

Dry Digital Medical Imaging with Phase Change Ink Jet

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Abstract

We accomplished our goal of matching the black color of medical images produced by silver halide film with phase change ink jet output. Although the absorbance spectra of the phase change ink jet output do not match the absorbance spectra of silver halide film, the print output is perceived as matching. This perception is explained by understanding the human visual system and the environment in which the medical images are viewed.

Introduction

This is the third in a series of presentations on the prospects for dry digital medical imaging printers.[1] The more recent presentation reviewed the marketplace requirements for an acceptable alternate (dry) hard copy system and briefly covered image quality and gray scale construction, media, costs, durability, archivability, environmental considerations, and printer throughput.[2] This paper will briefly review the offset phase change ink jet technology and discuss work done on ink development, color matching, and the optical density range achievable for a medical imaging printer utilizing this technology.

Existing Technology

The predominant medical imaging technology today utilizes silver halide transparencies. Transparencies are the preferred medium for diagnostic imaging because they are capable of a greater dynamic range in optical density compared with reflection prints (such as paper hard copy).[3] Silver halide films for medical imaging have proven extremely useful in medical diagnoses; however, they have several disadvantages. The capital equipment to expose and develop these films is expensive. The unexposed film has a limited shelf life and must be protected from light and other radiation sources. The films require chemical wet processing to develop and raise environmental concerns for disposal of the development chemicals.

In the past year, several manufacturers have introduced or indicated their intention of introducing a dry recording system that will compete favorably with conventional wet-processed silver halide systems. At the 1996 Chicago meeting of the Radiological Society of North America (RSNA) trade show, Sterling Diagnostic Imaging and Tektronix demonstrated a "works in progress" dry digital medical imaging printer that utilizes Tektronix proprietary phase change ink jet technology and inks. This system is based on Tektronix's offset phase change ink jet technology as demonstrated in the Phaser 340 and 350 printers.[4,5]

Offset Phase Change Ink Jet Technology

The basic operating principle behind phase change ink jet technology is illustrated in Figure 1. Solid, non-toxic, waxy ink is melted and delivered to the piezo-electric driven ink jet print head. The ink is specially formulated for very low viscosity at jetting temperatures, for proper viscoelastic properties at the temperature of the rotating drum, and for good durability of the final image at room temperature. The print head ejects drops onto a heated rotating drum having a liquid sacrificial layer that promotes the transfer of ink during the transfixing process. The drum temperature, must be lower than the jetting temperature, but higher than room temperature, allowing the ink to solidify to a rubbery viscoelastic state that remains malleable for offset printing onto either film or paper.

The print head contains four manifolds, with an equal number of nozzles per manifold. In a color printing application, each manifold would normally carry a single color, either magenta, cyan, yellow, or black ink. However, in this particular medical imaging application, different shades of black ink are used to achieve gray levels in monochrome printing. Ink droplets are placed across the width of the rotating drum, and in the direction of rotation. After the complete image is built up, it is transferred to preheated media, either transparency or paper, through a pressure transfix operation.

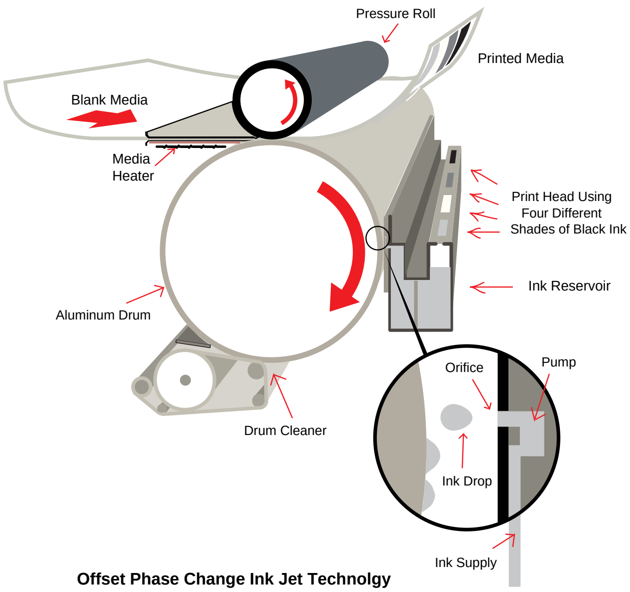

Figure 1

Medical Application of Ink Jet Technology

Tektronix has developed a special high resolution print head. Image construction methods provide the desired image quality and more than 256 gray levels with 1200 by 600 dpi addressability. The equipment size has been increased to accommodate the media size needed in medical imaging, up to 14 by 17 inches, while still retaining the capability of printing smaller output sizes on the same printer. The printer can produce a medical image of nominally 14 by 17 inches every two minutes.

Matching the Black of Silver Halide Film

Despite the equal absorbance across the visible spectrum

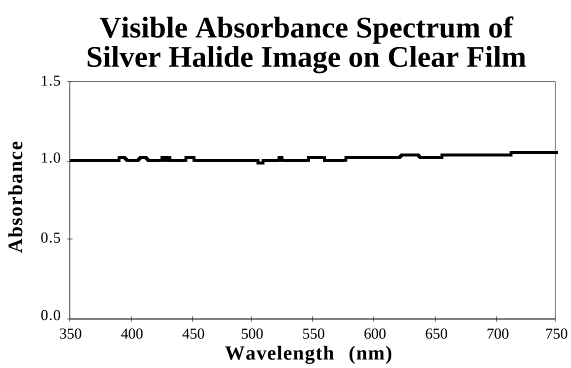

Figure 2

of a silver dispersion (see Fig. 2), the black produced from a silver halide image on clear film has a brownish-black appearance. The neutral black of medical imaging films is achieved by developing exposed silver halide on a blue-tinted film base (see Fig. 3).

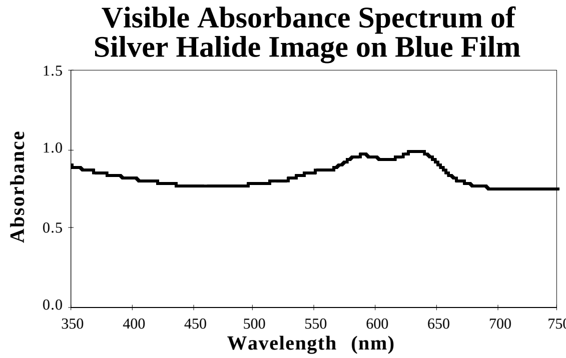

Figure 3

Color and Ink Development

To produce a comparable product, Tektronix designed an alternate combination of inks and, in collaboration with Sterling, media to yield similar overall color appearance as well as an excellent dynamic range in optical density. A D-min of 0.05 and a D-max of 3.1 were achieved on clear film and 0.2 and 3.2, respectively, on blue tinted film.

The black dye used in Tektronix's commercial phase change inks is a colorant that produces a neutral to blue-black shade, typical of the black color produced by printing inks on paper (see Fig. 4). If these inks are

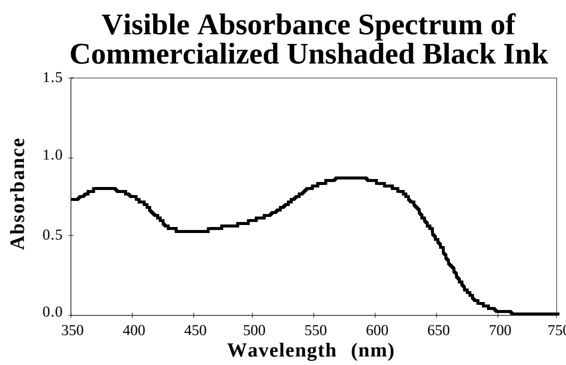

Figure 4

printed on the blue tinted film base that radiologists are accustomed to using, the resulting color is a bluish-black. Radiologists have been trained to read films that are a "particular shade of black" and their diagnoses are based on very subtle gradations of optical densities in this neutral black shade. The initial black ink images produced from the phase change ink jet printer were of diagnostic quality, but the bluish-black color was objectionable to the radiologists because it was different from the silver halide neutral black that they were used to viewing. When printed on clear film, the color was closer to expectations, but still different enough to be objectionable. Just as radiologists prefer that "particular shade of black," they have come to expect blue-tinted transparency film.

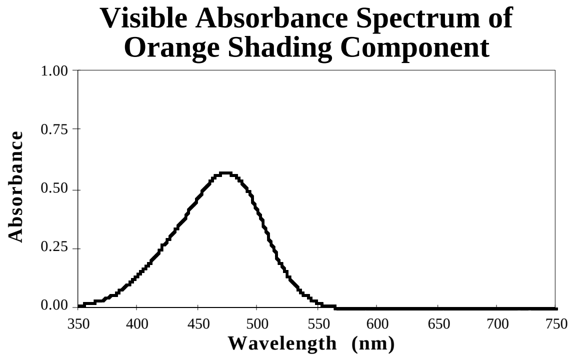

Figure 5

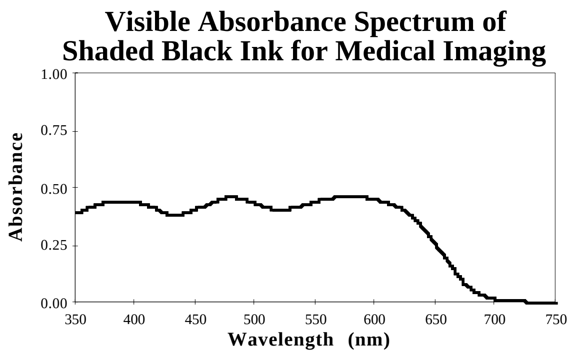

Figure 6

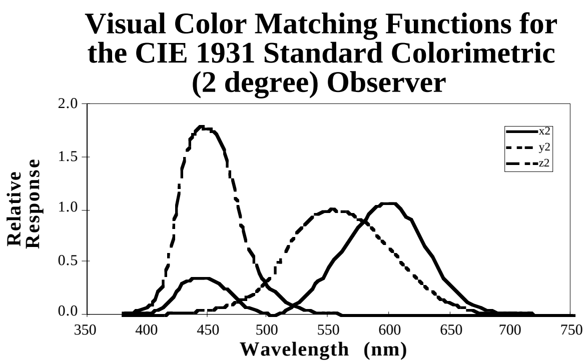

Figure 7

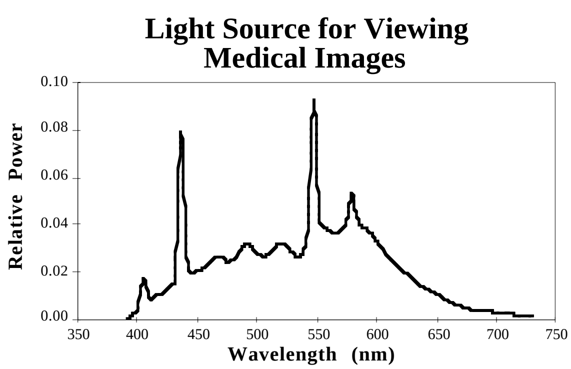

Figure 8

To meet the radiologists' color expectations, the "hole" in the black absorbance spectrum in the 475 nm region was filled by adding an orange shading component (Fig. 5). The new shaded black colorant system (Fig. 6) better matches the absorbance spectrum of a silver halide image throughout much of the visible spectrum, except the absorbance spectrum is completely transparent from 700 nm and higher. Although, human visual response spans from 380 to 780 nm.,[6] the amplitude of response above 670 nm is extremely muted (Fig. 7). In addition, the light boxes used to view these types of images have relatively low radiant power in wavelengths above 670 nm (Fig. 8).

Therefore, it has not been necessary to exactly match the absorbance of silver halide film above approximately 670 nm, due to the limits of human vision and the viewing system (fluorescent light box).

Conclusion

We have duplicated the black color and appearance of silver halide images with a phase change ink and ink jet printer.[7] While the absorbance spectrum of the phase change inks and silver halide are not identical, we have accomplished a duplication of the perceived black color in the environment that the images are to be viewed. Our focus studies indicate that radiologists prefer the black color achieved with our dye-based system to that of silver halide images. Our studies also show that the maximum density achievable with our dye-based system is at least as good as, if not better than, that of silver halide.

Acknowledgment

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