EB Web Printing

By Don Duncan, Wikoff Color Corporation. Updated by Paul Robinson, Wikoff Color Corporation.

Overview

Lithographic printing with UV and EB inks is the largest volume energy-curable printing process, consuming the majority of all the UV/EB inks produced. While there are many more sheet-fed presses, there is more ink sold for web printing because of the higher production rates for web presses. The majority of energy-curable web printing involves electron beam (EB) curing. To date, all EB lithographic printing is done on web presses, mainly for food packaging. EB has been limited to web printing because of the limitations imposed by the need to cure EB inks in an oxygen-free zone, although there has been research done and beta trials run for sheet-fed EB in the past few years.

EB web lithographic printing was a rapid growth area from the 1980s through 2000-2001, but from 2001 through 2005-2006, demand was fairly flat. Since then, growth has begun again. One can connect growth in EB printing and EB ink consumption with the number of new presses sold, and the number of press installations exactly mirror this growth pattern. Since EB curing units are fairly expensive, a printer will not buy one unless he can commit a press to EB printing. This normally leads printers thinking about presses through the “buy-or-convert” decision toward the “buy” side, which is another large capital investment. Therefore, times of economic uncertainty or recession make it more difficult to begin expansion into EB printing. It is common after making this commitment to run an EB web press 24/7 at as high a speed as possible (potentially over 1,000 ft/min). This is what makes EB ink volume and EB print output so large compared to UV sheet-fed presses that often run fewer days per week and at lower speeds.

Much of the growth has been at the expense of conventional oil-based sheet fed printing. The effectively instantaneous cure achieved with EB curing gives the printer the ability to ship immediately after coming off the press. The ability to respond quickly and not have the lag time and inventory problems caused by conventional ink drying rates are strong financial incentives for a printer to make a move to EB printing. The very low VOC emissions of EB inks vs. conventional inks are another advantage.

The chemistry of EB lithographic inks is similar to other energy-curable products in that photoreactive monomers and resins (usually acrylate chemistry) are combined with pigments. UV inks have the disadvantage of requiring a photoinitiator to pass the energy from the UV lamp to the ink. The energy output from an EB cure unit is high enough to cause curing directly without the use of an expensive photoinitiator.

Quick summary

More ink is sold for EB-web lithographic printing than for any other printing process.

Some of the key advantages to EB curing, as compared to conventional drying inks, are:

- High-press speed
- Low VOC emissions
- Instantaneous drying – giving the printer the ability to respond quickly

Variable-sleeve presses have revitalized the growth in EB curing and has opened up new markets for EB-lithographic web printing, such as flexible packaging and labels.

Several manufacturers of presses for EB web printing exist. Some new technology involving variable-circumference sleeves for litho plates and blankets has begun penetrating the market since 2005. This technology brings new options to litho printing and has revitalized the sale of EB web presses. The options for EB curing units are smaller, with one large and a few very small suppliers. The technology in EB curing units is complex and a significant barrier to entry. However, if sales of EB curing units continue to grow, other suppliers will emerge.

Markets

EB litho printing makes up more than one-third of the energy cure litho market and is, to date, 100% on web presses and around 80% to 90% for food packaging. Nearly all EB printing for food packaging is on either a board (SBS, CCN) or on polyboard. Some of the EB litho market is for labels that have a high need for chemical resistance. Newer applications for EB litho printing include flexible packaging and shrink sleeves, both printed on film.

Growth potential for EB

EB litho printing saw double-digit growth from 1990-2001 but was largely flat from 2001-2006. New press installations for

EB printing have begun again, largely due to innovations in press technology that improves the range of usable substrates and opens the technology to a new potential market – flexo/gravure printers on film for flexible packaging. If EB press manufacturers achieve significant penetration of these new customers, many of whom do not use litho printing at all, EB growth easily could go back to double-digit rates for several years.

Regional strengths

The United States is the largest market for EB lithographic inks. This likely will continue to be the case for at least another decade. EB lithographic printing is historically less common outside the United States due in part to the restrictions of 1) web-only processing, 2) the fairly high cost of an EB-cure unit and 3) the need to have big jobs with long run lengths to pay for the tooling for different carton sizes. However, there are new technology presses being sold, particularly in Europe that will use EB technology.

Benefits and limitations

Benefits

The primary benefits of EB web litho are:

1) It gives very sharp, good quality print.
2) It can be used on a wide variety of substrates.
3) It is a very green, low-emission process.
4) Good chemical resistance can be obtained.
5) The curing process is at low temperatures and will not damage temperature-sensitive stocks.
6) The EB curing process is normally on or off, fully cured or not at all vs. UV, where degrees of cure are seen.
7) There is no migration potential for photoinitiator in food packaging, since no photoinitiator is used in EB as it is in UV.
8) Production throughput rates on web presses can be high.
9) Web printing, particularly with new technology presses, is flexible and efficient.
10) The ink is fully dry and ready to ship immediately as it comes off the press.

Limitations

There are limitations of any technology. The primary ones EB litho face include:

1) A higher ink cost vs. conventional litho.
2) A higher operational cost for EB (electricity, nitrogen) vs. conventional.
3) A relatively high cost for a new press with built-in EB capability.
4) The inks in a wet, uncured state are skin and eye irritants.
5) EB inks typically have shorter shelf lives (~6 to 12 months) and require more delicate handling and storage (heat, UV-light exposure) than conventional inks.

Other issues

Several other important issues affecting the use and application of EB litho printing include presses, print quality, inks, operating conditions and safety.

EB units. The main factor that makes a press into an EB press is having an EB-cure unit installed after the last print station. EB inks are wet-trapped and cured all at once in one large EB unit. This curing must be done under a nitrogen atmosphere, since oxygen is an inhibitor to the EB curing process. If oxygen levels are not very low, the top molecular layer of the EB ink will not cure properly and the amount of electrons received by ink/coating are reduced. To minimize nitrogen consumption, the inlet and exit of the printed matter from the EB unit must be a very tight fit. It is largely for this reason that EB presses are all web presses. Openings large enough to handle sheet fed gripper bars would make nitrogen purging of the curing zone difficult and expensive.

Heat management (press). Electron beam usage for lithographic printing produces very little heat rise (3°F to 5°F) upon exit from the beam. The high energy of EB curing is sufficient to cause cross-linking of monomers and oligomers but also potentially can cause additional cross-linking of other chemistry, including the substrate modifying its physical properties. This high energy also can lead to breakage/fragmentation of some chemistries. The electron beam should be set to have just enough power to cure the ink film rather than penetrate far into the stock. At higher voltages some lightweight papers can become more brittle. There are studies of both the cross-linking of printing related substrates and chemistries, as well as potential degradation by-products. A discussion of target printing materials and chemistries with EB equipment suppliers, substrate and ink/coating manufacturers can help determine best choices. Properly set and an understanding of the curing variables, EB curing is a clean and quick low-temperature process.

Print quality. EB litho inks often have tacks in the high teens (at 1,200rpm) and print very sharp dots. On plastic, film, SBS or polyboard, EB inks deliver top-quality graphic images. However, with lower quality papers and boards, lower tacks may be required to prevent picking and piling. This, combined with stock roughness, can reduce the apparent print quality but no less than any other ink chemistry.

Inks: General information. Besides being curable, EB inks for litho printing have several features in common with conventional litho inks, such as they have a paste-like texture. As in conventional lithography, the best print quality is obtained with the thinnest film of the strongest and heaviest ink that does not pick or damage the stock while still working well with the fountain solution. EB inks are wet-trapped and must have the proper tack rotation. This is exactly the same as with conventional oil-based litho, although much UV litho is dry-trapped through the use of interstation curing lamps. Also, since the inks are designed to be energy-curable, the formulas have no added volatile organic compounds (VOCs), and thus are environmentally friendly. Because the inks are cured into a polymeric film, low odor and low migration can be achieved easily.

Inks: EB properties. EB inks are made up of a mixture of reactive monomers, resins (oligomers), pigments and additives. UV-curable inks contain, in addition, photoinitiators. UV light is absorbed by the photoinitiator, which converts the light energy into chemical energy. An electron beam is sufficiently energetic to create chemical energy directly in the monomers and resins. This chemical energy then causes the polymerization of the monomer/oligomer mixture into a cured ink film. The monomers and oligomers have different roles. The monomers are used to control tack and cure speed. Oligomers give the basic film-forming properties of the ink. Different chemical backbone structures of the oligomers impart such properties as hardness, flexibility, toughness, adhesion, pigment wetting, ink/water compatibility, cure speed etc. Additives include various modifying agents for controlling film surface energy, misting, slip/cof, rub resistance or pigment wetting.

Heat management (inks). In addition to stray UV light (even in the absence of a photoinitiator), premature ink curing can be caused by excessive exposure of the inks, even in unopened cans, to heat. Never store EB inks outside, in direct sunlight or in warehouses where the temperature can regularly exceed 100°F. If possible, shelf life will be greatly extended if inks can be stored below 80°F.

Safety. EB inks have some special handling issues. Many years of practical production history show that EB inks are safe, but they must be treated with respect. Some people develop allergic skin rashes upon contact with the components of EB inks. These rashes can be severe. Not everyone is sensitive to the inks – some people show little reaction, some are immediately sensitive, and some show the allergic reaction only after repeated exposure. These issues are handled by proper safety and housekeeping procedures. Monomers and oligomers have different levels of skin irritation. If left on skin long enough, all can cause some level of irritation, rash or burn. For instance, nonpermeable gloves should be worn when handling or cleaning up the ink. Ink spills should be cleaned up immediately. Any contact of the ink with unprotected skin should be washed immediately with soap and cold water.

Costs

Costs for EB lithographic printing can be divided into three major categories: 1) press-related costs (including new press purchases, press conversions to EB or other press modifications), 2) ink-related costs and 3) operating costs (utilities, nitrogen, fountain solution, etc.).

> **The United States is the largest market for EB-lithographic inks. This likely will continue to be the case for at least another decade.**

Press-related costs

A new press will cost several million dollars, but the incremental cost to make it an EB press is really of interest here. The installed cost of an EB unit on a web press, at the time of writing, is usually between $300,000 and $800,000. The cost of adding EB capability to a new press can be less than that of converting an existing press because, for existing presses, press components often have to be moved to make room for the EB capability. Also, new presses can be designed with many EB-friendly features built in. Variable-sleeve EB litho web presses have been introduced since 2005 that offer some clever printing technology, as well as being fully integrated with the EB curing unit.

Ink-related costs

EB inks, on the surface, look like UV inks but without a photoinitiator. One might expect, then, that EB inks should cost less than UV inks, since photoinitiators are expensive chemicals. All other things being equal, this is true. However, since EB inks often are used for food packaging, they require more expensive, lower odor and more highly purified components than do most UV inks. As a result, EB inks, in practice, are often more expensive than are UV inks. Both types of inks run two to three times more expensive per pound than conventional lithographic inks, but the 100% solids nature of EB inks and near 100% cure somewhat makes up for this differential.

Operating costs

While EB inks often require special fountain solutions, rollers and blanket rubber, the operating cost differential vs. conventional inks is not important for these issues. EB processing, however, has some special operating costs. An EB unit does require some regular maintenance and uses some electricity, but the primary operational cost is in nitrogen consumption. Effort must be made to eliminate nitrogen leaks and to minimize the slit in the EB unit where the web enters and exits to control nitrogen consumption.

Considering all the installation and operating costs for UV vs. EB, most people feel that the processes are similar enough in cost that cost often is not the deciding factor for a new press installation.

The curing process

Electrons, as used in EB curing, are high-energy particles that, upon striking the EB ink, transfer their energy to the ink. This energy begins the curing process, without the requirement of a photoinitiator. Once the curing process is begun, it proceeds exactly as does the UV curing process. The difference is in the energy source-UV light energy transferred to the ink through a photoinitiator, or EB energy transferred directly to the ink.

The electrons are formed by putting a high voltage between a negatively charged filament inside a positively charged metal chamber, which is mounted in a vacuum chamber. Electrons will flow in the vacuum between the negative and positive electrodes. There is a slit in the metal chamber to allow electrons to escape. Under this slit, a hole is cut in the vacuum chamber. This hole, or "window," is sealed with a metallic foil. The foil is strong enough to hold a vacuum but is transparent to the flow of electrons. At high voltage, some electrons will fall through the slit in the chamber and "rain down" through the metallic foil "window" onto the underlying printed matter. When the electrons hit the ink, the curing process begins. It is almost instantaneously complete. As soon as the printed matter exits the EB unit, it is completely cured and ready to handle, cut, fold and ship.

Unlike UV curing, ink color or ink film thickness does not affect the curing process. The electrons are powerful enough to overcome these issues and penetrate fully to the bottom of the ink film. Reducing oxygen concentration in the curing zone to very low (<200ppm) levels is critical. Oxygen will inhibit the curing process. If oxygen is allowed in the curing zone, the very top layer of ink/coating will not cure and will remain wet. However, if the oxygen sensor is set properly on the EB-cure unit, high-oxygen levels will cause the unit to shut down and prevent poor curing.

Assuming the EB hardware settings, like the oxygen sensor, are set properly and working, the "how do you know it's cured" question doesn't come up a lot. In UV printing, it is a regular question. With EB, the power of the beam in a normally operating unit will cause complete cure, and conditions that could cause partial cure will, instead, cause the EB unit to shut down. Even though the EB unit is reliable, that still doesn't remove the responsibility of the printer to do periodic QC testing of the printed product.

Also, when electrons strike matter, such as the web, they cause X-rays to be generated. This is well understood and is handled by shielding the EB curing zone to prevent X-ray leakage.

Conclusion

Lithographic printing is the oldest and largest of the energy-cure printing technologies. UV printing is divided between sheet-fed and web printing and is used for a wide variety of applications on many different substrates. EB printing is, to date, all web printing and is more than 80% is used for food packaging. Costs of owning an operating an EB press are greater than for a conventional litho press, but the advantages of instantaneous drying, essentially zero VOC emissions, high chemical resistance and high print quality often make EB lithographic printing the very best choice. ■

Electrons, as used in EB curing, are high-energy particles that, upon striking the EB ink, transfer their energy to the ink. This energy begins the curing process, without the requirement for a photoinitiator.