The Printing Technology of the Tektronix Phaser® 340

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Abstract

With the Phaser® 340 Color Printer, Tektronix commercialized a new high speed color printing process. The method and resulting engine architecture result from the combination of solid ink jet printing with drum-based off set printing. The benefits of this printing technology are plain paper printing in full color at multiple page per minute speeds and exceptional transparency quality. The basic elements of the engine include proprietary phase change inks, a page-wide print head, offset drum and transfer roller. A review of the engine architecture and its relationship to printer performance will be presented. Additionally, the characteristics of the core technology components will be summarized.

Introduction

The Phaser® 340 printer fills a long needed requirement for high speed color printing on plain paper. The printer's media independence is inherent in the solid ink technology that forms a basis for the product. Solid or hot melt inks have been previously commercialized by Tektronix, Brother, Dataproducts and Howtek. Except for Howtek, these previous products embodied a mechanism architecture that involved a shuttling print head much like the typical dot matrix impact printer. Commercial versions of the technology were limited to about one page per minute by this architecture because of the relatively large print heads and paper handling time overhead. Since ink solidification times are typically tens of milliseconds, print speed has not been limited by drying time. The Phaser® 340 embodies a new printing architecture that exchanges the high speed surface from the print head to the medium printed upon. This approach results in multiple page per minute printing speeds and the product features shown in Table I below.

Overhead transparency quality also has been limited for solid ink printers. Previously, Tektronix has used cold pressured fusing and lamination post processing to overcome the degradation caused by the spherical lenslets formed by solid ink drops. Brother/Spectra has also addressed this issue by re-heating and quenching the ink after transparencies are printed. The new printing process of the Phaser® 340 printer offers significant improvement in transparency quality, over these previous approaches without resorting to a post processing step.

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Table I. Phaser® 340 printer features

Print Speed:	4 ppm, 300 × 300 mode full color 2 ppm, 600 × 300 mode full color all transparency mode
Media:	A/A4 format Plain paper (16-32 lb auto feed/up to 80 lb. manual feed) Overhead transparency
Controller:	Adobe postscript level II with AMD 29030 RISC processor

Printer Architecture

The basic architecture of the Phaser® 340 printer involves using the print substrate as the fast axis, rather than the print head as embodied in serial printer architectures. Then, in order to further increase printing speed, ink jet nozzles are distributed across the page wide print drum and the print head is displaced twice the distance between nozzles (for interlacing). In order to increase the printing speed further and avoid complexity of paper handling, the printing is accomplished in offset fashion by first printing on an aluminum drum coated with silicon oil then transferring to the media. This arrangement, shown in Figure 1, allows multiple page per minute print speeds and the first embodiment is capable of 4 ppm.

The print head is a single device carrying all four colors, and the arrangement of nozzles arranged in four rows as shown in Figure 2.

Phase Change Ink

The ink formulation must satisfy the combined requirements of good color quality and durability on the media, of jettability in a piezo electric driven drop on demand ink jet device and of transferability from the print drum to the media. These requirements are summarized in Table II.

An ink formulation that satisfies the above constraints was constructed from materials used in prior phase change inks[1]. This formulation is summarized in Table III below. Dyes are added to the listed base materials to form yellow, magenta, cyan and black inks. As noted by Titterington et.al.[7] ink formulations derived from the teachings of Jaeger et.al.[1] were not acceptable for the new printing process.

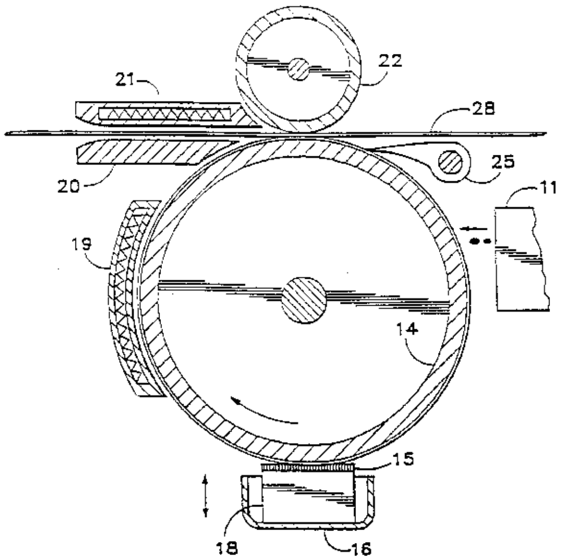

Figure 1. Phaser®340 Printer Architecture[8]

11 - Print Head, 14 - Print Drum, 16 - Silicone Oil Applicator, 19 - Drum Heater, 20 - Media Pre-heater, 22 - Transfer Roller, 25 - Media Stripper Fingers, 28 - Media

Print Head

The page-wide print head is capable of producing both 300 dpi × 300 dpi and 600 dpi × 300 dpi drops. It is piezo driven in the bending mode and is constructed from materials compatible with the ink. It was designed to achieve an imaging time of approximately 10 sec at 300 dpi. This was accomplished with 4 rows of 88 nozzles, each capable of up to 11,000 drops per second in the 300 dpi × 300 dpi mode. The 600 dpi × 300 dpi mode is accomplished through a wave form adjustment that reduces drop mass to approximately 65% of the 300 × 300 value. This mass reduction follows the method disclosed in a European patent application[3] by Burr et.al. The smaller mass is achieved by altering the spectral characteristics of the drive wave form so that a higher order mode of meniscus deformation is achieved. This concept is shown in Figure 3.

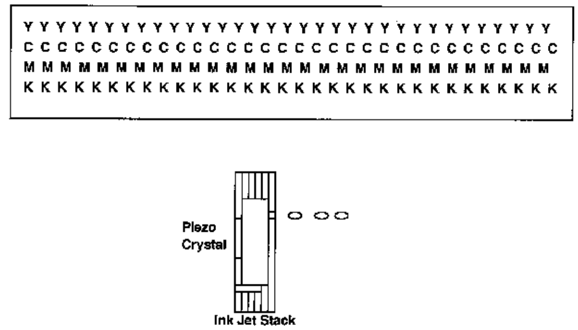

Figure 2. PCage-wide print head nozzle Arrangement

Y-Yellow nozzles, C-Cyan Nozzles, M-Magenta Nozzles, K-Black Nozzles

The fabrication technology employed in the page wide print head has been reported previously[2]. That is the 352 nozzle device is formed by diffusion bond/braze of etched stainless steel plates. The features in these plates form manifolds, ink inlets, pressure chambers and ink outlets for each device. When joined by the bonding process, hermetic seals are achieved.

Solid ink print heads are susceptible to performance degradation due to rectified diffusion. This phenomena has been described by others[2]. In brief, hydrocarbon liquids such as the molten waxes used in solid inks have a relatively high air solubility (as much as 3-4 times the air solubility of water). This high air solubility leads to rapid growth of trapped micro bubbles in the presence of acoustic waves like those generated in ink jet devices. However, bubble growth does not occur unless the acoustic pressure reaches a threshold level dependent upon bubble size. Therefore, wave form shaping can be used to control bubble growth and jetting degradation (see Roy et. al.[4]). For the Phaser® 340 printer, the wave forms used to generate the two drop masses have been shaped to also avoid micro bubble growth by rectified diffusion.

Transfer Printing Process

The purpose of the print process mechanism is to achieve 100% transfer of the printed image from the print drum to the media (plain paper and overhead transparency material) and good fixing. The solution of this problem

Table II. Ink Properties

Requirement	Ink Property
Durability of the printed image—ductile and resistance to cracking.	Glass transition temperature below ambient.
Good color quality—transparent in thin layers.	Amorphous in solid state and solubility parameter compatible with available colorants (dyes).
Jettable with piezoelectric drop on demand ink jet.	Viscosity range 11-15 cp at less than 150˚ C.
No blocking or transfer from the printed image at up to 60˚C	Sharp solid to liquid phase change at greater than 90˚C.
Efficient transfer of ink from print surface to media.	Malleable or rubbery state at temperatures above ambient and below 60˚C. No crumbling or shear banding at up to 1000 psi transfer pressure.

Table III. Ink Base Formulation[7]

Component	Transfer Printing Formulation (%)
Mono-amide	47
Tetra Amide	21.5
Tackifier	27
Plasticizer	4.5

is disclosed in a U.S. Patent by Bui et.al.[8] The efficiency of transfer and fixing depends upon the material properties at the transfer temperature as well as the pressure generated in the nip formed between the print drum surface and the transfer roller (see Figure 1). The physical properties of the phase change ink were tailored to maximize transfer efficiency. Also the anodized aluminum print drum is coated with a thin layer of silicone oil to facilitate release of the solid ink from the print drum surface. This layer is replenished via drum rotation past a maintenance cassette (see Figure 1). The parameters of the transfer process are listed in Table IV below. These process parameters result in dot gains approximately twice those achieved in direct printing.

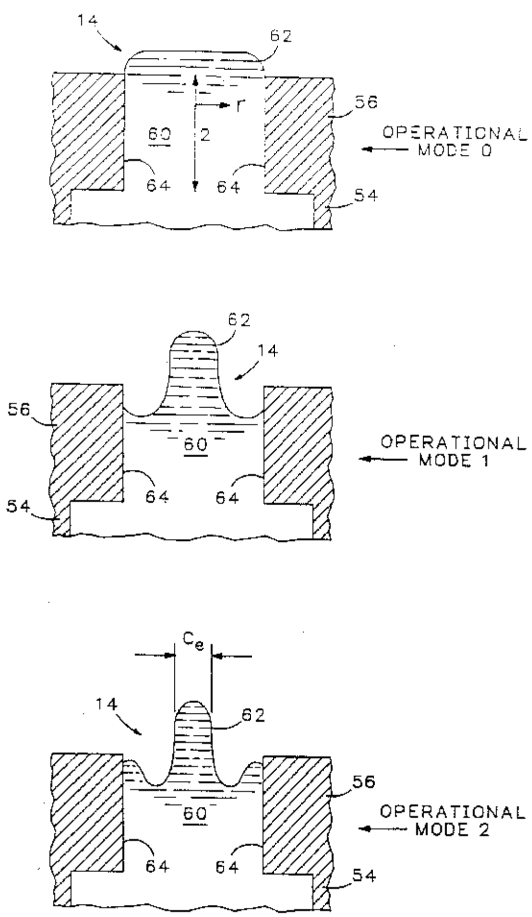

Figure 3. Modes of meniscus deformation for drop size modulation[3]

The rates of imaging and transfer embodied in the Phaser® 340 printer are 36.7 ips (inches per second) print drum surface speed and 5 ips paper surface speed during transfer. Since the page-wide print head contains 88 nozzles per primary color, 28 drum revolutions are required to produce the image and approximately 2/3 of the print time is allocated to imaging and 1/3 to paper handling, drum maintenance and transfer to the media.

Table IV. Transfer Printing Parameters [8]

Requirement	Process
Ink material at rubbery state/adheres to substrate	Pre heat substrate (< 100˚C) Heat drum (< 50˚C)
Spread and flatten ink drop on media.	Apply pressure (< 1000 psi)

The result of the print process is shown in the scanning electron microscope prints of ink dots on paper and transparency, (Figures 4 and 5). These prints illustrate good fixing of the ink to the media in the case of transfer to bond paper and the type of flat dot geometry that produces good projection of overhead transparency images. This process has been found to produce acceptable color overhead transparency quality without post processing such as heat and quench (Creagh et.al.[5]), and other methods described by Burke et.al.[6]

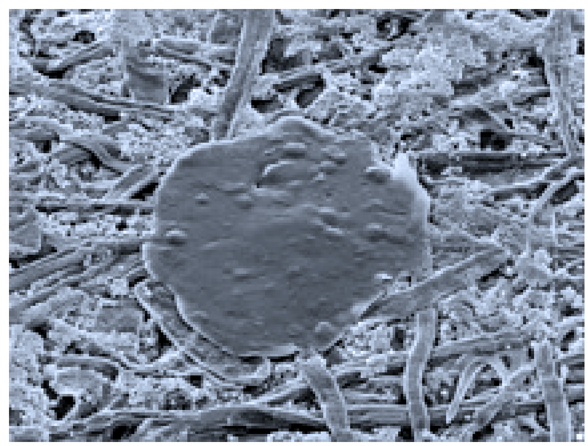

Figure 4. Scanning Electron Microscope: Image of ink dot on paper (1000 ×)

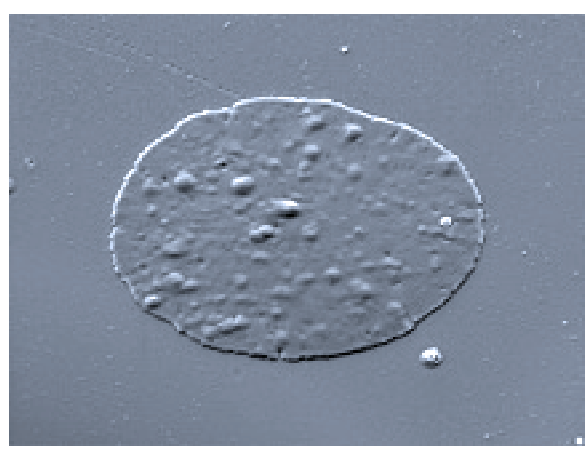

Figure 5. Scanning Electron Microscope: Image of ink dot on overhead transparency (1000 ×)

Summary

With the Phaser® 340 printer, Tektronix has commercialized a new solid ink printing process that significantly increases printing speed while also improving overhead transparency quality. This was achieved through an offset printing architecture, page wide print head and modified phase change ink formulation.

Acknowledgments

The creation and commercialization of the technology of the Phaser® 340 printer was the accomplishment of a group of engineers, scientists, and technicians known internally to Tektronix as the Rogue team.

References

1. C. W. Jaeger, D. R. Titterington, H. P. Le and J. J. Sopko, "Phase Change Ink Composition and Phase Change Ink Produced Therefrom", U.S. Patent No. 5,084,099, Dec. 1989.
2. R. L. Adams, "Phase Change Ink Jet Technology", *Proceedings IS&T's Ninth International Congress on Non-Impact Printing Technologies/Japan Hard Copy 1993*, October 1993. ***(see page 138)***
3. R. F. Burr, D. A.. Tence, H. P. Le, R. L. Adams and J. C. Mutton, "Method and Apparatus for Producing Dot Size Modulated Ink Jet Printing" Published European Application No. 0636477A2 (January 95), pending U.S. Patent.
4. J. Roy, D. Stanley, J. Buehler and R. Adams, "Method of Operating an Ink Jet to Reduce Print Quality Degradation Resulting from Rectified Diffusion", U.S. Patent No. 5,381,162, January 1995.
5. Linda T. Creagh, Steven J. Fulton and Charles W. Spehrley, "Hot Melt Inks and Projection Transparency", *Proceedings of IS&T's Sixth International Congress on Advances in Non-Impact Printing Technologies*, October 1991.
6. E. F. Burke, D. R. Titterington, J .D. Rise, J. B. Eriksen and C.W. Crawford, "Method For Processing Substrates Printed with Phase Change Inks", U.S. Patent No. 5,196,241, March 1995.
7. D. R. Titterington, L. V. Bui, L. M. Hirschy and H. R. Frame, "Indirect Printing Process for Applying Selective Phase Change Ink Compositions to Substrates", U.S. Patent No. 5, 372,852, December 1994.
8. L. V. Bui, D. R. Titterington, J. D. Rise, W. Jaeger, J. C. Mutton and H.P. Le, "Imaging Process", U.S. Patent No. 5,389,958, February 1995.

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