Foundations of Inkjet Head Technology

Inkjet printing has developed rapidly and is ever expanding into new markets and product niches. The research and development of new print heads, inks or functional fluids is at a staggering level as many manufacturers vie for future positioning. It is important to have a certain level of background knowledge that will allow one to navigate the purchase of any inkjet printer using knowledge about the manufacturers choice of inkjet head technology.

All inkjet head technologies are founded on electronically controlled ejection of drops of fluid from the printhead onto the requisite substrate. The droplet ejection, however, can be accomplished by a multiplicity of methods. Inkjet head technology can be classified as either continuous or drop-on-demand (DOD), with further sub-classes within each category.

Continuous inkjet technology ejects drops continuously, either directed to the substrate or to a collector for recirculation and reuse. With DOD, the drops are ejected according to the condition. These inkjet droplets are formed by the creation of a pressure pulse inside of the ink delivery chamber. The subcategories of DOD are defined by the various methods with which the pressure pulse is generated. These three major categories are thermal, piezo and continuous inkjet (electrostatic).

Thermal inkjet

Ichiro Endo, a Canon engineer in the year 1977, first discovered the principle of thermal inkjet. Thermal inkjet heads have certainly come a long way since those early desktop inkjet printer days.

Thermal inkjet heads vary in their design, but all have the same concept. The technology offers very small drop sizes, and high nozzle velocity combined with high nozzle density.

Inside of a small chamber containing the ink, drops are formed by rapidly heating a resistive element. The temperature of the resistive element quickly rises to several hundred degrees centigrade, causing molecules of ink to vaporize. The boiling ink quickly creates a bubble (pressure pulse) displacing ink in the chamber and forcing a droplet of ink to eject through the nozzle or orifice at the other end. The droplet that is ejected leaves a void (vacuum) in the chamber that is afterwards filled by replacement ink from a reservoir, in preparation for formation of the next drop.

The disadvantage of this technology is the narrowness of the range of fluids that

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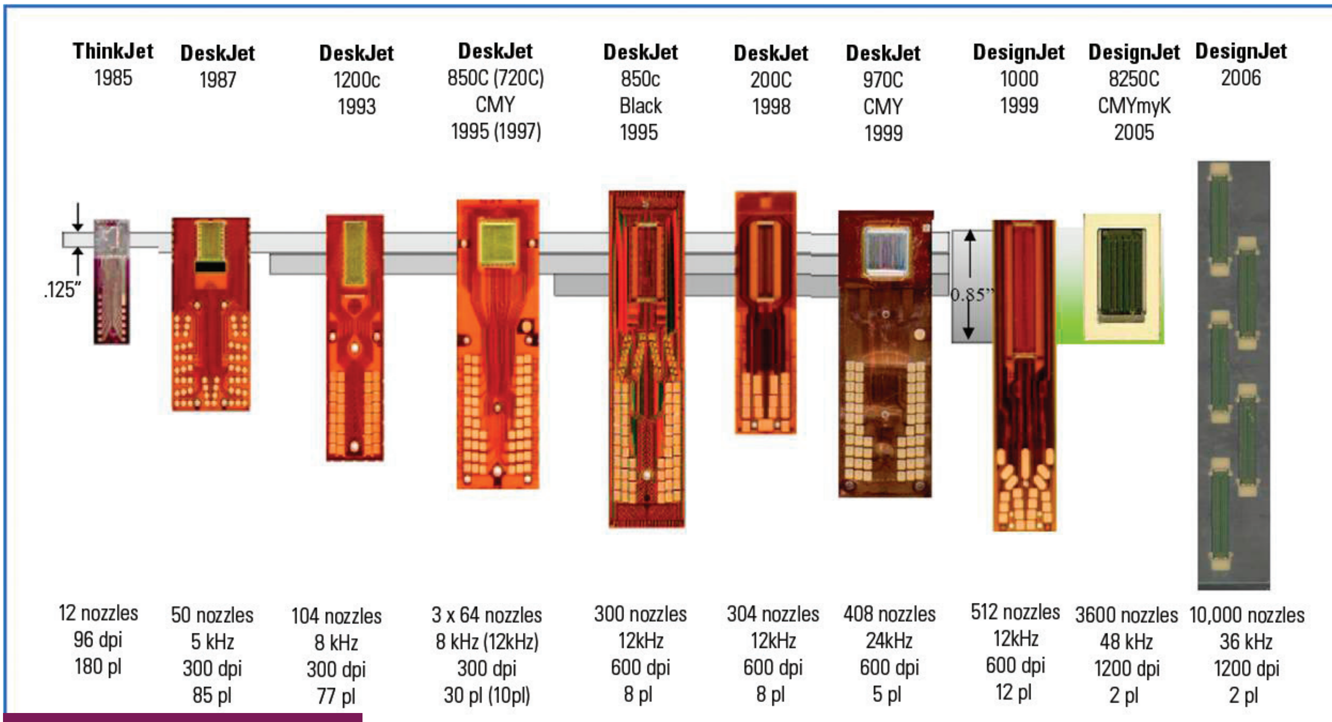
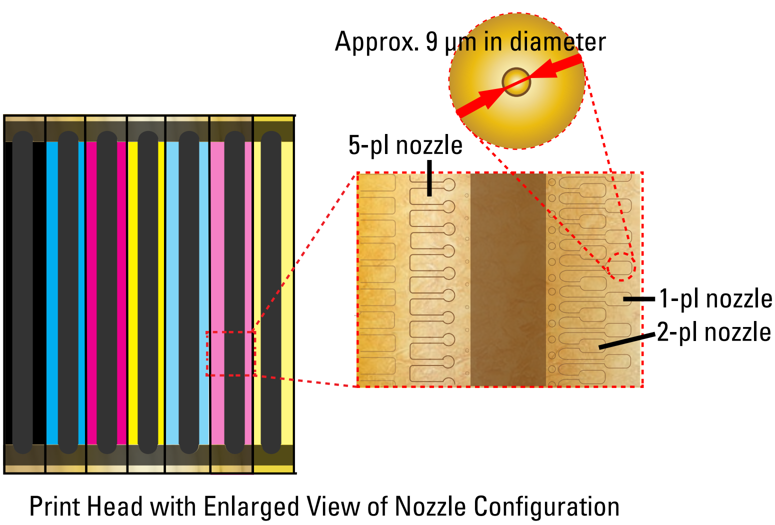


HP Thermal inkjet development



Canon FINE print head close up

can be used. The ink fluid for thermal inkjet must be designed to vaporize, and must be able to tolerate high local temperatures. Thermal inkjet heads also degrade from a process called cavitation. Cavitation being the formation and then immediate implosion of the heated bubble on top of the heating pad, causing stress and wear on the pad itself. However, technological advancements have produced thermal inkjet heads having very good life expectancies.

Achieving smaller droplet sizes and faster print speeds requires high-precision fabrication technologies to enable the placement of a greater number of nozzles over a wider area. Canon's FINE print heads have managed to pack a whopping 2,560 nozzles per color — that's 15,360 nozzles per head. These heads have been fabricated to include multiple nozzle sizes, as thermal inkjet (TIJ) heads cannot produce variable droplets. These heads have one, two and five pl nozzles in a special configuration.

The other major player is Hewlett Packard, who has achieved amazing nozzle density with its Edgeline Technology print head. This unit, having a 4.25-inch print swath, is an assemblage of five silicone print head chips placed in a staggered array in alignment.

The native resolution of this head is 1200dpi with an operating frequency of 48kHz. Each print head contains two rows of nozzles (10,560 per die), which can either print two colors simultaneously or print one color, leaving the other row in reserve as backup. With five dies on each head, we're looking at 52,800 nozzles per unit, capable of using either aqueous or latex based inks.

The Edgeline print heads are in HPs Latex printers and web presses. The web press, the T300 for instance, with a 30-inch print width needs 70 Edgeline print heads per paper side. For duplexing mode that's 140 print heads, which would be 7,392,000 nozzles, each firing a drop of ink 20,000 times a second, 148 billion drops, all landing in precision formation every second. Remember that all TIJ heads are consumable, with life spans linked to ink throughput volumes.

Kodak and Lexmark are other manufacturers of TIJ heads with desktop printers that are or were in the marketplace.

For wide-format printing, it's a battle between HP and Canon in the aqueous inkjet printer market, with HP being the sole provider of Latex printers having TIJ print heads. HP is also the only player utilizing TIJ in a single pass web configuration.

With TIJ heads finding a niche to grow into, the majority of the large/grand format roll to roll and flatbed printers on the market are integrated with inkjet heads that are Piezo powered.

Piezo Drop On Demand

Piezo heads, while sharing a common drop ejection technology, can be customized in their materials and options, making them well suited for inkjet printer manufacturers.

With DOD Piezo technology, certain crystals change their shape when voltage is applied. This flexion is enough to deform the ink chamber and generate a pressure pulse within. There are various designs for piezo head construction from the dozen or so manufacturers who manufacture them.

Inkjet heads have a myriad of purposes — one of those happens to fall into the graphics production realm. Other applications for heads include: marking and coding, postal and addressing, document processing, textile marking and printing, etching, photo voltaic, material deposition and precision fluid dispensing.

Inkjet heads have characteristics that can be generalized into the following subcategories:

- Fluid compatibility (aqueous, oil, solvent, UV, acidic)
- Operating temperature
- Number of nozzles
- Native resolution
- Print swath
- Construction material
- Fixed drop or variable drop
- Smallest droplet
- Environment suitability

The biggest demarcation between inkjet heads is that of fixed drop and variable drop technologies. Fixed drop is also known as binary, while variable drop is synonymous with grayscale. What's the difference and how it works is important to understand.

Fixed drop or binary heads are built to have a singular drop size specified in pico-liters (pl) or trillionths of a liter. The range is huge — going from 1pl all the way to 200pl or more. The benefits of fixed drop size are that large drops cover large areas faster than small drops. Large drops also have an inherently lower native resolution, so these types of heads are better suited to large printed projects or textiles and other requirements where resolution is not an issue.

On the smaller droplet end of the scale, we have the Durst Rho P10 series with 10pl drop Quadro Array print heads, with up to 1000dpi resolution. Even 1pl small drop heads are built for fluid deposition and printed electronics rather than for graphics applications.

Fixed drop heads can also have higher firing frequencies, denoted in kHz (kilohertz, 1000 cycles per second), than grayscale heads. Fixed drop inkjet printers can come in four or six colors, but remember that for large-scale projects, four colors will print faster than six, and multiple heads per color really makes printing fly.

There is a lot of debate about which is better (fixed drop or grayscale) and why, but it comes down to what kinds of products your business prints, printer cost, and the production rate you need to attain for profitability.

Grayscale or variable droplet print heads have a distinct advantage of changing resolution on the fly. This works by having a base droplet size and adding those together in flight to make a larger drop. Let's use an example where the base drop size is 6pl.

To get a 12pl drop, two pulses are sent to the ink chamber, and the drops meet in mid air to form a 12pl drop. The drop sizes a given head can produce are called levels.

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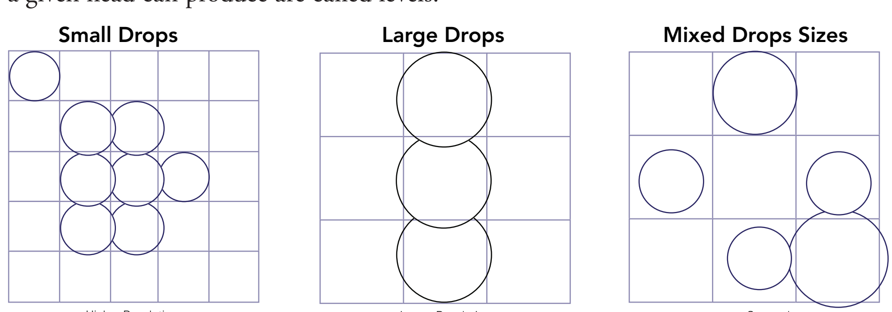
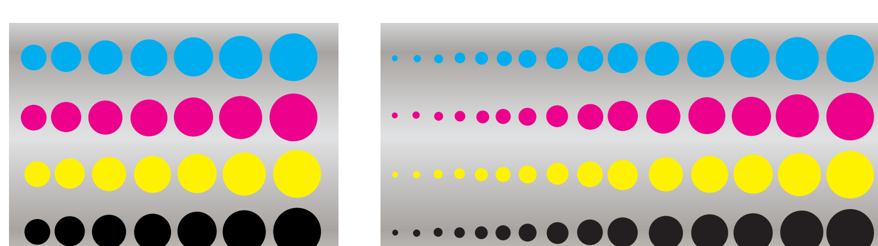
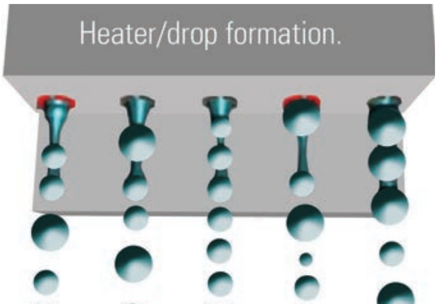
HP Edgeline print head



Fixed drops vs. variable drops



Grayscale drop sizes, eight and 16 level



Kodak Stream head technology

So an eight level head actually produces only seven drop sizes. Grayscale heads supporting 16 levels produce 15-drop sizes. For example, if the head has a 6pl base droplet, the drop size grows like this: 6, 12, 18, 24, 30, 36 and 42.

They are just simple multiples of the base-drop size. But, when we look at the firing rate, variable sized drops are slower to produce, which makes perfect sense. Looking at the frequencies of a 16 level grayscale head example, the base drop can be fired at the rate of 28.0kHz. When we invoke eight level drop sizes for the head, the firing rate drops down to 6.2kHz, and with all 16 levels utilized, the rate is reduced further to 2.8kHz. That's a reduction in the number of drops produced by a factor of 10, from base drop to 16 level operations. Variable drop heads will be slower to print than an equivalent fixed drop head, but the gain in fine text resolution and overall print acuity are the up side.

The typical way manufacturers will try to gain speed advantage from grayscale heads is to incorporate more ink channels per color. An ink channel is described as a row of nozzles that are dedicated to a particular color. It could also be an entire head unit dedicated to one color. This would be the typical scenario for a scan-based, or single pass printing system.

By scan printing, I mean a method of inkjet printing where a head carriage is passed back and forth, across the media surface while the media is transported intermittently. This can be reversed, as is the case in some flatbed printers. The substrate reciprocates under the array of heads, which are incremented across the media width.

Continuous Inkjet — High Speed

Continuous inkjet technology is a noncontact form of high-speed printing used to apply variable information to a variety of moving substrates. Originally designed to produce such variable information as dates, text and batch codes, it has moved on to full, four-color web speed production. Believe it or not, Lord Kelvin first patented this idea in 1867.

With this technology, a pump directs liquid ink from a reservoir to multiple minute nozzles, creating a continuous stream of ink droplets at a very high rate. A vibrating Piezo-electric crystal causes this rate of droplet creation or ejection. The rate at which the Piezo-electric crystal vibrates is called its frequency, and can range for CIJ from 50 kHz to 175kHz. That will produce 50,000 to 175,000 droplets per second per nozzle. The ejected ink droplets fly past an electrostatic field that imparts an electrical charge to them. Charged droplets then pass through a deflection field, directing them either onto the substrate, or to a collection gutter for reuse. The majority of the droplets are recycled, leaving only a small fraction used in the actual print. High-speed print capability is one of the major advantages of this type of inkjet head technology.

Kodak Stream technology is a continuous inkjet hybrid technology. By applying a regular pulse to heaters surrounding each of the nozzles in the print head, the ink is stimulated into breaking into fine droplets. By changing the size and shape of the pulse, the dot size and the speed of the dropping can be varied. Stream technology can generate drops at a frequency of 400kHz, which is fast enough to keep up with a conventional web offset press. And Kodak claims that it can pulse even faster. The closest competitor to the Prosper press is HP's Inkjet Web Press, which has a theoretical maximum dropping frequency of around 100kHz. DOD inkjets generally operate at 25-40KHz by comparison.

Stream was developed using MEMS technology, or Micro-Electro-Mechanical Systems, as are the HP Edgeline heads. MEMS is an advanced manufacturing method that uses techniques similar to those used in fabricating integrated circuits to create ultra-miniature inkjet structures within silicon. Stream uses a nozzle plate that combines mechanical elements and electronics on a shared piece of silicon.

Take Away

Head choices are just one of the many attributes in a complex printing system. Awareness of technology differences is a crucial element to choosing technologies that will work for your business model. With so many machine choices out in the market place, you need to be armed with as much information as possible.

Jeff Burton is SGIA's Digital Printing Analyst and provides solutions to digital printing production, color management and application issues, as well as digital equipment and vendor recommendations. In his more than 20 years in the industry, he has worked as production manager, member consultant, trainer, author of numerous technical articles, and presented at a variety of industry events.

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