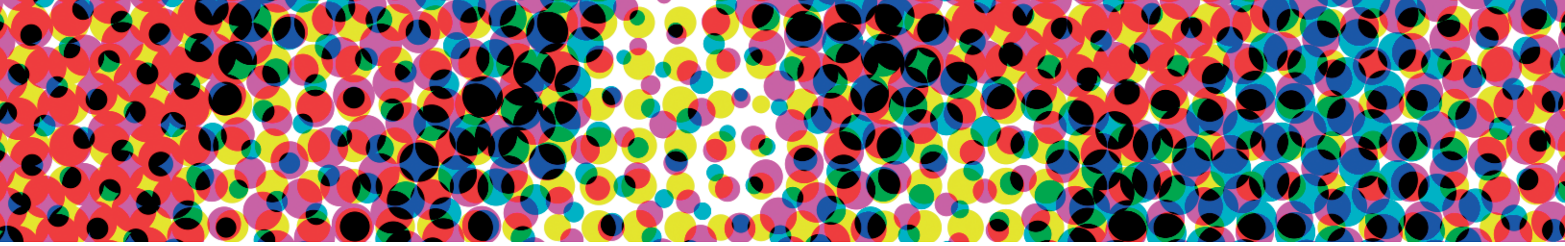

The Sericol Guide to UV Screen Printing

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SERICOL
More than ink…Solutions.
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This is the 2nd edition of the 'Sericol Guide to UV Screenprinting'.
It contains updated information in an easier to read format.

Information of particular importance is denoted in two ways.

sections focus on more detailed explanations of UV technology.

sections offer practical advice on getting the most out of UV ink technology.

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Foreword
Understanding the UV screen printing process

The advantages of UV inks and curing systems are well established. The ability to produce superior quality prints, faster and at lower cost, using more environmentally friendly chemistry is a strong argument in favour of any printing process. UV screen printing technology offers all this and more.

To realise the full potential of the UV screen printing process, however, requires a commitment to establishing and maintaining the highest quality standards throughout the entire production process. The very properties that make UV such a compelling business proposition can present challenges for even the most expert printer.

'The Sericol Guide to UV Screen Printing' is intended to help meet those challenges and exploit the huge advantages of UV screen inks. It provides a comprehensive user-friendly guide to producing consistent, controllable, high quality screen prints, using the latest UV printing technology, in your own shop, under real-world production conditions. As such there is an emphasis on practical, proven advice.

For those who are new to 'UV', the guide walks you through the theory and practice of UV screen printing, building knowledge and understanding gradually. Where appropriate, there are direct comparisons between printing with UV ink and traditional solvent-based ink, enabling you to evaluate the UV screen printing process with reference to a system that you are likely to already be familiar with.

More experienced users of 'UV' technology may prefer to use the guide as more of a reference tool – to find answers, clarification and advice on specific questions. By collecting together in-depth information from many expert sources, this guide should prove to be an invaluable printshop resource that will help to optimise the performance of any UV screen printing operation. However, printers will inevitably face challenges that are unique to their particular production set-up, working practices and print applications. Sericol's customer service teams are there to provide expert solutions for any problem or enquiry that may arise.

With over 30 years' experience as a global leader in the research, development and manufacture of UV screen printing inks, Sericol are perfectly placed to help realise the maximum return on investment in UV screen printing technology.

Sericol: More than ink...Solutions.

Chapter 1
An introduction to UV screen printing

What is UV screen printing? In simple terms, it is the process whereby a specially formulated screen ink is printed on a substrate and then converted from a fluid ink deposit to a solid ink film (cured) by exposure to high concentrations of ultra violet (UV) energy.

Ancient origins

The UV curing process itself has been recognised and applied for many thousands of years. The Ancient Egyptians, for example, documented a process that used the sun's rays to cure 'UV-sensitive' compounds in the bitumen coatings on the linen wrapping of mummies.

The use of UV rays to cure printing inks is a more recent development: research into UV printing can be traced back to the 1940s, and the first patent for a 'UV curable' printing ink was granted in 1946.

The printing industry witnessed a rapid growth in interest in this 'new' technology 20 years later, brought on by the introduction of the first solvent-restrictive legislation (the Los Angeles Pollution Act, 1966). Aimed at reducing the emission of volatile organic compounds (VOCs) into the atmosphere, the act heralded an age of heightened environmental awareness amongst governments, businesses and consumers. Faced with the prospect of ever tighter restrictions on the use of solvents and the rising cost of pollution control, the printing industry recognised the need for a long-term alternative to its traditional solvent-based ink chemistry. UV curable inks, which contain little or no organic solvents, offered a potential solution.

Research into UV printing processes accelerated during the 1970s as the potential performance benefits of UV inks became evident. As well as the environmental advantage, UV technology promised to solve the many drawbacks associated with traditional solvent ink technology. UV inks of the time were far removed from the refined products that are available today, and there were lingering doubts over the performance and user-friendliness of some early UV ink technology. It wasn't until the 1980s that the UV screen printing process really established itself as a viable alternative for screen printers. This coincided with significant investment by manufacturers into the research and development of UV printing ink components and formulations. The advances in UV chemistry were accompanied by corresponding advances in the design and manufacture of UV curing equipment.

Solvent and the environment

Legal restrictions on the use of organic solvents in screen printing inks stem from the fact that when the solvents evaporate - during ink mixing, printing and drying – volatile organic compounds (VOCs) are emitted into the atmosphere. Sunlight then acts as the catalyst in a photo-chemical reaction that turns the organic material into smog.

Smog has become a major environmental and health problem in many industrialised cities in the world and although individual national regulations vary, a reduction in solvent emissions and the improvement of working environments have become common regulatory themes.

Current technology

In recent years, the case for 'UV' has been further strengthened by the availability of specialised inks geared toward particular applications. There are now no limitations on what can or cannot be printed using UV ink.

Continuing advances in UV ink technology mean that many formulations out perform equivalent solvent inks. Clients have recognised such advances and many are now demanding the detail and quality of finish that is achievable with UV inks. Thus, the move towards UV is now also being driven by customer demand.

For the screen printer, the UV printing process delivers major productivity gains and significant cost savings in use. It also reduces turnaround times in line with the needs of today's 'just-in-time' marketplace.

The ongoing development of UV screen printing in recent years has also served as a catalyst for wider advances in the screen printing process generally, subsequently opening the door to new markets for the screen printer. Obvious examples include the advent of multicolour in-line machines (MCMs) and low energy curing systems, such as flash curing, which depend upon the use of UV inks.

UV technology has come a long way over the past 60 years. It has played and will continue to play a major role in the advancement of the graphics screen printing industry. In the future, mastery over UV technology will enable printshops to compete more effectively within not only the screen printing market, but the wider printing marketplace also.

Chapter 2
UV screen printing ink

UV ink represents a radical departure from traditional solvent-based ink technology and demands a new set of working procedures. In this chapter we will look at the types of UV ink that are currently available and learn how they are cured (converted from a fluid to a solid ink film).

First, it is imperative to establish the defining properties of UV inks. These are:

- UV inks contain little or no organic solvents; and
- UV inks cannot be 'dried' – they will convert from a fluid to solid state only when they are exposed to a high concentration of UV energy.

To better understand how UV inks work, it is useful to compare them with traditional solvent inks, which most printers will already be familiar with.

Solvent ink formulations

Solvent inks are manufactured from **resins** (polymers), in powder or granular form, such as acrylic, vinyl, polyesters, urethane and epoxy. These form the chemical backbone of the ink and give it its finished properties.

The resins are dissolved in a mix of volatile **solvents** to create a fluid of a suitable viscosity for printing. Traditional graphics screen printing ink formulations comprise between 60% and 75% petrochemical solvents (or organic compounds).

Pigment gives the ink its colour and opacity. It is dispersed in the fluid to ensure uniform pigment particle size and smooth printed colours. Pigments are selected according to their compatibility with resins, toxicity, lightfastness and cost.

Finally, **additives**, such as wetting agents and flow modifiers, are mixed into the ink to control its on-press performance.

Conventional UV ink formulations

Oligomers – Conventional UV inks are also manufactured using resins, which provide the body, wetting ability and adhesion properties of the ink. The resins are different to those used in solvent inks; they are in the form of viscous oligomers and are referred to as 'reactive resins'. Examples of oligomers used in UV inks include epoxy acrylate, polyester acrylate and urethane acrylate.

Monomers ('reactive diluents') are used to thin the oligomers to printable viscosities. In this sense, monomers fulfil the same function as solvents in traditional screen ink. Monomers are chemicals that not only thin the ink, but also help determine the adhesion and surface characteristics (hardness, flexibility and so on) of the cured ink film.

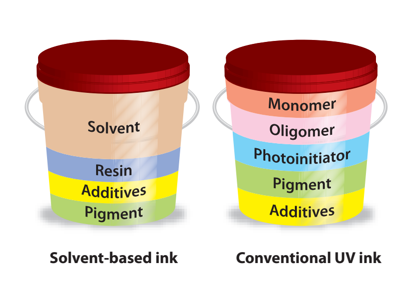


Fig 2.1

Photoinitiators are the key to the UV curing process. They act as a 'light antenna', absorbing UV radiation and initiating the curing process. Different photoinitiators are receptive to different wavelengths of UV radiation. For this reason, a combination of different photoinitiators is commonly used in a single ink formulation to ensure effective cure.

Pigments perform the same function as those used in solvent inks.

Additives in UV inks perform broadly similar functions as those used in solvent inks to modify ink viscosity/rheology.

Water-based UV ink formulations

Water-based UV inks use similar chemistry to Conventional UV inks, with one important exception: part of their monomer content is replaced with water. Like monomers, water acts as a diluent but plays no part in determining the final ink film characteristics. Water-based UV ink systems are described as 'hydrophilic' (water seeking), which means that the water content is closely associated within the molecular structure of the ink itself. Water-based UV inks are designed to deliver a reduced ink film thickness compared with conventional UV inks. Ink film thickness is one of the most important factors affecting the ink's curing response (see Chapter 4: UV Ink and The Curing Process) and limiting the thickness of the ink deposit is fundamental to achieving high finished print quality, especially when UV screen printing four colour process.

Figure 2.1 illustrates the chemical components of solvent and conventional UV inks.

Flash cure UV ink formulations

Conventional and water-based UV inks can be further sub-divided into continuous and flash curing formulations.

Flash curing UV inks answer to the needs of printers operating certain makes of multicolour in-line machines (MCMs) and those printing on to heat-sensitive substrates. The ink's formulation and, in particular, the technical parameters of the photoinitiators used in the ink, are different to those of continuous curing UV inks; they allow the ink to partially cure leaving a low tack surface when exposed to brief, high-intensity flashes of UV radiation. This enables the rapid overprinting of inks on multi-colour prints using MCMs, with a full cure following the final colour.

How the ink systems work

The means of converting a fluid ink into a solid ink film on a substrate is radically different for solvent and UV inks.

Solvent ink – Once a solvent ink has been printed on to the substrate, it is converted from a fluid (wet) state to a solid (dry) state by solvent evaporation. Heating the ink deposit accelerates the rate of solvent evaporation, hence the use of hot air jet dryers. Once all the solvent has been exhausted from the ink, a dry, solid ink film remains – the ink has effectively returned to its original resin form, but with the addition of pigment.

If the ink comprises 70% solvents, as shown in figure 2.1, then 70% of the ink you print onto the substrate will evaporate. This will leave only 30% of the original ink deposit in the dry ink film. Thus only a small proportion of the ink that you lay down on the substrate is utilised in the final print.

Figure 2.2 illustrates the relative thickness of the ink deposit and dried ink film for solvent ink.

Conventional UV ink contains little or no solvent and, therefore, cannot be dried by solvent evaporation. Pass a substrate printed with UV ink through a jet dryer and the ink will still be fluid when it emerges. To convert the ink from a fluid to solid form you must expose it to a high concentration of UV energy. This is achieved by passing the printed substrate under UV lamps that radiate UV energy. (Flash curing UV inks are covered separately, overleaf)

When the UV energy from the lamps strikes the ink it promotes a rapid chemical reaction that causes the various chemical components within the ink to cross-link together. This almost instantly converts the ink deposit from a fluid to a solid state. The cross-linking process is referred to as 'photopolymerisation' (see Understanding Photopolymerisation page 8). It is similar in principle to the reaction that causes the hardening of direct emulsions during the stencil making process.

Conventional UV inks are also referred to as 100% solids products; as there is no solvent to evaporate, all of the ink that you print on to the substrate is incorporated into the cured ink film. 'You get what you print'.

Figure 2.3 illustrates the relative thickness of the ink deposit and cured ink film for conventional UV ink.

Water-based UV inks are cured in the same way as conventional UV inks. The only difference being that the water content is displaced from the ink during the curing process, in much the same way as solvent evaporates when solvent-based inks are passed through a jet dryer. The thickness of the cured ink film will be less than that of the printed ink deposit. This is the main advantage of water-based UV ink compared with conventional UV ink; reducing the thickness of the ink deposit facilitates effective curing of the ink, and also delivers superior print quality. Early water-based UV ink formulations required the ink deposit to be heated to evaporate the water content before the ink was exposed to UV radiation. Sericol's water-based UV inks do not require pre-drying – the water content is displaced using the heat generated by the UV lamps and the heat generated by the chemical reaction taking place within the ink. The resulting cured ink film is not only converted to a solid state, but it also becomes water-resistant (hydrophobic).

Figure 2.4 illustrates the relative thickness of the ink deposit and cured ink film for water-based UV ink.

Figure 2.5 illustrates the considerable difference between the ink film thickness for solvent, conventional UV and water-based UV inks.

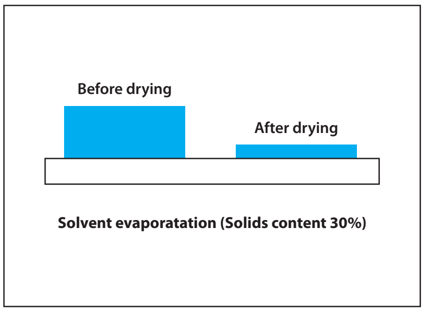


Fig 2.2

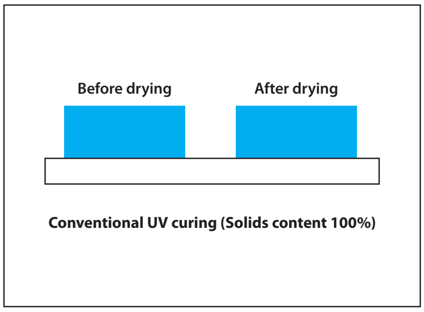


Fig 2.3

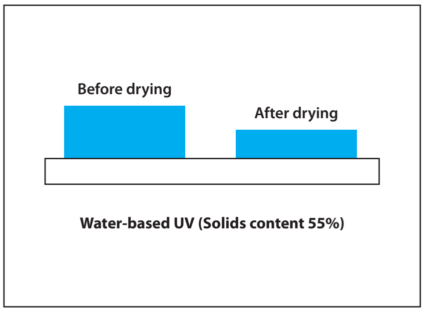


Fig 2.4

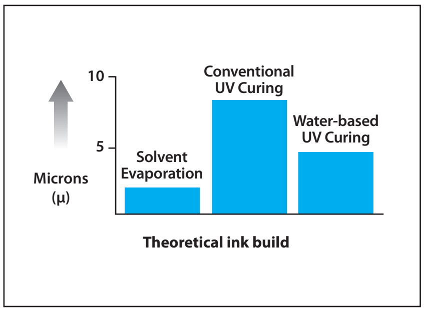


Fig 2.5

Understanding photopolymerisation (curing)

When UV ink is exposed to the correct intensity, density and wavelengths of UV energy, the photoinitiators in the ink are 'activated'. The photoinitiators undergo a chemical reaction, splitting at the molecular level to release 'free radicals'. These react with the oligomers and monomers in the ink and cause a rapid cross-linking reaction (polymerisation) that bonds the ink components together to form a stable polymer.

Once initiated, the chain reaction within the ink occurs very rapidly and continues until all of the available components have been linked together. At this point the fluid ink has been converted to a solid ink film and is said to have cured.

The ink is immediately cured to the point where the prints can be stacked with low risk of blocking. However, all UV inks undergo a period of post-curing, during which the polymerisation process continues to completion. Most post-curing activity times take place between 5 minutes and 24 hours, however the total post cure period can last several weeks, depending on the ink formulation. Certain ink additives, such as adhesion modifiers, can also affect the ink's post-curing time. During the post-curing period there may be changes to the adhesion characteristics and hardness of the cured ink film. Post-curing and substrate cooling can also cause the ink film to become more brittle.

The chemical reaction that takes place during the photopolymerisation process is irreversible. Once the reactive oligomers and monomers have cross-linked they are no longer reactive; they are stable. That is to say, the film ink cannot be converted back to a fluid state.

Like all chemical reactions, heat will help to promote the polymerisation process, but only once the process has been initiated. Heat alone will not 'dry' UV inks and create a solid ink film.

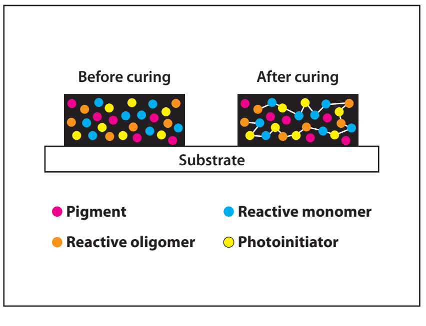


Fig. 2.6 illustrates the photopolymerisation process.

Flash curing inks, (whether conventional or water-based), undergo a curing process that's tailored to multicolour in-line printing. After the first colour has been printed, the ink is exposed to several brief, high-intensity flashes of UV radiation. The energy of each flash is great, but the UV radiation does not penetrate to any great depth through the ink. Nevertheless the UV energy generated by the flashes (see Understanding Photopolymerisation) cause the rapid polymerisation of the surface of the ink, which cures to a point where it can be overprinted with another ink. It is not necessary to achieve a complete cure at each printing station on an MCM, as the partially cured prints will not be stacked until after the final cure. When the last ink has been printed, the substrate passes through a 'conventional' UV curing unit to effect a complete cure of the entire ink deposit, as described above.

Chapter 3

Comparing UV and solvent-based ink systems

Having understood the different properties of solvent, conventional UV, water-based UV and flash curing UV inks, it is possible to compare the different ink systems and evaluate their strengths and weaknesses. To begin with, we'll compare conventional UV ink with traditional solvent ink. (Most of the observations in this section apply equally to water-based UV inks.)

Colour stability – Solvent-based inks are unstable: from the moment you place the ink into the screen, the volatile solvents begin to evaporate into the air. The evaporation rate is affected by the ambient temperature, humidity and rate of air flow across the ink, and is accelerated by the action of the squeegee as it moves the ink backwards and forwards across the screen during printing. Solvent evaporation is difficult to control and impossible to prevent.

In practical terms, partial solvent evaporation changes the viscosity of the ink in the screen and subsequently the thickness of the dry ink film. This changes the colour value of the print – a change that registers as a general strengthening of the colour. The effect is most noticeable with halftone and other transparent inks. To re-establish accurate colours, the screen must be cleaned and new ink added. This requires constant monitoring by the operator which reduces productivity.

Generally there are no solvents in conventional UV inks to evaporate and the viscosity of the ink remains constant until the ink is exposed to UV radiation. This puts the press operator in control; there is no reason to stop production to check colour accuracy as the colour value of the print will be the same throughout the production run.

Drying-in – The fact that UV ink does not convert to a fully cured form until it is exposed to UV radiation minimises or eliminates the risk of ink 'drying-in' the screen. This allows the use of higher mesh counts and the printing of fine detail images. Halftone prints using a screen ruling of up to 60 lpcm (150lpi) can be produced successfully, provided the stencil is capable of resolving this level of detail. As well as benefiting from the use of finer line screens, halftone prints also display greater highlight detail compared with solvent inks as there is little or no drying-in to block the passage of ink through the smaller stencil openings in the highlight areas. Generally, print runs made with UV inks more consistently match the original artwork than those made with solvent inks.

The minimising of drying-in has major benefits in terms of productivity. Using solvent ink, the operator will need to stop the press periodically, wiping the screens with solvent to re-wet and remove the dried-in ink. Similarly, if production is halted for even a few minutes – to adjust the registration or squeegee pressure, for instance – the screens may need to be cleaned. Production managers will also need to reserve time at the end of each shift for cleaning up, to prevent the ink from drying in completely.

Regular screen cleaning slows production, increases the risk of damage to the stencil, increases operator exposure to solvents and leads to a higher spend on cleaning materials and waste disposal.

When printing with conventional UV inks there is less requirement for the screens to be cleaned during the print run. This means less downtime and enables press operators to continue printing right up until the end of their shift. Screens are far easier, quicker and less expensive to clean, as there is no dried-in ink to remove, and stencils are less likely to be damaged or have to be re-made. Left over UV ink can be reused without fear of introducing dried ink residue which can block screens in future runs.

The absence of drying-in does require the printer to exercise more stringent controls over stencil-making procedures. When UV inks began to be widely used, some printers complained that the inks were attacking their stencils, causing pinholes. In fact, the ink was having no such effect – the pinholes were a result of less than perfect screen-making methods. In the past, there had been no penalty attached to using these stencils as the solvent ink had dried in rapidly, blocking the small openings almost immediately. With the UV ink, however, there was no drying in and every detail on the stencil – intended or not – was reproduced in the print.

Ink mileage – The mileage of UV inks is generally higher than solvent-based inks due to the combination of finer mesh and thin film stencils normally employed.

Opacity – For UV ink to cure thoroughly, UV energy must be able to penetrate the depth of the ink film. For this reason, the absolute opacity of some solvent inks cannot be matched in UV.

Ink cost – UV inks are more expensive than solvent inks, because the individual ink components cost more – monomers, in particular, are more expensive to manufacture than petro-chemical solvents. However, the higher 'mileage' of UV inks helps to offset their higher 'per litre cost', and is one of the reasons why UV inks can deliver cost savings in use when compared with solvent inks. Further savings are achieved by the increased productivity and reduced down time associated with UV inks.

Speed of cure – The UV curing process is completed rapidly. This allows for the effective curing of UV inks at line speeds of up to 45 m/min. There is also less delay when printing multiple colours, and a reduced requirement for secondary operations, such as the stacking and cooling of substrates between colours. Fast curing cuts the time between finishing printing and beginning post-production processes, such as trimming, embossing or die-cutting.

It is estimated that printing with UV inks delivers an increase up to 20% in production compared with solvent inks.

The near instantaneous curing of UV inks also limits the amount of time available for dust and other contaminants to collect on the surface of the wet ink deposit, thus preserving the print's quality of finish.

Re-wetting and blocking – Once UV ink has been cured, the change in the ink structure is irreversible. This virtually eliminates the risk of re-wetting and colours bleeding-through, even when overprinting a solvent ink.

Similarly, once the UV ink has been cured, the printed substrate can generally be stacked immediately. This speeds up production and minimises waste.

Surface finish – Cured UV inks have an inherently hard finish that is durable and resistant to abrasion. Most UV inks also have excellent resistance to chemicals and low thermoplasticity (they are less prone to softening when heated).

Space considerations – The absence of solvent and heaters needed to evaporate it means that UV curing units are far shorter than hot air dryers, occupying only 10% - 50% of the space. Thus, a given level of production can be undertaken in a smaller workspace with the attendant reduction in overheads, or production can be increased by adding further production lines without having to move to larger premises. The fact that the printed substrate has less distance to travel before it is available for stacking or post-production processing can also boost efficient use of space.

Energy savings – Continuous UV curing units are energy efficient, using only 10% - 50% of the energy consumed by a hot air dryer. Flash curing units are even more energy and cost efficient.

Unlike solvent inks, there is no need to install expensive pollution control measures when using UV inks. Not only does this provide a considerable saving in terms of capital outlay, it further reduces energy (and waste disposal) costs.

Substrate distortion – Many substrates are sensitive to heat, which causes them to shrink or become otherwise distorted, and adversely affects registration on multicolour prints. UV curing units produce a lot of heat, but the fast line speeds and short length of the curing units themselves mean that substrates are exposed to the heat for only a very short period of time. This can help to reduce the likelihood of substrate distortion and promotes more accurate registration. However, effective lamp cooling systems are required with more heat-sensitive substrates.

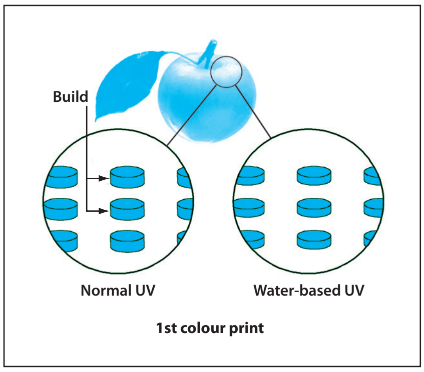


Fig. 3.1

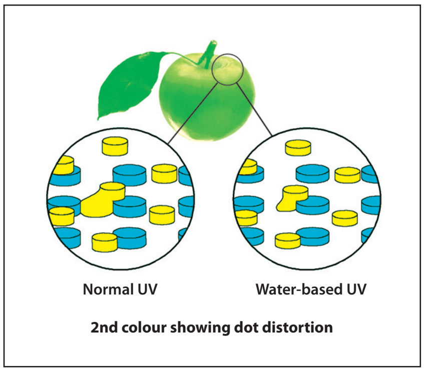


Fig. 3.2

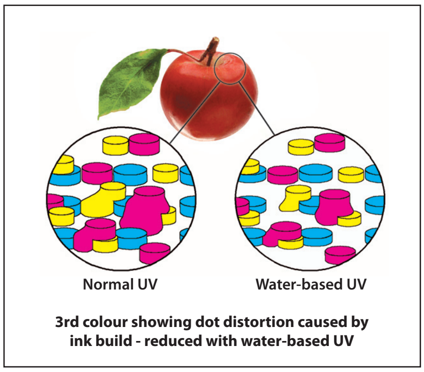


Fig. 3.3

The absence of solvents (which chemically attack the substrate) in UV ink and the fast rate of UV curing also minimises distortion of the substrate. Care must be taken with porous substrates as the UV ink that sinks into the materials may not be cured effectively, compromising the adhesion and appearance of the print.

Health and safety – UV ink has no flash-point, which means that, unlike solvent ink, it is not classified as a flammable material. It is safer to store, transport and use, and printshops could even benefit from lower insurance premiums.

There are none of the respiratory health risks associated with solvent emissions and using UV ink also makes for a more pleasant working environment.

Nevertheless, UV inks must be handled with care as they can cause eye and skin irritation. The UV curing process can also create ozone, which is a health hazard in large doses, and must be evacuated from the plant. Unlike solvent emissions, however, ozone has no environmental impact, naturally converting to oxygen once it comes into contact with the air outside the plant.

Water-based UV ink

A comparison between water-based UV inks and solvent inks would be similar to the above, with one or two important exceptions. A more useful comparison can be made between water-based UV inks and conventional UV inks.

Ink film thickness – Poor ink cure and adhesion is a risk with conventional UV inks unless ink deposit is precisely controlled. Water-based UV ink helps to alleviate this risk: part of the ink deposit (the water content) evaporates during the curing process leaving a thinner ink film for the UV radiation to pass through.

A reduced ink build dramatically improves print definition, especially on four-colour halftone prints. It also reduces dot gain, which can result in a darkening of the image, a loss of detail, in the shadow areas, and sudden tonal jumps. The combined result is vastly improved print quality: water-based UV ink delivers the best print quality currently achievable by the screen printing process.

Figures 3.1, 3.2 and 3.3 illustrate the difference in print quality between conventional and water-based UV ink systems on a four colour process print.

Colour stability – There is a trade off between thinner ink deposits and screen stability. Like the solvent content of solvent ink, the water in water-based UV inks will evaporate during the printing process. The rate of water evaporation is slower than that of some solvents, but ink viscosity is prone to change during a print run. This requires the press operator to check colour accuracy throughout production. Crucially, though, water-based UV inks do not dry-in.

Wash up and thinning – Water-based UV ink can be thinned and screens washed up with water. This is more convenient, environmentally friendly and less expensive than using additives to thin, or solvents for cleaning the ink.

Substrates – water-based UV inks are limited, to some extent, by substrate compatibility. Papers can swell, due to the ink's water content. Some degree of cockling may occur, though this normally drops out once the prints have been conditioned by standing in a normal environment for a few hours. Paper curl (where the sheet edge along the paper grain lifts up and does not recover) can occur, though generally this results from excessive curing arising from multiple passes through a hot UV curing unit.

Water-based UV inks are suitable for printing on to most papers of 150 gsm or heavier. However, they are suitable for use on a narrower range of substrates than conventional UV inks – for instance, only conventional UV ink formulations can be used for specialist applications such as bus sides or vacuum formed products. (See Chapter 14, What Can You Print With UV Ink?)

Flash curable UV inks

Flash curable UV ink demonstrates the same advantages and disadvantages as continuous curable and water-based UV inks, but its particular formulation does offer several additional benefits for multicolour in-line printing, especially on to heat-sensitive stocks.

Heat – The photoinitiators used in flash curable UV ink are able to react to the brief burst of energy from flash curing units, which, in contrast to continuous UV curing units, create much less build-up of heat. This makes flash curable UV ink useful for printing on PVC or large corrugated sheets, both of which are dimensionally unstable when heated. The absence of heat also benefits registration accuracy on most substrates, as the materials are less prone to shrinking or distorting.

Ozone – UV flash curing units do not create ozone during the flash curing process. Ozone is created in the final cure and it should be evacuated from the plant.

Production speed – When using continuous curable UV inks, the overall production speed is limited by the ink curing time; with flash curable UV inks, the short duration of the flash curing process means that, with the right combination of ink and substrate, production speed is limited only by printing speed.

Energy costs – UV flash curing units do not emit UV radiation continuously, so their energy consumption is lower than that of conventional UV curing units.

Ink costs – Flash curable UV ink typically costs more than continuous curable UV inks, primarily because of the more limited choice and higher cost of the photoinitiators.

Substrates – The choice of ink for specific printing applications is also restricted compared with continuous curable UV inks – conventional UV ink formulations, in particular. *(See Chapter 14, What can you print with UV?)*

Ink systems and substrates

Solvent-based

Paper - *The general formulation characteristics of solvent-based ink systems means that they will not distort papers to any great extent. Any paper shrinkage or movement is normally due to poor conditioning of the substrate prior to printing and may be explained as a loss of moisture in the heated stage(s) of the jet air dryer.*

Board - *Almost all boards are suitable for use with solvent-based inks.*

Plastic - *See relevant Sericol product information sheets for specific recommendations, and pay particular attention to the resistance properties required in the end application.*

Conventional UV

Paper - *Because of the heat output by UV curing units, prints may show a degree of shrinkage. Whether or not this becomes a problem is determined by the weight of the paper you have selected, as well as the line speed and number of passes through the UV curing unit. In addition to running these inks at their optimum cure speed to minimise shrinkage, treat 130 gsm as the minimum recommended paper weight. As with all inks, pre-production tests are essential.*

Board - *Since conventional UV ink is a 100% solids system, film thickness is high compared with solvent inks, so you must pay particular attention to the print finishing process. Cutting and creasing tests should be conducted when using a previously untested ink/board combination.*

Plastic - *Due to the high film thicknesses involved, there will be a tendency for prints made with UV curing inks on plastic substrates to show less flexibility – particularly when using lighter weight plastics, printing heavy coverage jobs or double sided work. As a general guide, it is not advisable to print double sided work on plastics (for example, PVC) with a thickness of less than 240 microns.*

For further information, see the relevant Sericol product information sheets. The recommendations included in the sheets pay particular attention to the resistance properties required in the end application.

Water-based

Paper - ***The inclusion of water as the primary thinner/diluent means that paper choice is critical, especially when using paper with a high surface coating, which acts like a sponge making the top of the paper swell, producing edge curl and paper creasing on overprints. As a general rule, you should not print papers of less than 150 gsm, and the minimum weight should be increased to 200 gsm on very large format prints.***

Board - ***Because these inks contain, on average, 20%-40% water, the film thickness achieved when using water-based UV systems are significantly lower than when using conventional UV inks. However, even though prints will be more flexible as a result, finishing remains an important consideration. Care should be exercised when using a previously untested board/ink combination – especially when cutting and/or creasing is part of the production process.***

Plastic - ***Although water-based UV ink is more flexible than conventional UV ink (because of the lower film weights involved) it is still advisable to use a minimum substrate thickness of 240 microns for double sided work.***

For further information, see the relevant Sericol product information sheets. The recommendations included in the sheets pay particular attention to the resistance properties required in the end application.

Equipment requirements – Flash cure UV inks are really of benefit when used in conjunction with a high speed multicolour in-line press – the partial cure afforded by the intermediate flash curing units would not be sufficient to prevent blocking if the prints were stacked between colours. However, the combination of a flash curable water-based UV screen ink printed on a multicolour in-line machine raises the quality and speed of the screen printing process to a new, previously unobtainable level.

In summary

UV screen printing inks have the potential to deliver increased production, greater consistency, superior definition and registration, less waste and a safer and more pleasant working environment. They are more expensive than solvent ink on a per kilo basis, but the efficiences they deliver can actually reduce costs when viewed on a total business perspective.

Chapter 4
UV ink and the curing process

The aim of the UV curing process is to convert a wet ink deposit to a solid ink film at production speeds that are commercially viable. An effective cure is achieved when the ink deposit is converted to a solid film throughout, exhibits a uniform surface finish and good adhesion to the substrate.

Here, we review the influence of the UV ink formulation on effective curing.

UV ink

Photoinitiators – Most UV inks contain between 1% and 5% photoinitiators by volume. Increasing the proportion of photoinitiators in the ink will generally increase the ink's curing response, speeding up the curing process. Most UV ink systems have additives, such as fast thinners containing photoinitiators, that are designed precisely for this purpose.

Photoinitiators should be added sparingly, however, as over-use can actually impede effective curing. Photoinitiators use UV energy to generate the free radicals that start the polymerisation process. If the density of photoinitiators is too high, those near to the surface of the ink will use up the available energy, preventing through cure.

Figure 4.1 illustrates how the concentration of photoinitiators affects the curing process.

(Controlling the amount of UV energy that reaches the ink tends to be a more effective way of increasing the ink's cure response than adding more photoinitiator.)

Pigments – The passage of UV energy is most affected by the pigment in the ink. Pigment acts as a barrier, absorbing, deflecting or reflecting the UV energy. The higher the pigment load, the more UV energy is absorbed or reflected and the less energy is available to the photoinitiators. It is for this reason that there is generally a limit on the opacity of UV inks – if the ink is too dense (opaque), UV energy will be unable to penetrate to the ink/substrate contact point, resulting in poor adhesion.

Figure 4.2 Illustrates the effect of pigment load on the passage of UV energy through the ink deposit.

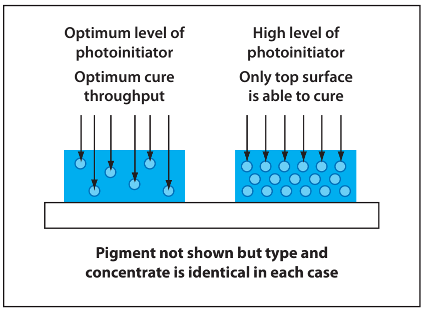


Fig. 4.1

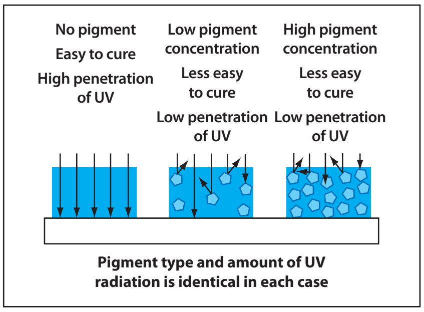


Fig. 4.2

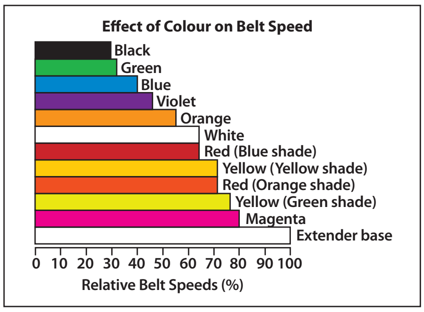


Fig. 4.3

Pigment colour plays a major part in determining the passage of UV energy. Some colours, such as magenta, transmit UV energy; other colours, such as white, do not. White pigment reflects UV energy, so less energy is able to reach the photoinitiators deeper in the ink deposit. Pigments such as green and black absorb UV radiation, reducing the ink's curing response even further. The most difficult ink to cure is that containing a combination of opaque and UV absorbing pigments – for example, a high density of white and green. **The cure response of such ink is often lower than that of ink containing green or white pigment only.**

The different energy absorption/reflectance characteristics of pigments means that you have to check the belt speed of the UV curing unit for each colour to allow enough UV energy to reach the ink to ensure effective through curing. For example, the belt speed required for a black ink is often three times slower than that required for a magenta ink.

Figure 4.3 shows the relationship between belt speed and ink colour.

Additives – There are various additives that can be used to influence the ink's cure response.

Clear Extender Base can be used to reduce the pigment concentration in UV ink. This has the effect of lowering opacity, allowing for an easier passage of UV energy through the ink deposit. This in turn increases the ink's cure response and the likelihood of effective cure.

Fast Thinner contains photoinitiators, which increase the ink's cure response, and it also reduces the ink's viscosity, its use can adversely affect intercoat adhesion.

Ink deposit thickness – The photoinitiators in the ink are evenly distributed – there is the same concentration of photoinitiators in the surface layer of the ink deposit as there is in the 'contact point' (at the ink/substrate interface). The intensity of UV energy reaching individual photoinitiators, however, is not equally distributed. The UV energy comes from lamps and reflectors that are positioned above the print. To reach the photoinitiators in the contact layer of the ink, the energy must travel through the ink itself. As the energy travels through the ink, it is absorbed and deflected by the ink components and energy is lost. The greater the depth of the ink deposit, the more energy is lost before reaching the contact point. For this reason, the ratio of UV energy reaching photoinitiators at the surface of the ink compared with that reaching photoinitiators in the contact layer can be as high as 100:1.

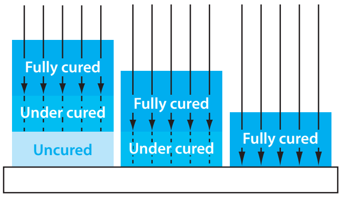
If the ink deposit is too thick, UV energy will not reach the photoinitiators at the contact layer, resulting in undercure. If insufficient UV energy reaches the photoinitiators the contact layer will remain uncured.

As explained in Chapter 2, conventional UV ink is a 100% solids systems – 'what you print is what you get.' Printing a precise deposit of ink, then, requires precise control over the following factors:

- Mesh type and count
- Stencil build
- Squeegee angle, durometer (hardness), pressure, sharpness and speed
- Flood bar angle, pressure and sharpness
- Print size

Figure 4.4 illustrates the effect of ink deposit depth on effective cure.

Ink temperature – Like all ink, the viscosity of UV ink is affected by ambient temperature. This can result in a higher ink deposit and corresponding increase in energy required for full cure. UV ink is optimised for use at temperatures of 21°C (70°F) or above. At lower temperatures the ink's curing rate may be reduced. At temperatures of 10°C (50°F) or below, cure speeds may be reduced by 50% or more.



Effect of ink deposit thickness on the passage of UV radiation

Fig. 4.4

Chapter 5
UV curing equipment

The main requirement of a UV curing unit is to produce specific wavelengths of UV radiation of sufficient intensity to promote effective curing of the ink deposit. It is, therefore, worthwhile considering precisely what is meant by 'UV radiation'.

Figure 5.1 The electromagnetic spectrum.

The electromagnetic spectrum

UV radiation is a form of electromagnetic energy, like visible light, X-rays and radio waves. It consists of photons, small packets of energy that travel at the speed of light and always in a straight line. Each photon has a distinct wavelength and its energy is a function of that wavelength – the shorter the wavelength, the greater the energy. Gamma rays, which are emitted in an atomic reaction, have extremely short wavelengths and contain a great deal of energy. Radio waves have longer wavelengths and contain much less energy.

Photons can be plotted along the electromagnetic spectrum according to their wavelength, which is measured in nanometers (nm). One nanometer is equal to one billionth of a metre (10^{-9} m). Photons with wavelengths between approximately 100 and 445 nm are referred to as ultra violet (UV) radiation or UV energy.

UV energy can be further classified by the wavelength of the photons, as shown in figure 5.2. The most important wavelengths for UV screen printing fall in the UVC, UVA and UVV bands. Photoinitiators used in UV inks are responsive to these photons, which have sufficient energy to release the free radicals that start the curing process.

Figure 5.2. VUV wavelengths are transmitted only in a vacuum, so they are largely irrelevant to graphics screen printing; UVB wavelengths can promote the curing process, provided that photoinitiators with appropriate absorbtion characteristics are included in the ink formulation.

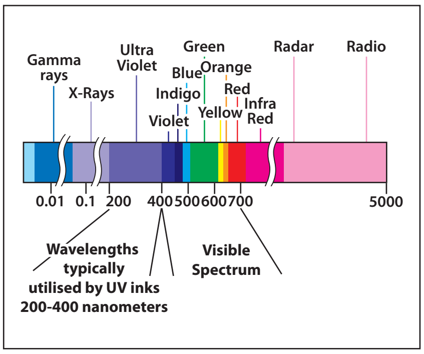


Fig. 5.1

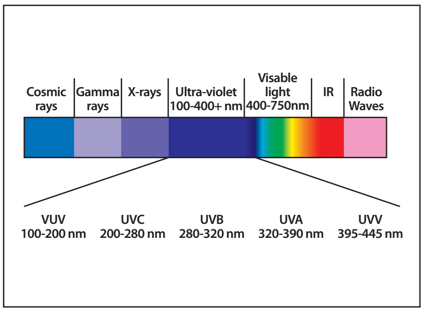


Fig. 5.2

Types of UV curing unit

UV curing units that can emit photons with wavelengths between 200 nm and 445 nm can be categorised in terms of continuous and flash output. Continuous curing units emit UV energy continuously, in much the same way that a desk lamp emits visible light. Flash curing units emit brief, intense bursts of UV energy, in much the same way that a camera's flash emits powerful flashes of visible light. The most commonly used UV curing units are of the continuous type and are based on medium pressure mercury vapour lamps, which offer the best compromise between cost, output and lamp life. There are three main unit designs:

- **the dedicated UV curing unit** – a free standing unit, often housing two UV lamps. It will cure UV ink only and cannot be used to dry solvent ink.
- **UV combi-jet unit** – a combined UV curing unit and jet dryer, it can be used with UV ink and solvent ink. It takes up more space and is more expensive to install than a dedicated UV curing unit, but is more versatile.
- **bridge UV curing unit** – a small, relatively simple unit housing one or two lamps, which is added across the belt of an existing jet dryer. It is as powerful as other options but often runs at higher temperatures (which could cause problems with heat-sensitive substrates), but it is relatively inexpensive to install. These units will cure UV ink only.

The best unit for your purposes will depend upon your production set-up, budget and the type of work you are producing.

All UV curing units comprise one or more lamps consisting of a bulb (the UV energy source), a reflector (which focuses UV energy on to the substrate) and, generally, a cooling system (to reduce the amount of heat that reaches the substrate).

At this point, it is important to clarify terminology. 'Lamp' is widely used to refer to both the bulb and the reflector assembly. To avoid confusion, we will refer to the source of the UV energy as the 'bulb', just as the source of visible light is referred to as a light bulb. Here, 'lamp' is used as an abbreviation for the 'bulb/reflector assembly'.

The bulb

UV curing units contain one or more medium pressure mercury vapour bulbs that act as the UV energy source. The bulb comprises a quartz tube, between 20 cm and 2.5 m in length, containing a small amount of mercury and a starter gas, such as xenon. High voltage electricity is passed across the conductors at each end of the bulb and strikes an arc through the xenon gas. This raises the temperature within the bulb, vaporising the mercury, which in its volatile state emits photons. Some of these photons will have wavelengths that fall within the UV energy range. Generally, the more UV energy the bulb emits, the more efficient the curing of the ink.

Bulbs have a power rating, which is calculated by dividing the electrical power applied to the bulb (in Watts), by the arc length of the bulb. The most commonly used bulbs have a rating of either 80 watts per centimetre (80 W/cm) or 120 W/cm. Generally, the more power that is applied to the bulb, the greater the energy output. However, the power rating is not a direct measure of total UV energy output, nor the effective UV energy output (that to which the photoinitiators will respond).

Figure 5.3 Illustrates the medium pressure mercury vapour bulb.

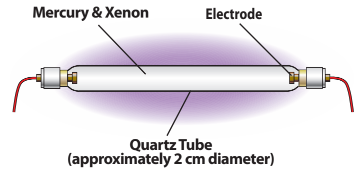
The bulb's UV energy output is defined in terms of irradiance, dose and wavelength mix.

Irradiance – is a measure of the intensity of the UV energy arriving at the surface of the ink. It is determined by a combination of:

- **the power of the bulb** – the more power applied to the bulb, the greater the irradiance;
- **the age of the bulb** – energy output and, therefore, irradiance, diminish as the bulb ages;
- **the diameter of the bulb** – the narrower the bulb, the higher the irradiance;
- **how the UV energy is focused on to the substrate by the reflectors** – the more focused the energy, the higher the irradiance;
- **the UV reflectivity of the reflector**

Irradiance varies as the ink passes through the UV curing unit, being at its peak directly under the bulb (or at the point where the UV energy is sharply focused). An irradiance profile shows the irradiance level in relation to distance from the bulb.

Typically, the greater the irradiance, the better the depth of cure. Similarly, increasing irradiance increases the activity of the photoinitiators, which can increase cure speed. If the irradiance is too low, the ink will not cure, however many times it is passed through the UV curing unit. It is very important, then, to establish the minimum irradiance required to effectively cure the ink and ensure satisfactory ink film adhesion. This is often referred to as 'the red line'.



Essential Features	Quartz tube Variety of lengths, 20 cm to 2.5 m Contains trace amounts of mercury Xenon as filling gas to start lamp	
Operating Conditions	Temperature	1110-1470F
	Mercury pressure	1-2 atmospheres
	Life	1000-2000 hours
	Power output	200 watts per inch
	Radiation output	15-20% Ultra-violet 5% visible 75-80% Infra-red

Fig. 5.3

Cure speed: irradiance v. dose.

	Lamp A	Lamp B
Lamp power (W/cm)	120	80
Peak irradiance (mW/cm^2)	900	600
Belt (cure) speed (m/min)	20	10
Dose (mJ/cm^2)	400	400

Fig. 5.4

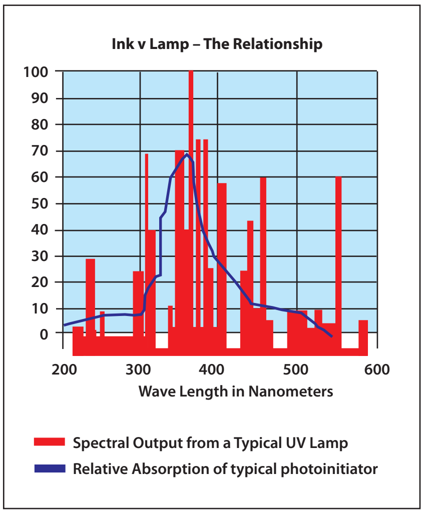


Fig. 5.5

Dose – is a measure of the 'accumulated' UV energy the ink receives as it passes through the UV curing unit. At any given irradiance, dose will depend on the belt speed and the number of passes through the unit. Slowing the belt speed or passing the printed substrate through the UV curing unit several times increases the dose, (but does not affect the irradiance).

To increase the depth of ink cure or increase the ink's cure response, it is more effective to increase the irradiance (the intensity of the UV energy) than the dose (the total amount of UV energy the ink receives). Increasing the dose can also increase the heat the substrate is subjected to, as discussed below.

Figure 5.4 demonstrates the effect of irradiance on speed of cure. Increased irradiance, as opposed to increased dose, is the best way to achieve a faster through cure.

Dose is important for ensuring a complete ink cure. Thus, you need to ensure that the ink receives the correct combination of irradiance and dose. This is determined by pre-production testing, using the ink manufacturer's recommendations as a starting point, and ongoing monitoring of these variables during production.

Spectral output – A UV bulb outputs photons with a broad range of wavelengths. Indeed, only 15-20% of the energy output by the bulb is UV energy. 75-80% of the energy is infra-red (which is manifested as heat - see page 25 for more details on heat) and 5% is visible light.

The bulb's UV energy output comprises photons with different wavelengths within the UV energy range. Its spectral output describes the the bulb's energy output (the intensity of UV energy) at each wavelength. Spectral irradiance describes the intensity of the UV energy at each wavelength arriving at the ink surface.

Figure 5.5 shows the spectral output of a typical (D Type) medium pressure mercury vapour bulb (see next page). Notice that the output is greater in some wavelengths than others. With this type of bulb the peak spectral output is at 365 nm.

To ensure effective curing, the peak absorbtion characteristics of the photoinitiators in the ink correspond to the peak spectral output of the bulb, and vice versa. That is to say, the receptiveness of the photoinitiators are matched to the UV wavelengths at which the UV energy is most intense.

The above point is crucial to the UV curing process and is worth emphasising. There is no point achieving high irradiance if the wavelength of the energy does not activate the photoinitiators in the ink. This would be like having a door key that's the right length, but the wrong shape to fit the lock. (Think of the key as the peak spectral output of the bulb, and the lock as the peak absorption characteristics of the photoinitiator. The key has to be the correct size [irradiance] and shape [wavelength] to fit the lock. Turning the key in the lock is akin to dose; even with a key that fits the lock, unless you turn the key sufficiently in the lock the door will fail to open.)

The UV energy arriving at the surface of the substrate that can be used by the photoinitiators is correctly described as 'effective irradiance'.

Figure 5.5 also shows the relative absorption characteristics of a photoinitiator. Notice that the wavelengths to which the photoinitiator is most receptive correspond to the wavelengths at which the UV energy output is higher.

Bulb manufacturers can control the spectral output of the bulbs by adding small amounts of metal halides to the mercury. This is referred to as 'doping' the bulb.

Why dope the bulbs? The performance properties of photons vary according to their wavelength, most notably the depth of ink deposit they penetrate and their influence over the characteristics of the cured ink film. By controlling the spectral output of the bulb, it is possible to influence the effectiveness of the cure and the ink film's finish. The performance properties of the key wavelengths are given below:

Figure 5.6 summarises the bulb types that are available.

Types of UV bulb

Bulb	Metal halide used to dope bulb	Effect on spectral output	Curing applications
H	None	None	Clear varnishes
D	Iron	Shifts peak of output to longer wavelength	Most screen inks
V	Gallium	Shifts peak of output to even longer wavelengths (into the visible light spectrum)	Opaque, difficult to cure inks, especially whites

Fig. 5.6

Lamp facts

Actual power

The higher the power rating of the bulb, the higher the potential UV energy output – so a bulb rated at 80 W/cm will emit less UV energy than a 120 W/cm bulb when both are set at full power.

Different bulbs of the same type and power rating may show markedly different performance characteristics however, so it would be a mistake to assume that swapping one make or model of bulb for another with the same rating would result in the same UV energy output.

Warm up period

Bulbs go through a warm up period – typically, 3-5 minutes – after they are switched on. During this time, energy output levels are unreliable. In some cases the bulb's energy levels fluctuate wildly, with output at particular wavelengths sometimes significantly higher than it is during normal operation. In many cases the peak energy occurs at different wavelengths during the warm up cycle. Other bulbs show a steady, gradual increase in energy output until the bulb stabilises at its operating energy output level.

Clearly it is important to know how long it takes for the bulb to stabilise, as attempting production under such changeable conditions would invite problems.

Bulb age

A bulb's energy output degrades over time; the electrodes within the bulb decay, deposits form on the inside surface of the quartz envelope, and the quartz itself may even change after lengthy exposure to the extreme heat generated within the bulb. However, bulb performance does not degrade uniformly – different wavelengths degrade at different rates. Some decrease in a gradual steady pattern, whilst others degrade erratically over time. The energy output tends to degrade more steeply at shorter wavelengths (254 nm) than at longer wavelengths (365 nm). The implications for the curing process depend upon the absorption characteristics of the photoinitiators in the ink (the wavelengths they respond to). However, the faster decrease in output at shorter wavelengths does suggest that surface cure needs to be more carefully monitored as the bulb ages (shorter wavelengths promote a surface cure and help to determine the surface characteristics of the cured ink film). Increasing the voltage (power) to the bulb may help to offset a decrease in the bulb's energy output as it ages.

The number of bulbs

Most UV curing units contain at least two bulbs. These bulbs generally have individual power controls, making it possible to achieve a combination of UV energy output levels. This is useful for managing dose. However, the increase or decrease of UV energy is not directly proportional to the power controls – that is, changing the power setting from full to half power does not necessarily halve the UV energy arriving at the surface of the substrate. Measurements must be taken with a radiometer (see Chapter 6) to determine the energy levels at the different power settings.

Power supply

The bulb's UV energy output can be greatly affected by the power supply. If the voltage falls, less UV energy is output by the bulb, so fluctuations in voltage, especially a voltage drop, can have a major impact on the curing process. You are advised to talk to your power company to discuss your power requirements for UV screen printing and the best way to ensure a consistent, reliable supply.

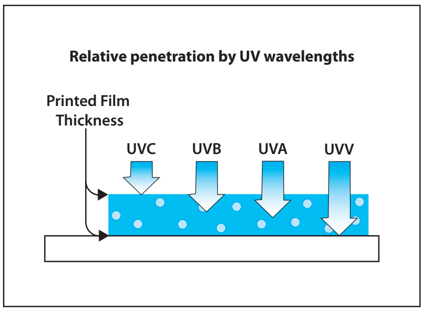


Fig. 5.7

Wavelength mix

For effective curing the UV bulb must emit sufficient energy in both the shorter and longer wavelength ranges. Insufficient energy in the shorter wavelengths can result in a tacky surface; insufficient energy in the longer wavelengths may result in adhesion failure. UV energy of the correct wavelengths is not enough by itself, however. The ink must also contain a balance of photoinitiators that react to all of the wavelengths produced.

UVC (200-280 nm) – These shorter wavelengths play an important role in the surface cure of the ink deposit. They help to determine the ink film's gloss and its chemical and abrasion resistance. Mercury, when it is vaporised, emits UV energy in this wavelength band.

UVA (320-390nm) – These longer wavelengths penetrate deeper into the ink deposit, ensuring throughcure and influencing the ink film's adhesion to the substrate. The spectral output of 'D' bulbs is controlled to ensure maximum irradiance at these wavelengths. Most UV inks are formulated to respond to photons in this wavelength band.

UVV (395-445 nm) – These even longer wavelengths are capable of penetrating deepest through the ink deposit, and are especially useful for curing more opaque ink formulations, especially those containing a high percentage of white pigment.

Figure 5.7 illustrates the relative depth of ink deposit the different wavelengths of UV energy penetrate to.

Reflectors

The main purpose of the reflector is to ensure that as much of the energy emitted by the bulb arrives at the substrate surface as possible. In practice, approximately 60% (but as much as 80%) of the UV energy arriving at the substrate surface will be reflected energy.

The reflector can also be used to control the 'spread' of UV energy – whether it is focused at a precise point on the surface of the substrate or dispersed evenly – and the amount of heat that the substrate is subjected to.

There are two main designs of reflector: elliptical and parabolic. The elliptical design is most common in graphics screen printing.

Elliptical reflectors – There are two variations on the elliptical reflector design, which can be described as 'gently curved' and 'tightly curved'. Both feature an elliptically shaped, highly polished metal surface.

Gently curved elliptical reflectors – Have the bulb located at one of the focal points of the ellipse, which causes the energy from the lamp to be concentrated into a narrow band at the second focus point. The bulb and reflector are positioned so that the second focus point is located precisely on the surface of the substrate. The narrow focused band of energy tends to produce higher irradiance than other reflector designs.

Figure 5.8 Illustrates a gently curved elliptical reflector and its irradiance profile.

Tightly curved elliptical reflectors – Also have the bulb located at one of the focal points. However, the curve of the reflector causes the second focal point to be situated halfway between the bulb and the substrate. This creates a wider band of energy at the substrate surface and lower irradiance.

Figure 5.9 Illustrates a tightly curved elliptical reflector and its irradiance profile.

Parabolic reflectors – Are also referred to as facet reflectors. They disperse the energy over a wide area of the substrate. This generally produces lower irradiance, but it also generates less concentrated heat, which can be an advantage when working with heat-sensitive substrates.

Figure 5.10 Illustrates a parabolic elliptical reflector and its irradiance profile.

Dichroic coated reflectors – There is another reflector option; dichroic coated reflectors are specially coated to be non-reflective to the infrared energy emitted by the bulb, and highly reflective to the UV energy. This has the advantage of reducing the surface temperature of the substrate as it passes through the UV curing unit – an important consideration for the reasons explained below (see Cooling systems Figure 5.12).

Figure 5.11 demonstrates how dichroic coated reflectors can significantly reduce temperature with only a slight reduction in UV energy/cure speed.

Reducing the effects of heat

Up to 80% of the bulb's energy output is in the infra-red wavelength band. The quartz tube absorbs infra-red energy and converts it to heat. As a result, the surface of the quartz tube can reach temperatures as high as 900°C.

Heat plays a useful role in curing UV inks, improving the ink's wetting abilities, promoting the polymerisation process at a molecular level once the photoinitiators have been activated, and starting the post-curing process. It is also essential that the surface temperature of the quartz envelope remains at 600°C or above as cooling it to below this temperature can cause the mercury inside the bulb to condense, resulting in a fall off or cessation of UV energy output.

The drawback of the bulb's high surface temperature is the potential for excessive heating of the substrate surface. This can cause substrate distortion or discolouration. It is necessary, therefore, to limit the amount of heat arriving at the substrate surface whilst maintaining the irradiance (intensity of UV energy arriving at the surface of the ink).

Belt speed – The simplest method to reduce heat related problems is to use a faster belt speed – the faster the belt is running, the less time the substrate is exposed to the heat from the bulbs. However, belt speed has an effect on the curing speed of the ink and it may not be practical to run the belt fast enough to limit the effects of heat without compromising effective cure. A fast belt speed alone is unlikely to be sufficient to prevent the distortion of heat-sensitive substrates.

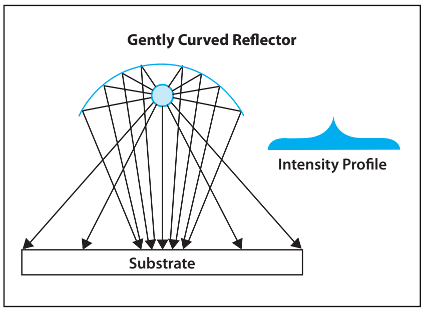


Fig. 5.8

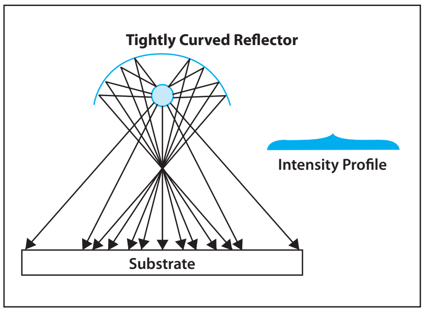


Fig. 5.9

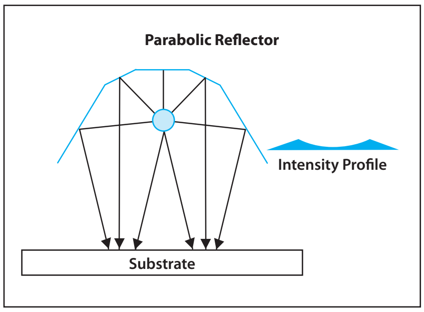


Fig. 5.10

Cure speed: Standard v Dichroic reflectors

Reflector type	Line (cure) speed m/min	Surface temperature rise °C
Non dichroic coated	21.1	29
Dichroic coated	19.7	18

120W/cm Type D bulb, black screen ink, 150 mesh, 10 mm polycarbonate

Fig. 5.11

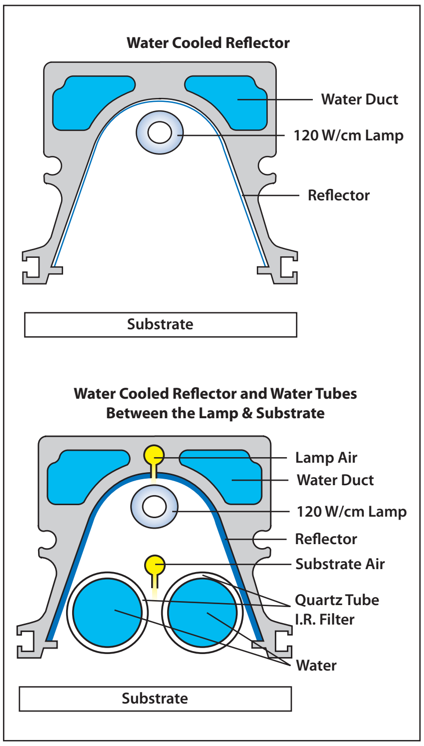


Fig. 5.12

Distance to substrate – Moving the bulbs further away from the substrate reduces the temperature at the substrate surface, but also reduces the irradiance. UV energy dissipates very quickly; doubling the distance the UV energy travels reduces its intensity by 75%.

Power setting – Most of the power supplied to the bulb is converted to heat, so reducing the bulb's power will also reduce the temperature at the substrate surface. However, there is a corresponding fall in the output of UV energy. This can reduce irradiance to unacceptably low levels, due to the effects of ozone production and oxygen inhibition (See Ozone production and oxygen inhibition page 27). You should aim to use the minimum amount of power required to achieve the necessary irradiance for effective curing. This reduces the level of heat as well as energy costs.)

It is possible to reduce the temperature at the substrate surface by using bulbs with a narrow diameter. The heat emitted by a bulb comes from the quartz tube surface, so reducing the bulb's diameter, reduces its surface area and results in a corresponding reduction in the heat emitted. Reducing the thickness of the quartz used in the tube can have a similar effect.

As mentioned previously, parabolic reflectors reduce the level of reflected heat (along with irradiance), compared with elliptical versions, and dichroic reflectors they significantly reduce heat (along with a smaller reduction in irradiance).

The most common and effective means of controlling temperature, however, is to include a cooling system in the UV curing unit. There are many different systems available, based on cooling air and/or cooling air and water.

Cooling can be accomplished by:

- passing filtered air over the surface of the bulb;
- passing filtered air over the surface of the substrate;
- cooling the reflector with clean, filtered water;
- filtering out the infra-red energy before it reaches the substrate by way of a quartz plate or water-filled tubes; and
- using cool air or refrigerated plates under the belt.

Figure 5.12 illustrates both a basic water-cooled reflector system and a more complex combination air- and water-cooling system in which water is used to remove heat from the reflector and air is passed on to the surface of the substrate. Two water-filled quartz tubes, located between the bulb and the substrate, filter out direct heat from the bulb.

Water-cooling is generally a more efficient means of dissipating heat than air-cooling, and the use of plates or water-filled tubes between the bulb and the substrate is the most effective way of reducing heat. This cooling method will also significantly reduce the UV energy. The loss in energy may be a necessary trade off when printing on highly heat-sensitive materials. The best advice is to test the substrates you will be printing through the UV curing unit before purchase.

Other features

Electrical ballast – UV curing units also include an electrical ballast comprising transformers and capacitors. This provides the high voltage required to generate the arc within the bulb and helps to maintain the constant, unfluctuating power supply required by the lamp (fluctuations in power supply will affect the energy output of the lamp and may compromise the curing process). Power controls allow the energy output of individual bulbs to be adjusted as required.

UV shields – The chamber of the UV curing unit shields press operators from the intense UV energy emitted by the lamps, which could harm the eyes and skin. Many units incorporate further energy shields and a series of fail-safe mechanisms that automatically shut off the bulb if access doors or panels in the unit are opened during use.

Conveyor belt – Dedicated, stand alone units and UV combi-jet designs incorporate a conveyor belt to transport the printed substrate underneath the lamps. Open mesh belts, constructed from Teflon® coated fibreglass, provide low heat transmission across the belt and help to prevent the collection of dust and other contaminants. For lighter weight substrates, especially at fast belt speeds, a vacuum bed will be required to prevent the substrate from lifting off the belt. Vertical substrate movement could affect the curing of the ink, or cause a fire within the UV curing unit if the substrate came into contact with the hot bulbs. Thin, heat-resistant wires, located below the bulbs, can be used to guard against the latter possibility.

Exhaust systems – Ozone represents a health hazard and, due to its instability, results in the rapid oxidisation of exposed metal areas within the UV curing unit. A vacuum exhaust system is used to evacuate the ozone to the air outside the plant where it safely disperses.

UV flash curing units

UV flash curing units are found on certain makes of multicolour in-line machines. Special doped bulbs (that contain no mercury) are used in place of the medium pressure mercury vapour bulbs found in continuous UV curing units. The bulbs are linked to capacitors that provide the power the bulb needs to emit high intensity flashes of UV energy with a duration of 5-10 milliseconds. As the printed substrate passes from the print station through the UV curing unit it receives 3-5 flashes. The capacitors recharge in less than a second and at that point are ready to discharge again.

A continuous UV curing unit housing medium pressure mercury lamps is located at the end of the line, after the final print station. This ensures effective curing throughout the depth of the entire ink deposit.

UV flash curing lamps emit low heat levels and the brief flashes of UV energy prevent the production of ozone, so there is no requirement for an exhaust system over these units.

Ozone production and oxygen inhibition

Oxygen absorbs UV energy at wavelengths of 220 nm or lower. Photons with these wavelengths contain sufficient energy to break the molecular bonds of the oxygen; the two Oxygen molecules (O_2) splitting to become separate O_1 atoms. These atoms readily attach themselves to other O_2 molecules in the air to form ozone (O_3). The UV energy used during this process is no longer available to the photoinitiators in the ink. More importantly ozone also absorbs UV energy at longer wavelengths, further reducing the effective irradiance and the likelihood of successful curing.

It is essential, therefore, that the bulb is powerful enough to emit sufficient UV energy to ensure adequate irradiance in spite of the energy loss attributable to oxygen and ozone absorption.

There are special quartz tubes that filter out the wavelengths below 220 nm to prevent ozone production, but this inevitably results in the filtering out of longer wavelengths also, which can defeat the purpose of the exercise.

The problem of ozone production is exacerbated by what is referred to as oxygen inhibition. When shorter wavelengths of UV energy activate the photoinitiators at the surface of the ink, the resulting free radicals are equally disposed to react with the oxygen molecules in the air above the ink as the oligomers and monomers within the ink. This can affect the speed and effectiveness of curing. The irradiance at the shorter wavelengths, therefore, must be sufficient to generate heightened activity in the photoinitiators, so that there are enough free radicals, in spite of oxygen inhibition, to promote rapid polymerisation of the surface layer of the ink.

Low powered bulbs emit insufficient UV energy in the shorter wavelengths to overcome the barriers of ozone production and oxygen inhibition. Hence, the requirement for powerful bulbs with a high UV output that also, unfortunately, generate a great deal of heat. *(See Nitrogen curing units, page 28.)*

All continuous UV curing generates ozone, which must be exhausted.

Nitrogen aided UV curing

One solution to the problem of oxygen-inhibition and the requirement for powerful bulbs that generate a lot of heat, is to conduct the UV curing process in an inert atmosphere. By replacing the air above the substrate with an inert gas, such as nitrogen, all the free radicals produced by the photoinitiators will be available for use in the polymerisation process. This removes the requirement for powerful bulbs and the temperature at the surface of the substrate is greatly reduced.

The drawback of nitrogen UV curing is the added complexity and expense of the UV curing units and the cost of purchasing and storing the nitrogen. For these reasons, nitrogen UV curing units are not widely used by graphics printers and are not compatible with multicolour in-line printing.

Maintaining your UV curing equipment

Regular maintenance of UV curing units is important in order to standardise the UV energy output of the equipment as far as possible. The aim is to establish the necessary conditions for effective curing to take place and then maintain those conditions as far as possible.

Lamps

'Cleanliness' is the operative word. An accumulation of dust or dirt on the bulb or discolouration of the quartz tube will increase the heat generated by the lamp and reduce the efficiency of the bulb in terms of UV energy output, hindering the curing process. The accumulated material also acts as a 'key' for more material to accumulate on top.

Cleaning

Bulbs should be cleaned regularly – every 2-4 weeks, dependent on conditions in the printshop, using isopropyl alcohol and a soft lint-free cloth. It is especially important that you do not handle the bulb during the cleaning process (or during installation/replacement), as oils in your skin will be deposited on the tube leading to discolouration and weakening of the quartz. Wearing cotton gloves whilst handling bulbs is recommended.

Rotating

The bulbs should also be rotated through 90°, in the same direction each time, every time they are cleaned. This is because, as the bulb ages, deposits build up inside the bulb and adhere to the quartz tube. Rotating the bulb ensures that the build up of material is evenly dispersed, minimising the impact on the bulb's performance. Longer bulbs will also tend to sag slightly over time. This affects the bulb's position in relation to the reflector, altering the focus of the UV energy and, therefore, irradiance. Rotating the bulb helps to minimise the effect.

Replacement

Bulb manufacturers will generally guarantee UV bulbs for the first 1000 hours at full power, though in practice 1500 to 2000 hours is a more realistic life expectancy. The actual useful life of the lamp will be dictated by the frequency of turning the bulb on and off (the more starts and stops the shorter the bulb life) and the power settings used (running the bulb at half power, for instance, will increase its life). Maintain an accurate record of hours in use (many UV curing units have an 'elapsed time' display) and the number of starts so that you know in advance when the bulb is likely to need replacing.

Make sure that any replacement bulb is precisely the same as the old bulb – different bulbs have different UV energy output levels and different spectral wavelength distribution characteristics, which can affect the curing process.

The reflector

A clean reflector is as important as a clean bulb – up to 80% of the energy arriving at the substrate surface may be reflected energy, so any dust, dirt or surface imperfections on the reflector will have a major impact on the curing process. It is estimated that a dirty or dusty reflector can result in a 40-60% reduction of UV energy. Clean the reflector regularly using isopropyl alcohol and a soft lint-free cloth. Inspect the cleaned reflector closely; check for pits or other surface imperfections and be prepared to replace the reflector periodically.

It is always a good idea to check with the lamp manufacturer for precise cleaning instructions as some reflector surfaces may be coated and require particular care procedures.

The cooling system

Impurities in the air or water used to cool the bulb can absorb UV energy, reducing irradiance. Air filters, in particular, require replacing on a regular basis. De-ionised water can be used with water-cooled systems.

Chapter 6
Measuring UV energy

Accurate measurement of UV energy provides the necessary information to determine and maintain optimum conditions for effective curing. In the absence of accurate measurement you are, to all intents and purposes, 'printing in the dark'.

There are a variety of different measuring devices available. Each type interprets the energy arriving at the substrate surface in different ways. The first task is to establish the key variables that should be measured. Then it is a question of determining the best equipment for your needs (and budget), understanding how to use it and learning to interpret the information it provides.

What to measure

In the past, it was common practice to measure dose only – the total accumulation of UV energy arriving at the ink surface as the print passed through the UV curing unit. Measuring instruments and materials were designed to provide this information. Even the ink manufacturers limited the UV energy guidelines they provided for their products to the recommended dose, which is normally quoted as the belt speed in metres per minute with a specific intensity lamp.

The analogy of 'cooking times' can be used to illustrate the inherent failing of this approach to UV energy measurement. Suppose a recipe has instructions that contain cooking times in 'degree (°) hours' only. If the recipe calls for 100° hours, would you cook the ingredients for one hour at 100°, or 30 minutes at 200°, or 15 minutes at 400°. The end result would be very different depending on the combination of time and temperature you chose.

The same principle applies to curing UV inks; increasing dose by increasing irradiance would have a very different effect to increasing dose by slowing the belt speed or passing the print through the UV curing unit several more times.

The primary reason for measuring UV energy is to optimise the relationship between the energy received by the ink and the ink's chemistry. The key variables with regard to UV energy are: irradiance, dose and spectral output. So, for full control over the curing process ideally you need accurate information on each of these variables.

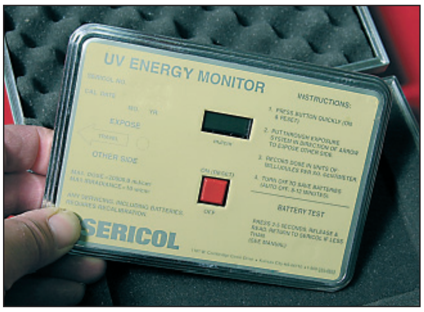


Fig. 6.1

Measuring devices

Some measuring instruments are designed to measure and record all three key UV energy variables; others measure just one or two. The following devices are commonly used to measure UV energy.

Radiometers – generally referred to as 'light bugs' *(see Figure 6.1)*, are used to provide irradiance readings. They take sample measurements at pre-defined time intervals as they pass through the UV curing unit. The measurements are recorded and the sample showing the highest irradiance determines the peak irradiance reading.

Fig. 6.1 Typical light bug commonly used in printshops.

The measurements are taken over a defined range of UV energy wavelengths – say, a 10 nm band. This means that different radiometers can give very different readings for the same bulbs, depending on which range of wavelengths they are calibrated to measure. Differences in viewing angle can also affect results. For these reasons it is best to take all measurements using the same device.

Integrating radiometers – measure peak irradiance and can also measure dose, by adding together all the irradiance samples recorded during the radiometers passage through the UV curing unit.

Spectroradiometers – record very precise measurements of spectral irradiance – the irradiance at a specific wavelength. They can take measurements from a single wavelength (a specific nanometer measure) or even a one half nm band if required. They do not evaluate dose.

Radiochromic film – measures dose by changing colour. It is attached to the printed substrate and the dose is calculated by visually comparing the colour of the film when it exits the UV curing unit to a reference chart or by taking more precise colour readings using a densitometer. However, the usefulness of radiochromic film is restricted unless the wavelengths to which they are responsive is known. Some radiochromic film is re-useable.

Continuous lamp measurement systems – are highly sophisticated and will be beyond the routine requirements of most screen printers. They measure the UV energy output of the bulb constantly. Heat-resistant probes are located within the UV curing unit and take sample readings every few seconds. The readings are fed to a computer, which provides a constantly updated display of bulb energy output.

The systems have impressive data reporting functions and can be programmed to give an immediate warning of changes to UV energy output. Bulb age can be monitored and its effect on energy output can be tracked. The systems can even give a warning when the bulbs need to be replaced. Press operators can be warned if energy output moves outside pre-defined parameters during production.

The probes measure wavelengths from 200 nm-450 nm and allow for the monitoring of energy output at each wavelength. They can measure multiple bulbs simultaneously and can measure any level of UV energy output.

The cited drawback of these systems is that they measure bulb output rather than the UV energy arriving at the surface of the ink so the impact of dirty reflectors is not considered.

Using measuring devices

The accuracy of the measuring device will depend to some extent on how it is used. You must be aware of the potential shortcomings of the particular device you are using and the measuring method it employs. Otherwise you may be misled by the readings.

Maximum irradiance – Unlike continuous lamp measurement systems, radiometers have a limited irradiance range – that is, there is a maximum irradiance that they can measure accurately. This might be 5 W/cm or 10 W/cm, for example. If a very efficient, high-powered bulb is used and the irradiance exceeds the limit of the radiometer's measuring range, the device will give a false peak irradiance reading. The error will be compounded by an integrating radiometer, as the 'under-reporting' of irradiance will also affect the accuracy of dose readings. Check the manufacturer's specifications for the device you are using and consult the bulb supplier for information on maximum irradiance levels.

Sampling rates – The rate at which a radiometer takes sample readings as it passes through the UV curing unit can affect the accuracy of the information it provides. If the interval between samples is relatively long and the device is passed through the curing unit quickly, the radiometer may miss the peak irradiance – it might take a sample just before or after the point at which the UV energy arriving at the substrate is greatest.

Figure 6.2 illustrates how a slow sampling rate can cause a radiometer to miss the point of peak irradiance.

The solution to this problem is to run the belt slowly so that the device takes more sample readings as it passes through the unit, then extrapolate the results to the faster belt speed used for production. Alternatively, use a radiometer that has a fast sample rate – some are capable of recording more than 2000 samples per second.

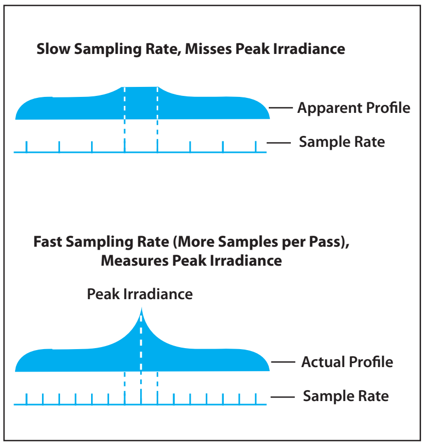


Fig. 6.2

Measuring wavelength As stated previously, measuring UV energy helps to achieve the best fit between the energy and the chemistry of the ink. However, this requires that the measuring device is capable of measuring the actual range of wavelengths that most influence the curing of the ink.

If the wavelength range the radiometer is calibrated to measure fails to include wavelengths that are important to the curing of the particular ink being used, vital information will be missing. For example, if there is a fall off in the output of short wavelengths, but the radiometer measures only longer wavelengths, improper surface curing or a change to the surface characteristics of the ink film may result, but there will be no clue as to the reason. The irradiance readings will remain high because the readings are taken from a band of longer wavelengths only. The capability to select different wavelength bands allows separate measurements of all the wavelengths that are important to the curing of a particular ink. The inability to measure various wavelength bands is a major drawback of radiochromic film.

Using the information

Armed with an accurate measuring device and the knowledge of how to use it and how to interpret the results, it is possible to establish the baseline of the equipment and monitor its ongoing performance. This is the basis of process design and monitoring.

Chapter 7
Measuring and recording the curing process

Establishing the 'baseline data' for your UV curing equipment is fundamental to effective UV curing. The aim is to identify the so-called 'red line' – the point at which the ink fully cures. It is also important to establish the point at which the substrate overheats (that is, the substrate reaches a temperature inside the UV curing unit that causes distortion).

Every curing unit is different and each printshop will be using different combinations of printing equipment, curing units, inks and substrates. There can be no definitive data for correct UV curing process design, only general guidelines. This means that you must carry out the necessary testing yourself and establish the data for your own operation. This is a straightforward process that takes time, but it is worth it.

It is important that measurements are made when your production line is operating effectively – **don't wait until something goes wrong and your prints are failing to cure. There is no point in measuring a failing process.** Ideally, process design should begin at the time the UV line is installed, when the lamps are new and everything is running correctly. If you are already printing with UV and want to implement a monitoring programme, make sure that you record the age of the lamps in your UV curing units (in hours elapsed) at the time you make your readings.

The process involves measuring, testing and recording the key parameters that influence effective UV ink curing – belt speed, UV energy and temperature. This requires the use of some specialised equipment, such as a radiometer, thermocouple etc. (Thermal Test Strips can be used in place of thermocouples.) If you are put off by the prospect of further capital investment in measuring equipment, ask yourself whether a photographer would attempt to earn a living without investing in a lightmeter. The devices mentioned above are as much tools of the UV printer's trade as the UV curing unit itself.

Essential data

The most important data to establish is:

- the combination of belt speed and UV energy output at which the ink first reaches full cure;
- the combination of belt speed and UV energy output at which the substrate first overheats.

Measuring belt speed

Before you start to measure the UV energy and temperature, however, you must first check the accuracy and repeatability of your UV curing unit's belt speed controls. Belt speed influences both dose and substrate temperature – the slower the belt speed, the higher the dose and substrate temperature at any given lamp output setting. Repeatability is more important than accurate speed settings – you need to know that the belt will run at the same speed at any given belt speed setting every time.

Select a variety of belt speed settings on the belt speed control – 15 m/min, 25 m/min, 35 m/min, for instance. Now measure the actual belt speed at each of these settings.

Begin by measuring the length of the belt, then place a mark on the belt and use a stopwatch to measure the length of time in seconds it takes for the belt to make one complete revolution. Divide '60' by the number of seconds recorded on the stopwatch and multiply the result by the length of the belt. So, for example, if the belt is 8 m long and it takes 120 seconds for it to make one complete revolution it would be travelling at:

60 / 120 = 0.5

0.5 x 8 = 4 m/min

It doesn't matter so much if the belt is moving at 4 m/min at the 3 m/min setting, provided that it consistently moves at 4m/min at that setting. To check consistency, repeat the exercise twice. If the belt speed at any given setting varies by more than 2-3% between runs have the belt speed control checked and repaired before progressing any further.

Alternatively, a contact tachometer can be used to measure belt speed accurately.

Measuring energy & temperature Once the belt speed has been shown to be reliable, you can move on to measuring the UV energy and temperature during the curing process. (The following examples assume that you are using a 2-lamp set-up. The approach is equally applicable to larger set-ups, however – you just take more measurements.)

Maximum belt speed – Set the UV curing lamps to full power, having made sure that they are fully warmed up and output is stable. Set the belt to run at a speed that is slightly slower than your preferred production speed. Pass a print, made on the substrate you will be using, with the ink you will be using, through the UV curing unit and test for cure. Provided that the print cures effectively, set the belt to run 2 m/min faster and repeat the exercise. Keep repeating this exercise, increasing the belt speed by 2 m/min, until the ink first fails to cure. This is the upper 'red line'. Attempting to run the belt at this speed or faster, with the lamps on full power, will lead to undercure. To be on the safe side, it is generally a good idea to specify a top belt speed that is 10% - 20% slower than this. That way, you have a 'safety margin' and prints are less likely to suddenly fail (undercure) if, for example, UV energy output falls due to the effects of lamp ageing. The exercise should be repeated at the different lamp power settings – for example, one lamp at half power, one on full; one lamp off, one lamp on full. (You can test with one lamp off and the other at half power, though there will usually be insufficient energy at this setting for effective curing.)

Minimum belt speed – Next, you need to establish the slowest belt speed you can use before heating of the substrate exceeds its maximum temperature rating. This is especially important when printing with inks containing opaque pigments which may need to be passed through the UV curing unit at slower speeds to achieve effective cure. Remember, the slower the belt speed, the longer the substrate remains in the chamber of the UV curing unit, and the higher the substrate temperature at any given lamp power setting.

Set the lamps to full power and set the belt speed slightly faster than your preferred production speed. Put a thermocouple or thermal test strip on the substrate and pass it through the UV curing unit. (Make sure that there is adequate clearance inside the chamber of the unit before you begin.) Providing that the temperature reading does not exceed the substrate's maximum temperature rating, set the belt to run 2 m/min slower and repeat the exercise. Stop when the thermocouple reading is higher than the substrate's maximum temperature rating. This is the lower 'red line'. Again, it is wise to allow a 10%-20% safety margin. Repeat this exercise at different lamp settings – for example, one lamp on full, one lamp at half power; one lamp on full, one lamp off.

Now make a print and run it through the UV curing unit with the lamps on full power and with the belt speed set slightly faster than the slowest belt speed, as determined above. Check that the print is not over cured (see Chapter 8: Testing For Effective Ink Cure.) If the ink is over cured, repeat the exercise with another print, but this time run the belt 2 m/min faster. Stop when the print shows no sign of over-curing. This is your minimum belt speed. Bear in mind, however, that over-curing is uncommon with modern UV inks.

These tests must be conducted with each range of ink you use, and for each individual colour. Belt speeds will vary according to the ink's pigment content.

Using this data, you can ensure that you always work within the 'Process Window' that will achieve effective cure without damaging the substrate.

Mastering the process

The key to good process design and monitoring is to take accurate measurements, regularly, and record the data religiously. Over time, the information you amass will allow you to take ever greater control over the UV curing process. In time, you can even extend your data to predict UV lamp life as part of a preventative maintenance programme. Similarly by recording UV energy output over time, you will be better able to predict how lamp ageing will affect the curing process. This will allow you to be proactive in preventing unwelcome surprises in the midst of an important production run.

Good process design and regular monitoring helps you to keep your presses running and producing effectively cured prints. By designing and monitoring the curing process properly, you can make changes to production parameters instantly, maximising efficiency and minimising waste.

Chapter 8
Testing for adhesion and effective ink cure

How do you know whether the ink deposit on your prints is effectively cured or not? The following tests provide all the necessary information.

Testing ink cure

Any testing procedure for effective curing must also establish whether the ink you are using is compatible with the substrate you are printing on. UV ink systems are not 'universal', and certain inks are simply not designed to adhere to certain substrates. Also, UV inks are more sensitive than solvent inks to substrate defects, such as excessive plasticiser levels on the face film or other types of contamination. Incompatibility between the ink and the substrate, therefore, can even prevent a cured ink film from adhering to the surface of the material.

To check for ink/substrate compatibility, begin by referring to the ink manufacturer's recommendations.

1. Print appearance – Produce a proof print on to the substrate and check for reticulation. If reticulation is visible, try printing the ink on another type of substrate. If the same problem occurs, the ink may be contaminated. If the second print is good, however, the reticulation is likely to have been caused by plasticiser or some other contaminant on the surface of the material, meaning that the substrate is incompatible with the ink.

Look also to see whether the surface of the ink looks solid but shows signs of wrinkling. This could indicate that the ink film is under cured at the contact point. Providing that there is no sign of reticulation, you can proceed with mechanical tests for ink cure and adhesion.

Figure 8.1 illustrates reticulation. This indicates possible ink/substrate incompatibility.

2. Fingernail scratch and adhesive tape tests – Scratch the ink film with your fingernail to check whether it is solid throughout and follow this with an adhesive tape test; rub down some good quality adhesive tape across the print and then tear it away. If the ink film flakes off the substrate easily, and there is little or no ink residue on the stock, it is likely that the ink and substrate are incompatible (but make sure that the surface of the substrate has not been ripped away, as opposed to just the ink). If the ink and substrate are incompatible and the ink comes away from the material, the flakes of ink are likely to be dry and will crumble when rubbed between your fingers. A more aggressive scratch test is to break the ink film with a palette knife or coin. A finger nail test is then conducted from the broken ink film edge.

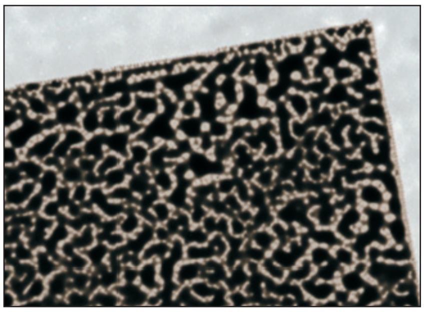


Fig. 8.1

Fig. 8.2

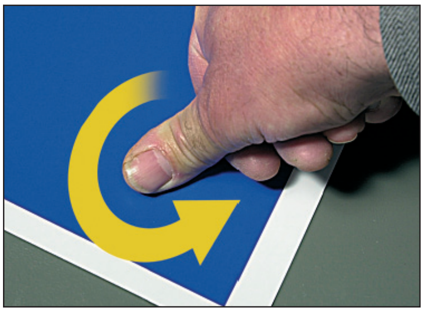


Fig. 8.3

3. Post cure – The chemical reactions involved in curing UV ink are not totally completed in the curing unit itself. While up to 90% of the chemical bonds needed to give adhesion etc, are completed, there is a post cure period when chemical bonds continue to be made.

Until recently it was believed that post cure was completed within 24 hours. Study has shown that although much of the post cure activity does take place within 24 hours it is now thought the total post cure period can last for a few weeks.

This is importmant to recognise as the UV cure process, and post curing, can cause shrinkage of the ink film which puts stress on the material. In the case of self-adhesive PVC the stress manifests itself as cracking or shattering (embrittlement) of the substrate.

It is therefore important to be cautious if your results immediatley after curing are borderline for embrittlement as the additional post cure stress may cause more serious problems later on.

Selection of inks is all the more critical on lighter weight substrates as embrittlement is more likely to occur. There are UV inks especially developed to minimise the effect of embrittlement. This is achieved by using more flexible raw materials that are generally more expensive. Post cure still takes place in these inks but the overall embrittlement of substrate is greatly reduced.

To rule out the effect of post-curing, re-test the proof print after two hours. If the ink film is still easily detached and comes away in relatively large flakes or sheets you can be reasonably certain that your ink and substrate are incompatible. However, before you consider an alternative ink for the application, check whether the ink manufacturer can recommend an adhesion modifier that will improve the ink's adhesion characteristics on difficult substrates.

Be aware, however, that some additives have trade-offs with regard to pot life, a post-curing requirement or loss of ink film flexibility.

If there is no suitable adhesion modifier available, or using an adhesion modifier results in an unacceptable trade off, you will have to identify another ink/substrate combination.

Figure 8.2 Illustrates the fingernail scratch test for ink and substrate compatibility.

4. Thumb twist test – Finally, put your thumb on to the ink film, apply pressure and twist. If the ink film feels dry to the touch and you cannot separate it you probably have achieved an effective cure. If the ink film breaks or smears and the contact layer is soft and gelatinous, the ink is only partially cured. In this case, you are also likely to notice ink residue on the surface of the substrate.

Figure 8.3 illustrates the thumb twist test for effective cure.

5. Cross hatch and tape test – If the visual inspection and fingernail scratch and adhesive tape test results are good, apply the cross hatch and tape test to confirm the level of cure. Cut through the printed ink several times at 90° angles, rub down a good quality adhesive tape over the cut lines, then rip the tape off. Cure is considered to be good if only 5% - 15% of the ink is removed during this test. If, however, a significant portion of the ink film releases with the tape, but the ink film appears to be splitting in thickness with part of the contact layer remaining on the substrate, it indicates that the ink is achieving adhesion but is under cured. In this instance, the portion of the contact layer remaining on the substrate will appear soft, indicating the lack of throughcure.

Figure 8.4 illustrates the cross hatch and tape test for confirming the level of cure.

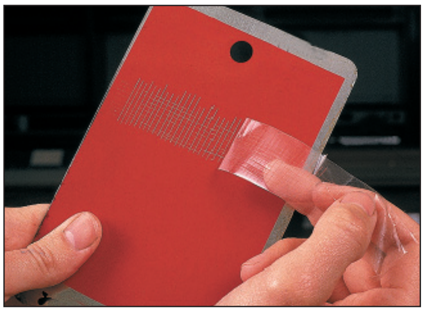


Fig. 8.4

6. Testing for over cure – Most Sericol inks are not susceptible to over cure. However, excessively high lamp output, slow belt speeds or numerous passes through the UV curing unit can cause trichromatics and less opaque line colours to suffer from problems with intercoat adhesion.

To test for over cure, bend the substrate then perform a fingernail scratch and adhesive tape test. If the ink film flakes off when you bend the substrate or perform the mechanical tests, (and you have previously established that the ink and substrate are compatible), the print is likely to be over cured.

To test for problems with intercoat adhesion, cure the colour several times. On a 5-colour job, say, print the colour, run the print through the UV curing unit four times, then overprint with the same colour and cure the print again. Perform a fingernail scratch test on the print to ensure that the ink film does not flake off. If after several passes through the UV curing unit the ink adheres satisfactorily you are unlikely to experience any problems with over cure/intercoat adhesion during production.

7. Performance testing – As well as testing for ink and substrate compatibility, undercure and over cure, you should also perform all the necessary post-performance tests prior to production – such as, the print's suitability for die-cutting, forming, scoring and embossing, plus resistance to abrasion, chemicals and weathering.

Step	Test	Effect	Diagnosis
1.	Visual inspection	Reticulation	Ink and substrate incompatible
		Wrinkled surface Ink deposit still fluid	Ink film under cured Ink film uncured
2.	Fingernail scratch and adhesive tape test	Ink detaches from substrate as dry flakes - no ink deposit on stock	Ink and substrate incompatible
		Ink film breaks, leaving gelatinous deposit on stock	Ink film under cured
3.	Cross hatch and tape test	Ink film splits with part of contact layer remaining on substrate	Ink film under cured
		Ink removed from substrate	Possible ink and substrate incompatibility
4.	Thumb twist	Ink film breaks, leaving gelatinous deposit on stock	Ink film severely under cured

Figure 8.5 the testing procedure for ink cure and adhesion

Chapter 9
Pre-press for UV screen printing

UV inks have the capability to consistently produce more detailed and higher quality prints than solvent ink, though this capability also makes them far less forgiving of, for example, incorrect mesh selection or imperfect stencil production. As with all aspects of UV screen printing, every step in the pre-press process must be geared to controlling the thickness of the ink deposit. It is essential, therefore, to understand and manage mesh selection, stencil preparation and print design, and harness modern repro techniques to control ink performance on-press.

Mesh selection

UV ink is printed through finer meshes that make it possible to lay down a thinner ink deposit. The absence of drying-in means that there is no risk of the ink blocking the smaller mesh openings, so it is possible to exploit all the advantages that higher mesh counts have to offer. These advantages include the capability to resolve very fine detail, including small reversed out text, and reproduce superior line and dot definition. With water-based UV inks, the use of fine meshes also helps to minimise substrate distortion by limiting the amount of ink (and water) coming into contact with the substrate.

Sericol has conducted extensive research into the optimum mesh for use with UV inks. Having tested a wide variety of grades, mesh counts, weave patterns, thread diameters and so on, 150.34 (PW) mesh is recommended for the optimum balance of ink deposit and print definition and durability for both conventional UV and water-based UV inks.

Figure 9.1 illustrates the influence of the mesh on conventional UV ink deposit and water-based UV ink deposit.

34 micron thread diameter – Finer threads tend to reduce ink thickness slightly and tests show that good results are achieved with a thread diameter of 34 microns. More important, perhaps, is the need to standardise on one size of thread, as changing to a different diameter will change the ink deposit and is likely to have a noticeable effect on the appearance of the print.

Plain weave (PW) – Plain weave mesh produces a lower stencil thickness than an equivalent twill weave mesh, which helps to reduce the thickness of the ink deposit.

Thread colour – Dyed (orange or yellow) mesh performs better than white mesh at higher mesh counts, where the scattering of light during stencil exposure causes undercutting of fine detail in the image. However, white mesh is recommended for use with direct projection exposure units (see Stencils for direct projection units – opposite).

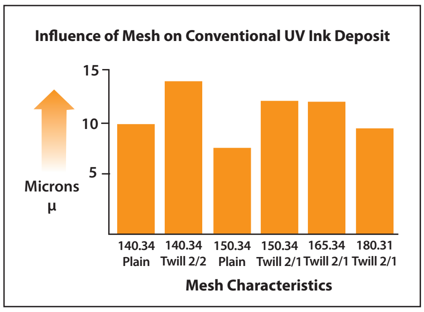


Fig. 9.1

Stencils for direct projection units

Projection units have been used for some time to produce stencils for multi-sheet 4-colour posters. However, they are now being used more often with the finer halftone screen rulings used in point of purchase display work. In general, low magnification (up to 5x) is used for finer halftone PoP prints whereas higher magnification (up to 12x) is used for coarser halftones as used for multi-sheet billboards.

Essentially the screen-making techniques are broadly the same, with one clear difference. White mesh tends to be used, rather than coloured mesh which will increase exposure time to such an extent that stencil throughcure becomes difficult to achieve, especially at higher magnifications. The same mesh counts are used as with conventional stencils.

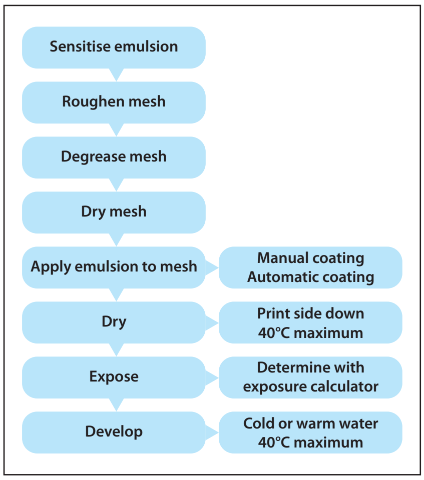


Fig. 9.2

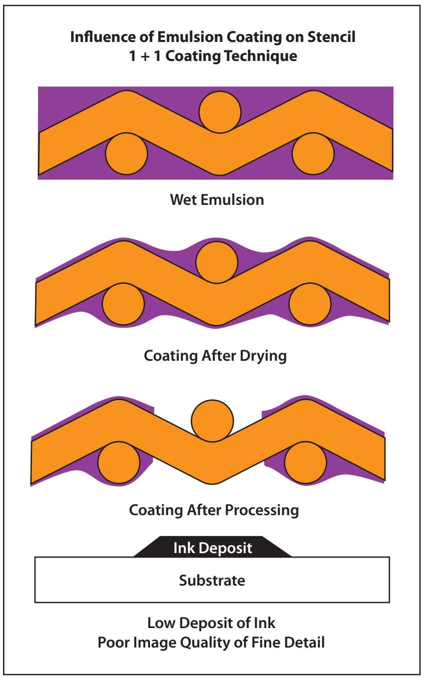


Fig. 9.3

Mesh tension

As with all forms of screen printing, it is important to ensure that all the screens used for a particular job are tensioned the same. Different tensions can lead to differences in the thickness of the ink deposit, which will affect curing rates, and will also lead to misregister between colours. These undesirable effects are most noticeable on larger format images where differences in mesh tension are amplified due to frame size.

Priority should be given to consistency rather than excessively high tensions, but wherever possible, meshes should be stretched to give an optimum tension of 18 N/cm or above – dependant on frame size. It is easier to achieve and maintain consistent tension when the mesh is stretched on to good quality low deflection metal frames, which Sericol recommend for all UV screen printing.

Stencil selection

A high quality, high definition stencil delivering high resolution and durability is required to complement the excellent performance characteristics of UV ink. Diazo-photopolymer emulsion systems are most suited for use with both conventional UV and water-based UV inks. They give excellent print quality, are resistant to water, so can be used with water-based UV inks, and are simple to expose correctly, having wide exposure latitude. (If a capillary film stencil is required, a thin water/solvent-resistant 18 or 20 micron capillary is the recommended type.)

Stencil making

Degreasing – Thorough mesh preparation (for both new and used screens) is extremely important. New screens should be degreased before use to remove any water-repellent residues left from the mesh manufacturing process. This reduces the risk of pinholes; bear in mind that UV inks do not dry-in, so the ink will transfer through every opening on the stencil, including the smallest of pinholes. Use a purpose designed product, such as Sericol's Xtend Prep, to degrease the mesh and improve stencil adhesion, but take care as other preparations can be so abrasive that they damage the mesh.

Coating techniques – The correct coating of the mesh plays a critical role in the control of stencil build and its effect on ink deposit thickness. When coating the mesh, a balance must be struck between a higher stencil build that gives superior definition but excessive ink film thickness, and a lower stencil build, which gives a thinner ink deposit but poor definition and reduced life. For fine detail work, printers should produce a stencil with low build and a smooth surface – sometimes measured as Rz value.

1 + 1 coating technique – Applying one coating on each side of the mesh gives an even coat when wet, but as the emulsion dries it shrinks back to the mesh. The low stencil build delivers a thin ink deposit, but print quality can suffer due to the poor stencil edge profile.

Figure 9.3 illustrates the 1 + 1 coating technique and its influence on stencil build and the printed ink deposit.

1 + 3 coating technique – Applying one coating on the print side and three on the squeegee side (drying print side down) results in a stencil that does not shrink back to the mesh as much when it dries and produces a flatter surface. (As a general rule, the higher the solids content of the emulsion, the less it will shrink on drying and the flatter the surface.) The print quality is superior, but the ink film thickness is increased. This could cause problems with curing and could compromise the final print quality on process prints.

1 + 2 coating technique – The recommended coating technique involves applying one coating on the print side, followed by two on the squeegee side, all wet-on-wet. When dried print side down, this produces the best combination of ink deposit thickness and print quality.

Figure 9.4 illustrates the 1 + 2 coating technique and its influence on stencil build and the printed ink deposit.

In four-colour printing, the ink deposit must be the same for each colour. To achieve this the stencil build must be the same for all the screens. The key variables to control to achieve consistent results are:

- the coating speed
- the type of coating trough used
- the side of the screen coated last

An additional important factor in controlling emulsion deposit and stencil build from screen to screen is the amount of emulsion in the trough; the trough should be kept full at all times. For best results, use an automatic coating machine.

Figure 9.5 illustrates the advantages and disadvantages of manual and automatic emulsion coating.

Drying the screen – Once coated, the screens should be dried horizontally, squeegee-side up, so the emulsion can build on the print side of the screen. Dry the screen at temperatures up to 35°C, with some air flow to remove the expelled water. (The emulsion should never be dried at temperatures above 40°C.)

While the actual temperature is important, so is the humidity – raising the temperature in a drying area reduces the humidity so that the water leaves the coating. However, if that water isn't removed, equilibrium will be reached and the screen will not dry. It is particularly important that stencils for use with water-based UV inks are thoroughly dried and, having been dried, are not placed where they can reabsorb moisture – for instance, in the vicinity of a washout booth.

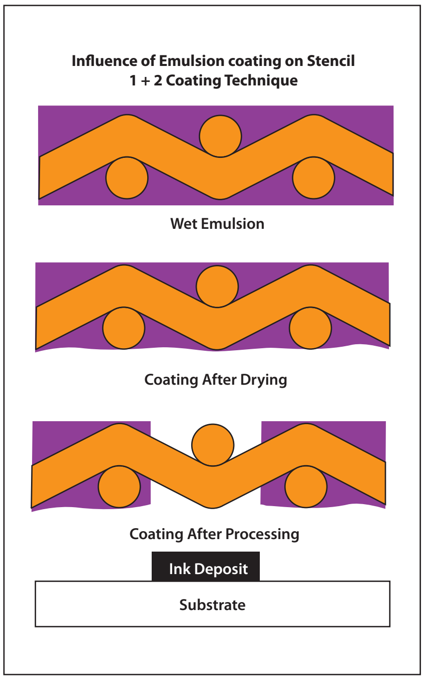


Fig. 9.4

Manual Coating	**Advantages** More suited to small screens Inexpensive **Disadvantages** Speed/pressure variation Uneven emulsion thickness Inconsistent exposure Non-standard procedure
Automatic Coating	**Advantages** Controlled emulsion thickness Consistent exposure Repeatable results Faster production Standards procedures

Fig. 9.5

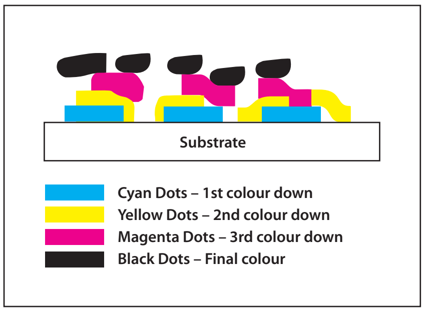


Fig. 9.6

Exposing the stencil – The correct exposure should be assessed using an exposure calculator to ensure optimum print quality and durability.

The imperative, here, is cleanliness. Film positives, in particular lamp bulbs and the glass in the vacuum frame must be spotless to prevent pinholes. It is essential to inspect the stencil closely once it has been exposed, and to ensure that any imperfections are thoroughly spotted out – remember, UV inks will print even the smallest pinhole. Use sensitised emulsion for spotting out and ensure that it is thoroughly dry before re-exposure. Alternatively, use a spot out filler. Xtend Screen Filler WR is a good choice for water-based UV inks. It has the advantage of air drying, so re-exposure is not required and it can be used on-press for stencil repair.

Figure 9.2 on page 42 summarises the processing sequence for direct emulsions.

Colour separation

The control of ink film thickness is especially important when process printing with UV ink. As well as affecting the curing process, an excessive ink deposit will compromise print quality in the following ways:

- Smearing, or 'gaining', of the halftone dots, reducing the definition of the image, affecting colours and creating tonal jumps;
- impaired lay down of the final colour – successive thick ink deposits may prevent all of the ink printed through the final screen from reaching the substrate;
- revealing unwanted grey tones within darker colours as a result of even slight misregistration in areas where there is a large deposit of cyan, magenta and yellow;
- increasing dot gain with the subsequent loss of shadow details; and
- giving prints a 'Braille-like' appearance, or variations in gloss from midtones to shadows.

Figure 9.6 shows how excessive ink deposit can impair the lay down of the final colour.

Digital separation techniques can be used to tailor the colour separations so as to optimise the ink deposit on the print and avoid the problems outlined above. The relevant techniques are **under colour removal** (UCR) and **grey component replacement** (GCR), both of which can be carried out in Adobe Photoshop®. Both work by replacing some of the cyan, magenta and yellow inks with black ink. This reduces the total weight of ink printed and thickness of the ink film, improving ink cure and print quality and reducing ink costs.

UCR – reduces the amount of cyan, magenta and yellow in the darkest neutral and near neutral colours of an image and increases the amount of black accordingly. UCR becomes active in any area of the image where the total ink percentage of cyan, magenta, yellow and black exceeds the specified total ink limit. You need to determine the optimum total ink limit for your press and the type of ink you are using – it will be between 240% and 340% depending on the printing conditions.

To select the appropriate UCR settings for your press and printing parameters in Photoshop®, first open the Separation Set-up dialogue box and click on the UCR button. Then set the total ink limit by entering the percentage value in the appropriate box.

Figure 9.7 shows the Photoshop® Separation Set-up dialogue box for UCR and GCR settings.

GCR – Whereas the effect of UCR is concentrated on darker areas, GCR works to replace some of the grey component with black in every area of the image where cyan, magenta and yellow inks overprint each other. The amount of each of the three inks to be replaced by black can be specified by the operator.

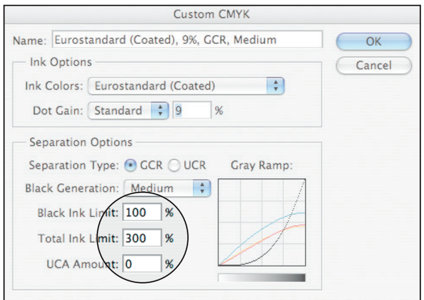
To set GCR in Photoshop, open the Separation Setup dialogue box as before (GCR is automatically selected as the default) and set the total ink limit. Now choose a 'black generation setting' using the pull down menu. Ignore the 'None' setting which generates a colour separation using no black value. The default setting is medium. This is most likely to give optimum results. You can also use the custom command, which lets you adjust the black generation curve manually.

Using GCR results in a marked reduction in the amount of coloured ink used. However, you must be especially careful to control dot gain on the black screen as even a small amount can severely affect the brightness of the finished print.

Dot gain – Controlling the size of the dots is central to accurate colour and tonal reproduction on halftone prints. This involves measuring the amount of dot gain on a proof print (with a densitometer) and compensating for any increase in size compared with the dots on the artwork by adjusting the size of the dots output on to the film positives. Dot size on the positives is adjusted by altering the size settings for each percentage dot in Photoshop.

You will notice that the densitometer readings from a proof print produced with water-based UV ink show that dot gain is significantly less than for a proof print produced with solvent-based ink. The use of finer meshes and lack of drying in also result in a wider tonal range, as small highlight dots are less likely to disappear through the smaller mesh openings, and small stencil openings in the shadow areas are less likely to fill in. So in effect, the proof print will more closely match the original artwork. Moving to a UV or water-based UV ink system means you will need to output new film and make new screens for existing designs as using the film positives that were output using dot gain parameters for solvent-based inks will result in unsatisfactory prints.

Figure 9.8 compares the dot gain adjustments in Photoshop for a solvent ink (bottom) and a water-based UV ink (top). Note that less adjustment is required for the print made with water-based UV inks.



Setting 'Total Ink Limit' in Adobe Photoshop

Fig. 9.7

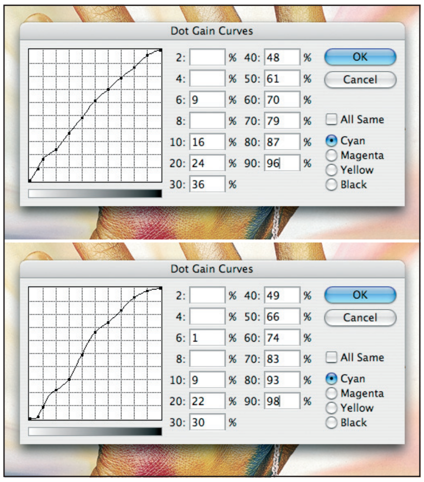


Fig. 9.8

Chapter 10
Printing UV ink

In general terms, printing with UV ink calls for the same skills and techniques as those required for printing other types of screen ink. However, these skills and techniques must be used with greater precision. UV ink is less forgiving of imperfect equipment and technical errors, and demands a standardised printing process that incorporates the highest quality controls.

As described earlier, the thickness of UV ink deposit remains after curing and, to achieve the finest details, the print deposit needs to be minimised. This chapter outlines the key factors involved in controlling and optimising ink deposit.

Fingerprinting the press

Fingerprinting the press by producing control prints using the ink, mesh and press parameters you will use to produce the final job is recommended. Just as you must measure and understand the role of UV energy in order to design and monitor the curing process, so you must measure and understand the on-press variables that affect the final print.

The values in figure 10.1 are examples of typical printed halftone dot percentages for the different types of UV inks. Before you specify any adjustments to your separated film positives, it is vital that you 'fingerprint' the print process. This involves printing a control strip consisting of specific and known halftone areas using the mesh, stencil, ink and machine combination you will be using to produce the final job. You can then take densitometer readings from the printed area and compare them with readings taken from the proof supplied by the client or repro house. This will give you the necessary amount of dot gain that must be built in to your film positives.

Conventional UV curable ink systems

The primary consideration with this type of ink is its build characteristics. The very nature of 4-colour process printing requires that the inks are printed together, building up layers of ink on top of one another. UV curable ink systems contain little or no volatile component, so the cured ink film weight is likely to be relatively high and, unless tightly controlled, will have a dramatic affect on the appearance of the printed halftone dots.

Figure 10.2 shows a gradation curve for conventional UV curable inks.

In areas where dots are partially overlaid on one another, there will be a tendency for the overprint to spread. In areas where the dots are printed between previously printed dots there is a possibility that the dot will either underprint or not print at all. This is especially noticeable when printing the third and fourth colours. However, you can take advantage of the many benefits of using UV inks and produce a high standard of printing, provided you take care to control the ink build.

Actual % dot reproduced on print vs ink type

Film Positive	Conventional UV	Water-based UV
10	14	11
20	27	23
30	38	33
40	50	44
50	62	54
60	70	65
70	80	74
80	85	83
90	94	92
100	100	100

Fig. 10.1

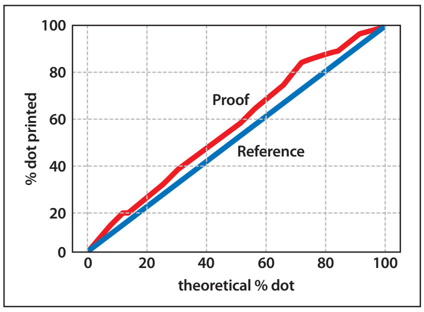


Fig. 10.2

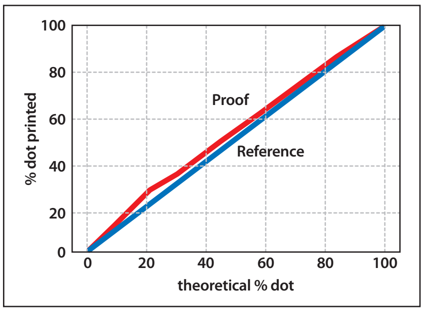


Fig. 10.3

Water-based UV curable ink systems

20 - 40% water content, coupled with the general production advantages of UV technology, makes this type of ink system capable of excellent dot reproduction. Since the build of the printed ink film approaches that produced using an evaporative ink system the quality of the halftone dots printed in subsequent layers is improved.

Figure 10.3 shows a gradation curve for water-based UV curable inks.

A look at the gradation curve for water-based UV curable inks shows that they accurately reproduce the halftone dots on the positive. Only slight alterations to the separations to move the curves closer to that of the proof are required.

The very nature of UV ink systems means that press parameters – such as, stencil profile, squeegee pressure and 'off contact' distance – can vary slightly from colour-to-colour and from job-to-job without unduly affecting the ink's dot reproduction characteristics. This makes it possible to control how the inks behave with a much greater degree of accuracy and consistency. In other words, any adjustments you make to the gradation curves are not complicated by the ink's performance – you can accurately predict the effects of any alterations to the separations, as you don't have to worry about complicating factors, such as drying in, dot spread, high ink build and so on.

The most important point to understand, is that modern ink and repro technologies allow you to control what the ink does, rather than the ink controlling what you do.

Printing set-up

All screen printing presses fitted with a UV curing unit are suitable for printing UV inks, and multicolour in-line machines, in fact, depend upon their use. However, there are some areas of press design and maintenance that need to be considered in detail.

As stated, UV inks give the most consistent print quality but can be unforgiving of errors. Conventional UV ink transfers every detail from the screen to the substrate, including unwanted detail arising from stencil and equipment imperfections. The use of fine meshes and the transparency of the ink compound this performance characteristic. Similarly, variations in ink deposit thickness across the print can result in marked colour shifts and variations in ink curing performance.

Print bed – For the reasons outlined above, the print bed must be uniform and level. Whereas a slightly warped or dented surface may have little discernible effect on the appearance of a print made with solvent ink, the same equipment flaws will significantly compromise the quality of a print made with UV ink.

Accurate press controls – The ability to make fine, accurate adjustments to squeegee angles, pressure and speed, off-contact distance and flood bar angles and pressure is necessary to ensure a consistent, controllable ink deposit. For 4 colour process work with UV inks, the press should be capable of registration accuracy to 1/100th of a millimetre.

Precise control over press parameters is worthless unless you can rely on the settings to remain constant throughout the production run. The squeegee has a very important role in determining ink deposit thickness, so it is especially important that the squeegee angle, pressure and speed remain constant throughout the stroke.

Printshop environment – A consistent printshop environment is also important. Controlling the ambient temperature and humidity will help to standardise ink performance; minimising airborne contamination will help to prevent dust falling on to the screen and being reproduced on the print; and blocking direct sunlight from screens will eliminate the risk of partial polymerisation of UV ink.

Maintenance – A regular preventative maintenance schedule will help to ensure that consistent performance of the press is maintained.

Squeegees and flood bars

The squeegee – blade material, durometer, profile, edge sharpness, angle and pressure – is likely to have greater impact on the appearance of the final print than any other press variable. Correct squeegee choice, care and use are fundamental to successful screen printing with UV ink.

Squeegee blade material – Squeegee blades, often referred to as squeegee rubber, are in fact normally made of polyurethane, a material which gives good resistance to the combination of raw materials used in UV screen inks. It is inevitable though, that inks that are developed to gain chemical adhesion on plastic substrates will also attack the squeegee material.The polyurethane blade will absorb some UV monomers, causing swelling and softening of the print edge, making it more susceptible to damage which can be reflected in the print quality. The issue of squeegee attack is increasingly common as UV inks are being developed for a wider variety of plastics - requiring more aggressive monomers. Squeegee life can be extended by having 2 or 3 sets for each machine and rotating their use to permit the monomers to evaporate.

Squeegee durometer (hardness) – UV inks require squeegees with a higher shore rating compared with solvent-based inks. Similarly, you may need to use squeegees with a slightly higher shore if you are printing on a cylinder press. As well as resisting the monomers in the ink, harder squeegees give better definition and transfer less ink on to the substrate, reducing ink deposit thickness. A durometer of 70° - 75° shore is recommended for flatbed presses and 75° - 80° for cylinder machines.

Squeegee profile – A sharp, square edge profile is generally recommended, as rounded or bevelled squeegees deposit more ink. However, be careful not to use overly thin blades as they may bend, which can also result in a heavy ink deposit.

Accurate dot reproduction

An ink which gives accurate dot reproduction has advantages, as it gives a more predictable and controllable result than an ink which exhibits significant levels of dot gain on printing. This makes it possible to exercise far more control over how adjustments to the film positives will affect the final print. Bear in mind that dot gaain will vary from substrate-to-substrate, stencil-to-stencil and press-to-press. It would be counterproductive to try to formulate an ink for all combinations of production parameters. By using an ink which allows you to reliably and accurately predict the effects of any changes to the separations, you can tailor the separations to any combination of stencil, press or substrate parameters. In other words, you control the performance of the ink to suit whatever machinery, stencil and substrate you are using. If you alter any of these parameters, you simply amend the separations accordingly.

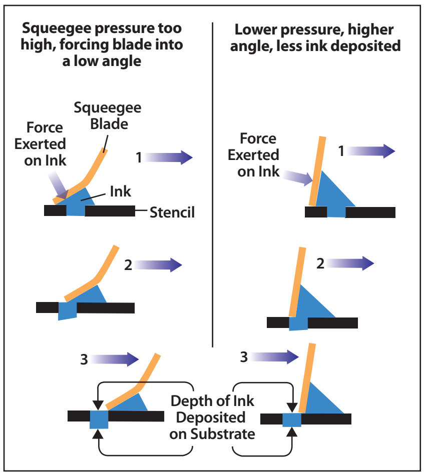


Fig. 10.4

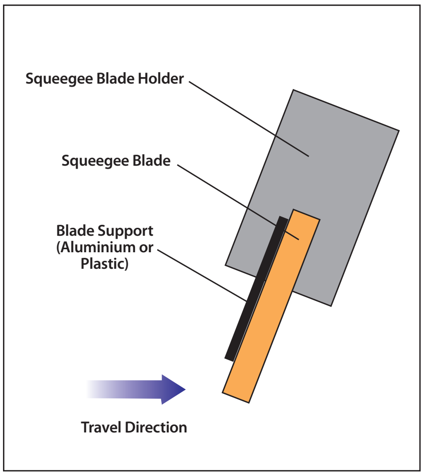


Fig. 10.5

Squeegee edge sharpness – The squeegee must have a perfectly straight edge to exert equal pressure over its entire length and lay down a uniform ink deposit. Variable pressure will lead to variable ink deposit on the substrate and potential problems with curing and colour matches. Check carefully to make sure that the squeegee is flat and clean along the edge. Every printshop should own a good squeegee sharpener and use it as often as is necessary to ensure that the edge remains perfectly sharp and straight. Precise dressers may be slightly more expensive than simple belt sanders, but they result in a higher quality printing edge.

Squeegees should be allowed to stand for at least 24 hours before sharpening to permit monomers/solvents to evaporate. This recovery time will result in the best resharpened edge.

Squeegee angle – Determining the most appropriate squeegee angle for your press is a vital part of the fingerprinting process. Generally, an angle that matches the shore of the squeegee (70° - 75° for a flatbed press, and 75° - 80° for a cylinder press) will give the optimum results. Consistency is the priority; make sure that the squeegee is locked in tight and the angle is the same throughout the production run.

Squeegee pressure – You should aim to use the minimum squeegee pressure required to provide good coverage. This will depend upon the substrate you are printing on. To determine the minimum pressure for each substrate, produce a series of test prints, reducing the squeegee pressure on subsequent prints until the squeegee just fails to provide complete coverage. Then increase the squeegee pressure again until perfect coverage is achieved.

If the pressure setting causes the squeegee blade to bend, or severely changes the squeegee angle, print quality will inevitably suffer. Setting a heavy squeegee pressure tends to force more ink through the mesh, resulting in a heavier ink deposit, and loss of detail through exaggerated dot gain. Therefore, if you find that the ink is not passing easily through the mesh, don't be tempted to simply increase the squeegee pressure; consider the ink viscosity, squeegee durometer or squeegee angle as well.

Figure 10.4 illustrates the effect on ink deposit by applying too much pressure during the print stroke.

Blade support – Many problems with excessive flexing of the blade, or loss of proper squeegee angle and pressure, are caused by an excessive depth of squeegee blade below the holder. For optimum squeegee function, therefore, it is recommended that you use the minimum depth of blade below the holder. This can be achieved by cutting down the blade, or by inserting a rigid aluminium or plastic support (shim) behind the blade. The necessity for support has been largely superseded by triple layer squeegees.

Figure 10.5 illustrates the use of a blade support to improve squeegee performance .

Stroke speed – The slower the squeegee stroke, the more ink you will deposit – a major consideration when you are seeking to minimise the ink build with conventional UV curable inks. A faster stroke speed will generally reduce ink deposit, improve quality and production speed. However, rheology of the ink has a great effect on the speed at which an ink can be printed so simply increasing stroke speed is not always possible.

Flood bar set up will also have an important influence over the finished print. Again, these general pointers are intended to help you control the uniformity and thickness of the ink deposit.

Flood bar alignment – Check that the flood bar is straight and has been fitted correctly. Misalignment of the flood bar will cause more ink to be deposited in some areas of the print than others. The edge of the flood bar should be routinely inspected as a dent or nick can create a sharp point which could tear a screen.

Flood bar angle – The flood bar angle affects the thickness of the ink deposit in the same way as the angle of the squeegee. A low (accute) angle gives a heavier ink deposit, a verticle or obtuse angled flood coater deposits a correspondingly lower ink film ensuring that mesh openings are merely 'fed' rather than filled with ink.

Flood bar pressure – Use the minimum pressure to provide an even flood coat. Too much pressure will force too much ink into the mesh openings, resulting in a heavier ink deposit. It can also damage the screen fabric itself, especially if the flood bar edge is uneven or damaged. For best results, set the flood bar snug to the mesh.

Flood bar profile - For the reasons outlined above, thin metal flood bars are generally preferable to bars with a thicker, rounded profile.

Off-contact/peel off

A high off-contact setting compromises registration, colour balance and definition. It requires greater squeegee pressure to bring the mesh into contact with the substrate, causing a heavier ink weight deposit, a larger degree of dot gain and the possibility of premature mesh and stencil breakdown. Excessive off-contact can also lead to various print flaws. Bear in mind, also, that the more the mesh is stretched to make contact with the substrate, the greater is the likelihood of print distortion. For these reasons, select the lowest possible off-contact settings. As a general guide, off-contact should be set at about 1.5 mm. The maximum off-contact you should consider using is usually between 3-5 mm depending on screen size and mesh tension. Likewise, if your print equipment has a peel-off function, it is recommended that it is set at the minimum required to lift the screen from the bed immediately after the squeegee has passed. Increasing off-contact and/or peel-off should not be used to compensate for low tension meshes.

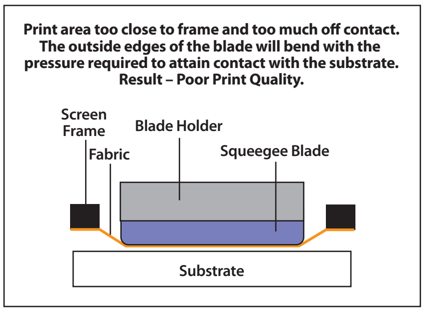


Fig. 10.6

Print area – Do not be tempted to print tight up against the screen frame; the additional pressure required to print near the frame will result in poor print quality.

Figure 10.6 shows incorrect set-up, with the print area too close to the screen frame and excessive off-contact distance. The combined effect is to cause the outside edges of the squeegee blade to bend, resulting in a poor quality print.

Static eliminators

Static electricity can be a problem, especially when printing on to plastics substrates. It causes feed problems as the substrate 'sticks' together or to the bottom of the screen. Static also attracts dust particles to the surface of the substrate, which then attach themselves to the underside of the screen, and show in the print.

Static can be controlled by using static eliminators. It can also be reduced by controlling the humidity of the printshop environment – (more static is generated in conditions of low humidity). Lowering off-contact distances and squeegee pressure reduces the amount of friction between the squeegee and the screen, which in turn reduces the amount of static build up.

General guidelines

The following pointers will help you to produce superior prints and avoid common production pitfalls associated with the use of UV inks.

Visual inspection – Check for the effects of excessive pressure or a blunt squeegee blade by inspecting the inside of the screen. If the screen is not reasonably dry/clean by appearance or to the touch (that is, there is a slight residue of ink in the screen) following the squeegee stroke, the squeegee did not properly print the ink. Test the sharpness of the squeegee blade; if it is found to be blunt, replace it with a sharpened squeegee immediately. If the squeegee is sharp, check the squeegee pressure angle and speed settings and adjust them accordingly.

Flood coat – Don't leave the screen in the flood coating cycle for any longer than necessary: correct flood coating just fills the mesh openings with ink; extending the flood coating cycle can result in more ink passing through the mesh openings and a heavier ink deposit.

Squeegee use – Do not print with the same squeegee for more than one shift or one day at a time as with some UV inks the squeegee is likely to swell or soften unacceptably. (Some squeegee and ink combinations may even require a change of squeegee every four hours or more frequently to maintain consistent ink deposits.)

Allow a minimum of 24 hours after printing prior to resharpening. This gives the squeegee time to recover from the effects of the monomers in the ink. Different squeegees have different recovery rates; check the thickness of the blade at set intervals after printing to calculate how quickly the squeegee you are using recovers.

Ideally printers should have three squeegees per press and rotate them on a three day cycle. At any point in time, then, one squeegee is in-use on the press, another is being prepared for use the following day and the last is being prepared for use the day after that. In this way, each squeegee has two days to recover. Just prior to using the dried squeegee again, inspect it for damage, and sharpen and reset it as required.

Downtime – Whenever the press stops for an extended period it is good practice to print the screen clear and remove the squeegee from the screen. Clean off any ink and wipe the squeegee dry. Avoid leaving the squeegee submerged in or exposed to UV ink for longer than necessary, as some UV inks will cause the blade to swell and soften. For extended downtime, cover the screen (with a piece of cardboard, for instance) so that there is no risk of direct sunlight falling on the screen and causing premature, partial polymerisation of the ink in the screen.

Wash up – Make sure that screens are washed up thoroughly using the appropriate cleaning agents. If there is a residue of UV ink in the mesh and the screen is exposed to direct sunlight the ink residue will gradually cure and the screen will be stained.

Chapter 11
Colour matching

The reproduction of accurate, consistent colours is fundamental to high quality screen printing. UV ink poses its own set of challenges in this regard, not least because of the greater expense of the ink itself, which makes waste management more critical. However, by implementing tight controls across all aspects of colour-management and printing, accurate, consistent colour can be assured.

There are three steps to accurate colour reproduction.

Step one

The first, essential step is to identify a reputable, reliable manufacturer of UV ink products that can offer accurate, colour-matched ink recipes.

Sericol is a global Pantone®* licensee and conducts all of its colour-matching by hand. All recipes are based on real matches, made by experienced, expert colour-matchers, not computer-generated predictions.

Step two

Having identified your ink supplier, you must decide whether to handle colour management in-house, or let the manufacturer prepare the colour-matched ink for you. For those printers that prefer to outsource, Sericol can offer an expert colour-matching service that supplies mixed, colour-matched ink – to your own or Pantone® references – that's ready for use. For printers whose colour-match requirements are too numerous, too small a volume or too unpredictable for outsourcing, in-house colour management is the more appropriate option.

Sericol's extensive product offer helps to illustrate the range of options available.

Sericol Pantone® Formula Guides – The Sericol package follows a tiered approach that caters for all requirements. The entry level is the Sericol Pantone® Formula Guides. They contain Pantone®-approved recipes for simulating colours in the Pantone 1000 Color Guide.

Sericol Pantone® Scale – Comprises a precise weighing scale and is pre-programmed with a database of all the Pantone-approved formulas. The Scale uses a quick and easy to follow, step-by-step approach to calculating the necessary weight of each ingredient to produce a user-specified quantity (batch) of a particular colour. There is even a recalculation facility to correct weighing errors.

Figure 11.1 illustrates the Sericol Pantone® Scale.

Fig. 11.1

**PANTONE® is the property of Pantone, Inc.*

Fig. 11.2

Colour Dispensing Systems – The most sophisticated colour management tools are ink dispensers. These are aimed at large format PoP printers using (predominantly) a single ink system. The dispensers automate the weighing, mixing and dispensing processes to eliminate human error and provide the most accurate and repeatable colour matches available. Repeatability is an important benefit of this type of system as it allows you to mix smaller batches of ink, knowing that if you require more ink the subsequent batches will be identical to the first. This makes it easier to mix only the amount of ink you require for a job, which can lead to major cost savings with UV ink. The dispensers also offer sophisticated stock management functions, including the capability to use 'returns' in new ink mix formulations, and the option of a modem link to the nearest Sericol Service Centre for automatic replenishment of ink stocks.

When assessing any colour management system, it is important to consider not only the accuracy and repeatability of the colour matches achieved, but also how long it takes for the ink room staff to achieve them. Sericol's colour management systems are aimed at delivering the most accurate and easily repeatable colour matches possible in the shortest length of time.

Figure 11.2 illustrates a typical colour dispensing system.

Colour control on-press

Throughout this guide there is repeated reference to 'reducing or limiting' the thickness of the UV ink deposit to ensure an effective cure.

Effective cure is only half the story, though; the thickness of the ink film will also have a major influence over how colours are reproduced on the print. It is more accurate, therefore, to refer to the need for a 'consistent thickness of UV ink deposit'. UV ink base colours tend to be highly pigmented but relatively transparent. To give the best results, the ink generally requires some opacity and this is achieved by adding white pigment to the base colours.

With a truly opaque ink (one that light cannot penetrate), the light falling on the ink film is absorbed or reflected by the surface of the ink only. The thickness of the ink film is not important in terms of print colour.

UV ink is never totally opaque; it is always translucent (light is able to penetrate it). This is logical when you recall that longer wavelengths are better able to penetrate further through the ink than shorter wavelengths and visible light comprises longer wavelengths than UV energy. So, if the shorter UV wavelengths are able to penetrate the ink to effect the cure, the longer light wavelengths will also be able to penetrate the ink.

With a translucent or transparent ink, some of the light falling on the ink will be absorbed or reflected at the surface, whilst the rest will penetrate into the ink film. Some of the light penetrating the ink film will be absorbed or deflected and some will strike the substrate, bouncing back through the ink to the viewer's eye. Thus, the depth of ink film will have a major influence over the colour perceived by the viewer.

Figure 11.3 illustrates the difference between the passage of light falling on an opaque ink film and that falling on a translucent UV ink film.

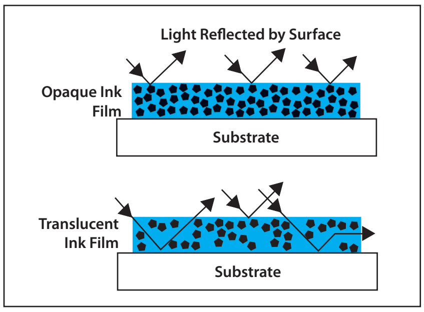


Fig. 11.3

UV ink is formulated to reproduce a particular colour when printed at an optimum film thickness. The ink manufacturer will be able to provide the relevant information for a particular ink system. Variations from the original ink film thickness result in variations in the colour. Printing double the thickness of ink, for example, will dramatically alter the colour on the print. Controlling the thickness of the ink deposit, then, is as important for accurate colour reproduction as it is for effective curing.

Step three – Proofing colour

Before proceeding to the proofing stage, you must ensure that the ink is of the correct viscosity for the mesh count of the screen you are using and the press you will be printing on. Most Sericol colours print well straight from the pot, though some colours when used on certain substrates and presses may require viscosity modification. You should be able to determine the correct viscosity of the ink by printing a given colour on your press, according to the ink manufacturer's advice.

To proof the colour, mix a small amount of the ink and make a print using a clean screen, stretched properly and the same durometer and type of squeegee you will be using during production. Bear in mind that you are likely to obtain a different ink film thickness when printing a small area on a small format press for proofing purposes and a large area on a large format press during production, even though you are using the same combination of ink, mesh and stencil. The larger format press will tend to deposit a thicker ink deposit than the smaller press because of the larger volume of ink on the screen and the longer duration of the flood stroke.

Accurate measurement of the print's ink film and colourmetric value will give you the information you need to match your proof prints to the production parameters, as well as monitoring the printing process during production. Colour matches are only accurate and reproducible when the ink film on press is the same as the colour that has been approved. Once you have established that the colour match is accurate under production conditions, you can mix the required volume of ink for the production run. Calculating the required volume is straightforward using the coverage estimator and automatic batch sizing functions found on the Color Manager Software and Colour Dispensing Systems. Use a power mixer to ensure that the ink is stirred thoroughly, especially when the ink temperature is below 21°C. (Ink Dispenser Systems mix the ink automatically before dispensing it.)

Once the job has been complete, store any unused ink in a well-sealed container, labelled with all the relevant information regarding the formulation. The stability of UV ink means that any unused ink can readily be stored after the job is finished for use at a later date. Keeping good records of the formulation makes it easier to use any returns when formulating another colour. As mentioned previously, Ink Dispenser Systems can factor 'returns' into new ink mix formulations automatically.

Chapter 12
The economics of UV

There is a common perception amongst screen printers that printing with UV ink is more 'expensive' than printing with solvent ink. This belief is based on the higher per litre cost of UV ink and the requirement for capital expenditure on new specialised equipment (primarily UV curing units) for anyone wishing to begin working with UV ink.

In fact, UV ink-based production is a cost effective alternative to solvent-based ink production, when all of the variables affecting job costs are taken into account.

It is not possible to present a definitive argument in favour of UV ink on economic grounds as the cost benefits will vary between different printshops, depending on their particular operational set up and the type of work they undertake. However, it is possible to review the general economic advantages and disadvantages of UV ink. It is also possible to present 'real-world' case studies of printers that have switched from solvent ink to UV ink and possess, therefore, costs data relating to both types of ink system.

Ink mileage – The greater mileage (or 'yield') of UV ink helps to offset the higher per litre cost. A conventional UV ink can deliver a greater mileage than traditional solvent ink.

Investment in curing equipment – Many newcomers to UV printing will already be operating production lines that include jet air dryers and the switch to UV ink will require some additional expenditure on an UV curing unit. The actual cost will depend on the type and make of unit purchased, the size of the unit and what it is capable of doing – for instance, a combination UV curing unit and jet air dryer costs approximately 50% more than a dedicated UV curing unit. This investment is unavoidable, though the major cost savings associated with UV production should ensure a short payback period (see Case Study overleaf).

Whilst the kilo for kilo cost of UV inks is significantly higher than solvent-based inks, the true cost in use of UV inks is affected by a number of factors, as follows:

Space savings – The smaller size of dedicated UV curing units compared with jet dryers means that more production lines can be housed in the same factory space, so turnover and profits can be increased with no requirement to extend the print room or incur higher overheads.

Running costs – The reduced need for ventilation and more efficient curing process means that UV curing units use approximately 20% less energy than jet dryers; so the more expensive energy becomes and the more lines, you operate, the greater the cost savings associated with UV ink. However, maintenance of UV curing units tends to be higher than for jet dryers as the lamps required regular cleaning and must be replaced after 2000 hours of use.

Investment in pollution control equipment – With UV ink, there is no need for the expensive pollution control measures required when working with solvent ink. The cost of an UV curing unit can be further offset against this saving.

Screen cleaning and stretching – UV ink requires far less solvent for screen cleaning. Reduced staining of meshes means that the frequency of screen stretching is reduced.

Mesh – The finer mesh counts used for printing UV ink are more expensive than the coarser meshes generally used for printing solvent ink. However, these costs must be offset against the increase in mileage and consistent print quality achievable with UV ink and the aforementioned reduction in screen cleaning and stretching costs.

Waste disposal charges – These costs are significantly lower for UV ink, on account of the reduced requirement for disposal of waste solvents, cleaning rags, containers, packaging and substrates.

Ink storage – UV ink and waste does not need to be stored in special flammable goods areas, unlike solvent ink and waste.

Productivity – Perhaps the main economic advantage in favour of using UV ink is the substantial time savings and productivity boost that these inks are capable of delivering. Jobs printed with UV ink can be completed much faster than those using solvent ink and Sericol predicts that UV ink gives an average 20% increase in production. That's the equivalent of producing the same amount of work in just under six and a half hours as you would expect to produce in an eight hour shift using solvent inks.

A Case Study

The following information summarises the findings of a report produced by a UK Government department, which conducted an extensive appraisal of the economic and environmental benefits to a UK screen printing company of replacing traditional organic solvent inks with water-based UV ink.

The Case Study report states that:

The printer in question operates a multi-million pound turnover business producing two and three dimensional display material for retailers. Over the previous three years, the company had modified most of its printing lines to accept both UV and solvent inks. (At the time of the Case Study, the company had increased its use of UV ink from 10% to approximately 30% of its total production, by coverage, and had plans to increase usage to 80-90% of production in the future.) Since installing the UV lines, turnover had more than doubled and the quality improvements associated with water-based UV ink had opened up new markets.

The decision to introduce water-based UV ink was based on the company's concerns about the need to install expensive pollution control equipment for use with solvent inks. Until then, solvent ink had been used for all jobs. Improved product quality, particularly in relation to four-colour process work, was also regarded as being important in terms of the company's future success.

The company upgraded five of its seven printing lines to accept both UV and solvent ink. The total capital investment was only 50% higher than the cost of installing the non-productive pollutioncontrol measures required to meet local pollution control regulations. The Case Study identified that by operating four lines/day continuously on 250 days/year, total savings from printing all jobs with UV inks would give a **payback of about eight months**.

Over the three year period since the company introduced UV inks (for 10% of production rising to 30% production), similar net coverage was achieved using 4,800 litres less ink and 3,500 litres less thinners. The UV inks were found to be easier to remove from the screens, reducing the amount of solvent and time taken to clean each screen. This **reduced screen cleaning costs by 50%**. A reported reduction in staining meant that re-stretching was required 200 fewer times.

With UV inks, only two sheets of substrate were wasted each time the line stops, compared with at least 10 sheets of substrate for solvent ink. **The lower substrate waste substantially reduced purchasing and disposal costs.**

The company calculate that the faster curing time of UV ink means that **jobs are completed 25%** faster than with solvent ink. Additionally UV lines are restarted after a stoppage without having to be wiped down with solvent or flooded with ink, and there is no longer any need for operators to stop their press half an hour before the end of their shift to clean the screens – the screens are simply covered and left overnight. Screen changeover times have also been substantially reduced using UV inks. Taken together, these time savings give the company **a productivity advantage of at least 30%** when working with UV ink compared with solvent ink. The company estimates that its annual productivity saving alone per line per year as between 16% and 22% of the original capital expenditure on each UV curing unit.

The company reports that:

The use of UV inks has allowed us to extend the boundaries of our screen printing capability. Clients remarked on the improved quality, and potential **new markets have opened up** now that we can compete in areas that were previously the preserve of lithography. The change to UV inks will also allow us to minimise our solvent emissions – and thus satisfy environmental legislation – without the need for major investment in pollution control equipment.

Chapter 13
Health and safety

Like any industrial process, screen printing requires appropriate attention to all matters relating to the health and safety of the workforce. Whilst many of the health risks associated with solvent ink are eliminated when working with UV products, specific safety precautions are required. Operatives should be educated about the health and safety risks involved and trained in good industrial hygiene practices. Regular maintenance of all equipment and certain modifications to your plant should form part of your overall health and safety programme.

Good practice

Much of the good practice relating to the safe handling and use of UV ink and curing equipment is based on common sense. However, it is important that all operatives are given information on the potentially harmful nature of UV ink and thinners and are trained in the safe handling and use of these materials. Knowledge of how to care for personal protective equipment and how to respond in the case of accidents will minimise the health risks.

The following recommendations provide a guide to good practice:

- Eating, drinking, or smoking should not be allowed in areas where any printing ink is handled.
- Gloves, hands and arms should be washed regularly with soap and water, and hand creams used to reduce skin irritation due to the frequent washing.
- Operatives should avoid touching equipment with contaminated gloves or other items of protective clothing, as the transferred ink could later come into contact with unprotected skin.
- Do not use solvents to wash UV ink from the skin, as they increase the likelihood of the chemicals penetrating through the skin, which may increase the risks of dermatitis.
- Solvents may be used for the cleaning of printing equipment, provided the operative wears appropriate protective clothing.
- Do not carry rags contaminated with solvents or UV ink in the pockets of work clothing. This practice will increase the risk of skin irritation and dermatitis significantly.
- All spills and leaks of UV ink should be cleaned up immediately. Be sure to remove all leaking containers from the area of the spillage. Proper protective equipment should be worn in any clean-up procedure.

Specific health issues

The health issues associated with UV ink can be separated into those concerning exposure to:

- UV ink;
- UV energy and/or ozone from the curing unit; and
- solvents used in screen cleaning and re-use.

UV ink – Advances in photoinitiator technology and UV curing systems mean that the monomers employed in current ink formulations pose a much lower risk to health than early UV formulations.

UV ink contains acrylate monomers and oligomers, which can cause irritation of the skin, eyes and other mucous membranes. People respond differently when they come into contact with the ink – some experience no irritation, others display obvious symptoms. In this way, people's response to UV ink is akin to an allergic reaction. The different reactions may be due to the individual's 'natural sensitivity' to the chemicals (just as hayfever sufferers are more sensitive to pollen or grass seed) or it may be a function of 'cumulative sensitisation', brought about by repeated contact with the product.

It is important to be aware that any irritation tends not to reveal itself immediately, so exposure can remain unnoticed for some time. UV ink does not 'dry out', so any ink that comes into contact with the skin or eyes will remain there until it is physically removed. Prolonged direct contact can have more serious consequences, such as chemical blister burns. In the worst cases, people can suffer dermal sensitisation. This is a life-long condition and requires workers to have no further contact with the product that caused the sensitisation.

Most monomers and oligomers are not volatile, (they do not evaporate), so the risk of inhalation is low. The lack of solvent content means that the serious health risks associated with solvent vapour inhalation are eliminated. Similarly, UV ink has no flash-point, so there is a much lower fire hazard compared with solvent ink.

The UV curing unit – The potential health risks associated with UV curing units relate to exposure of the skin and, in particular, the eyes to intense UV energy, and the inhalation of ozone, which may be produced when short wavelengths of UV energy are absorbed by oxygen molecules in the air.

Exposure to intense UV energy can result in eye irritation and may cause temporary problems with vision. The energy can also cause skin damage similar to sunburn. Ozone is hazardous if inhaled in large doses and can cause eye, nose and throat irritation, headaches and nausea. (See Factory ventilation.)

Solvents – These are used for cleaning up (screens and so on). They can cause eye irritation, irritation of the lungs and/or skin, excessive tiredness, headaches and nausea and loss of consciousness. Longer-term health risks include dermatitis (from repeated skin contact) and even damage to the central nervous system, liver, kidneys or the blood.

Many solvents are also highly flammable and present significant fire hazards in use and storage. Solvent vapour can travel long distances, raising the risk of a flashback if ignited.

Equipment and factory issues

UV curing unit – A properly designed curing unit should have fixed or interlocked energy shields, which prevent radiation escaping from the curing chamber. The unit should stop the emission of radiation automatically if an access door is opened or energy shield removed during use. Check before purchase that the unit has these safety features and never allow unqualified personnel to adjust the energy shielding without qualified supervision.

Ozone is harmful by inhalation. You may need to fit a local exhaust ventilation system to remove from the factory any ozone produced by the UV curing unit.

Factory ventilation – A powered, wall-mounted fan drawing fresh air into the factory will help to provide good general ventilation on the factory floor. The aim is to ensure that fresh air flows past the worker, then past the equipment before it is extracted from the factory. Printing and curing equipment should be located accordingly and air recirculation systems are not recommended.

It is advisable to carry out a visual inspection of the ventilation equipment at least once a week to check that it is working correctly and for signs of damage. By regularly monitoring the performance of the ventilation system you will notice any deterioration over time and be in a position to take early remedial action. Implement a regular servicing programme as recommended by the manufacturer.

Personal protective equipment (PPE)

Workers will reduce the likelihood of direct contact with UV ink by wearing the appropriate safety clothing – check the product's safety data sheet to determine what clothing is necessary.

Sericol recommends the use of nitrile disposable gloves for shorter term use and 0.4 mm or thicker nitrile gloves for longer exposure activities, especially prolonged contact with cleaning and diluting solvents. It is essential that gloves are changed regularly and disposed of immediately if they are damaged.

Suitable full length clothing, such as disposable overalls, should be worn when handling uncured ink. A rubber apron is a good option when there is the possibility of being splashed with solvent. Shoes should protect the entire foot and rubber boots are preferable when there is a possibility of walking in solvent or liquid chemicals or when working in situations where spills could occur.

Protective clothing contaminated with smaller amounts of UV ink can be laundered in an alkaline detergent and re-used. Heavily contaminated clothing should be changed immediately and stored in a labelled container for industrial laundering. Always launder at a commercial laundry – do not remove the contaminated clothing from the factory to the home for domestic cleaning. Leather goods, such as shoes and belts, cannot be effectively decontaminated and should be replaced.

Respirator equipment is not generally required for most tasks involving UV ink.

Eye protection is recommended for workers handling any type of chemical. A full-face shield is appropriate if splashing is likely. Safety goggles that absorb UV radiation are recommended for those working in close proximity to the UV curing unit. However, it is more important to educate workers to never look directly at the UV lamps or strong reflections, even when they are wearing safety goggles.

Barrier creams will facilitate the washing off of ink (or other materials) that manages to penetrate gloves or other protective clothing. However, creams are not a substitute for protective gloves or other items of protective clothing. The cream should be applied to clean skin and should not be applied after exposure to ink or solvents. After-work creams should be used as part of a skin-care programme.

First aid

The following statements are taken from the Health and Safety Data Sheet for a typical UV ink. They represent general guidelines but users are strongly advised to obtain a data sheet for the specific range of inks being used.

General information – Never make an unconscious person vomit or drink fluids. Immediately remove any clothing soiled by the product.

After inhalation – Supply fresh air; consult doctor in case of complaints.

After skin contact – Immediately wash with soap and water and rinse thoroughly. If skin irritation continues, consult a doctor.

After eye contact – Rinse open eye for several minutes under running water. Then consult a doctor.

After swallowing – Give patient copious amounts of water to drink and provide fresh air. Call for a doctor immediately.

Chapter 14
What can you print with UV ink?

UV screen printing offers many advantages over printing solvent inks, but historically these advantages have been offset by the lack of availability of suitable products for more specialised applications. Until recently, for example, solvent ink was the only option for printing on to treated polyolefin materials, vinyls for bus and taxi sides, and sheet plastics for vacuum forming.

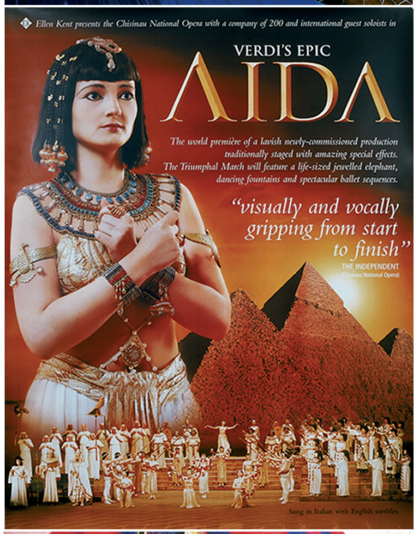
This is no longer the case; Sericol now offer a UV alternative for each of its solvent inks, meaning that there is now a UV ink for every graphics application. Furthermore, the UV ink is not only a match for the solvent equivalent, but in most cases out performs it.

In order to offer this comprehensive portfolio of products, Sericol's R&D departments around the world have pioneered a number of unique UV ink formulations that have no viable alternative in the marketplace. For instance, a common problem with early UV inks was their lack of flexibility. The combination of the polymerisation process, whereby all the ink components are linked together in a complex chemical chain, and the depth of the ink film, meant that UV prints tended to be rigid with high embrittlement characteristics and susceptible to cracking. This is why they were unsuitable for applications such as bus side vinyls. Sericol's unique Uviplast Hiflex ES four-colour process ink solves this particular problem, by delivering superior flexibility and extremely low embrittlement. Similarly, Uviplast Omniplus UL is sufficiently flexible to withstand vacuum forming of the printed substrate.

Always pioneering new UV products, Sericol has developed a new oligomer chemistry that greatly improves flexibility and adhesion. This new oligomer chemistry is known as Balanced Matrix Technology and is used in Displaymaster XX.

The current Sericol UV product range is grouped into four distinct 'series' – Aquaspeed, Uviplast, Uvispeed UV curing inks and Uvibond UV curing overprint varnishes. Each series is characterised by a common core value. Within each ink series there are up to six ink ranges for different applications.The Aquaspeed series, for instance, comprises only water-based inks. Product names ending in 'Z' denote that the ink is suitable for use with low energy curing systems, such as flash curing.

The logical categorisation of the Sericol UV ink portfolio is intended to make correct product selection as straightforward as possible. The current ink portfolio is summarised over leaf to illustrate the breadth of graphics applications catered for by current UV ink formulations. (Contact your nearest Sericol Service Centre for specific advice on ink selection.)



Uvispeed - *UV inks for display*

	Poster AZ	Multiflash UZ	Gloss UG	Matt UM
Finish	Matt	Satin	Gloss	Matt
Substrates				
Lightweight Papers	✓	✓	✓	✓
Heavy Papers	✓	✓	✓	✓
Boards	-	✓	✓	✓
Flexible PVC	-	✓	-	✓
Rigid PVC	-	✓	-	✓
Coated Polyethylene	-	-	-	✓
Polystyrene	-	-	-	-
Polycarbonate	-	-	-	-
Acrylic	-	-	-	-
ABS	-	-	-	-
Sheet Polypropylene	-	-	-	-
Fluted Polypropylene	-	-	-	-
Properties				
Conventional UV Ink	✓	✓	✓	✓
Water-based UV Ink	-	-	-	-
Conventional UV Cure	✓	✓	✓	✓
Low Energy UV Cure (Flash)	✓	✓	-	-
Water Resistance	✓	✓	-	✓
Quick Start Gel	✓	✓	-	-
*Suitable for outdoor use***	✓	✓	-	✓
Thinning/Cleaning				
Thinner	ZE637	ZE637	ZE637	ZE807
Cleaner	ZT639	ZT639	ZT639	ZT639
Colour Range				
Trichromatics	✓	✓	✓	-
Line Colours	-	✓	✓	✓
Pantone® Matching System*	-	✓	✓	-

Pantone® is the property of Pantone, inc.

*** See Product Information Sheet for more details*

Aquaspeed - *Water-based UV inks for display*

	Display VQ	Display YZ	Display LZ	Flute FZ
Finish	High Satin	High Satin	Satin	Gloss
Substrates				
Lightweight Papers	-	-	-	-
Heavy Papers	✓	✓	-	✓
Boards	✓	✓	-	✓
Flexible PVC	✓	✓	✓	-
Rigid PVC	✓	✓	✓	-
Coated Polyethylene	-	-	-	-
Polystyrene	-	-	✓	-
Polycarbonate	-	-	-	-
Acrylic	-	-	-	-
ABS	-	-	-	-
Sheet Polypropylene	-	-	**	-
Fluted Polypropylene	-	-	**	-
Properties				
Conventional UV Ink	✓	✓	✓	✓
Water-based UV Ink	✓	✓	✓	✓
Conventional UV Cure	✓	✓	✓	✓
Low Energy UV Cure (Flash)	✓	✓	-	✓
Water Resistance	-	-	✓	-
Quick Start Gel	-	✓	✓	-
*Suitable for outdoor use***	-	-	✓	-
Thinning/Cleaning				
Thinner	Water/ZE818	Water/ZE818	ZE844	Water/ZE807
Cleaner	Water/ZT639	Water/ZT639	ZT639	Water/ZT639
Colour Range				
Trichromatics	✓	✓	✓	✓
Line Colours	-	-	-	✓
Pantone® Matching System*	-	-	-	✓

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*** See Product Information Sheet for more details*

Uviplast - *UV inks for plastics*

	Omniplus UL	2000 UP	Hiflex ES	Multidyne LY	Displaymaster XX
Finish	Gloss	Gloss	High Satin	High Satin	Satin
Substrates					
Lightweight Papers	-	-	-	-	-
Heavy Papers	-	-	-	-	-
Boards	-	-	-	-	-
Flexible PVC	✓	-	✓	-	✓
Rigid PVC	✓	✓	✓	-	✓
Coated Polyethylene	✓	✓	-	-	-
Polystyrene	✓	✓	-	-	
Polycarbonate	✓	✓	-	-	-
Acrylic	✓	✓	-	-	-
ABS	-	✓	-	-	-
Sheet Polypropylene	-	-	-	✓	**
Fluted Polypropylene	-	-	-	✓	**
Properties					
Conventional UV Ink	✓	✓	✓	✓	✓
Water-based UV Ink	-	-	-	-	-
Conventional UV Cure	✓	✓	✓	✓	✓
Low Energy UV Cure (Flash)	-	ZE824	ZE824	ZE833	-
Water Resistance	✓	✓	✓	✓	✓
Quick Start Gel	-	-	-	-	✓
*Suitable for outdoor use***	✓	✓	✓	✓	✓
Thinning/Cleaning					
Thinner	ZE834	ZE807	ZE829	ZE818	ZE844
Cleaner	ZT639	ZT639	ZT639	ZT639	ZT639
Colour Range					
Trichromatics	✓	✓	✓	✓	✓
Line Colours	✓	✓	-	✓	-
Pantone® Matching System*	✓	✓	-	✓	-

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*** See Product Information Sheet for more details*

Chapter 15
Hints and tips

Troubleshooting

The following will help you to identify some of the common problems faced by screen printers using UV technology. It suggests checks to determine what is causing the problem, plus practical advice on appropriate corrective action.

P. The ink is coming out of the UV curing unit wet or only partially cured.

S. Lamps: *check that the lamps are turned on! Check that they have'warmed up' and have reached their 'stabilised state' – the intensity levels of the various wavelengths vary dramatically up to 5 minutes after a lamp is switched on.*

Next, test for irradiance and dose. Check the output of the UV lamps using a radiometer. UV energy is not visible to the eye, so you have no way of knowing whether there is a problem with the lamps unless you measure their output.

Power setting: *check that the UV curing unit is at the correct power setting – have the lamps been set to a lower power setting by mistake?*

Power supply: *have power supply checked for consistency. A fall in voltage results in reduced radiant output from the lamps.*

Clean lamp assembly: *check that the bulbs and the reflectors are clean – a build up of dust or other airborne contaminants can significantly reduce the level of UV energy reaching the ink deposit.*

Bulbs: *Look for a build up of material inside the bulbs' quartz tubes, or sagging of the tube itself, both of which can lead to a reduction in the UV energy reaching the ink.*

Age of bulbs: *check the age of the bulbs – UV output falls with age. Do the bulbs need replacing? Check their output with a radiometer.*

Belt speed: *have you have set the correct belt speed for the particular colour of ink you are curing at the time? Belt speed will need to be slower for inks containing opaque pigments, such as white, green and black.*

Rule out adhesion failure due to ink and substrate incompatibility by carrying out the appropriate tests and reprinting the job on another type of substrate.

Substrate: *check also the porosity of the substrate – is ink being absorbed into the material preventing full curing.*

If you fail to identify any problems with the UV curing unit, turn your attention to the ink deposit thickness; check the press variables affecting the print.

Mesh: *check that you are using the recommended mesh.*

Stencil: *check that the screen-making department used the correct stencil coating technique and check stencil build.*

Squeegee: *check that you are using the correct type of squeegee; check its sharpness and angle; measure the thickness of the squeegee blade to identify any swell – to minimise the risk of swell, try replacing the squeegee with a fresh one every few hours, or at least alternate squeegees on a day-to-day basis.*

If all other variables are acceptable, take a look at your ink.

White pigment: *if the ink contains a high density of white pigment, try replacing some of the white with a clear extender base.*

Pigment load: *if the ink contains a high density of pigments that absorb UV energy, try reducing the opacity of the ink using extender base.*

Photoinitiators: *if you have already added extra phototinitiator, check that you haven't exceeded the recommended maximum level.*

Ink temperature: *if the ink temperature is below 10°C, cure response may be slowed by up to 50%. Adjust the power of the lamps and/or belt speed to compensate or, preferably, raise the temperature of the ink itself. (High speed mixing with a good power mixer will normally bring the ink temperature up, and viscosity down, within a few minutes. However, the ink will cool again if the ambient temperature in the printshop is low).*

P. Poor cure of base colour on multicolour print.

S. Butt registration: *overprinting a colour with a very opaque colour could prevent throughcure of the base colour. The solution is simple – use butt registered artwork. Butt registered artwork will also avoid the potential 'Braille' effect caused by printing thick films of conventional UV ink on top of one another.*

P. No/poor intercoat adhesion – one colour not adhering to the other.
(Most UV formulations do not exhibit problems of intercoat adhesion.)

S. *Extender Base:* *If you let a colour down considerably with Extender Base to achieve a certain shade you have increased the effective cure speed. Try running the colour through the UV curing unit several times to see whether there is a problem.*

Belt speed: *check whether you are running the belt slower than necessary – this may lead to over-curing.*

Lamps: *check the lamp settings – too much lamp power at slow speeds will tend to make the ink surface extra-hard, leading to problems with subsequent colours.*

Overprinting: *when producing a multicolour print, it is better to print the faster curing colours first. The slower curing colours can be more easily over cured, increasing the chances of poor intercoat adhesion.*

P. Marginal adhesion

S. *Cure:* *check proper cure; run the print through the UV curing unit several times and note whether this improves the adhesion.*

Opacity: *the density of the pigment in the ink may be too high for the ink to cure properly – reduce opacity using extender base.*

Substrate: *print on to a different stock. If the ink prints well on the other substrate there may be ink/substrate incompatibility; wipe surface of substrate with isopropyl alcohol prior to printing to remove any surface contamination.*

P. Poor adhesion on polyolefins

S. *Corona treatment:* *low surface energy of a substrate leads to poor ink adhesion. Corona treatment raises the surface energy of non-coated substrates. Non-top coated polyolefins should be corona treated to between 42 and 54 dynes/cm^2.*

P. Special mix colours not curing well
(Multiple pigment combinations – particularly those containing black or white – can result in a too high pigment density, preventing proper curing.)

S. *Opacity:* *reduce the opacity of the ink with an extender base until effective curing can be achieved. Sericol recommends using the tinting white and black where required for special colours.*

P. Poor print quality

S. Checklist: *screen tension; squeegee type, durometer, sharpness, angle and pressure; off-contact.*

Substrate: *try printing on a different stock to determine whether substrate deficiencies are causing or exacerbating problems.*

Flood: *UV ink flows much faster than solvent ink, so too much flood will cause detail to 'gain' or fill in. Sericol recommends a tight flood with little or no time between flood and print. A loose or heavy flood will result in printing up to 50% more ink through the mesh.*

P. Pinholes

S. Mixing the ink: *ensure that the ink is mixed thoroughly before introducing it to the screen.*

Substrate: *print on to a different stock. If the ink prints well on the other substrate there may be ink/substrate incompatibility; wipe surface of substrate with isopropyl alcohol prior to printing to remove any surface contamination; some plastics may have a high surface tension level that prevents the ink from wetting properly.*

P. Ink sticking, blocking or offsetting in the stack.
(Most UV ink is non thermoplastic when completely cured. If the ink is not completely cured and the sheets are stacked when they are too hot, some surface ink/substrate blocking is possible.)

S. Curing: *check that the ink is cured effectively and is not still wet when it exits the UV curing unit.*

Radiometer readings: *check the UV curing unit to ensure that you are not obtaining only heat, and no UV radiation.*

Belt speed: *are you using a slow belt speed (to cure a thick ink deposit, perhaps)? The slower the belt speed, the more heat the substrate is subjected to and the greater the likelihood of blocking if the ink is not thoroughly cured when the sheets are stacked. Try printing a thinner ink deposit and using a faster belt speed.*

P. Conventional UV ink appears to be thickening in the screen or any type of UV ink displays 'skinning' on the top of the ink in the screen

S. Stray radiation: *the screen is likely to be exposed to unintentional UV radiation. Check that direct sunlight is not falling on to the screen and check the energy shields on the UV curing unit to ensure that no UV radiation is leaking out of the unit and reaching the ink in the screen. If you suspend printing whilst there is ink in the screen (to take a lunch break, to check registration or colour accuracy, or even when the factory closes for the night or weekend), place a piece of cardboard over the screen to prevent any UV rays from reaching the ink.*

P. Ink trails or dribbling, can occur when ink drops from the flood bar or squeegee during the flood stroke. When these inks are in the image area of the screen, dark lines can appear in the print. This is the most noticeable when printing transparent colours.

S.

1. *Thin the ink more - this will not stop the ink dropping from the coater/ squeegee but will facilitate greater inkflow through the mesh, thus hiding these trails.*

2. *Slow the machine down - slowing the print and flood strokes often eliminates the problem.*

3. *Change the squeegee conditions by:*
(a) *Using a little more pressure.*
(b) *Using a lower, less upright angle*
(c) *Using a softer rubber. All of the above will increase ink flowthrough the mesh.*

4. *Reduce the gap between the squeegee and the flood coater and make sure that the gap is full of ink at all times.*

5. *Varying the flood thickness (both thicker and thinner) may sometimes help to eliminate ink trails depending on the type of ink being used.*

6. *Probably the best solution is to use a higher deposit mesh, preferably one with a greater percentage open area, to allow the ink to pass more easily through the mesh onto the substrate eg moving from a 150.34PW to a 150.31PW or a140.34PW may help.*

P. The ink will not flow (orange peel or bubbles)

S. *Ink viscosity:* *try reducing viscosity by 3 – 5% by weight using UV reducer (thinner).*

Squeegee: *make sure that it is sharp; check how long it has been in use and swap for 'rested' squeegee if there are signs of swelling; check that the pressure is not too high.*

Off-contact: *minimum off-contact is recommended.*

Mesh tension: *check that it is between 18N and 24N. (Low tension compromises print quality.)*

Substrate: *print on to a different stock. If the ink prints well on the other substrate there may be ink/substrate incompatibility.*

Seek expert advice: Contact Sericol.

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