The Printing Technology of the Tektronix Phaser® 340*‡

Ronald L. Adams†

Tektronix, Inc., P.O. Box 1000, Wilsonville, Oregon 97070

With the Phaser® 340 color printer, Tektronix commercialized a new high-speed color-printing process. The method and the engine architecture result from the combination of solid ink-jet printing with drum-based offset 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 printhead, offset drum, and transfer roller. A review of the engine architecture and its relationship to printer performance is described. Additionally, the characteristics of the core technology components are summarized.

Journal of Imaging Science and Technology 40: 383–386 (1996)

Introduction

The Phaser® 340 printer fulfills a long-needed method 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 previously been commercialized by Tektronix, Brother, Dataproducts, and Howtek. Except for the Howtek system, these previous products embodied a mechanism architecture that involved a shuttling printhead much like that of the typical dot matrix impact printer.

Commercial versions of the technology were limited to about one page per minute (ppm) by this architecture because of the overhead time associated with reversing direction of the relatively large piezoelectric printheads and the paper-handling time. Because 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 enables high-speed printing because the print surface, rather than the shuttling printhead, is moved at high speed. This approach results in multiple ppm printing speeds and the product features shown in Table I.

Overhead transparency quality also has been limited for solid-ink printers. Previously, Tektronix has used cold pressured fusing and post-processing lamination to overcome the degradation caused by the spherical lenslets formed by solid ink drops. Figure 1 is a scanning electron microscope (SEM) image of solid ink on a transparency that illustrates the typical geometry of the lenslets formed after the ink has solidified on the transparency. Brother/Spectra has addressed this issue by reheating and quenching the ink after transparencies have been 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.

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 member, rather than the printhead as embodied in serial printer architectures. In this case, the fast member is the surface of a rotating drum. Then, to further increase printing speed, ink-jet nozzles are distributed across the page-wide print drum, and the printhead is displaced twice the distance between nozzles (for interlacing). To increase the printing speed further and avoid the complexity of paper handling, the printing is accomplished in offset fashion by first printing onto an aluminum drum coated with silicon oil and then transferring to the media. This arrangement, shown in Fig. 2, allows multiple ppm print speeds, and the first embodiment is capable of 4 ppm.

The printhead is a single device carrying all four colors, and the nozzles are arranged in four rows, as shown in

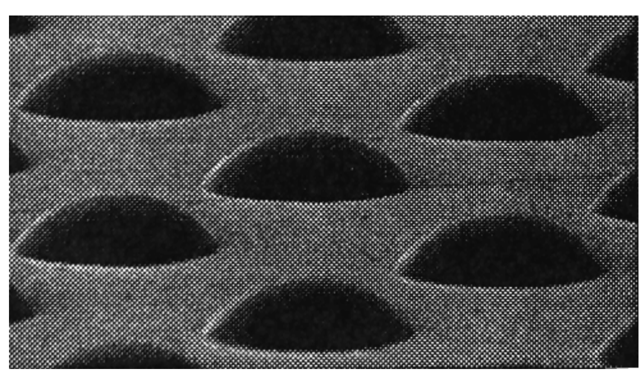

Figure 1. Scanning electron microscope image of ink on transparency media after direct printing (1000×).

Original manuscript received March 12, 1996.

* Phaser® is a registered trademark of Tektronix, Inc.

† IS&T Member

‡ Presented in part at IS&T's 11th International Congress on Advances in Non-Impact Printing Technologies, October 29–November 3, 1995, Hilton Head, South Carolina.

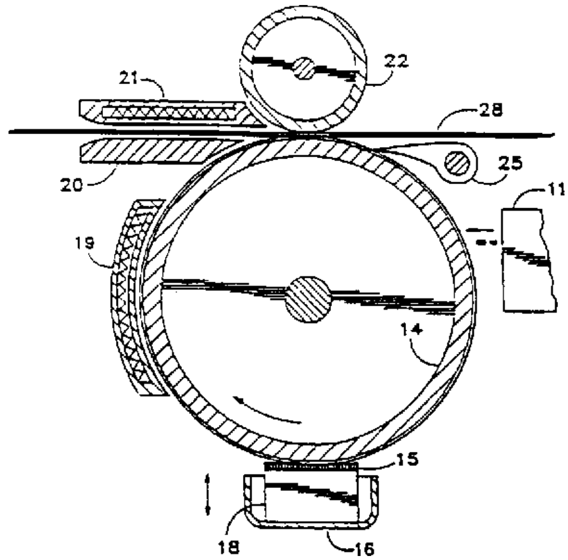

Figure 2. Phaser 340 printer architecture.[6] 11, printhead; 14, print drum; 16, silicone oil applicator; 19, drum heater; 20, media pre-heater; 22, transfer roller; 25, media stripper fingers; 28, media.

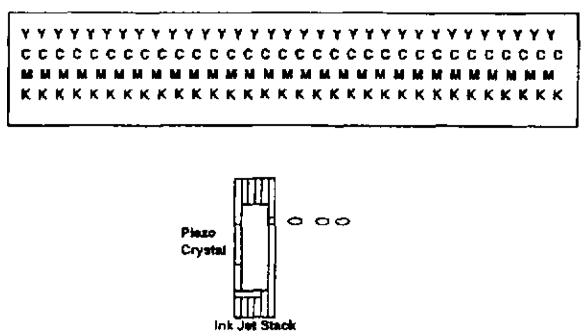

Figure 3. Page-wide printhead nozzle arrangement. Y, yellow nozzles; C, cyan nozzles; M, magenta nozzles; K, black nozzles.

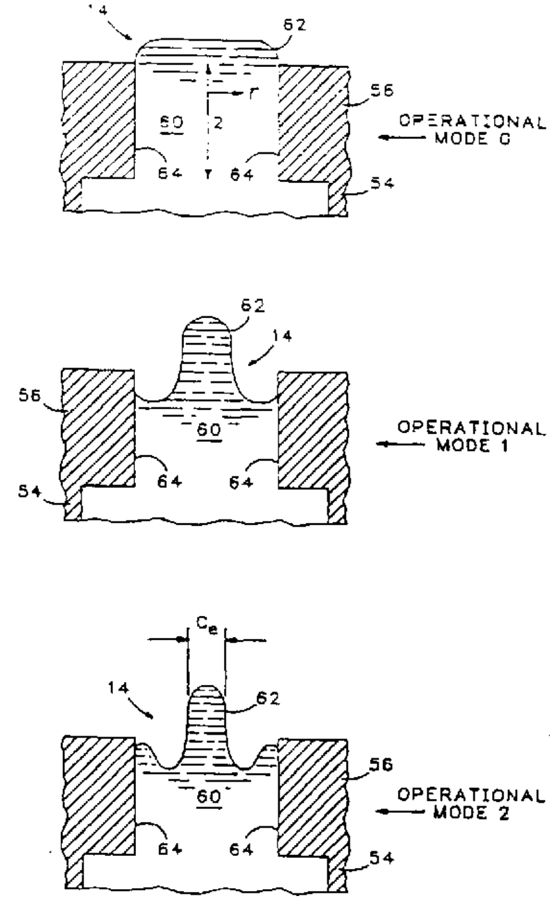

Figure 4. Modes of meniscus deformation for drop-size modulation.[3]

Fig. 3. Each row contains 88 nozzles, and the color arrangement allows secondary colors to be printed in the sequences YC, YM, and CM, because the drum motion is top down relative to the printhead.

Phase-Change Ink

The ink formulation must satisfy the combined requirements of good color quality and durability on the media, of jettability in a piezoelectric-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 constraints of Table II was constructed from materials used in prior phase-change inks.[1] This formulation is summarized in Table III. Dyes are added to the listed base materials to form yellow, magenta, cyan, and black inks. As noted by Titterington et al.,[2] ink formulations derived from the teachings of Jaeger et al.[1] were not acceptable for the new printing process.

Print Head

The page-wide printhead is capable of producing both 300 × 300 dpi and 600 × 300 dpi drops. It is piezo driven in the bending mode and is constructed from materials compatible with the ink. The printhead was designed to achieve an imaging time of approximately 10 s at 300 dpi. This was accomplished with four rows of 88 nozzles, each capable of up to 11,000 drops per second in the 300 × 300 dpi mode. The 600 × 300 dpi mode is accomplished through a wave-form adjustment that reduces drop mass to approximately 65% of the 300 × 300 dpi mode value. This mass reduction follows the method disclosed in a European patent application by Burr et al.[3] 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 Fig. 4.

TABLE II. Ink Properties

Requirement	Ink Property
Durability of the printed image: ductile and resistant 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 piezo electric 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*

Component	Transfer Printing Formulation (%)
Monoamide	47.
Tetraamide	21.5
Tackifier	27.
Plasticizer	4.5

* From Ref. 20

The fabrication technology employed in the page-wide printhead has been reported previously.[4] 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 the plates are joined by the bonding process, hermetic seals are achieved.

Solid ink printheads are susceptible to performance degradation due to rectified diffusion. This phenomenon has been described by others.[4] In brief, hydrocarbon liquids such as the molten waxes used in solid inks have a relatively high air solubility (as much as three to four times the air solubility of water). This high air solubility leads to rapid growth of trapped microbubbles 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 that is dependent on bubble size. Therefore, wave-form shaping can be used to control bubble growth and jetting degradation (see Roy et al.[5]). For the Phaser 340 printer, the wave forms used to generate the two drop masses have been shaped to avoid microbubble 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), along with good fixing. The solution of this problem is disclosed in a U.S. Patent by Bui et al.[6] The efficiency of transfer and fixing depends on 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 Fig. 2). 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 Fig. 2). The parameters of the transfer process are listed in Table IV. These process parameters result in dot gains approximately twice those achieved in direct printing.

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. Because the page-wide printhead contains 88 nozzles per primary color, 28 drum revolutions are required to produce the image. Approximately two-thirds of the print time is allocated to imaging and one-third to paper handling, drum maintenance, and transfer to the media.

The result of the print process is shown in the SEM prints of ink dots on paper and transparency, (Figs. 5 and 6). 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 overhead transparency images for projection. This process has been found to produce acceptable color overhead transparency quality without post-processing, such as heat-and-quench treatment (Creagh et al.[7]) and other methods described by Burke et al.[8]

TABLE IV. Transfer Printing Parameters*

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

*From Ref. 6.

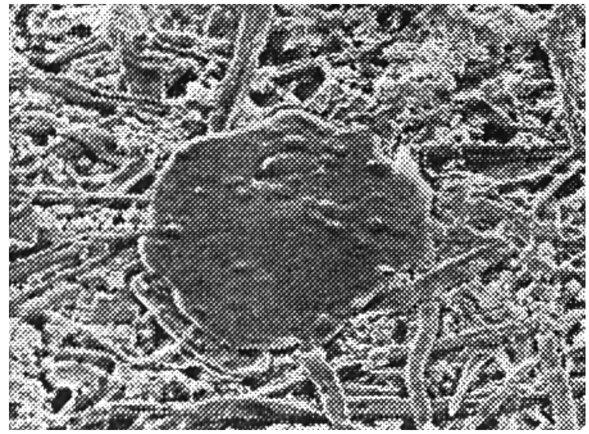

Figure 5. SEM image of ink dot on paper after transfer printing (1000×).

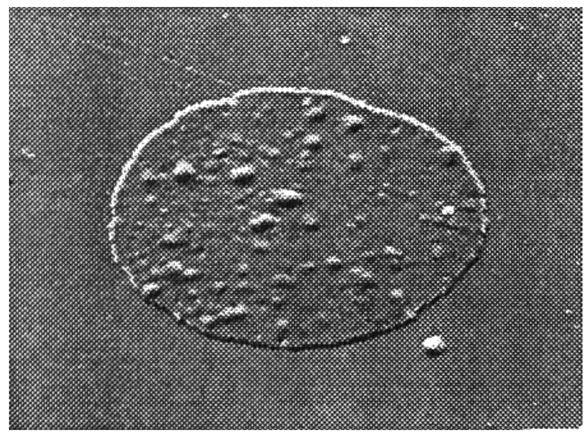

Figure 6. SEM image of ink dot on overhead transparency (1000×).

Summary

With the Phaser 340 printer, Tektronix has commercialized a new solid-ink printing process that significantly increases printing throughput while also improving overhead transparency quality. These properties were achieved through an offset printing architecture, page-wide printhead, 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 5,084,099 (Dec. 1989).
2. 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, US Patent 5,372,852, (Dec. 1994).

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, US Patent 5,495,270 (1996).
4. R. L. Adams, Phase change ink jet technology, *Proceedings of IS&Ts 9th International Congress on Non-Impact Printing Technologies/ Japan Hardcopy 1993*, (Oct. 1993).
5. J. Roy, D. Stanley, J. Buehler and R. Adams, Method of operating an ink jet to reduce print quality degradation resulting from rectified diffusion, US Patent 5,381,162 (Jan. 1995).
6. L. V. Bui, D. R. Titterington, J. D. Rise, C. W. Jaeger, J. C. Mutton and H. P. Le, Imaging Process, US Patent 5,389,958 (Feb. 1995).
7. Linda T. Creagh, Steven J. Fulton and Charles W. Spehrley, Hot melt inks and projection transparency, *Proceedings of IS&T's 6th International Congress on Advances in Non-Impact Printing Technologies*, (Oct. 1991).
8. 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, US Patent 5,196,241, (March 1995).