Digital technology and more specifically inkjet printing was forecasted by many to be the death knell of the screen printing industry when the SGIA Expo first began showcasing this technology so many years ago. While it is true wide and super wide format inkjet printers have taken much of the large format graphic printing market once dominated by screen printing, and Direct-to-Garment printers keep improving their capabilities and reach into textile printing market, inkjet has not forced screen printing into obsolescence. In fact the two disciplines seem to complement each other, offering screen printers more choices and variety of services to their print buyers.

The screen printing industry also embraced digital technology for imaging screens many years ago with the introduction of Computer-to-Screen (CTS) or Direct-to-Screen (DTS) imaging systems as a way to advance the process. CTS imaging includes all technologies that image the screen directly from a digital file without the use of film positives of which two technologies are currently used: inkjet masking and digital direct exposure. And now with new CTS systems and the surge in LED exposure systems screen printers have many exciting screen making options to choose from for imaging and exposing screens.

Focusing on the fundamental principles of screen making this article will clarify the choices and analyze the benefits and limitations of each choice explaining key misunderstood unintended consequences of choosing one system over the other.

Understanding, Categorizing & Assessing Options

CTS IMAGING SYSTEMS		EXPOSING SYSTEMS	
Masked (Inkjet)	**Maskless (Direct exposure)**	**Static (Stationary)**	**Dynamic (Moving)**
Water-based ink	Mercury vapor UV lamp	Single-Point	Single-Point
Wax-based ink	LED UV lamp	Multi-Point	Multi-Point

CTS systems saves time and money spent outputting, cutting, tagging, transporting, repairing and storing film positives by reproducing images created in the art department directly onto coated screens without using film positives, let alone the cost of the film.

Since exposure glass and vacuum frames are no longer needed, no time is spent cleaning film positives/vacuum frame glass and waiting for the vacuum drawdown. Even exposure times are shortened by ~45% because the exposure glass prevents ~45% of the UV transmission unless you've invested in iron free tempered glass that Mark Coudray tested and found to block only ~15% of the UV transmission.

Moreover, precision image placement of CTS systems has significantly reduced time required registering screens in each print head.

CTS imaging systems can be broken into two categories: masked and maskless. Masked systems use inkjet technology to apply ink onto a coated screen forming the UV mask traditionally created by film positives, whereas maskless systems do not apply a UV mask but instead image AND expose in one step utilizing a digital light processor (DLP) which scans the surface of a coated screen exposing the negative non-image areas allowing the positive image to washout during developing.

CTS Technologies	Masked (Inkjet)	Maskless (Direct Exposure)
Textile		
Graphic		

Masked Systems:

- Image is printed onto a pre-coated screen using an opaque ink or wax
- Screens are exposed and developed conventionally
- Have lower initial cost
- Have an additional consumable cost of the ink to create the mask
- May not provide as high dpi resolution options offered by some maskless systems
- Primarily manufactured to meet the needs of T-shirt and small format graphic printers
- Larger choice of emulsion options especially when used with static (stationary) exposure systems to be explained in *categorizing exposure systems* section

Maskless Systems:

- The image is formed on a pre-coated screen by exposing the negative (non-image) areas of the screen with modulated UV light
- Screens are developed conventionally
- Have higher initial cost
- Do not require ink (UV masking agent)
- Higher resolution output options available
- Primarily manufactured to meet the needs of medium to large format graphic printers
- Image and expose in one step
- Must traverse more of the screen (compared to masked systems) to cure all non-image emulsion coating
- Typically requires ultra-fast exposing emulsions to meet throughput expectations
- Being a maskless system, incidental light unintentionally exposes parts of the image area

Masked CTS Systems are equipped with either a water-based or a wax-based inkjet head.

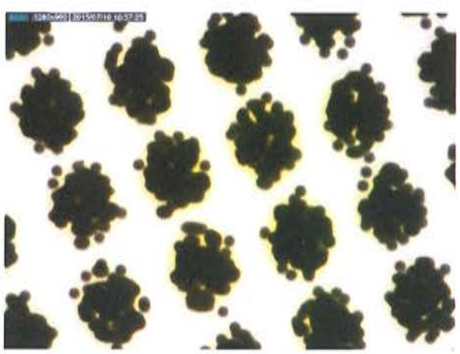
Water-based
Systems that use water-based inkjet inks are typically equipped with less expensive print heads, however, the ink in these systems may not be compatible with all emulsions depending on the hydrophobic, hydrophilic and surface tension (dyne/cm.) properties of the emulsion. These physical properties alter how water-based inks behave when adhering to the emulsion surface.

Since water-based inks don't dry as quickly as wax-based inks they may flow on contact with the screen and pool in the emulsion valleys formed by the screens mesh openings possibly causing coverage variations between the peaks (thin coverage areas) and the valleys (thick coverage areas) of the mesh surface. The higher the Rz value (surface roughness of the screen) the more pronounced these variations are likely to be.

Questions remain whether water-based inkjet inks may adversely affect the stencil's edge definition, as moisture absorbed into the unexposed emulsion may cause slight swelling, erosion and result in incomplete emulsion crosslinking at this critical area of the stencil.

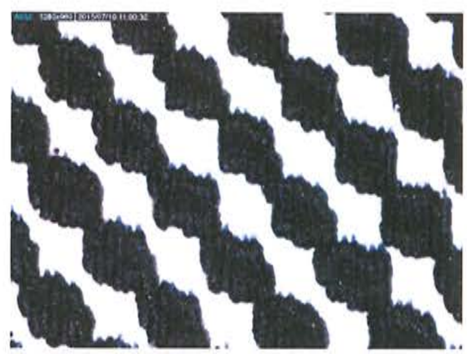
Water-based inks tend to have more satellite dots as seen below resulting in reduced edge definition.

Water-based



600x1200 dpi, 55 lpi, uni-directional

Wax-based

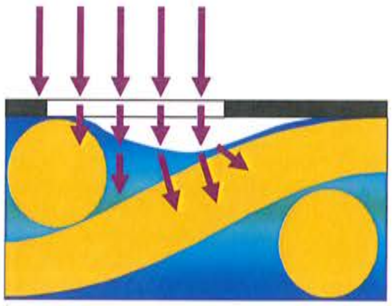


600x600 dpi, 65 lpi, uni-directional

Wax-based
Wax-based inks are phase change inks which means they change from a solid to a liquid and in flight begin to change back to a solid. By the time the ink lands on the screen it is solid so the chemical properties of the emulsion have no effect on these inks, as the ink "freezes" on contact with the screen.

Screens with higher Rz values (typical for coarser mesh screens) have little to no impact on the shape, size and density of the ink using wax-based systems, which explains why they can image screens in the vertical position and conversely all water-based ink systems must image screens in the horizontal position to help prevent the ink from running after contact.

UV Light

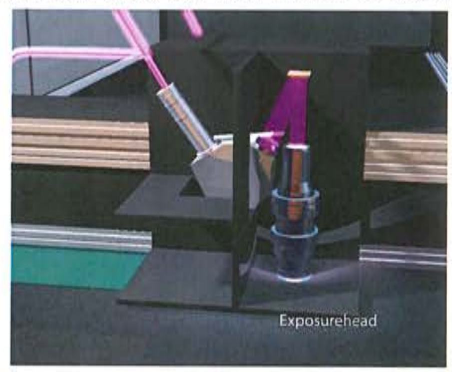


At first blush, the biggest limitation of masked systems may appear to be limited resolution capability, but actually customers of masked systems report the printed resolution achieved rivals that of much higher resolution imagesetter film. One customer using a wax-based CTS system presented two process color shirts showing that the shirt printed using a 1200 dpi imagesetter film positive appeared to carry less tone than the shirt printed using their 600 dpi wax-based CTS system.

Although the customer compensated for tonal compression by adjusting their artwork output file to and more accurately render their previous work done with film positives, the better resolution is primarily explained by the fact that film positives cannot conform perfectly to the surface contours of the emulsion whereas inkjet media can. Since film positives cannot seal perfectly – even with ample vacuum drawdown as depicted above – light leaks into the gap between the emulsion and film.

Another perceived limitation comparing masked vs. maskless systems may be the additional consumable cost of the wax/ink. Perceived because as I explain the next section the limitation of the maskless systems may outweigh the limitations of the masked systems for some applications.

Maskless CTS Systems image and expose in one step precisely exposing only the non-image areas of the coated screen eliminating the need to apply a UV mask first before exposing the screen. These systems utilize an x-y plotting mechanism like masked inkjet systems do but instead of using an inkjet head they use a UV exposure head that controls the light output by way of a digital micro-mirror device (DMD) with over 800,000 micro-mirrors. Each micro-mirror represents a pixel size image that can direct light onto the screen or change the angle of the mirror to direct light away from the screen as the head travels over the image areas of the screen, as illustrated at the right.



Maskless systems are equipped with either conventional UV, LED, or laser light sources. The two primary systems in North America are mercury vapor and LED exposure lamps. These systems are predominately used by medium to large format graphic screen printers but smaller size units are beginning to make some inroads into the T-shirt printing market especially in Mexico and Central America.

Conventional UV

LED

Conventional UV

SignTronic Stencil Master Systems use a conventional 330 watt UV bulb with a wide spectral output between 350-420 nanometers (nm) and provide either 1270 dpi or 2400 dpi resolution capability. SignTronic also uses high quality optics. Conventional UV exposure bulbs degrade with age, therefore, it is recommended to replace them at approximately 600 hours of use.

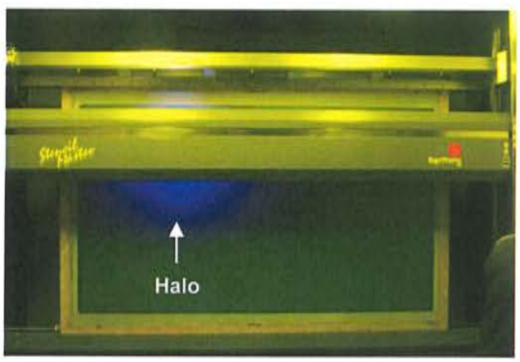
LED

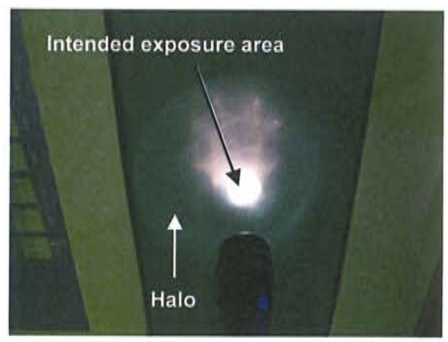
CST Systems use LED UV light and provide 740, 1000, 1270, 2000, and 2540 dpi resolutions depending on application requirements. Unlike conventional UV bulbs LED's output a very narrow UV spectrum, therefore CST uses two different wavelength LEDs, 385 nm and 405 nm. LEDs generate less heat and consume less energy. They do not degrade over time providing consistent UV output over the life of the bulb. According to CST's website, they provide a 5,000 imaging hour guarantee.

Exposure Calibration Challenges with Maskless CTS Systems

While many may believe the biggest challenge to embracing maskless systems to be the initial cost, it may actually be their absence of a UV mask and the reliance on super-fast exposing emulsions to meet advertised screen throughput expectations. The vast majority of customers using these systems use the fastest available SBQ emulsions which often lead to unintended consequences.

In the picture below left you see a halo of stray light shining on un-protected emulsion beyond the intended exposure area. In the picture below right is a simulation of the exposure area and surrounding halo of incidental light using a pinpoint focused flashlight, which may depict this more clearly.





The white spot in the center represents the intended exposure area, while all the remaining light around that circle represents the halo. Although the irradiance (intensity) of this incidental light is significantly weaker, it is still enough to partially crosslink emulsion, primarily when emulsions with the highest light sensitivity are used.

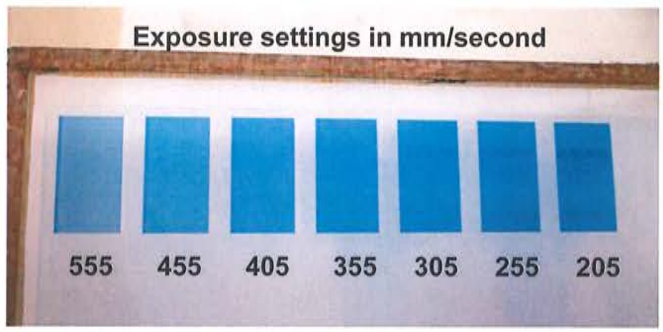
It is important to understand how stray light can affect the ability to determine optimum exposure. Stray light can cause difficulty opening fine details especially when using insufficient water pressure is used to develop screens. This leads one to incorrectly believe they've overexposed the emulsion. When UV exposure is reduced (faster imaging speed) finer positive details begin to open up while sacrificing negative details which may wash off the screen. Only emulsion on the substrate side of the screen is fully cured while emulsion closer to the squeegee side is under cured jeopardizing its chemical and mechanical resistance.

"It appears as if the emulsion is over exposed AND under exposed at the same time," a colleague once reported when describing this phenomenon.

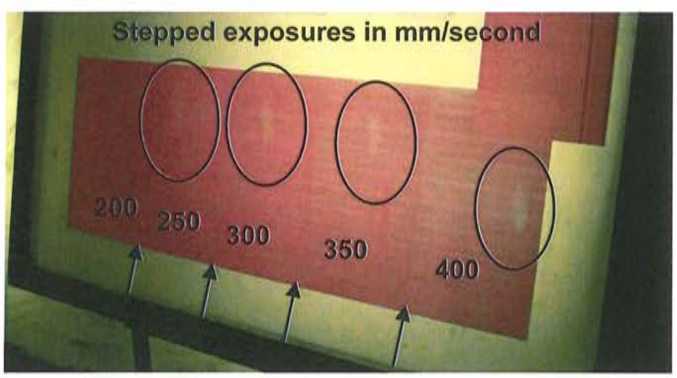
The solution requires establishing optimum exposures based on the emulsion's ink, chemical and mechanical resistance (level/depth of cure) rather than resolution and then adjusting artwork output files to compensate for tonal compression and lost details. Unfortunately, customers struggle to dial this aspect of their screen making process in because they establish exposures predominantly based on speed and resolution.

As with traditional light sources, a series of bracketed exposures should be used to determine completeness of cure or stencil durability. When under-cured the processed stencil will show color variations from one exposure step to the next before reaching optimum exposure. The step where the stencil first becomes darkest in color with no observable color change in subsequent steps indicates where the emulsion is adequately cured through its coating thickness.

The screen pictured right shows an exposure test where solid sections of emulsion are exposed at successively slower speeds to determine emulsion hardness level. Optimum hardness is achieved at ~255 mm/sec., the first exposure step the emulsion stops changing color. Note how the emulsion gets darker with each reduction in speed until this point.



The screen pictured below also shows emulsion changing color and the weakness of the lighter colored (under-cured) emulsion steps. With CTS exposure systems the higher number represents less (not more) exposure, as these values represent speed (not time). Gently rubbing a finger on the squeegee side after developing the screen – as seen in the circled area – reveals this weakness, as a significant amount of emulsion is removed. In this example, the only exposure speed that cured the emulsion adequately was 200 mm/sec., as you can still see slight emulsion removal at 250 mm/sec.



Once this test is complete, another screen is imaged with a halftone test pattern using the exposure setting for optimum emulsion hardness. This screen is then printed and halftone values measured to determine the level of adjustment required in the artwork's output file to obtain the desired resolution in print.

Automatic screen washout systems are often purchased to develop screens produced with direct exposing CTS systems but unwittingly often lack enough water pressure to adequately remove partially exposed/hardened emulsion left in screens caused by stray light which adds to the confusion over calibrating exposure settings.

For example, a printer developed two identical screens imaged on their CTS exposure system, one with a hand held pressure washer and the second in a newly purchased automatic developer. The screen developed in the automatic developer failed to open the 3% - 10% halftone dots, while the screen developed with the hand held pressure washer opened them with ease. If in the market for an automatic developer, one may want to inquire about the maximum available pressure and conduct the same test described above before deciding on the make and model.

Categorizing Exposure System Choices

EXPOSING SYSTEMS	
Static (stationary)	**Dynamic (moving)**
Single-Point	Single-Point
Multi-Point	Multi-Point

Exposing Technologies	Static (Stationary)	Dynamic (Moving)
Single-Point		
Multi-Point		

Static
Static exposure systems are those whereby the light source and the screen remains stationary during exposure. These systems expose the entire screen or multiple screens at once and provide a continuous dose of UV light until optimum emulsion cure through to the squeegee side is achieved. These systems often allow for the widest variety of emulsion choices. Static systems are available in single-point or multi-point configurations.

Dynamic
Dynamic exposure systems expose only a very small portion of the screen at a time. Either the light source moves across a stationary screen during exposure or the screen moves underneath a stationary light source. Since these systems provide only momentary exposure, they rely on their close proximity to the screen to cure the emulsion. Customers trying to achieve manufacturers advertised screen throughput speeds are limited to only the fastest exposing SBQ emulsions. This does not come

without compromise as we will discuss later. Dynamic systems are also available in single-point or multi-point configurations.

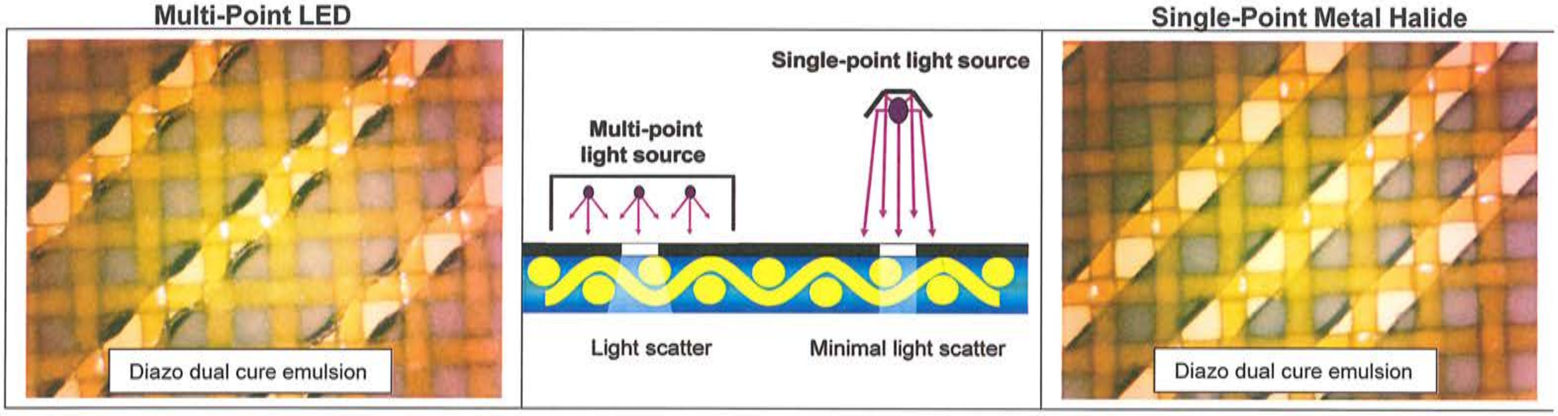
Single-Point

Single-point light sources use a single bulb or column of light. Static single-point systems require sufficient distance away from the screen to achieve uniform coverage. There is some decline of UV energy at the perimeter of the exposure area as light must travel farther to reach these areas. UV falloff is minimized through the use of specially designed reflectors that redirect stray light toward the perimeter areas and by establishing the correct distance between the light and screen. Single-point lights are available as static or dynamic systems.

Multi-Point

Also available in static or dynamic configurations, static multi-point light sources use multiple arrays of LEDs or florescent tubes matching the width and length of the desired exposure area to provide uniform coverage, or matches only the width of the screen when provided in a dynamic configuration. While multi-point light sources may often provide better light uniformity than single-point systems, however, without a parabolic lens to collimate the light they also scatter light more than single-point systems causing undercutting of the motif/artwork. Misconceptions exist involving this point, as some believe they provide better light collimation than single-point systems due to their closer proximity to the screen. The illustration and microscopic photographs below show the differences between the two systems. Note the difference in mesh bridging, edge definition and line width.

Multi-Point LED | **Single-Point Metal Halide**



Emulsion Curing with LED

LED exposure equipment sales is soaring with more variety of LED exposure systems on display at trade shows year after year. UV-LED exposure systems generally offer the following advantages vs. metal halide systems:

- Exposure speeds (primarily with SBQ emulsions) match the speeds of high wattage metal halide systems and surpasses those of lower wattage metal halide systems
- Utility savings due to low power consumption
- Much longer bulb life than metal halide bulbs
- More efficient - producing much less heat
- As a result, the exposure room and vacuum frame glass remains much cooler and may help the dimensional stability of film positives and prevent films and emulsions from sticking to the glass

LED systems come in many styles and configurations and are available in each of four primary categories:

Static "Single-Point" (Saati Pro-Lite 450)

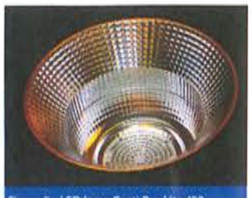


Figure 5: LED lamp Saati Pro-Lite 450

While this unit does not fit the classic description of a single point light source by using a single bulb, it does consolidate a cluster of LEDs in the approximate space occupied by a conventional 5,000 watt metal halide bulb so can be classified as a single-point system. This light source is unique in that it combines principles of a conventional single-point light source with LEDs clustered together. The pebbled reflector may cause light scatter but not to the degree true multi-point systems do.

Static Multi-Point This category offers the widest selection and are the most economical

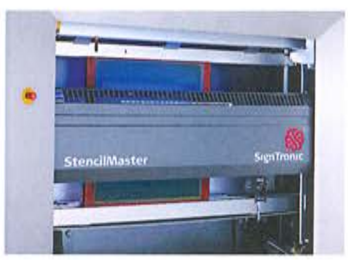
NuArc Starlight
395 nm wavelength

Vastex E2000

Light Speed
385 + 405 nm

Lawson LED 5000 CTS

Dynamic Single-Point (CST Computer-to-Screen – image and expose in a single step)



CST uses two LEDs of different wavelengths, 385 and 405 nm, and comes in a horizontal model for T-shirt printers and a vertical model for graphic printers.

SignTronic uses a conventional UV exposure bulb.

Dynamic Multi-Point (M&R STE, Douthitt)

These units use a narrow LED panel that exposes screens as the screen travels underneath the light bar. M&R's STE on the left however is a CTS imaging system whereas the Douthitt unit is not. The Douthitt unit uses a parabolic lens in front of their LEDs to help collimate the light.

Static & Dynamic Multi-Point (M&R STE 2)

M&R's second generation STE incorporates both dynamic and static exposure in one system to provide added versatility. Screens can be exposed in a stationary position at the rear of the machine for additional time needed for slower emulsions and also exposes as the screen travels under the same light bar used on their first generation model. Customers who prefer using diazo dual cure emulsions that require longer exposure times than can be reasonably achieved using the STE will prefer the STE 2.

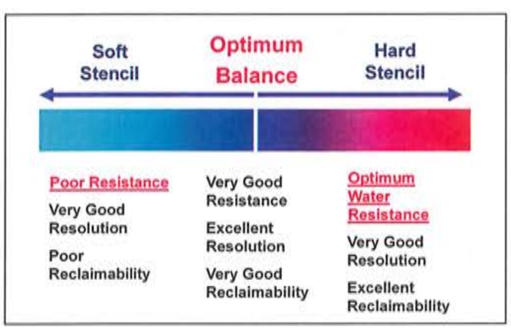
LEDs emit an extremely narrow band of UV. Many LED light sources emit UV light at 405 nm. Some exposure units incorporate two different wavelength LEDs typically 385 and 405 nm. Others may offer slight variations of this.

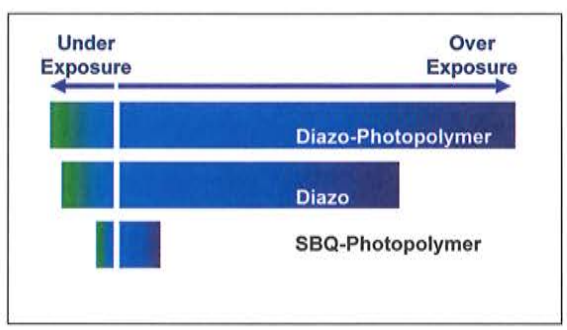
As the trend continues toward dynamic digital CTS exposure equipment we see increasing demand for faster exposing emulsions. Emulsions once considered fast (~30 seconds) on static light sources are now considered slow on dynamic light sources due to the very short duration of exposure required by scanning-type light sources.

Weighing Risk vs. Reward

The reward is significant and clear. Customers eliminate the need for film positives and all the associated steps like outputting, storing, cleaning and registering them to your screens. They also eliminate the need for a vacuum frame which saves a tremendous amount of time wasted cleaning glass and waiting for the blanket to drawdown. Eliminating this step has all but eliminated pinholes. CTS systems precision image placement within microns has reduced press set-up time immensely.

What is not as clear is the potential unintended consequences of using super-fast exposing emulsions. Consumers must consider that in order to provide the exposure speed required to increase throughput, they may be sacrificing processing and exposure latitude as well as resolution, resistance and repeatability.

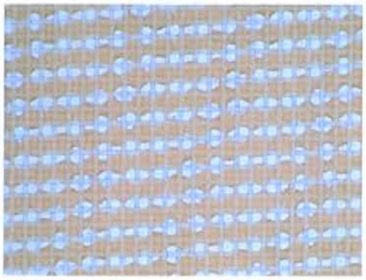




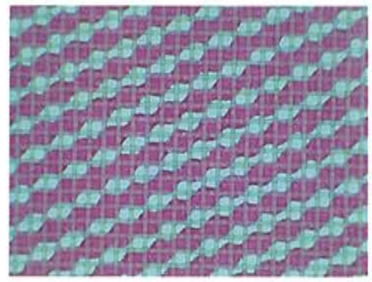
The illustrations above shows exposure latitude and comparisons between diazo, diazo-photopolymer and SBQ (pre-sensitized one part) emulsions. The white vertical line represents where optimum exposure lies. Note that SBQ emulsions have significantly less over exposure latitude than diazo and diazo-photopolymer formulations and more importantly even less under exposure latitude.

Super-fast vs. fast exposing SBQ emulsions. Highly reactive emulsions sometimes give up resolution for speed as illustrated in pictures below showing two different SBQ emulsions imaged on the same mesh with a 50% halftone dot of the same frequency at optimum emulsion cure as determined with an exposure calculator. Both pictures were taken at the same magnification.

50% halftone at optimum 8 second exposure



50% halftone at optimum 18 second exposure



Super-fast exposing SBQs require tighter process control in the screen department. Measuring and controlling key variables like stencil thickness becomes critically important. Printers get lulled into a false sense of security – especially those who have automatic coating machines – thinking they have consistent stencil thicknesses. Although coating machines are capable of very precise, repeatable coatings, most printers do not realize that stencil thicknesses can vary due to two lesser known variables: changes in fill volume and emulsion viscosity.

HOW TO BETTER CONTROL STENCIL THICKNESS

Consistency – Fill Level

Consistency is the key to controlling stencil thickness and many variables influence stencil thickness such as coating angle, speed and pressure, but none more so than coating trough fill level and changes in emulsion viscosity. Screens coated using full troughs produce thicker stencils than screens coated with low volume of emulsion in the troughs. Unless you have a coating machine with automatic trough filling – and who does – make sure you top off your emulsion early and often, especially when using very fast exposing SBQs.

After witnessing a customer coating a batch of 110-80 mesh screens on their coating machine I realized they were unaware of this because the coating troughs were refilled only after changing the dwell time – time between when troughs tip up and the coating commences – from shortest (due to full troughs) to longest (due to near empty troughs) and seeing an incomplete coating at the start of the coating cycle.

To illustrate the impact this was having on their stencil thickness, we measured the stencil thicknesses and Rz values of the coated screens showing that full troughs coat thicker than near empty troughs.

Trough Fill Level	Volume	EOM Actual	% EOM Ratio	Rz Value
Full	155 grams	11 µm	10.18%	15.3
Medium	101 grams	9 µm	8.33%	16.4
Low	67 grams	7 µm	6.48%	18.7

Stencil quality can be difficult to control using super-fast emulsions with this degree of stencil thickness variation. Since super-fast emulsions typically have super-narrow exposure latitude, inconsistencies in copying properties (resolution, edge definition and mesh bridging) will occur with only slight changes in stencil thickness.

Consistency – Emulsion Solids & Viscosity
You may be asking yourself, how can emulsion solids & viscosity change? Don't emulsion manufacturers produce consistent product with tight specification tolerances? Of course they do. Both solids and viscosity change when water evaporates from emulsion sitting in the coating troughs or open containers. The dryer the environment the faster this occurs. Oftentimes screen coating and drying is done in the same room, which is equipped with heaters, dehumidifiers and fans to expedite screen drying. These conditions cause emulsions to thicken quickly.

A customer reported that when using half depleted buckets of emulsion their coating machine applied too thick of a coating although they had not changed any settings on the machine. The customer was asked to measure the viscosity of a new, freshly sensitized bucket and compare it to a half full bucket using a Zahn cup viscometer. The half depleted bucket was twice the viscosity indicating that quite a bit of water had evaporated from the emulsion changing its physical properties. The half empty bucket not only had a much higher viscosity but solids content too resulting in thicker coatings.

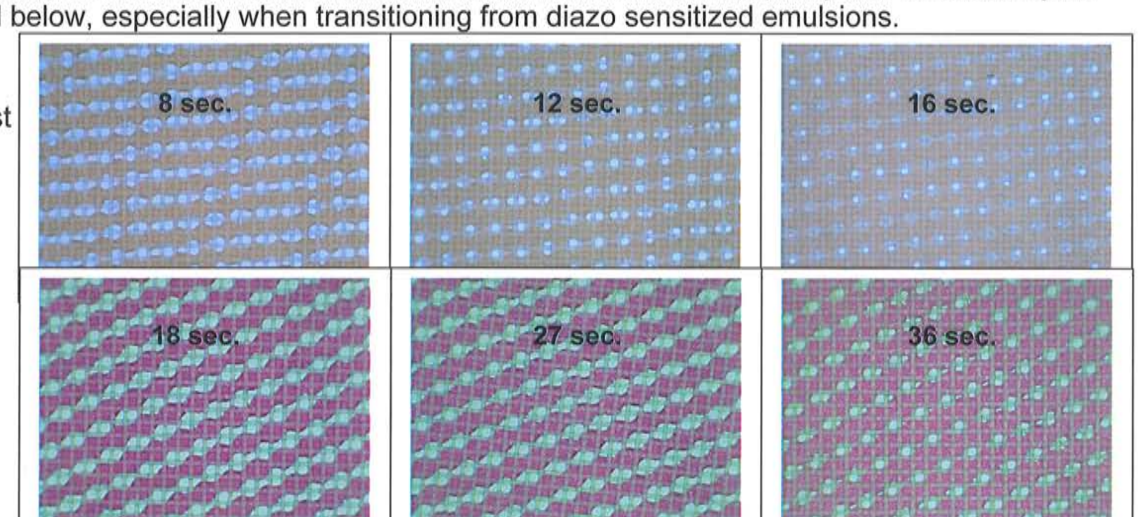
The customer had a very nice drying room with air circulation, elevated temperature and dehumidification. Unfortunately, their coating machine was in the same room causing the emulsion to thicken rapidly. To solve this problem they built a separate drying room for their coated screens and replaced their dehumidifier with a humidifier for their coating room.

The Golden Rule: *coat in a swamp and dry in a desert*, but too few printers know or follow this rule. As mentioned, when using very fast SBQ emulsions any change in emulsion-over-mesh (EOM) or stencil thickness may have a pronounced effect on stencil resolution and durability compared to much slower exposing (~400-600%) but more forgiving diazo and diazo dual cure emulsions, which have much more processing and exposure latitude.

Super-fast vs. Fast Exposing SBQ Emulsions – Re-thinking Exposure Speed
Fast exposing SBQ's may provide a better balance between speed, quality and consistency as illustrated below, especially when transitioning from diazo sensitized emulsions.

Super-fast

Fast



As demand for faster throughput increases, one needs to realize that switching to super-fast emulsions ironically may not help, as many believe. Screens cannot be developed in 8 seconds and due to lack of processing latitude screen rejects/re-makes will likely increase decreasing productivity. So, the bottleneck may not be exposure time but developing time instead.

Unless equipped with multiple washout booths and employees to match, printers will not be able to keep up with the screens. A pre-soak developing tank will help reduce the time required for the final washout, but when we're talking about 8 second exposure times, let's be realistic. Informed, careful consideration should be given to emulsions that meet the broadest range of expectations: speed, resolution, resistance and processing latitude to name a few.

Screen Automation – Developing
Here, a brief discussion about automatic developing is warranted. Screen department automation including automatic developing is becoming more popular. Most automatic developers on the market today provide very limited water pressure and/or volume, therefore require multiple passes – which requires extra time – to develop screens. This too should be taken into careful consideration when deciding on screen room automation equipment.

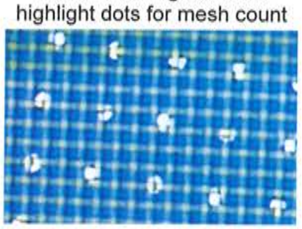
Moreover, developing with low pressure may hinder resolution of fine details for a few reasons:

1. Water Resistant Emulsions
2. Thick Stencils
3. Art-to-Mesh Relationship
4. Light Scatter or Undercutting

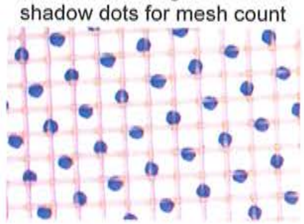
As water based inks grow in popularity, so too will the use of water resistant stencils. Some countries in fact have discontinued the use of plastisol inks all together in favor of water-based systems. Understandably, water resistant emulsions take longer to washout than non-water resistant emulsions since emulsion must first solubilize in water.

Additionally, much of the halftone artwork used for plastisol printing (often printed with 305-34 mesh) remains at the same dot size or LPI although the mesh counts used for printing water-base are coarser. Dot-to-mesh relationships are out of kilter and few amend their output files to compensate for the resulting tonal compression i.e. loss of details.

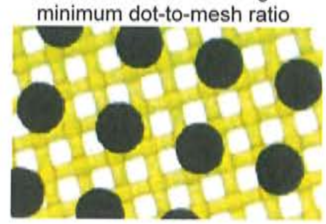
Stencil showing too small highlight dots for mesh count



Stencil showing too small shadow dots for mesh count



Film on mesh showing minimum dot-to-mesh ratio



Paradoxically, as technological advancements in screen making become more commonplace, light scatter or undercutting is more common too due to increased use of multi-point light sources and maskless CTS imaging systems.

Here again, we have unintended consequences. Earlier we categorized todays imaging and exposing options, two of which are maskless imaging and multi-point LED exposing systems. Stray light from these systems partially exposes the image area making fine details difficult to wash out. This combined with increased use of super-fast, water-resistant emulsions and coarser mesh counts with thicker stencils explains why high water pressure is needed to adequately open fine details.

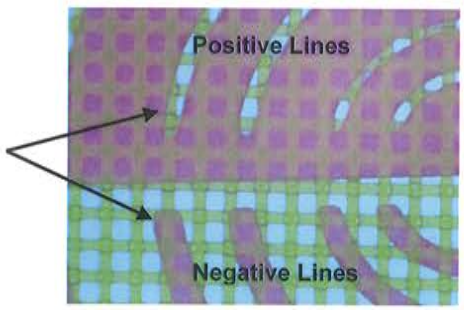
The benefit of using high pressure developing is evident even when using masked imaging systems without super-fast emulsions. Using a wax-based CTS imaging system, two 305 mesh screens were imaged with a 65 LPI test pattern consisting of 100 boxes, each with a different halftone dot ranging from 1-100. The first screen was rinsed out using a hose end sprayer using mains pressure and was able to open up highlight dots down to seven percent, while the second screen was rinsed out using a 1,700 psi hand lance pressure washer with a 45 degree spray angle at ~12 inches distance from the screen and was able to open up highlight dots down to three percent.

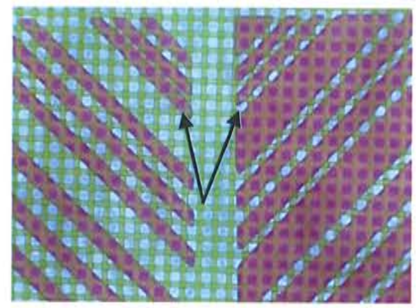
Comparing Single-Point to Multi-Point Light Sources Using a Fast SBQ Emulsion

While the fast SBQ emulsion looks good using a multi-point LED, fidelity is compromised, illustrated by positive lines closing in and negative lines enlarging.

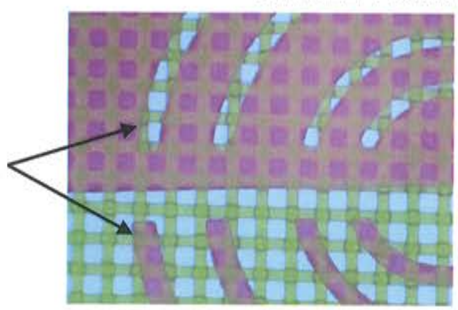
Resolution fidelity is the ability to reproduce the original art with high accuracy. The positive and negative lines are the same size on the artwork but note the discrepancy between the positive and negative lines when imaged on a multi-point light source. Artwork produced with higher fidelity is observed with a single-point metal halide.

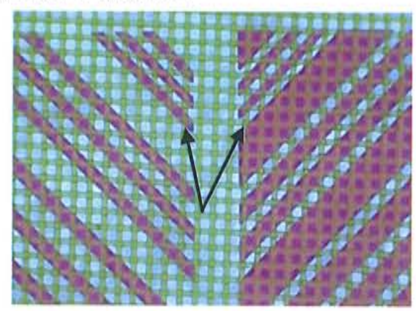
MULTI-POINT LED



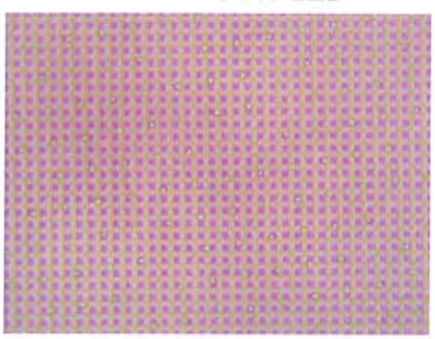


SINGLE-POINT METAL HALIDE

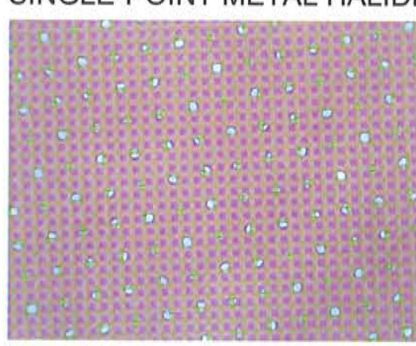




MULTI-POINT LED



SINGLE-POINT METAL HALIDE

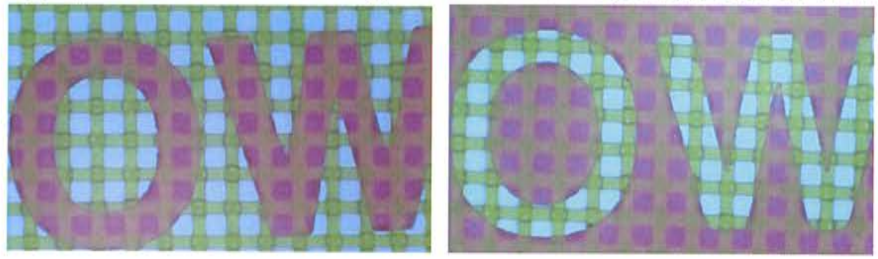


The pictures to the left show a 10% 55 LPI halftone dot on 156-64 Yellow mesh exposed for optimum cure. Single-point light sources do a better job of preventing light undercutting or scatter than single-point systems as illustrated here.

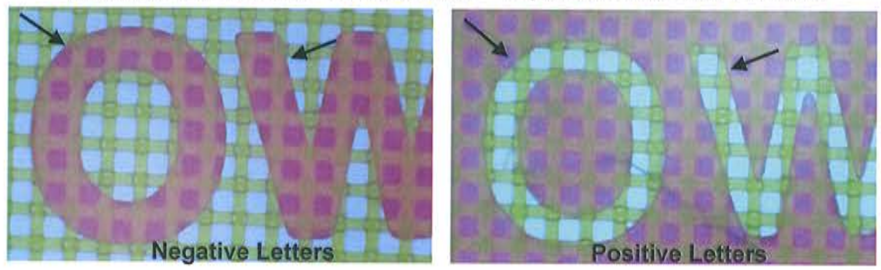
While mesh bridging and edge definition looks very good with both single-point metal halide and multi-point LED exposure systems using this particular fast exposing SBQ emulsion, better fidelity between positive and negative text is exhibited with the single-point metal halide exposure system vs. the multi-point LED system.

Imbalanced weight or thickness of the positive vs negative letters is observed on the multi-point LED

Single-point 5K Metal Halide @ 40" distance – Optimum cure at 16 sec.



Multi-point LED @ ~3" distance – Optimum cure at 14 sec.



With so many different types of imaging and exposing systems in the market now and with ink systems continuing to evolve, it's time to ask ourselves what emulsion is best for my system. As ink and screen making systems evolve, emulsions have too.

Just as we categorized imaging and exposing systems earlier, categorizing emulsions may help us better understand which ones are most compatible with the current imaging and exposing systems.

There are four primary categories of emulsions (Diazo, Diazo Dual Cure, SBQ, SBQ Dual Cure) that can be classified by:

- The type of sensitizer (Diazo or SBQ)
- The number of light sensitize components (One [Single Cure] or Two [Dual Cure])

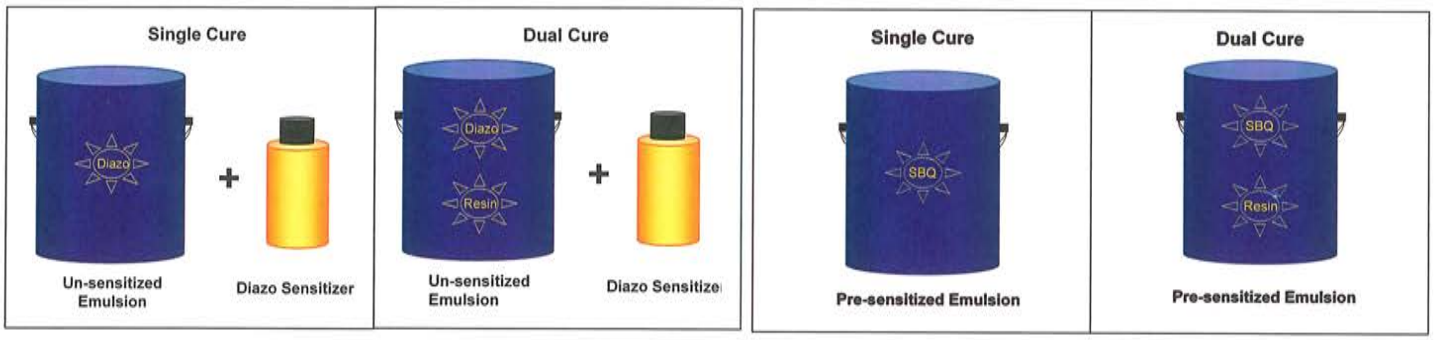
Number of Curable Components →		Single Cure	Dual Cure
Type of Sensitizer	Diazo	Diazo	Diazo Dual Cure
	SBQ	SBQ	SBQ Dual Cure

Most know diazo emulsions because they come with a small bottle of powder (sometimes syrup) that is typically dissolved in water and mixed into the emulsion. What is not as well know is the difference between single cure and dual cure emulsions or that SBQ (a.k.a. "pure photopolymer") emulsions also come in single cure and dual cure formulations.

In simplest terms the primary difference between single cure and dual cure emulsions is single cure emulsions have one curable component and dual cures have two. Both diazo and SBQ sensitized emulsions come in single cure or dual cure formulations.

Dual cures (both diazo and SBQ) contain UV curable resin, single cures (both diazo and SBQ) do not. Dual cures are **capable** of dual resistance (solvent & water) but it is not a given, so one needs to be careful. Single cures are not. Important to note that single cures offer single resistance to either solvent ***or*** water, but not both. The drawings below uses an icon of the sun to represent each curable component (diazo, SBQ, resin) contained within each type of emulsion.

DIAZO SENSITIZED EMULSIONS SBQ SENSITIZED EMULSIONS

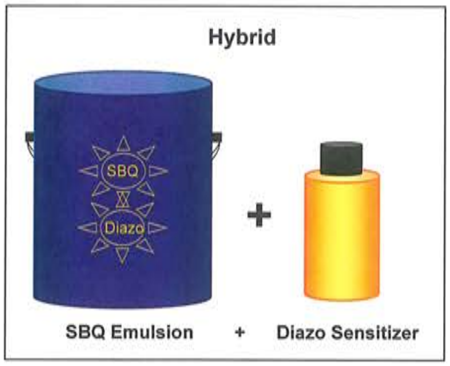


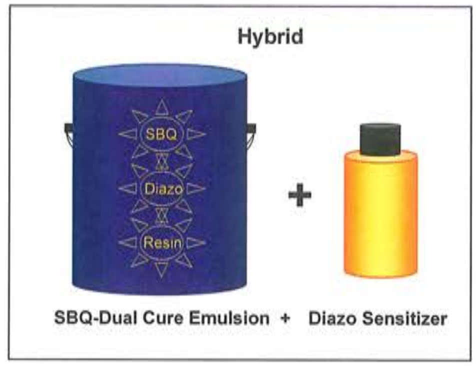
Many T-shirt printers have traditionally used single cure emulsions but are now using inks that may require both water and solvent resistance, something single cure emulsions do not necessarily do well. Co-solvent water-based inks like many of the new high solids acrylics (HS-A's) require not only water resistance but solvent resistant too from an emulsion. Also, some plasticizers used in new eco-friendly plastisol inks require greater solvent resistance than is currently provided by some single cure emulsions.

The trend in emulsions is towards dual cures, but not the diazo dual cure emulsions you typically think of, but SBQ dual cures. As SBQ dual cures do not use diazo, they are much faster exposing than diazo dual cures. This makes them better equipped to handle the demand for faster throughput required by busy shops and those investing in CTS equipment with integrated LED exposure systems. Compared to single cure SBQs, dual cure SBQs typically have better copying properties (resolution, mesh bridging and edge definition) and solvent resistance.

Some confusion exists about the term "hybrid", as some but not all SBQ dual cures are described as "hybrids". An argument can be made to support this definition of hybrid, however, the inconsistency may be confusing for those seeking a clear understanding of their emulsion makeup. If UV curable resin is the defining trait of a "hybrid" emulsion, as implied by the above definition, then diazo-dual cures – which also contain UV-curable resin – should also be considered hybrids.

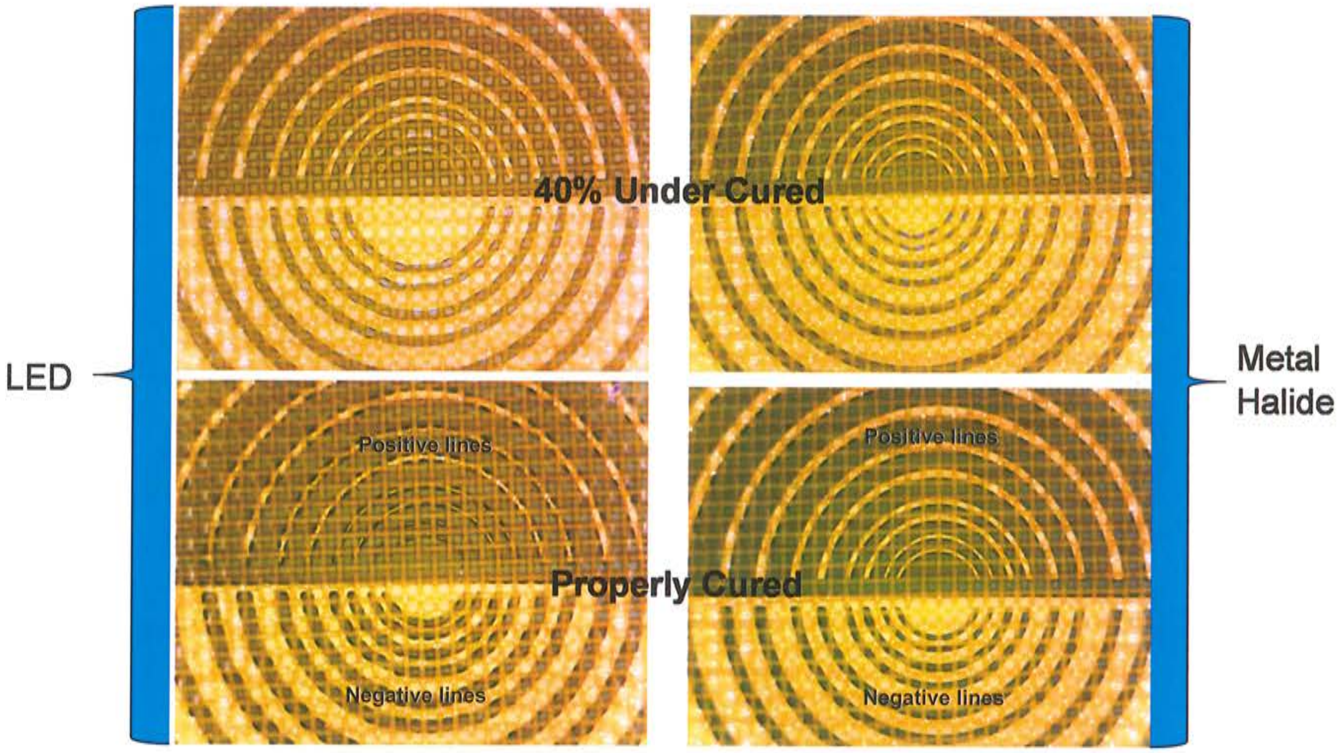
Hybrid, by definition, is the offspring of two plants or animals of different species or varieties; or an article made by combining two different elements, which more accurately describes what occurs when diazo is added to an SBQ or SBQ dual cure emulsion. By adding diazo to SBQ emulsions, one is combining two different varieties of emulsion (diazo + SBQ) together which better fits the hybrid definition and should be easier to understand. The drawings hopefully help you to visualize the difference between emulsion categories. The table below offers further clarification.





Emulsion Category	Common Characteristics
Diazo	• Two-component • Either water **or** solvent resistant, but not both • 4-8 times slower exposing than SBQ systems • Economical single cure
Diazo-Dual Cure	• Two-component • Formulations capable (but not given) of providing both water **and** solvent resistance • ~4-8 times slower exposing than SBQ systems • Highest resolution, mesh bridging & edge definition capability of all systems, as well as chemical & mechanical resistance
SBQ	• One-component – no mixing • Either water or solvent resistant • ~4-8 times faster exposing than diazo systems • Economical single cure
SBQ-Dual Cure	• One-component – no mixing • Formulations capable (but not given) of providing both water **and** solvent resistance • ~4-8 times faster exposing than diazo systems • Highest resolution & chemical resistant SBQ system
Hybrids (Adding diazo to SBQ emulsions)	• Increases wet strength, chemical & mechanical resistance • Increases exposure times ~ 400% depending on quantity diazo • Decreases pot life to ~4-6 weeks @ 68°F • May or may not increase resolution depending on emulsion, exposure system and degree of emulsion cure

Comparing Single-Point to Multi-Point Light Sources Using Diazo Dual Cure Emulsion
Resolution fidelity is better with the single-point metal halide than with the multi-point LED. Even 40% under exposed the multi-point system cannot match the fidelity of the single-point system properly cured.



The enormous exposure latitude of diazo dual cure emulsions is clearly illustrated by the two microscopic pictures above right exposed with a single-point metal halide. When properly cured, light scatter and undercutting is very evident with multi-point exposure systems as illustrated by the positive lines (negative looking in stencil) closing in and negative lines (positive looking in stencil) enlarging.

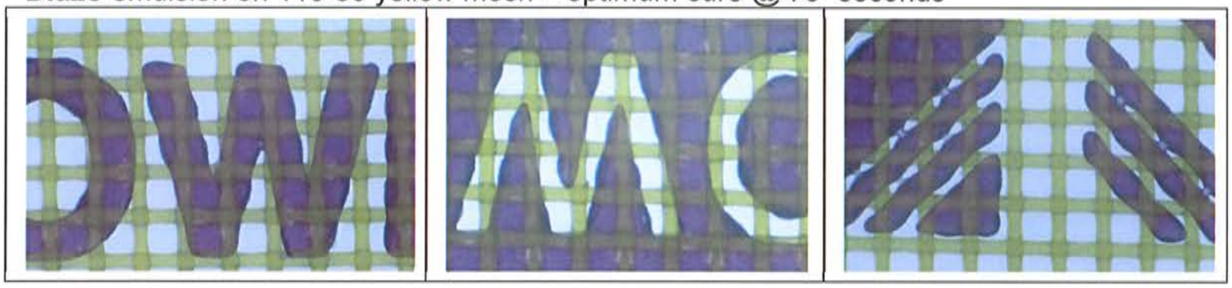
Taking a close look at both of the under cured stencils you will notice how thin the LED exposed stencil is by the light color of the emulsion in the mesh openings compared to the metal halide exposed stencil. Thin stencils are weaker and more susceptible to pre-mature breakdown. Note that the two smallest (50 micron) negative lines were destroyed and fell off the screen during developing.

The takeaway from this section is not only that multi-point light sources do not have the same copying properties as do single point systems which provide better light collimation, but ironically the mesh bridging and edge definition of diazo dual cures seems to suffer more than SBQ and SBQ dual cures when exposed with multi-point light sources in comparison to single-point metal halide sources. Ironic because generally speaking diazo dual cure emulsions provide better mesh bridging and edge definition than SBQs.

The same can be said for single cure diazo emulsions. Note the waviness of the lines of the diazo emulsion in the pictures below, while the SBQ dual cure with diazo additive (hybrid) exhibits better bridging.

Comparing emulsion categories using a Multi-Point LED Light Source

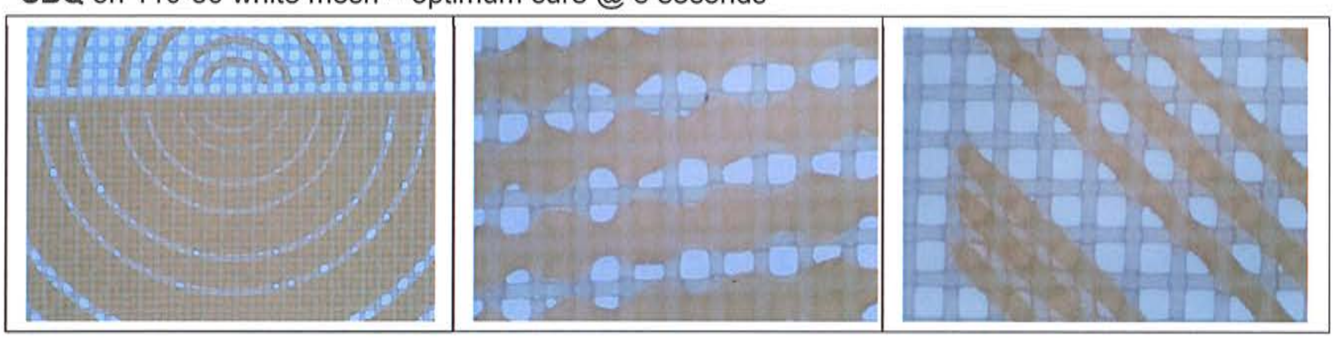
Diazo emulsion on 110-80 yellow mesh – optimum cure @ 78 seconds



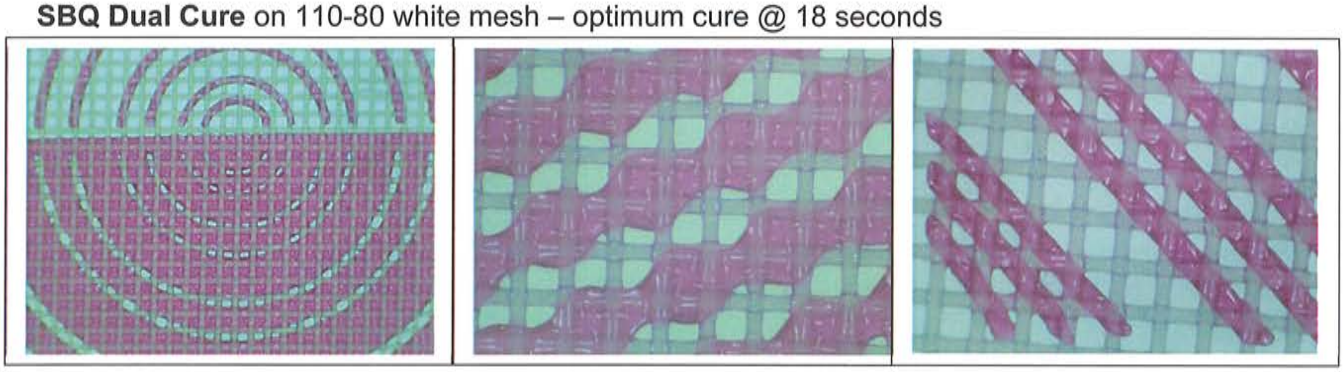
The following Diazo Dual Cure stencils below were exposed on a different LED light source. Note the big difference in exposure times between the diazo emulsions above vs. diazo dual cure emulsions below. Diazo & Diazo Dual Cure emulsions typically expose at approximately similar times. This shows a notable difference in exposure speed between LED exposure systems and more evident with Diazo and Diazo Dual cure emulsions than with SBQ and SBQ Dual Cures.

Diazo Dual Cure on 110-80 white – opt. cure @ 210 sec; 156-64 yellow mesh – opt. cure @ 210 sec.

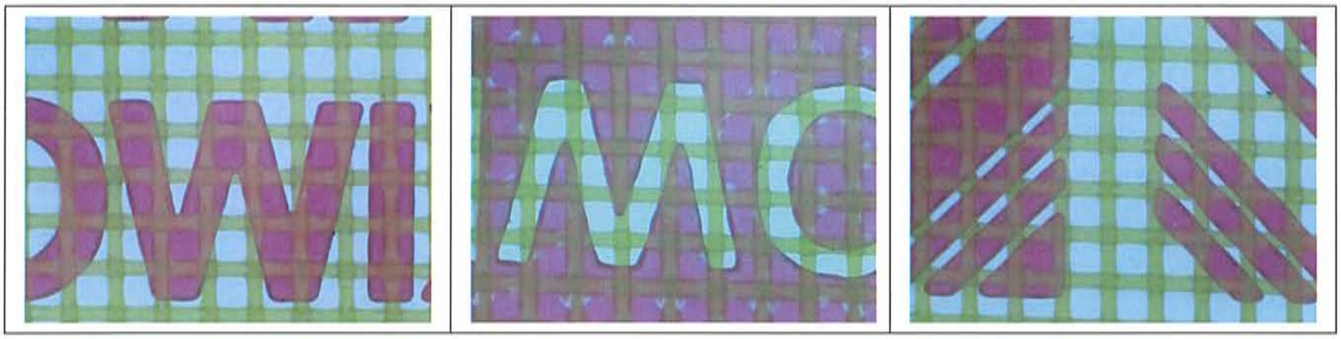
SBQ on 110-80 white mesh – optimum cure @ 8 seconds



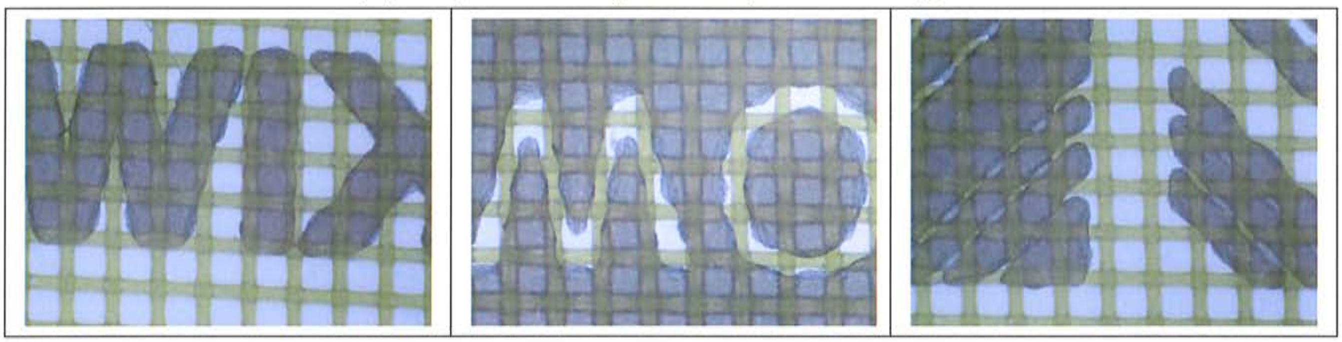
SBQ Dual Cure on 110-80 white mesh – optimum cure @ 18 seconds



SBQ Dual Cure + Diazo (Hybrid) on 110-80 yellow – optimum cure @ 78 seconds



SBQ Dual Cure + Diazo (Hybrid) on 110-80 yellow – optimum cure @ 78 seconds



The two SBQ Dual Cure + Diazo stencil images were imaged on the same LED light source and exposure times calculated using a KIWO ExpoCheck exposure calculator. This suggests that general statements regarding the compatibility of an emulsion type with LED exposure systems cannot be made without further qualification. Although test results imply that certain emulsion categories appear to be more compatible with multi-point LED systems than others, this shows that the specific formulation makes a significant difference too.

Summary

Both textile and graphic screen printers are embracing digital technologies and screen department automation at a rapid pace. Today's printers have so many imaging & exposing options as well as emulsions to choose from and with it comes confusion. This paper tried to make sense of it all by categorizing each available option and explaining the primary strengths, weaknesses, opportunities and threats or unforeseen variables. A SWOT analysis.

Textile printers purchase the vast majority of the masked inkjet CTS systems while graphics printers purchase the majority of the maskless direct exposure CTS systems due to their larger format and higher resolution capability.

Direct exposure CTS systems use a scanning mechanism to expose, which require super-fast SBQ emulsions to meet advertised throughput expectations. Using such light sensitive emulsions causes a degree of unintended curing in the image areas due to stray light. Developing finest halftones thus requires higher pressure to penetrate and open these fine details, something most automatic screen developers don't offer at the present time.

Ink jet CTS systems adheres a UV mask directly to the surface of the emulsion providing somewhat better protection from light scatter and undercutting than traditional film positives, which rely on a film carrier that cannot conform as perfectly to each peak and valley on the surface of the screen even with exceptional vacuum. Without perfect adherence, light creeps underneath the artwork. Inkjet CTS systems therefore will help to minimize light scatter experienced when using multi-point light sources.

Look for manufacturers of direct exposure CTS equipment to market smaller size machines into the textile market once dominated by Inkjet CTS equipment and for manufacturers of Inkjet CTS equipment to improve resolution capabilities and market larger machines into the graphics market.

Multi-point light sources – like the new LED systems flooding into the market – offer many advantages over conventional light sources, but do cause light scatter to occur more quickly and severely than single-point light sources do. Look for advances in this area, as light source manufacturers improve light collimation through the use of parabolic lens.

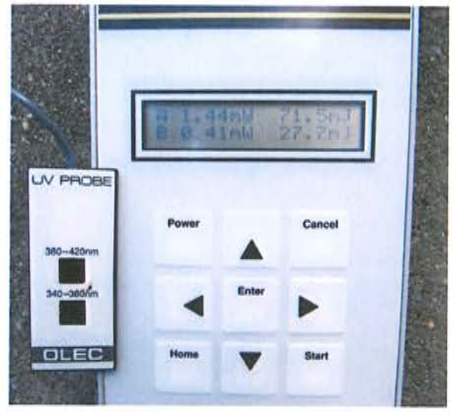
In the pursuit of customer satisfaction printers are pushing for faster throughput and job turnaround. Some who once used diazo dual cure emulsions with a single-point light, now using a fast SBQ or SBQ dual cure emulsion with an LED light report having inconsistencies and difficulty printing really high resolution. This is primarily attributed to three factors:

- Multi-point light sources exhibit more undercutting of artwork
- Fast SBQs typically have less exposure/processing latitude and resolution than diazo dual cures
- When switching from plastisol to water-based inks, one cannot print the same level of resolution using coarser meshes that one used to print using finer meshes

Unfortunately, this causes printers to further under expose screens attempting to capture some of the detail lost. While this causes less of a problem when printing plastisol, it causes premature breakdown when using water-based and discharge inks. Printers must now measure and control their screen making variables, such as stencil thickness, dry times, relative humidity and level of emulsion cure like never before to prevent rejected screens and re-makes.

Results from testing several imaging and exposing systems provided interesting and some unexpected results. The following is a list of general observations comparing static multi-point LED light sources vs. a high quality static single-point 5K metal halide light source at 40" distance:

1. A UV radiometer was unable to measure any milliwatt (mW) UV output between 340-420 nanometers despite its ability to cure SBQ/SBQ dual cure a.k.a. pure photopolymer emulsions as quickly as a single-point metal halide measuring 4.5 mW & 5.0 mW



2. Using an LED light source white vs. yellow mesh achieved optimum cure at approximately the same times, whereas using metal halide light sources yellow mesh requires 50-80% longer exposure time compared to white mesh of the same mesh count.
3. Loss of fidelity & exposure latitude were observed using LED exposure systems.
4. SBQ & SBQ Dual Cure emulsions exhibited better than expected edge definition & mesh bridging (in most cases) using LED exposure systems and the least quality discrepancy between the LED and the single-point metal halide exposure systems.
5. Diazo & Diazo Dual Cure emulsions exhibited poorer than expected copying properties compared to SBQ and SBQ Dual Cure emulsions and greater quality discrepancy between the exposure systems.
6. SBQ & SBQ Dual Cure emulsions closely match exposure speed of 5K metal halide @ 40" distance.
7. Diazo & Diazo Dual Cure emulsions require ~1.5 times the exposure time using LED exposure systems.

Conclusion

While digital and LED technologies bring exciting changes to our industry worldwide, it is incumbent upon screen printers and screen making departments specifically to acquire a more comprehensive understanding of the fundamental principles of screen making. With this knowledge along with thorough measurement and precise control of screen making variables, the benefits these new technologies provide may be fully realized without a long, steep learning curve.

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