Paper compatibility with next generation ink-jet printers

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Typical office papers were studied to determine printing quality and compatibility with modern ink-jet printers.

The latest generation of ink-jet printers differs significantly from those introduced only a few years ago. These new printers are much less paper sensitive and, in fact, claim to print letter-quality text and graphics on "plain papers." Plain papers are defined in this application as the copier and bond papers commonly found in the office environment. Although we have found that these printers performed acceptably on many U.S. office papers, a substantial variation in print quality was observed. Indeed, some office papers yielded unacceptable print quality on these second-generation printers.

The objective of the study reported here was to determine the properties of papers responsible for this print quality variation.

Thermal ink-jet technology

Hewlett-Packard's DeskJet, DeskJet Plus, and Canon's BJ-130 typify these new second-generation plain paper ink-jet printers. Each of these drop-on-demand printers uses electrical energy to boil a small volume of ink, which provides momentum to eject an ink drop. Arrays of drop generators form the printing engine. The inks used in these printers are typically a solution of water, a soluble dye added as colorant, and a humectant such as diethylene glycol. Optimum print quality is achieved on copier and bond papers by proper ink formulation and design of the drop characteristics.

For example, one ink-jet printer introduced just five years ago produced drop volumes of approximately 220 picoliters at 96 dots per inch (DPI). Because of this low resolution, optimum print quality was obtained only on very absorbent papers designed specifically for the printer. This special paper allowed the ink drop to expand to a dot diameter approximately four times larger than the theoretical in-flight drop diameter. In contrast, second generation printers have a much higher resolution of 300 DPI and above. They produce tightly controlled drop volumes near 140 picoliters and depend only on a factor of two for the spread of the ink drop on office papers. Decreasing the dot spread needed for optimum print quality reduces the printer's dependence on the paper enabling these second-generation printers to print on the wide range of papers found in the office[1].

Test methods and procedures

The objective of this study was to show which properties of office papers correlated with print quality in second-generation ink-jet printers. Twenty U.S. copier and bond papers were selected for this work, independent of their respective importance in the market. In addition, two ink-jet papers were included to contrast the properties of these special papers with those of plain office papers.

All paper samples were tested for print quality, chemical constituents, and physical properties. Print quality was evaluated by a committee of judges composed of nine typical office workers, not trained scientists. The panel compared the paper samples to the print quality standards shown in **Fig. 1**. Each paper sample was printed on three different sheets, and each sheet was submitted to the print quality committee at three different times. A print quality rating for each sample was obtained by averaging all ratings from the committee. Photographs of print samples with "acceptable" and "unacceptable" print quality are shown in Fig. 1.

Physical properties were tested using TAPPI test methods under controlled environmental conditions. Penetration rates were measured using a commercial instrument based on the Bristow concept from Noram Instruments (Point Claire, Que.). All penetration rates were measured using ink-jet ink as the penetrant. Contact angle measurements over time were obtained using water and ink-jet ink.

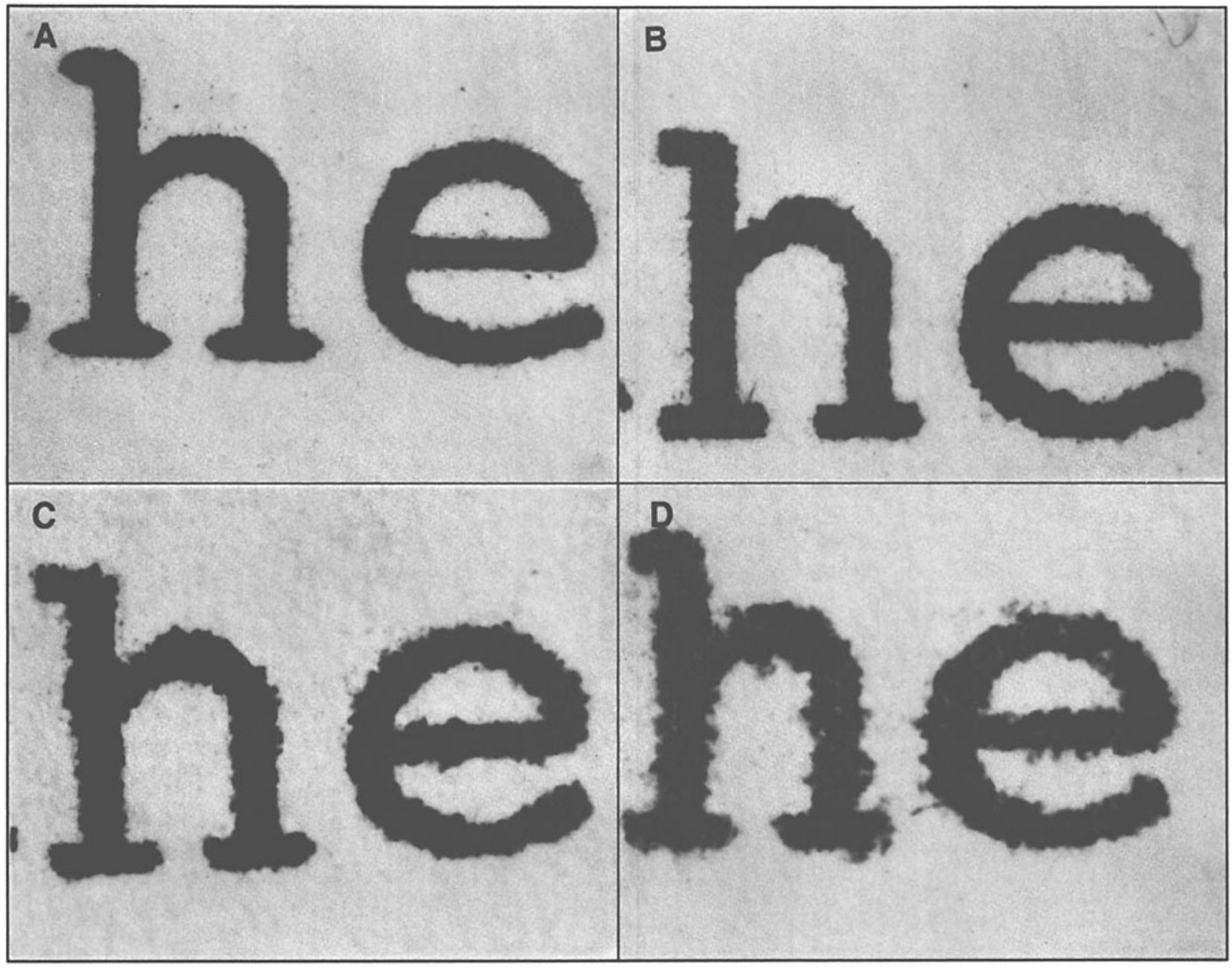
Results and discussion

As summarized in **Table I**, porosity, ash level, and optical properties of papers showed no correlation with observed print quality. Smoothness also showed no correlation; print

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[1]Bares, S. J., Printing on Plain Paper with a Thermal Ink-Jet Printer, Hewlett-Packard Journal (1988).

1. Samples of print quality: (a) is a print standard defined with print quality = 8; (b) is a print standard defined with print quality = 5; (c) is a print sample determined by the committee to be "acceptable" (3.3± 0.8); (d) is a print sample determined by the committee to be "unacceptable" (0.1± 0.3)



quality on paper samples spanning the range from 135 to 352 were judged to be quite good. Meaningful correlation was found only in those tests which probed liquid penetration. **Figure 2** shows how print quality depends on the ink penetration rate as measured by the Bristow technique[2]. Only papers with ink penetration rates less than 0.25±0.05 $mL/m^2s^{1/2}$ produced acceptable or better print quality. Special ink-jet papers, which can have penetration rates over ten times greater than normal office papers, yielded poor print quality on second generation ink-jet printers.

All liquid penetration rates are controlled by the sizing levels of office papers. The significance of the surface penetration rate, as measured by the Bristow apparatus, suggests that surface sizing plays a dominant role in determining ink-jet print quality. Contact angles, which help to determine penetration rate, also showed good correlation to print quality. Instead of measuring just the surface sizing level, the total sizing level of a paper, determined by the Hercules Size Test (HST), is commonly measured. Because of the scatter in the data shown in **Fig. 3**, HST proved unreliable in predicting paper performance even though increasing the total sizing level generally improved ink-jet print quality. The same results were obtained using either standard sizing solution or ink-jet ink in the HST.

Conclusions

In plain paper ink-jet printers, print quality is dependent primarily on ink penetration rate. Papers with penetration rates above 0.25±0.05 $mL/m^2s^{1/2}$ will not produce acceptable print quality regardless of their other properties. Print quality on papers with penetration rates below this level will vary between "acceptable" and "excellent." These specifications can have a dramatic effect on the performance of office papers in second-generation ink-jet printers.□

[2]Lyne, M. B., and Aspler, J. S., Wetting and the Sorption of Water by Paper under Dynamic Conditions, Tappi J. 65(12): 98(1982).

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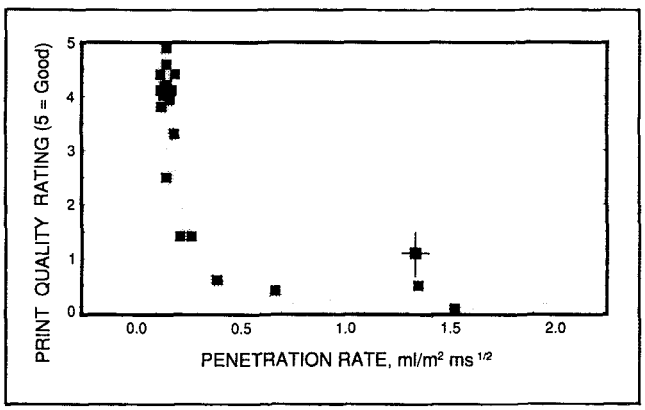
I. Print quality and physical test results of papers used in this study

Code	Paper type	B.W. 1300 ft²	Caliper 0.001 in.	Brightness, %	Opacity, %	Smthns, s.u.	Porosity, mLs/min	Parker Print Surf, 10kg	Herc. Size Test, 10kg	Contact angle after 120 sec mL/m² avg.	Contact angle after 120 sec ms½ Std. dev.
1	Ink-Jet	20.0	4.24	87.2	89.0	218	175	6.28	0	0	0
2	Ink-Jet	20.2	4.36	88.6	85.3	173	153	5.23	0	0	0
3	#1	20.2	5.21	90.4	85.2	352	144	8.29	318	93.9	62.5
4	Prem. #1	20.0	4.60	90.1	82.3	272	162	7.66	190	92.1	65.0
5	Prem. #4	20.1	4.39	85.6	88.8	205	270	6.36	133	71.4	36.9
6	Prem. #4	19.8	4.08	83.3	88.2	136	211	5.74	61	93.0	52.4
7	Prem. #4	20.5	4.26	83.4	87.9	137	144	5.85	125	93.5	57.2
8	#4	20.4	4.04	80.0	88.2	129	197	5.64	74	94.0	63.8
9	#4	20.1	4.02	82.5	91.4	171	202	6.55	3	0.0	0.0
10	Prem. #4	20.7	4.08	84.6	87.9	135	136	5.43	124	100.2	70.1
11	#4	20.0	4.16	82.4	87.1	250	242	7.46	51	102.6	69.5
12	#4	20.0	41.8	79.2	88.1	161	244	6.22	38	94.0	68.5
13	Prem. #4	19.9	4.22	82.7	88.3	174	169	6.49	10	48.2	13.0
14	#4	20.2	4.17	81.5	82.0	178	222	6.29	3	0.0	0.0
15	Prem. #4	20.1	4.18	83.4	88.8	152	243	5.75	8	28.3	0.0
16	Prem. #4	20.4	4.30	82.0	88.6	221	267	6.77	90	101.9	74.1
17	Prem. #4	20.0	4.49	82.4	91.9	214	298	6.50	3	0.0	0.0
18	Prem. #4	19.7	4.15	84.2	86.7	170	138	6.80	114	96.9	69.4
19	Prem. #4	20.3	4.29	82.6	87.1	231	206	6.64	178	85.8	67.5
20	#1	20.1	3.89	83.0	87.0	153	156	5.96	64	98.3	64.0
21	Prem. #4	20.5	4.07	84.8	87.7	163	140	6.52	122	101.2	70.6
22	#4	21.1	3.98	85.2	87.0	140	278	5.31	171	70.3	51.2

I. Continued

Bristow penetration mL/m² avg.	Bristow penetration ms½ Std. dev.	Ash, %	Fiber length, mm	Panel print, avg.	Judge quality, st. dev.
5.5	0.8	8.24	1.02	1.1	1.2
5.9	0.5	4.20	1.08	0.5	0.8
0.121	0.013	2.80	0.79	4.4	0.8
0.151	6.29	0.97	4.6	0.8	0.8
0.216	0.018	8.67	1.38	1.4	1.1
0.140	0.004	10.45	0.99	4.0	0.8
0.149	0.010	9.78	1.07	2.5	0.9
0.193	0.003	0.93	4.4	0.9	0.9
1.340	0.055	10.68	0.83	1.1	0.9
0.151	0.015	9.47	1.07	4.9	0.9
0.189	0.002	12.54	1.38	3.3	0.8
0.143	0.003	9.31	0.93	4.2	0.7
0.397	0.013	11.88	1.45	0.6	0.9
1.524	0.006	8.83	1.03	0.1	0.3
0.674	0.072	8.80	1.04	0.4	0.7
0.175	0.019	8.77	1.12	4.1	1.2
1.351	0.083	11.80	0.94	0.5	0.7
0.138	0.008	9.09	1.05	4.1	1.3
0.141	0.003	8.80	1.31	4.2	1.0
0.146	0.003	8.48	1.14	4.1	1.0
0.123	0.004	9.75	1.13	3.8	0.6
0.269	0.014	9.79	1.29	1.4	1.1

2. Observed ink-jet print quality on office papers plotted versus the ink penetration rate as measured by the Bristow technique



3. Observed ink-jet print quality on office papers plotted versus the sizing level (determined by Hercules Size Test).

