Improved dewatering of sheets by a petroleum hydrocarbon

L. Rahman and C. H. Tay

Senior research chemist and principal scientist, respectively, Abitibi-Price Inc., Research Centre, Sheridan Park, Mississauga, Ont., Canada L5K 1A9

ABSTRACT *A petroleum hydrocarbon applied in the form of spray on the surface of handsheets enhanced the dewatering, or increased the consistency, during pressing and drying. Results from differential scanning colorimetry and thermogravimetric analysis indicated that the removal of water from the hydrocarbon-treated sheets took place at a lower temperature and required less energy than the control sheet. The addition of the petroleum hydrocarbon did not have any significant effect on the sheet properties.*

KEYWORDS
Analysis
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Physical properties
Pressing
Solvents
Water removal

Little work has been done on the use of a solvent for enhancing the drying of sheets. However, the use of methanol to enhance the drying of deacidified old book paper was studied by Kelly and Fowler (*1*). The effect of solvents on the drying rate of printing ink was studied by Leskinen and others (*2–4*). Studies were made on the use of solvents for the production of multicolored paper (*5–7*). Extensive studies were also made on the use of various solvents for paper coating in specialty products such as photoreceptor (*8–12*) and ink-donor sheet (*13–18*).

The idea of enhancing the removal of water during pressing and drying was based on a novel process claimed by J. G. Penniman (*19*). According to the process, a water-immiscible petroleum hydrocarbon applied to the sheet after the formation stage enhances the water removal by reducing the interfacial tension. Reportedly, the process generates an increase of about 10% in web consistency out of the press and a savings of 30% or more in drying energy. It is also claimed to produce a thinner, smoother, and stronger sheet.

Penniman's process also affords a means of introducing functional chemical additives to improve properties such as wet and dry strength, debonding, softness, sizing, brightness, and color. This new procedure completely avoids the destructive effect of "anionic trash" and can result in virtually 100% retention and effectiveness.

The objective of our study was to determine the effect of a water-immiscible petroleum hydrocarbon (which is a mixture of petroleum hydrocarbons, mainly isoparaffins) on the removal of water during pressing and drying and on sheet properties.

Results and discussion

Table I summarizes the effect of the petroleum hydrocarbon on dewatering of Noble and Wood handsheets during pressing and drying. The table shows that the treatment of the handsheet with the hydrocarbon enhances the dewatering during pressing and drying by an average of 2.4% and 18.3%, respectively.

Table II summarizes the water retention values of the fiber pads formed on a Buchner funnel. The addition of the hydrocarbon on the surface of the fiber pad increased the consistency by 7.8%.

Table III summarizes the results of the differential scanning calorimetry (DSC) measurements on Noble and Wood handsheets with and without the hydrocarbon treatment. The hydrocarbon-treated samples (Nos. 2, 3, and 6) show lower starting and peak temperatures of the endotherms than their corresponding controls (Nos. 1, 4, and 5, respectively). The treated sheets (Nos. 2, 3, and 6) required lower heat energy to remove the water from the sheet than the corresponding controls (Nos. 1, 4, and 5, respectively).

Figure 1 shows the DSC scans of sample Nos. 1-4 of Table III. These thermal scans indicate that the endotherm peak of the treated samples (Nos. 2 and 3) occurred at lower temperatures than the corresponding controls (Nos. 1 and 4). **Figure 2** shows the DSC scans of sample Nos. 5 and 6 of Table III. Again, these scans show that the endotherm peak of the treated sample (No. 6) occurred at a lower temperature than the control (No. 5). These DSC scans show that the removal of water from the hydrocarbon-treated sheets takes place at a lower temperature and requires less energy than the control.

The greatest energy use occurs during the drying of the paper product, particularly in the manufacture of thicker grades of paper product. In

I. Effect of a petroleum hydrocarbon on dewatering of Noble and Wood handsheets

No. of tests	Kind of treatment	Consistency at different stages, % After first pressing	After second pressing	Diff. between control and treated	After drying cycle	Diff. between control and treated
3	None, control	22.6	24.9	...	66.3	...
3	36 kg/ton hydrocarbon (overall average) sprayed after first pressing	24.0	27.3	+2.4	84.6	+18.3
1	47 kg/ton hydrocarbon sprayed after first pressing	24.3	28.0	+3.1	87.8	+21.5
1	37 kg/ton hydrocarbon sprayed after first pressing	24.0	27.8	+2.9	80.6	+14.3
1	25 kg/ton hydrocarbon sprayed after first pressing	23.6	26.1	+1.2	85.4	+19.1

one case of linerboard manufacture, for example, 88.6% of paper mill steam usage was reported to be at the drying cylinders.

Drying is a relatively expensive process, and the cost of drying is always a major part of the process cost of the final paper. Thus, any savings in energy in the drying stage of a hydrocarbon-treated sheet would directly result in cost savings.

II. Water retention values before and after centrifuging and the effect of the petroleum hydrocarbon on dewatering

No. of Tests	Kind of treatment	Consistency, % Before	After	Diff. between control and treated
2	None, control	12.7	17.9	...
2	16.2 kg/ton hydrocarbon	12.4	25.7	+7.8

Figures 3A and 3B represent the sections of DSC scans of sample Nos. 5 and 6 of Table III, respectively. In these cases, both the starting temperature of about 325°C and the peak temperature of about 353°C of the exotherms are much higher than the glass transition temperature (115-145°C) of the wood lignin (*20*). Therefore, these exotherms were probably the result of the decomposition of the lignocellulosic materials. However, the starting and peak temperatures and the energy requirement of the exotherm of the hydrocarbon-treated sample (Fig. 3B) are slightly lower than those of the control (Fig. 3A).

Figure 4 shows the TGA (thermogravimetric analysis) scans of the Samples 1-4 of Table III. TGA conditions of these samples were set in such a way that it became isothermal at 86°C. This isothermal temperature of TGA was selected because it corresponded to the temperature of the drum dryer of the Noble and Wood machine. TGA scans of the hydrocarbon-treated samples (Nos. 2 and 3) reached the isothermal temperature at higher consistency (greater loss in weight due to increased drying) than the corresponding controls (Nos. 1 and 4).

Figures 5A and **5B** show the TGA scans of sample Nos. 5 and 6 of Table III. The thermogravimetric analyses of these samples were conducted without any preselected isothermal conditions. Figure 5A revealed that it took only 114°C for the hydrocarbon-treated sheet to reach a constant dry weight, while it took 135°C for the control. Figure 5B indicated that it took approximately 10 min for the hydrocarbon-treated sheet to arrive at a constant dry weight, compared to more than 12 min for the control. Therefore, like the DSC scans described earlier, TGA scans also demonstrated that the treatment of a sheet with a petroleum hydrocarbon reduced its drying energy requirements quite significantly.

Table IV summarizes the physical properties of the handsheets of untreated and hydrocarbon-treated samples. Half of both untreated and treated samples were calendered. As shown in Table IV, there was hardly any improvement in properties of the treated sheets, contrary to what was claimed by the Penniman Process (*19*).

Conclusions

A petroleum hydrocarbon increased the consistency of the sheet during pressing by 2.4% and during drying by 18.3%. This enhanced dewatering (7.8%) was also demonstrated by the test for the water retention value.

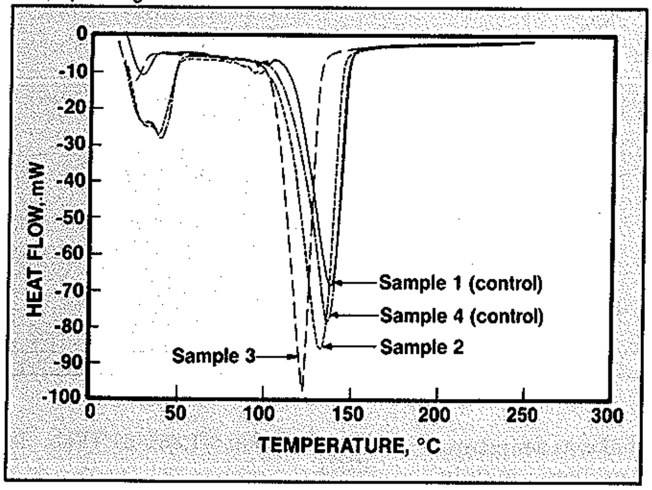
DSC and TGA results indicate that the removal of water from the hydrocarbon-treated sheets takes place at a lower temperature and requires less energy than the control.

There was hardly any difference in physical properties between the untreated and the hydrocarbon-treated sheets.

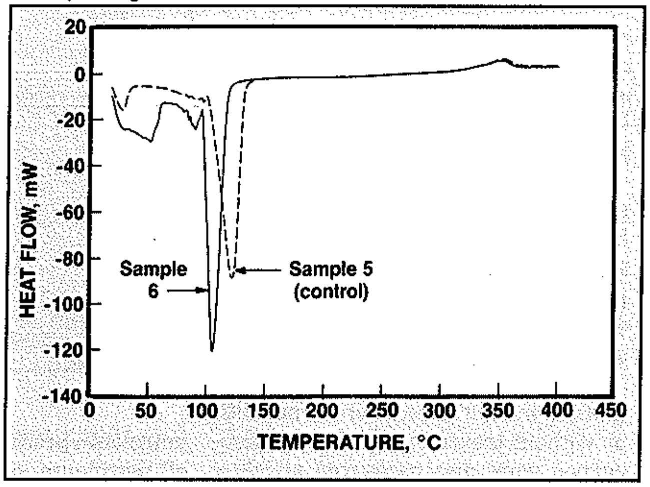
III. DSC on handsheets with and without the hydrocarbon treatment

Sample no.	Kind of treatment	Starting temp., °C	Diff. beteween control and treated, °C	Peak temp., °C	Diff. between control and treated, °C	Energy required to remove water, J/g	Diff. between control and treated, J/g
1	Control for No. 2, once cold pressed	115.03	...	138.27	...	1280	...
2	Sheet formed, sprayed with the hydrocarbon (16.8 kg/ton), then cold pressed	109.5	5.53	132.35	5.92	1059	221
3	Sheet formed, cold pressed, sprayed with the hydrocarbon (14.8 kg/ton) then cold pressed again	104.68	9.88	122.35	13.4	952	129
4	Control for No. 3, twice cold pressed	114.56	...	135.75	...	1081	...
5	Control for No. 6, twice cold	102.99	...	122.55	...	1020	...
6	Sheet formed, cold pressed, sprayed with the hydrocarbon (7.1 kg/ton), then cold pressed again	97.17	5.82	105.42	17.13	841	179

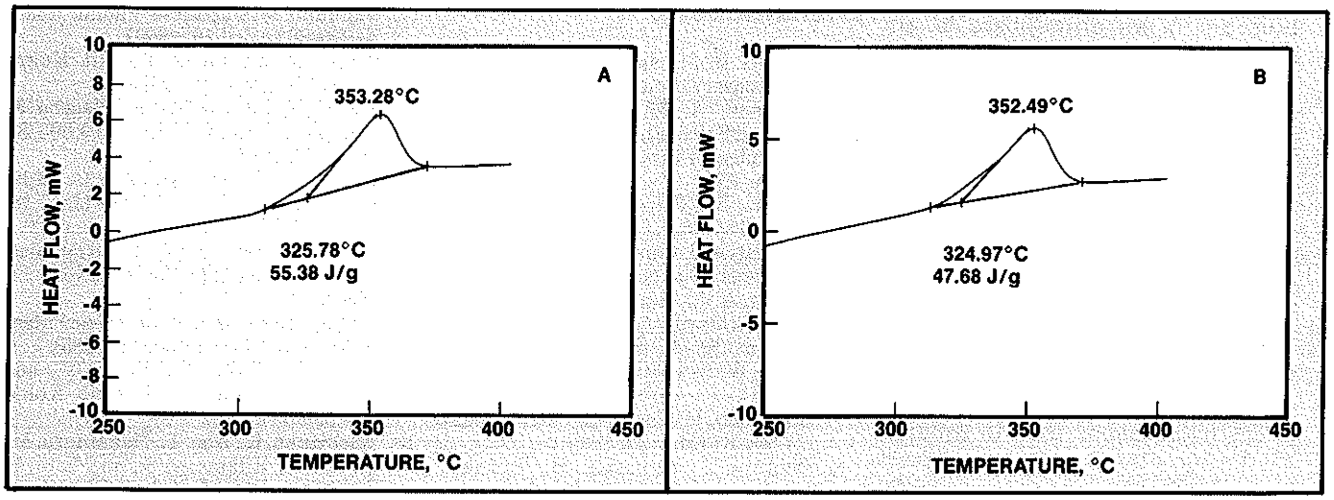
1. DSC scan of Samples 1-4, showing that the endotherm peaks of the treated samples occurred at lower temperatures than the corresponding controls



2. DSC scans of Samples 5 and 6, showing that the endotherm peaks of the treated samples occurred at lower temperatures than the corresponding controls



3. A section of the DSC scans of Sample 5 (A) and Sample 6 (B), showing the exotherm peak of an untreated sample



IV. Physical properties of the untreated and hydrocarbon-treated handsheets

Treatment	Basis weight, g/m²	Caliper, mm	Density, g/cm³	Opacity, %	Mullen, kPa	Tear, mN	Tensile, N/cm	Strain, %	Breaking length, km	Gloss, %	Printsurf F/W S10, µm
Untreated and uncalendered	54.3	0.205	0.265	98.0	2.1	6.85	22.6	1.89	4233	2.92	9.21
Treated with 7.1 kg of hydrocarbon per ton and uncalendered	55.2	0.207	0.267	98.2	2.01	7.02	23.0	1.85	4245	3.16	9.29
Untreated and calendered	55.9	0.105	0.534	98.4	2.04	5.36	21.1	1.91	3844	11.38	3.39
Treated with 7.1 kg of hydrocarbon per ton and calendered	54.8	0.103	0.533	98.3	1.9	5.02	21.1	1.74	3982	11.5	3.49

Experimental procedures

Handsheets (Noble and Wood) were made using headbox stock from one of our newsprint mills. Some of the handsheets were treated with the petroleum hydrocarbon in the form of spray on the top surface before and after cold pressing. Consistencies of the sheets after pressing between felts and drying in the rotary drum dryer were measured. Several of the untreated and hydrocarbon-treated handsheets were also used for TGA and DSC measurements. Physical properties of the handsheets before and after calendering of the untreated and treated sheets were measured.

Water retention values of the fiber pads formed in a Buchner funnel with or without treatment with the hydrocarbon were also measured at 900 *g* for 30 min using a centrifuge (*21*).

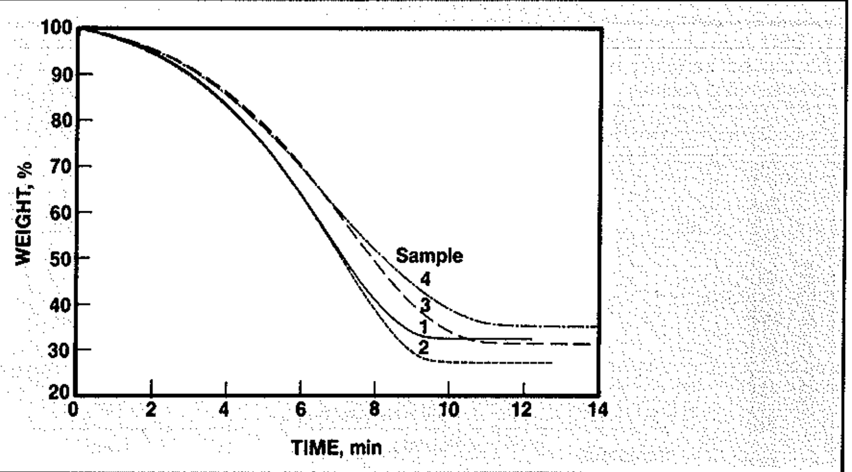
Thermogravimetric analysis was carried out using a Dupont 951 Thermogravimetric Analyzer and a 9900 program in an atmosphere of air flowing at a rate of 100 cm³/min.

A set of samples were heated at 10°C/min up to 86°C and was then held isothermally at this temperature. Another set of samples were heated at 10°C/min up to 140°C.

Differential scanning calorimetry measurements were carried out using a Dupont 910 Differential Scanning Calorimeter with a 9900 program. Samples were heated at 10°C/min up to 250°C or 400°C in an atmosphere of air flowing at 100 cm³/min.

The hydrocarbon used to enhance the drying of the sheet was a commercially available, water-immiscible, petroleum product that was a mixture of petroleum hydrocarbons, mainly isoparaffins, with a boiling temperature in the range of 350-400°F.

4. TGA scans of Samples 1-4



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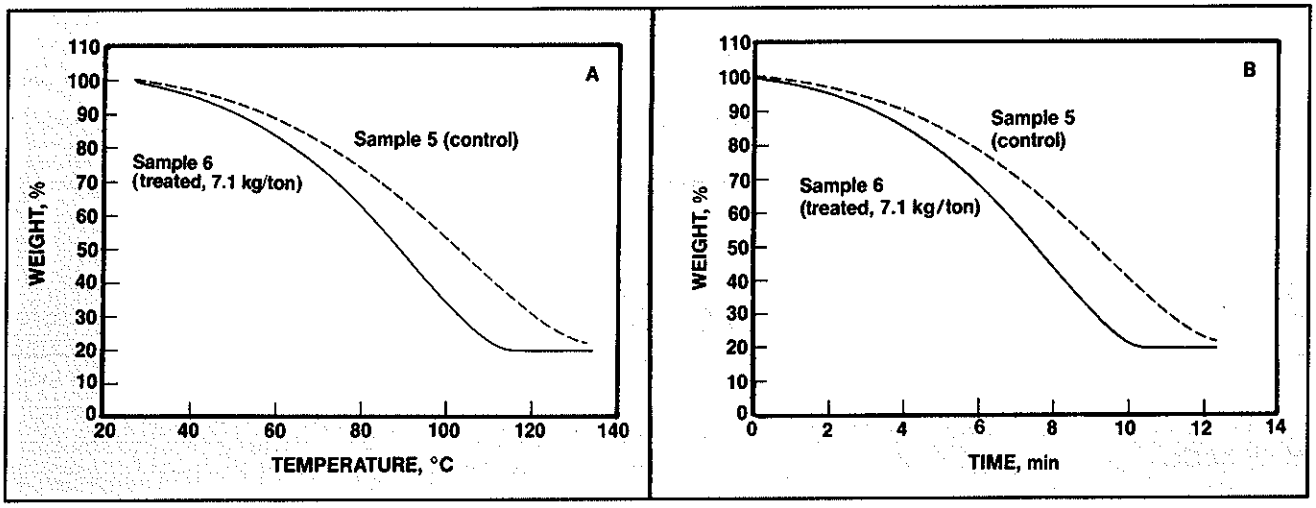
5. TGA scans of Samples 5 and 6, plotted on time (A) and on temperature (B)



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