood pulp, baled hardwood pulp, and coated broke as in Furnish A, and the fibers represent a geographical location in between that of Furnishes A and C, i.e., in the central part of the United States. The fibers in Furnish B were approximately 30% coarser than the fibers in Furnish A, but not as coarse as the fibers in Furnish C.

During the paper machine trial, the hardwood fibers in Furnishes A and B were refined to a target freeness level of 450 mL CSF. The softwood fibers were refined to adjust the freeness level in the tickler refiner to a range of 350–400 mL CSF. Fillers and wet-end additives were added to the furnishes according to the mill production specifications.

Coating basestocks were produced from Furnishes A and B on a fourdrinier paper machine with a Tri-Nip press. Several rolls of 66-g/m² coating basestock were produced during the paper machine trial. The coating basestock produced from Furnish C was obtained on a fourdrinier paper machine with a top-wire former and a Tri-Nip press. The basestock from Furnish C had a basis weight of 74 g/m². All of the trial basestock was coated using a high-speed pilot coater with the same clay/$CaCO_3$-based formulation. The basestock was coated at about 12.5 g/m² on each side. The coated rolls were then calendered using a pilot compact calender to simulate supercalendering conditions.

Table II lists the physical properties of the basestocks made from the three furnishes. Despite the differences in basis weight, ash content, and Gurley porosity, etc., the tensile strength and optical properties of the three basestocks are fairly comparable. Tear strength for the basestock from Furnish C was higher than that of the other two basestocks, probably because of its higher basis weight, lower sheet bulk, and differences in fiber refining.

Measurement of Parker print–surf roughness and Sheffield smoothness showed that Furnish A gave the roughest surface, Furnish C gave the smoothest surface, and Furnish B was in between these two extremes. The severe two-sidedness in surface roughness observed for the three basestocks is a result of formation on a fourdrinier followed by Tri-Nip pressing.

Under equivalent papermaking conditions, shorter and thinner fibers generally impart a smoother surface than do longer and thicker fibers. However, **Fig. 1** shows an approximately linear relationship between Parker print–surf roughness and sheet bulk, suggesting that the difference in basestock surface roughness is a function of the papermaking process rather than the fiber quality. As seen in Fig. 1, surface roughness increased linearly with sheet bulk, regardless of the fibers used at similar basis weight.

Coating application with rigid-blade metering greatly reduced surface roughness, as shown in **Table III**. The reduction increased with increased coat weight, as expected. The coated Furnish C paper was still the smoothest of the three basestocks, indicating that the coated roughness depends on the basestock roughness. However, the coated Furnish B paper was rougher than the coated Furnish A paper, the reverse of what had been the case before the coating application. It is postulated that the once-dried softwood fibers used in Furnish B tended to spring back (puff) more upon rewetting than the never-dried softwood fibers in Furnish A. Therefore, it appears that basestock surface roughness as well as fiber drying history are critical factors in determining the roughness of coated/uncalendered sheets, while fiber dimension appears to be a secondary factor.

Final finishing was carried out on a pilot compact calender with one pass through four nips, which simulated supercalendering conditions in the mill. All papers were calendered under the same nip loads (constant calendering). The felt side was calendered first to the steel roll to minimize two-sidedness in the finished sheet.

Table IV lists the physical properties of the coated/calendered papers. Surface roughness of the coated/calendered papers decreased with increasing coat weight, as seen in **Fig. 2**. Sheet gloss of the coated/calendered papers increased with increasing coat weight, as seen in **Fig. 3**. Furnish A was the smoothest, followed by Furnish C and then Furnish B when compared at equal sheet bulk. This roughness ranking order is different from the base-stock roughness ranking order, suggesting that basestock roughness does not solely determine the surface roughness of the coated/calendered web.

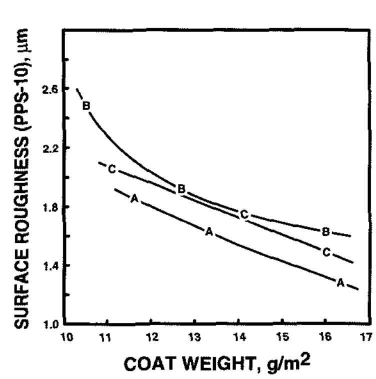
There is an apparent relationship between fiber stiffness and the calendering demand of paper. Fibers with thin, flexible walls have higher plastic-

IV. Properties of coated/calendered webs produced from three furnishes

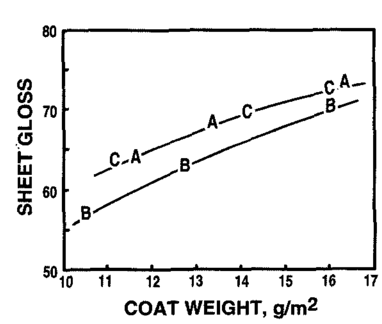
Properties of coated/calendered web	*Furnish A (northern)*	*Furnish B (central)*	*Furnish C (southern)*
	Sheet properties		
Basis weight, g/m²	88.3	89.5	101.4
Opacity, %	94.1	92.8	94.6
Gurley porosity,[a] s/10 mL	163	147	109
Caliper, µm	83.8	83.8	94.0
Bulk, cm³/g	0.950	0.937	0.926
Coat weight, g/m²			
Wire side	13.3	12.7	14.1
Felt side	12.1	12.1	12.6
Gloss units			
Wire side	68.1	62.6	69.4
Felt side	70.6	65.8	71.5
Roughness (PPS-10)[b], µm			
Wire side	1.63	1.91	1.74
Felt side	1.91	2.29	2.03
	Printed sheet properties		
Print gloss[c]			
Wire side	88.3	86.2	86.6
Felt side	91.2	89.5	92.1
Ink density[c]			
Wire side	2.27	2.29	2.30
Felt side	2.24	2.24	2.25
Print rank[d]			
Wire side	2	5	6
Felt side	1	4	3

[a]Gurley porosity measured at 3.084 kPa (high pressure)
[b]PPS-10: Parker print-surf roughness measured at 980 kPa
[c]Print gloss and ink density are measured on 400% ink coverage solid black targets.
[d]1 = best and 6 = worst; ranked using all-pairs comparison method

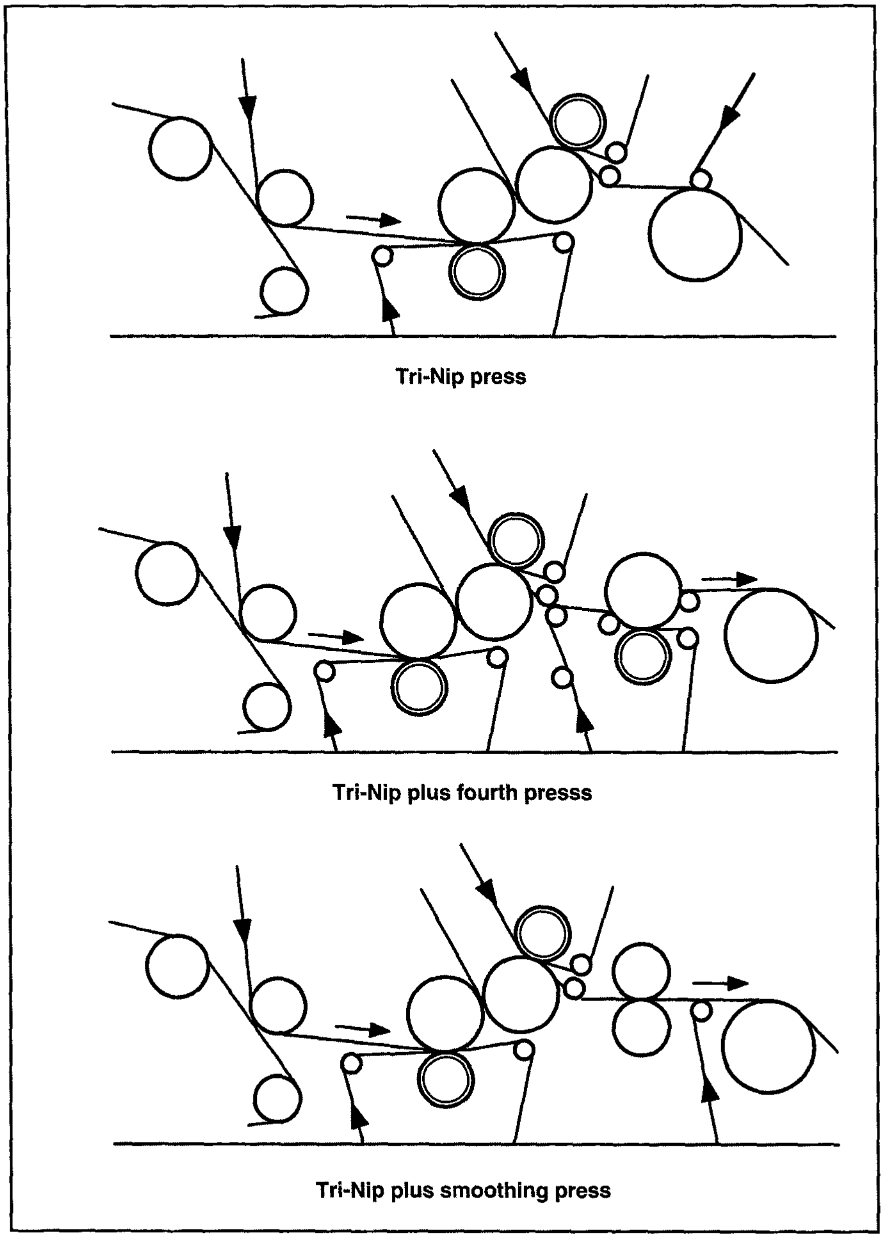
2. Parker print-surf roughness (PPS-10) as a function of coat weight for the coated/calendered basestocks made from Furnishes A, B, and C (wire side)



3. Sheet gloss as a function of coat weight for the coated/calendered basestocks made from Furnishes A, B, and C (wire side)



4. Press arrangements for producing uncoated basestock



ity and are more compressible, making it easier to develop surface smoothness through calendering. The coated/calendered basestock produced from Furnish A is smoother than that from Furnishes B or C, indicating the greater flexibility of the northern fibers, which are much thinner than the central and southern fibers (Table I). On the other hand, the fact that the coated/calendered basestock from Furnish C was smoother than B probably reflects the influence of a top-wire former and the fiber drying history. The top-wire former (Furnish C) improves basestock surface smoothness by increasing the retention of fines and fillers. Once-dried fibers (Furnish B) are stiffer and more resilient than virgin fibers, resulting in a less compressible coating basestock.

The calendered rolls were printed using a commercial web offset press. The print-quality rankings are shown in Table IV. On the wire side, Furnish A was the best, followed by Furnish B and then Furnish C. On the felt side, Furnish A was the best, followed by Furnish C and then Furnish B. Thus the smaller northern fibers gave a better print quality than the larger fibers from the central and southern regions. The difference in print quality for the basestocks produced from Furnishes B and C was relatively small.

Interestingly, the felt side printed better than the wire side, even though the felt side was rougher for all three basestocks (Table IV). This confirmed our previous observation that the surface roughness characterized by the air-leak method (Parker print-surf) does not solely determine the offset-print quality. A similar observation was reported by McDonald *et al.* *(4)* on the letterpress print quality of newsprint. The poor print quality with the wire side is thought to be related to (a) low fines and filler content because of asymmetrical dewatering in the forming section and (b) less densification because of the low structural pressure in the press section of the paper machine.

Effect of a fourth press

The Tri-Nip press is a common press sequence used on high-speed paper machines producing lightweight grades. **Figure** 4A illustrates the Tri-Nip press, which consists of a cluster of rolls with three nips and no open draws. The Tri-Nip press has a double-felted first press followed by two single-felted inverse presses, with the felt on the top side and the granite roll on the bottom side of the paper in the last two nips.

This Tri-Nip press-roll arrangement has a potential for inducing sheet two-sidedness because of (a) the smoothness differences between the granite press roll and the felt and (b) the asymmetrical dewatering in the second and third nips. When the sheet is pressed against the granite roll, its smoother surface is imprinted on the paper. When the paper is pressed against the rough surface of the press felt, a rougher paper surface will be generated because of the surface replication of the felt, as described by McDonald *et al.* *(4, 5)*. MacGregor has suggested an alternative mechanism *(6)* to explain the surface-roughening effect on the felt side—the density gradient in the z-direction, which results in differences in shrinkage. In addition to the two-sidedness in roughness, the wet pressing generates (a) a higher density on the felt side due to a higher structural pressure and (b) a lower density on the granite-roll side due to a higher hydraulic pressure (lower structural pressure) *(7–10)*.

To compensate the two-sidedness shortcoming of a Tri-Nip press, some newer machines have a single-felted fourth press after the Tri-Nip press *(11)*, as shown in **Fig. 4B**. In the fourth nip, the smoother bottom side is pressed against the felt, while the rougher top side is pressed against the granite roll. This fourth press nip also removes water from the bottom side of the paper, resulting in the application of a higher structural pressure to the bulkier bottom side, which helps reduce the density two-sidedness *(9, 10)*. Thus a fourth press, in theory, counteracts the two-sidedness created in previous nips and affects surface roughness and print quality *(5)*. Sheet two-sidedness of coating basestock produced on fourdriniers with a Tri-Nip press is a major issue. Consequently, we sought to determine the effects of a fourth press on the surface smoothness and print quality of coated web offset paper.

The two rolls of coating basestock manufactured from Furnish C were produced from the same furnish on separate paper machines of the same type. Both machines are equipped with a Tri-Nip press, and one machine is equipped with a fourth press after the Tri-Nip. **Table V** shows the physical properties of the basestocks. With the Tri-Nip pressing, the wire side is significantly smoother than the felt side. With the use of a fourth press, the felt side became smoother than the wire side, and the total roughness was reduced. The total roughness reduction is probably due to the more uniform web compaction with the fourth press as compared with the Tri-Nip press *(9)*.

V. Properties of basestock, coated, and coated/calendered webs produced from Furnish C—with and without a fourth press

Web properties	Basestock: Tri-Nip + 4th press	Basestock: Tri-Nip	Coated: Tri-Nip + 4th press	Coated: Tri-Nip	Coated/calendered: Tri-Nip + 4th press	Coated/calendered: Tri-Nip
Sheet properties						
Basis weight, g/m²	74.2	75.5	100.0	102.2	100.0	102.2
Opacity, %	87.7	88.9	96.4	95.6	94.5	94.6
Gurley porosity[a], s/*X* mL	12	12	40	46	108	109
Caliper, µm	99	99	109	112	97	94
Bulk, cm³/g	1.34	1.31	1.09	1.09	0.97	0.92
Coat weight, g/m²						
Wire side	...	...	13.3	14.1	13.3	14.1
Felt side	...	...	12.4	12.6	12.4	12.6
Gloss units						
Wire side	...	...	29.1	29.1	67.8	69.4
Felt side	...	...	31.5	30.1	72.2	71.5
Roughness (PPS-10)[b], µm						
Wire side	8.49	7.35	4.32	4.00	2.11	1.74
Felt side	7.08	9.20	3.91	4.73	1.63	2.03
Smoothness (Sheffield), cm³/min						
Wire side	165	138	...	...	...	...
Felt side	148	158	...	...	...	...
Printed sheet properties						
Print gloss[c]						
Wire side	...	...	...	...	87.7	86.6
Felt side	...	...	...	...	90.3	92.1
Ink density[c]						
Wire side	...	...	...	...	2.26	2.30
Felt side	...	...	...	...	2.20	2.25
Print rank[d]						
Wire side	...	...	...	...	3	4
Felt side	...	...	...	...	1	2

[a]Gurley porosity for basestock was measured at 1.22 kPa (low pressure), so units are s/100 mL. Gurley porosity for coated and coated/calendered webs was measured at 3.084 kPa (high pressure), so units are s/10 mL.
[b]PPS-10: Parker print–surf roughness measured at 980 kPa
[c]Print gloss and ink density are measured on 400% ink coverage solid black targets.
[d]1 = best and 4 = worst; ranked using all-pairs comparison method

Both rolls were coated using a high-speed pilot coater with the same coating formulation under identical coating conditions. After coating application, the roughness of the two sides of the basestock remained (Table V). The felt side was rougher than the wire side for the basestock produced with only the Tri-Nip press. For the basestock produced with a Tri-Nip plus a fourth press, the felt side was smoother than the wire side, and the total roughness of the coated/uncalendered sheet was reduced.

Calendering did not change the relative roughness between the two sides of the paper, as shown in Table V. The use of a fourth press simply reversed the roughness on both sides. Total roughnesses as well as other physical properties of the paper were not greatly affected by the use of a fourth press. However, print-quality ranking was marginally in favor of the use of a fourth press (Table V). This improved print quality is probably due to the more uniform densification of the sheet with the fourth press *(9)*. Thus the use of a fourth press in the manufacture of coating basestock may be justified by the higher web dryness, better control of roughness two-sidedness *(9)*, and a slight improvement in offset-print quality.

VI. Properties of basestock, coated, and coated/calendered webs produced from Furnishes A and B—with and without a smoothing press

Web properties	Basestock				Coated				Coated/calendered			
	Furnish A		Furnish B		Furnish A		Furnish B		Furnish A		Furnish B	
	Tri-Nip	Tri-Nip + smth. press	Tri-Nip	Tri-Nip + smth. press	Tri-Nip	Tri-Nip + smth. press	Tri-Nip	Tri-Nip + smth. press	Tri-Nip	Tri-Nip +smth. press	Tri-Nip	Tri-Nip + smth. press
Sheet properties												
Basis weight, g/m²	66.5	66.8	67.4	67.4	89.6	92.7	92.1	90.8	92.9	92.3	92.1	92.1
Opacity, %	85.0	84.0	84.0	83.0	96.7	95.3	95.6	96.8	83.0	84.0	82.0	85.0
Gurley porosity,[a] s/X mL	21	13	24	37	82	83	77	92	215	200	250	290
Caliper, µm	94.0	94.0	93.4	96.4	106.9	104.9	109.0	104.6	79.8	83.3	79.8	78.7
Bulk, cm³/g	1.44	1.39	1.40	1.43	1.19	1.13	1.18	1.15	0.86	0.90	0.87	0.85
Coat weight, g/m²												
Wire side	...	...	...	...	13.5	13.0	14.4	14.2	13.5	13.0	14.4	14.2
Felt side	...	...	...	...	10.6	11.3	11.3	10.9	10.6	11.3	11.3	10.9
Gloss units												
Wire side	...	...	...	...	...	...	...	...	77.0	74.0	78.0	79.0
Felt side	...	...	...	...	...	...	...	...	72.0	68.0	72.0	75.0
Roughness (PPS-10)[b], µm												
Wire side	10.8	10.0	11.3	11.0	6.90	5.01	6.64	5.45	1.54	1.47	1.58	1.48
Felt side	12.0	11.1	12.3	11.7	8.94	5.74	8.81	6.37	1.66	1.43	1.71	1.49
Smoothness (Sheffield), cm³/min												
Wire side	250	210	275	260	...	...	...	...	44	31	44	45
Felt side	290	250	315	285	...	...	...	...	39	29	39	43
Printed sheet properties												
Print gloss[c]												
Wire side	...	...	...	...	...	...	...	...	92	91	92	96
Felt side	...	...	...	...	...	...	...	...	88	89	88	92
Ink density[c]												
Wire side	...	...	...	...	...	...	...	...	1.76	1.75	1.77	1.75
Felt side	...	...	...	...	...	...	...	...	1.81	1.80	1.78	1.72
Print rank[d]												
Wire side	...	...	...	...	...	...	...	...	3	7	4	1
Felt side	...	...	...	...	...	...	...	...	6	5	8	2

[a] Gurley porosity for basestock was measured at 1.22 kPa (low pressure), so units are s/100 mL. Gurley porosity for coated and coated/calendered webs was measured at 3.084 kPa (high pressure), so units are s/10 mL.
[b] PPS-10: Parker print–surf roughness measured at 980 kPa
[c] Print gloss and ink density are measured on 400% ink coverage solid black targets.
[d] 1 = best and 8 = worst; ranked using all-pairs comparison method

Effect of smoothing press

A smoothing press is a feltless nip formed with smooth rolls located after a Tri-Nip or a fourth press section and before the dryer section. The smoothing press is illustrated in **Fig. 4C**. Although the smoothing press does not remove water, it improves surface smoothness on both sides *(7)*. The additional nip impulse also may enhance web consolidation.

The effect of a smoothing press was evaluated using basestocks (Furnishes A and B) produced on mill fourdrinier paper machines equipped with a Tri-Nip press and a smoothing press. Each of the basestocks was produced from its constituent furnish with and without the smoothing press in operation. The nip load for the smoothing press was 36 kN/m at a machine speed of about 670 m/min.

The effect of a smoothing press on basestock properties is shown in **Table VI**. In the case of both Furnishes A and B, the smoothing press improved surface roughness on both sides at the cost of a slight reduction in sheet bulk and opacity because of the additional pressing. The roughness two-sidedness was also improved, with slightly larger roughness reduction on the initially rougher felt side than the wire side (granite-roll side). Measurement of Sheffield smoothness showed the same trends. Clearly, the use of a smoothing press after a Tri-Nip press reduced surface roughness and two-sidedness of the uncoated basestock.

The advantages of a smoothing press were still apparent after coating. Table VI shows that the coated basestock produced with a smoothing press was much smoother than basestock produced without a smoothing press. The smoothing-press roughness reduction was greater for Furnish A than for Furnish B, which was probably a result of the greater "spring back" of the once-dried softwood fibers in Furnish B.

After calendering, the paper produced with a smoothing press remained smoother and less two-sided than paper produced without a smoothing press (Table VI). The slight reduction in sheet bulk and opacity with the use of a smoothing press is no longer recognizable after coating and calendering. The beneficial effects from the use of a smoothing press are likely to be related to the smoothing effect and enhanced web consolidation. Both factors probably lead to a smoother surface and less surface roughening when the sheet is rewetted during coating and printing operations.

All the papers were printed using a commercial web offset press. Print gloss was measured on 100% black image, and print quality was ranked on a full-color printed image by a panel of eight judges. Printing results are listed in Table VI. The paper produced using a smoothing press was ranked significantly better than that without a smoothing press, with the exception of the wire side of Furnish A. Print gloss correlated positively with the print-quality ranking, confirming our previous observation *(2)*.

Conclusion

Print quality and the physical properties of coated wood-free publication-grade papers were evaluated as functions of fiber source and press configuration.

Under similar papermaking conditions, fiber furnishes from the northern United States produced a sheet with slightly better surface smoothness and offset-print quality than sheets produced from central U.S. and southern U.S. fiber furnishes. Fibers from these latter regions are significantly longer and thicker. Overall, the impact of fiber sources on print quality was smaller than expected, probably a result of the high coat weights used in the experiments.

A fourth press nip after a Tri-Nip press reverses the roughness two-sidedness of coated/calendered sheets. The basestock side exposed to the felt in the last nip tends to produce a rougher coated/calendered surface than does the side exposed to the smooth roll. Although the total roughnesses—as well as other physical properties of the finished paper—did not appear to be greatly affected, the offset-print quality was slightly improved with the use of a fourth press.

The use of a smoothing press after a Tri-Nip press reduced roughness, reduced two-sidedness in the roughness, and improved the offset-print quality of the coated/calendered paper. This is thought to be due to the smoothing effect and enhanced web consolidation that occurs within the unfelted nip, leading to a smoother surface and less surface roughening upon rewetting during coating and printing operations. TJ

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