Improvement of Ink Jet Printer Performance by Modifying Office Papers

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Introduction

Since 1989, Hewlett-Packard (HP) has worked with the paper industry to understand and improve the image quality of inkjet printing on commonly available office papers . This effort has grown into what is now called the Office Paper Program (OPP). OPPcurrently interacts with key members of the paper industry with the charter of removing "plain paper" performance and variability as customer dissatisfiers.

HP currently markets two different types of inkjet printers for desktop use. The top end printers (PaintJet XL 300, DeskJet 1200C) use a quartz bulb to heat the paper prior to imaging. This results in improved media independence because the ink vehicle is vaporized before wicking and color bleed can occur. However, the lower cost DeskJet 500, DeskJet 500C and DeskJet 550C (and the DeskWriter series for Macmtosh) do not use a heater. To produce excellent print quality, these printers are more dependent on the physical and chemical properties of paper . OPP's efforts are focused on improving paper performance in these printers.

Print Quality Defects

Inkjet print quality (PQ) is the result of several interactions:

* ink <—> paper (e.g. wicking);
* pen <—> paper (e.g. spray); and
* pen <—> printer (e.g. carriage drive accuracy).

One of the first tasks confronted by OPP was to understand how to differentiate between these interactions so that paper effects couldbe isolated. This was accomplished by 1) developing a detailed description/explanation of each defect and 2) creating a "sprayless" test pattern for wicking evaluation. These were then shared with the paper industry.

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There are three principal PQ issues associated with commonly available office papers: wicking, color bleed and variability.

Wicking

The most noticeable PQ defect associated with monochrome ink jetprinting is winking or feathering. This defect (figure 1 a) is caused when ink flows along or within cellulose fibers, forming an image where none was intended This defect is observed to avarying degree in papers world-wide (figure 2).

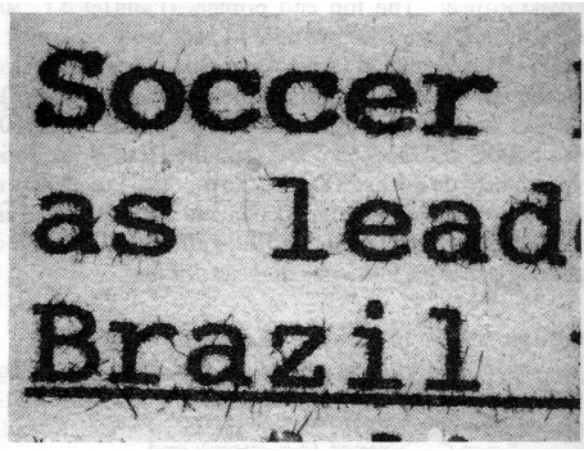

Figure 1a. Example of Wicking

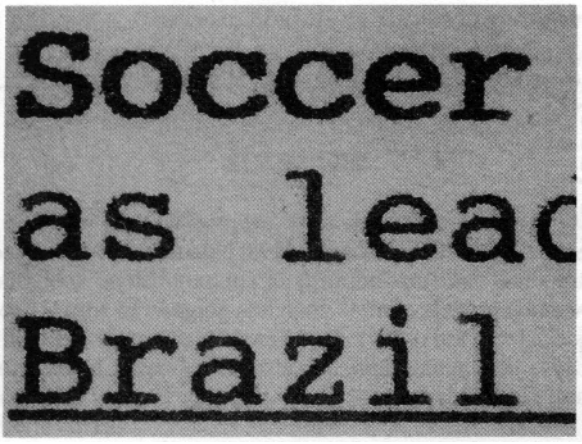

Figure 1b. Same paper after improvement

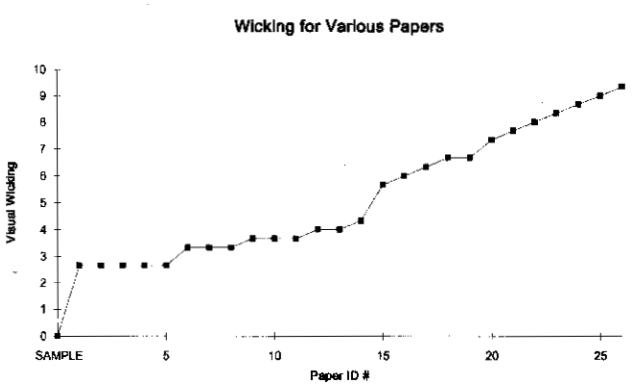

Figure 2. Wicking for various papers

Color Bleed

When color images are printed with inkjet, the most noticeable problem is bleed, where one of the three color Inks (cyan, magenta or yellow) mixes before drying with an adjacent ink. This is most noticeable when one of the colors is composite black, which is made up of equal amounts of each color ink. This defect is observed as a blurring of the intended boundary between colors (figure 3).

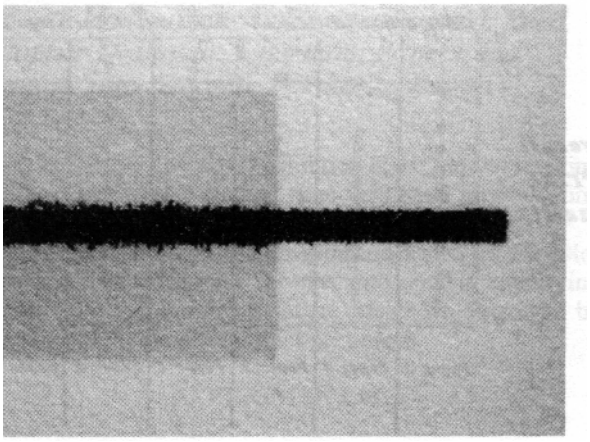

Figure 3. Example of color bleed

Variability

Significant variation in ink jet performance is also observed in certain papers. Figure 4 illustrates this variability for overall print quality. This variation is present both within a ream and from carton to carton of paper. This indicates that paper machines are not being controlled with respect to inkjet quality both across the width of the machine (cross direction or CD) and from day-to-day (machine direction or MD).

IIP Approach to Improving Paper

OPP initially worked in parallel on two general tasks to influence the paper industry to modify paper to be ink jet "friendly": 1) establish working relationships and 2) develop ink jetprinting standards . Printer users were also consulted for guidance during this process.

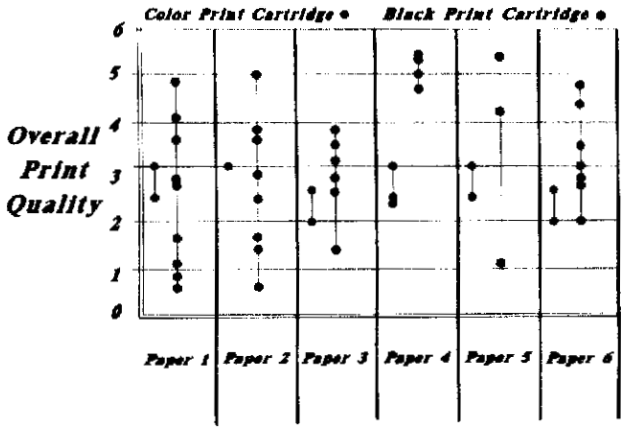

Figure 4. Variablity within reams

Paper Partners

Beginning in 1991, meetings were held with paper manufacturers in the US, Europe and Asia to discuss ink jet printing technology, its growth, its impact on desktop printing and its future direction. Subsequent meetings were held to review progress on improvement to papers and to discuss marketing programs to make HP customers aware of the papers. OPP also established relationships with key paper merchants because these distributors have frequent direct contact with desktop publishing customers.

Table 1. Paper Chemcial Additives

Chemcial Type	Examples	Use	Effect on InkJet Print Quality
Filler	PCC[1], Clay TiO[2]	Replaces fiber Increases brightness Increases opacity	Possible effect on drytime
Stock Sizing	ASA[2], AKD[3] Rosin	Modifies water repellency	Wicking, Bleed
Surface Sizing	Starch SMA[4]	Modifes water repellency	Wicking, Bleed

[1]Precipitated calcium carbonate
[2]Alkenyl succinic anhydride
[3]Alkyl ketene dimer
[4]Styrene maleic anhydride

The third key partner in OPP's efforts are the paper chemical companies. In addition to cellulose fiber, several types of chemicals are added to paper to improve performance and reduce cost. Some of these are shown in Table 1. OPP is working with these companies to better understand the effect of these products have on ink jet performance.

Acceptance Criteria

A key subject during meetings with the paper industry was the review and approval of the *Paper Acceptance Criteria for the HP DeskJet500C (Criteria).* The first edition of this document was distributed in

November 1992. It provides the paper industry with several tools to measure inkjet print quality. The first is a specification covering 30 attributes of ink jet printer performance (Table 2). Additionally, the *Criteria* specify or define the test methods to be used to measure each of the specified parameters. This document also contains a brief description of ink jet technology and color science. The last section ofthe *Criteria* describes the User Survey that formed the basis for setting the specification limits. This survey was international in scope and included participants with a mix of job type, age and gender. The four attributes evaluated were black text appearance, black optical density, color bleed and hue preference.

The *Criteria* also includes discs containing five test files that allow users to perform onsite evaluation of ink jet paper performance.

A copy of the *Criteria* may be obtained by sending a request to: Hewlett Packard, Office Paper Program, 16999 West Bernardo Drive M/S 61U66, San Diego, CA 921271899, or call (619) 592-4460.

Acceptance by IIP

The results from one paper trial to improve ink jet print quality are shown in Figure lb. If a paper meets the *Acceptance Criteria* specifications it is recognized by HP as a qualified paper. HP is considering marketing programs that would make current and new printer customers aware of this paper's performance.

Note that the changes requested in papers to improve ink jet print quality are not at the expense of any other performance factor. The resulting products are"multi-purpose papers" that will function well in xerographic copiers, laserprinters and ink jet.

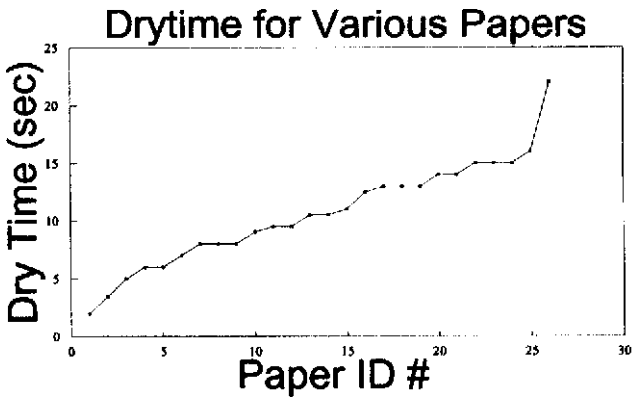

Figure 5. Drytime for various papers

Table 2. Minimum print quality specifications and test methods.

Parameter	Specification	Text	Method	Reference
Black				
Text	≤ wick # 4	2.1.2	visual	fig. 1.4
Optical Density	OD_{min} ≥1.2 %D<8	2.2.1	measurement	
Mottling	None allowed	2.2.2.1	visual	fig. 1.5
Cascading	None allowed	2.2.2.2	visual	Fig. 1.6
Bronzing	None allowed	2.2.2.3	visual	
Color-to-Color Bleed				
Black to yellow	until 4/94 ≤ bleed #5	3.1.2	visual	Fig. 2.3
Black to yellow	after 4/94 ≤ bleed #3	3.1.2	visual	Fig. 2.3
Color Appearance				TAPPI T524-om-86 & fig.s
red	score > 0	3.2.4.1	measurement	fig. 5.1-5.2
yellow	score > 0	3.2.4.1	measurement	fig. 6.1-6.2
green	score > 0	3.2.4.1	measurement	fig. 7.1-7.2
cyan	score > 0	3.2.4.1	measurement	fig. 8.1-8.2
blue	score > 0	3.2.4.1	measurement	fig. 9.1-9.2
magenta	score > 0	3.2.4.1	measurement	fig. 10.1-10.2
composite black	OD ≥ 0.90	3.2.2	measurement	
Mechanical Performance				
sheet feed		4.1	operational	
missed-feeds*	≤ 2 failure in 1000			
multi-feeds*	≤ 2 failure in 1000			
jams*	≤ 1 failure in 1000			
*total combined	≤ 2 failure in 1000			
skew	≤ 0.06 mm/cm	4.2	operational	
wet cockle	≤ 1 failure in 1000	4.3	operational	fig.s 11 & 12
Black Waterfastness	D OD ≤ 0.20	5.1		fig. 13
Black Highlighter Smear	D OD ≤ 0.20	5.2	measurement	fig. 14
Lightfastness				fig. 15
black	D E* ≤ 10	5.3	measurement	TAPPI T524-om-86
red	D E* ≤ 60	5.3	measurement	TAPPI T524-om-86
green	D E* ≤ 50	5.3	measurement	TAPPI T524-om-86
blue	D E* ≤ 70	5.3	measurement	TAPPI T524-om-86
cyan	D E* ≤ 60	5.3	measurement	TAPPI T524-om-86
yellow	D E* ≤ 30	5.3	measurement	TAPPI T524-om-86
magenta	D E* ≤ 85	5.3	measurement	TAPPI T524-om-86
composite black	D E* ≤ 50		measurement	TAPPI T524-om-86

Future Paper Requirements

As ink jet technology continues to mature, there will be new demands placed on paper. In particular, the rate at which ink can be applied to paper will exceed the rate of drying, leading to smearing for stacking paper paths. The rate of drying varies widely across US and international papers (figure 5). OPP is working with HP's ink development teams to insure that paper chemistry is a part of ink design. Research and development by the paper industry is also underway to quantify and improve drytime performance.

A specification and measurement method for dry time will be added to the *Acceptance Criteria* during 1993.