Greener Ink Technology for Wide and Super-Wide Format Inkjet Printing

Howard Doumaux, Phillip Cagle, Jorge Castaño Aspas, Hewlett Packard; San Diego, U.S.A.; Sant Cugat del Valles, Spain

Abstract

Hewlett Packard has recently introduced a novel water-based outdoor durable ink and printer solution for the wide and super-wide markets: the HP Designjet L65500. Printed images exhibit good lightfastness (with and without lamination), and durability similar to conventional solvent-based inks. The heated printing system enables imaging on a broad range of media designed for solvent ink printers, including inexpensive uncoated vinyl. Low cost, easily replaceable thermal inkjet print heads provide excellent service life and high reliability. The ink is water-based, low VOC, and HAPS-free, and as a result, no special ventilation systems are required. Image durability is provided by a novel synthetic polymer dispersion. The ink formulation and printer design considerations enabling this breakthrough technology will be discussed, including ink durability, printer dryer design, and print head reliability.

Introduction

The wide and super-wide format outdoor printing space is currently supported by two primary ink technologies: solvent and UV curable. Each technology has unique advantages, and will continue to compete in the large format market for years to come. Despite many obvious advantages with respect to environmental stewardship, aqueous ink technologies have not made a significant impact in outdoor printing to date. Aqueous inks have traditionally been restricted to indoor applications due to reduced image durability, higher cost per copy, slower printing speeds, and the inability of many commercial printhead technologies to tolerate aqueous fluids.

HP recently introduced Scalable Printing Technology (SPT), a high speed thermal inkjet printhead technology capable of serving multiple market segments, from home/office printers up to high speed industrial and commercial applications. Advances in manufacturing processes allow low cost production of SPT arrays with a high nozzle packing density of 1200 nozzles per inch. The new 4.25" HP Widescan printhead with SPT technology contains 10,560 nozzles. This high nozzle count enables very high throughput. In order to take advantage of this printing speed in the wide format market, a new aqueous ink technology and printing system were developed.

This paper describes the new Hewlett Packard Latex ink technology and the Designjet L65500 printing system. The ink and the printing system were engineered together to create a new printing technology capable of high speed printing on a wide range of inexpensive large format solvent medias, with a level of image quality, permanence, and durability that matches solvent inks but with a greatly reduced environmental impact.

Latex Ink Technology

Inks for outdoor applications have a number of requirements that are significantly different than traditional aqueous inks used for indoor graphics. The ink must be able to adhere to non-porous uncoated media like vinyl banner, and provide a lightfast, durable ink film that is not only waterproof, but resistant to scuffing and attack by cleaning products.

Solvent inks are well-suited to the challenges of outdoor applications. Solvent inks are capable of wetting out low surface energy media like vinyl. They generally use soluble inexpensive copolymers like PVC/PVOAc as pigment binders. These materials are water-insoluble, scratch resistant, and have excellent adhesion to vinyl. The solvents used in solvent vehicles are designed to attack vinyl for maximum adhesion and improved drying while still retaining pigment dispersion stability and printhead reliability.

Despite these advantages, solvent inks can have environmental, health, and safety (EHS) issues from solvent emissions, and the inks are coming under increasing regulatory pressures. Manufacturers have responded to these issues by developing friendlier formulations (e.g. "low", "lite", "mild", "eco", "bio" -solvent inks), typically moving from more volatile HAPs-containing solvent systems to non-HAPs, lower volatility systems with better occupational exposure limits.

HP feels that the market will move toward aqueous ink technology capable of solvent ink performance on outdoor media. We will provide more focus on this technology over solvent base systems. Aqueous inks are low cost and generally have a preferable EHS profile. Aqueous inks have a number of disadvantages relative to solvent inks that make this a challenging problem. Adhesion and rub resistance, drying vs. image quality, and long-life printhead reliability were all issues faced during the development of the HP Latex ink technology.

HP Latex inks contain pigmented colorants, a proprietary latex, co-solvents, surfactants, and water. The pigmented colorants were specially selected to provide excellent ink stability, high color gamut, competitive print permanence (also known as lightfastness), and high gloss. The proprietary latex polymer provides excellent durability to harsh outdoor conditions and mechanical abrasion, at a level competitive with prints produced by solvent printers. The co-solvents and surfactants work with the other ink components to optimize ink stability, printhead reliability, image quality, and print durability.

Drying and Vehicle Design

On nonabsorbent, nonporous media like vinyl, high speed drying is critical to control image quality. Contrary to widely held beliefs, many of the solvents used in wide format solvent inks are not highly volatile (and solvent volatility has been decreasing over time as manufacturers work to improve solvent emission profiles).

Table I shows a list of boiling points and relative evaporation rates for a few common solvent ink vehicle components. Even in high humidity, water is more volatile than most of the solvents used in wide format inkjet printing.

In addition to water, aqueous inks for drop on demand printheads also require lower volatility cosolvents for reliable printhead performance (wetting, decap, etc.). In thermal inkjet (TIJ) printheads, non-volatile materials are often added to control resistor interactions with pigments and polymers. Many traditional cosolvents used in TIJ inks have very high boiling points (> 280° C), and are effectively non-volatile, even in heated applications (Table 2). This is not an issue on porous media, since the cosolvents will wick into the media, but on non-adsorbent, non-porous plastic films like vinyl, the cosolvent will remain on the media surface, and the resulting water resistance will be poor. For printing on nonporous materials, the ink vehicle must either be substantially volatile, or the residual materials must be incorporated into the ink/media surface.

Table 1. Solvent ink solvent volatility.

Solvent	Boiling Point (°C)	Relative Evaporation Rate (n-BuAc = 1)
water	100	0.48 (0% RH) 0.09 (80% RH)
cyclohexanone	155	0.3
DPG methyl ether	188	0.035
2-butoxyethyl acetate	192	0.03
DEG ethyl ether	200	0.02
NMP	204	0.04
γ-butyrolactone	204	0.03
TEG monobutyl ether	304	<0.01

Table 2. Traditional TIJ cosolvent boiling points.

Cosolvent	Boiling Point (°C)
glycereth-26	>300
glycerol	290
tetraethylene glycol	314

The materials used in solvent inks tend to be excellent solvents for vinyl film (and good solvents for the soluble binders in the ink, all of which have solubility parameters similar to PVC). The initial drying of solvent inks occurs not only through evaporation, but also by absorption into the vinyl surface. While surface attack by the solvent improves adhesion of the ink film, there are some downsides: some solvent inks can attack thin self-adhesive vinyl to such an extent that the dimensional stability of the vinyl film is affected, and in some cases the adhesive on the back side can be impacted. While water will not attack plastic films, once the water evaporates from an aqueous ink, the residual cosolvents can attack the fluid interface for improved drying and ink adhesion, but without the negative impact to the media.

Ideal cosolvents for TIJ inks are water-soluble, but very few of these materials will attack vinyl. However, we were able to map out a 'toolbox' of cosolvents for printing on vinyl that would not only attack vinyl [1], but could also be removed with moderate heating (Figure 1). The lower cosolvent levels relative to solvent inks eliminate dimensional stability issues on thinner vinyl.

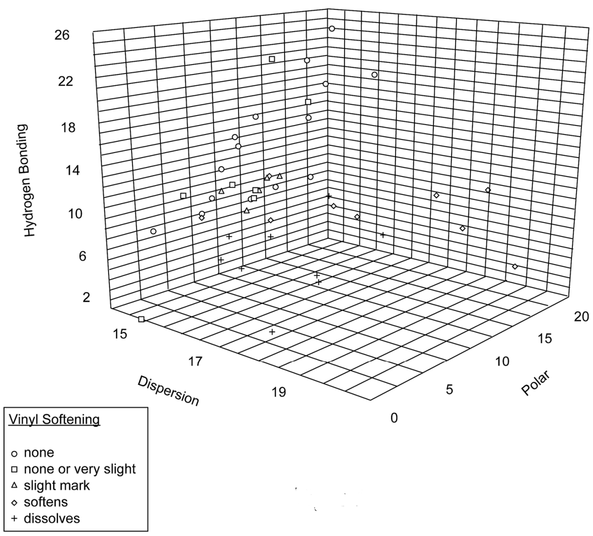

Figure 1. *Vinyl softening vs. Hansen solubility parameter.*

A number of these materials also proved useful as latex coalescents, which allowed the use of harder, high Tg latex binders that could be cured at reasonable temperatures and times:

Latex Minimum Film Formation Temperature vs. Solvent:

Water: 79°C
Cosolvent A: 75°C
Cosolvent B: 70°C
Cosolvent C: < 45°C

Environmental, health, and safety (EHS) concerns were another critical selection criteria for the cosolvents and other vehicle components in the HP Latex inks. We were able to balance the EHS constraints with the required performance to generate low odor, low VOC inks that do not contain hazardous air pollutants (HAPs) or carcinogenic, mutanogenic, or reproductive toxins (CMRs), and do not contain materials that would be considered hazardous waste.

Image Durability

Obtaining high water resistance from aqueous inks can be a challenge. Water-soluble resins tend to either have high levels of rewettability, or interact strongly with the resistor in thermal inkjet heads leading poor print reliability and quality. Latex polymer dispersions are an obvious approach, but historically have proven very difficult to jet reliably, due to resistor interactions and nozzle clogging. Through a combination of vehicle, polymer, and printer design, we have worked through many of the reliability issues that have plagued similar efforts in the past, allowing the HP Latex inks to provide solvent levels of durability combined with high reliability. Table 3 shows a durability comparison between the HP Latex inks in the HP L65500 printer with two solvent inks: the HP Designjet 9000s (low solvent), and a commercial "biosolvent" ink.

Table 3. Taber Linear Abraser wet and dry rub resistance (1 = no image damage, 2 = moderate damage, 3 = severe damage).

Test	HP Designjet L65500	HP Designjet 9000s	Commercial Biosolvent Ink
Water	1	1	1
Soap	1	1	1
Windex Blue® glass cleaner	1	1	2
Diesel	1	1	3
Gasoline	2	3	3
Isopropanol	2	2	3
Dry Rub	2	2	3

Two types of durability were tested: mechanical abrasion, and print permanence. Mechanical durability was assessed using a Taber 5750 Linear Abraser with two tips: a CS-10 rubber abrasive tip (to simulate scuff and scratch), and a polyester cloth wetted with a test fluid on a Crockmeter tip (to simulate wet rub by cleaners and other fluids). Various fluids were used to pre-wet the cloth prior to rub testing. Samples were rubbed 6 passes using a 600 g tip pressure, then graded on a 1 to 3 scale to assess damage: 1 (no image damage), 2 (moderate damage), and 3 (severe damage). The HP Latex ink has similar durability as the HP Designjet 9000s low solvent ink, and significantly better durability than a commercial 'biosolvent' ink.

L65500 Printer Design

The Designjet L65500 printer is the first implementation of the new HP Latex technology, and it includes a set of new drying subsystems to enhance and optimize the print quality, and cure the latex ink film.

Image Quality Control

Since the ink does not absorb into vinyl and other traditional outdoor media designed for solvent inks, high-speed printing requires that the ink be partially dried as it is laid down, otherwise the ink droplets tend to coalesce and flow, leading to inter-color bleed and area fill uniformity issues. The HP L65500 printer is a 104" scanning system where the printhead moves orthogonally to the media advance. Figure 2 shows a schematic of the printer. Three HP Widescan printhead modules (4) containing 31,680 nozzles are mounted on a carriage (1). As the carriage scans and prints across the swath, radiant heat (2) and airflow (originating from the curing module) are applied to the freshly printed image in order to "pin" the ink and control image quality. The printheads are staggered relative to each other to maximize the print zone drying time between carriage passes. The printed image then advances through the curing module (3), where additional radiant heat and fresh airflow complete the drying and cure the ink. After passing through the curing module, the ink is completely dry and ready for use. To move the wide media rolls, the motorized input and output rollers are controlled with a new Optical Media Advance Sensor (OMAS). The OMAS can detect and correct for media advance variability for banding-free output.

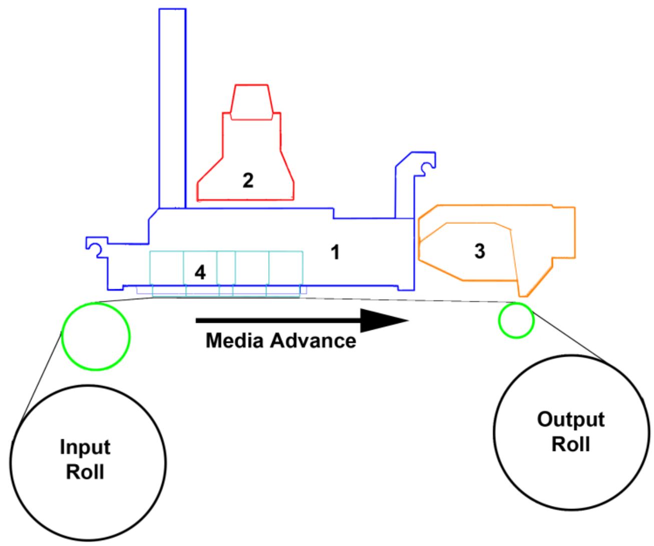

***Figure 2**. Schematic of the HP L65500 printer carriage and dryer.*

Figure 3 shows the temperature profile of the media in the drying (2) and curing zones (3), and Figure 4 shows the relative rate of water and cosolvent evaporation throughout the process.

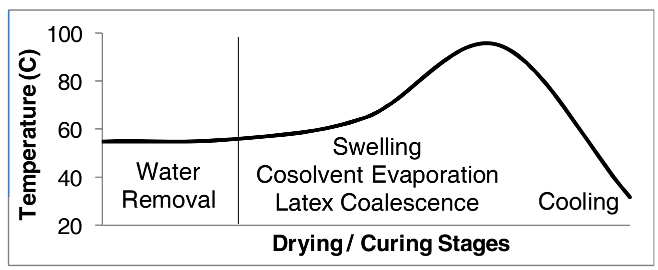

***Figure 3**. Temperature evolution throughout the drying and curing process.*

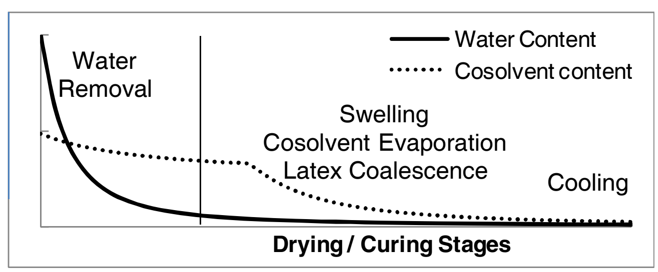

***Figure 4**. Relative rates of water and cosolvent evaporation in each drying stage (water and cosolvent loss are not on the same scale).*

Conclusions

HP Latex inks are the first "no compromises" aqueous ink solution for the outdoor wide format market, combining solvent ink levels of light fade and durability with a lower overall environmental impact at a competitive cost. The ink technology is enabled by new subsystems in the HP Designjet L65500 printer that ensure high image quality control, fast throughput, and long-life reliability.

References

[1] Phillip Cagle, U.S. Patent Application US2007/0084380.

Author Biography

Howard Doumaux received his B.S. in Chemical Engineering from Lehigh University in 1989, and his PhD in Chemical Engineering from the University of Minnesota in 1995. Howard has worked at Hewlett Packard as an ink chemist since 1997. While at Hewlett Packard Howard has worked with a wide range of ink chemistries utilizing both dye and pigment colorants, and has been awarded eight U.S. patents.

Phillip Cagle received his B.A. in Chemistry from the College of Wooster in 1987, his Ph.D. in Inorganic Chemistry from the University of Illinois at Urbana-Champaign in 1992, followed by postdoctoral studies at the University of Utah. Phillip has worked at Hewlett Packard as an ink chemist since 1995, working on a range of pigmented ink technologies, including polymer development and UV curable inks.

Jorge Castaño received his B.S. in Applied Physics from Universidad Autonoma de Madrid in 1990, and made Ph.D. studies in Surface Sciences in Universidad Complutense de Madrid in 1995. Jorge has worked at Hewlett Packard since 1995 in large format printer and writing system design, and has been awarded eleven patents.