Image Permanence: Commercial Signage/Fleet Graphics

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Abstract

The permanence or durability of outdoor signage and fleet graphics depends on three main factors. These factors are the construction, the application, and the environment in which the graphic is exposed. Fade resistance is but one property that determines the permanence. More printing of outdoor signage is being done more by digital printing and less by screen printing. The fade resistance of graphics printed by piezo ink jet inks is approaching that of graphics printed by conventional screen printing methods. Retained solvents, though, are limiting the permanence of some demanding graphics printed by solvent-based piezo ink jet inks.

Introduction

Factors Affecting Permanence

The permanence, or durability, of a graphic is the ability of a graphic to meet or exceed the expectations of a customer over a specified time. That is, the image quality and appearance of the graphic will still be acceptable under the conditions of use. As a corollary, the stated claims of permanence by a manufacturer of a graphic or the manufacturer of a component of a graphic are only as good as the written warranty behind the claims. To many people, permanence means only one thing—fade resistance. Fade resistance is an important part of permanence, but only a part, as will be noted. Further, there has been lately a change from printing images by the conventional methods of screen printing and lithography to digital printing by thermal ink jet, electrostatic, and now piezo ink jet. This paper will address the effect the change of printing methods can have on the overall permanence of a graphic, specifically the differences in permanence between graphics made by screen printing and solvent-based piezo ink jet printing.

The permanence of a graphic is dependent on three main factors. They are the construction of the graphic, the application, and the environment. All three factors need to be considered when determining the permanence of a graphic regardless by what method the graphic was generated. A graphic can consist of many layers as exemplified in Figure 1 although not all layers are present in each graphic. The Figure notes the top layer as a clear coat or overlaminate. Clear coats and overlaminates are used for improving abrasion resistance, improving chemical or solvent resistance, meeting a required coefficient of slip (as in graphics for floors), or improving the fade resistance. Clear coats and overlaminates are not always present on a graphic. The next layers would be the image from the inks on the top of the ink receptive layer. The inks and ink receptive layer have specific properties depending on where they will be applied. For example, an application to flexible-sided trucks needs to be more flexible than a graphic applied to flat metal substrates. If the ink receptive layer is to be applied to a substrate, it will need a pressure sensitive adhesive (psa). The type of psa used will be determined by the purpose of the graphic. For example, a different psa would be used for a removable graphic than for a more permanent application. The last layer, not always present in all graphics, would be the substrate. This is the surface to which the marking (clear coat/overlaminate, ink, ink receptive layer, psa) is applied and can vary from floors, the side of trucks, awnings, concrete sidewalks, wood, metals, glass, or what have you.

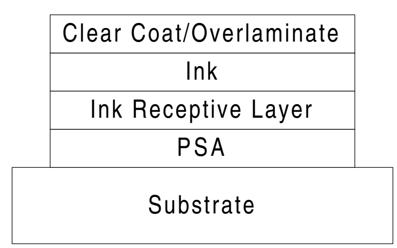

Figure 1. Schematic of the Possible Layers in a Typical Graphic Construction

A typical graphic is composed of many layers of materials. Each one must be compatible with the other for proper functioning as a total graphic. Every interface is subject to adhesion failure if the two layers are not compatible. The use of an overlaminate or clear coat, ink, ink receptive layer, and psa with the wrong properties for the application and exposure environment can result in the failure of the graphic, regardless if the ink has faded or not. Figure 2 shows a graphic on a truck side with corrugations. The ink has not faded but most would agree that the graphic has lost its permanence or usefulness because the graphic has experienced shrinkage and tearing.

Figure 2. Graphic Exhibiting Shrinkage and Tear

Figure 3 shows a graphic in which the clear coat and ink layers are delaminating from the ink receptive layer. Again, the inks have not faded but there is no doubt that the graphic has lost its permanence. Further, one cannot easily determine if the problem was because of ink and clear coat defects, or because of a defect in the ink receptive layer, or simply because three good components were mutually incompatible.

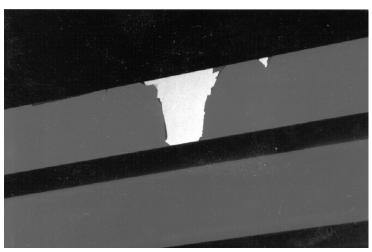

Figure 3. Graphic Exhibiting Delamination of Clear Coat and Ink Layers

Figures 1—3 emphasize that the inks are but one of several components of a graphic. It has been common for some ink manufacturers to claim that their inks will last for a specific number of years. Often this claim is only for resistance to fading on one ink receptor. Such a claim is meaningless in view of Figures 1—3 and other factors presented below. An ink can have dramatically different fade resistance depending on what ink receptive layer it is applied to, what overlaminate or clear coat is applied, if any, what type of graphic it will be used in, and the location and environment where the graphic will be located. Further, one should be cognizant if the claims of ink fade resistance are based on actual outdoor weathering tests of the inks in the same graphic construction to be used in the application or if the claims are based on artificial weathering studies of an unrelated construction. The relationship between the number of hours weathered and the expected lifetime outdoors is extremely difficult to make. As noted (1) in ASTM method G 151 (Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources) in section 4.1.3, "Even though it is very tempting, calculation of an *acceleration factor* relating *x* h or megajoules of radiant exposure in a laboratory accelerated test to *y* months or years of exterior exposure is not recommended." Further, the Atlas Electric Devices Company, the world's largest supplier of test equipment and outdoor exposure services, recently published a guidebook[2] that states:

How Many Hours In An Artificial Test Instrument Equal One Year of Natural Exposure?

Without a doubt, this is probably the most often-asked question during any discussion on weathering. If someone stated, "The answer to that question is exactly 1200 hours," you would probably question their technical capabilities and common sense, knowing all the variables that exist in our environment.

The best that one can hope for from a single accelerated test is to have a good rank correlation between the artificially-weathered graphics and the graphics in their service environment.[3—5] That is, the ranking of artificially-weathered graphics may be in the same order as when the graphics are weathered outdoors. The ranking is usually done by a Spearman rank correlation. A Spearman rank correlation coefficient of 1 defines a perfect test. Predictions of ink and graphic performance by artificial weathering methods are valid only when the test procedure has a rank correlation coefficient approaching 1 and there is an outdoor weathering history of the inks in the same graphic construction. Samples can then be studied by the artificial test procedure and the results will be able to predict to a reasonable degree if the new graphic will perform equal to, better than, or worse than a graphic of known outdoor weathering.

Florida and Arizona should be used as reference locations for weathering in the United States. Florida is hot and humid and will determine if a graphic is susceptible to fungal growth and if it is moisture sensitive along with being susceptible to UV radiation. Arizona is extremely hot with high UV radiation. This location will determine if a marking is susceptible to high temperatures along with UV radiation.

Graphics can be indoors or outdoors, as a permanent vertical sign facing south or facing north, as a permanent non-vertical sign as on awnings, or graphics can be on the sides or on the tops or hoods of trucks and vehicles. Some graphics have an open back such as with awnings whereas some graphics have substrates that can become quite hot with sunlight. With regards to UV radiation from the sun, a graphic on a south-facing awning at 45 degrees relative to the horizon can experience up to twice the radiation of a vertical sign facing south and up to four times the radiation of a vertical truck vehicle graphic. A graphic applied at 45 degrees relative to the horizon or applied at a nearly horizontal position can be subjected longer to dew or rain than a graphic applied vertically. This can be important if the graphic is sensitive to moisture or acid rain. Thus, the type of application can have a significant influence on the permanence of a graphic.

The location in the world will determine the amount of radiation the graphic will receive during its expected lifetime. The local environment might also be one of high humidity that supports fungal growth or might be an environment of high acid rain or industrial pollutants. The location of the graphic might be one near high winds and sand that can result in sand being embedded into the graphic. Or, the area might have a high concentration of insects or birds that leave deposits on the graphic. The above might not have an effect on the fade resistance of an ink but could have a definite effect on the permanence of a graphic.

Screen Printing versus Solvent-Based Piezo Ink Jet

Screen printing is a printing process in which the ink is pushed through a fabric onto an ink receptive layer. The thickness of the ink deposit is determined by the type of screen fabric, the emulsion used, and the mesh of the fabric. Conventional solvent-based screen printing inks when printed have a solids content of around 30—40%.

UV-curable screen printing inks are 100% solids (no volatile solvents). Further, with solvent-based screen printing, only one ink is printed at a time and dried before the next ink is printed. Printers in the United States at one time would dry markings made by solvent-based inks in a batch oven to remove most retained solvent. With the UV-curable screen printing inks, the inks and clear coat cure with no or negligible solvents penetrating the ink receptive layer or psa. With solvent-based screen printing, dried ink film thicknesses of 6—12 microns are typical whereas UV-curable screen printing inks cure to an ink film thickness of around 8 microns. With the solvent-based piezo ink jet printing of graphics, all four (or six) inks are jetted at once with all inks being dried at once. The inks have typically a % solids of around 10. The wet film thickness of the inks will be determined by the nominal drop volume of the piezo printhead being used and the resolution being printed. For printheads jetting a nominal 70—80 pL drop with a resolution of around 360 dpi, one can expect a wet film thickness of around 10—14 microns. This will result in a dried ink film thickness of around 1 micron.

Graphics Printed by Solvent-Based Piezo Ink Jet

Solvent-based piezo ink jet inks are routinely used to make graphics for outdoor use. The market response to the use of piezo ink jet printing to make quality graphics has been overwhelming. With the use of the correct graphic components and processing conditions, graphics can be made that have permanence and fade resistance approaching that found in graphics made by conventional screen printing. The components of the graphics for printing by solvent-based piezo are improving such that one could argue that within a few years the fade resistance of these graphics will be every bit as good. Piezo ink jet printing is being used routinely to make quality graphics for banners, billboards, graphics for floors, graphics for windows, point-of-purchase and trade show displays, bus graphics, and other signage.

There are still some graphics, though, in which conventional screen printing graphics can have an edge over graphics made by solvent-based piezo ink jet inks. These are graphics in which solvent retention can have a serious impact on permanence. As noted above, there are major differences at this time in the % solids of the inks and in the drying of graphics between conventional solvent-based screen printing and solvent-based piezo ink jet printing. There is basically no retained solvent in graphics printed by UV-curable screen printing inks. Retained solvent can cause some ink receptive layers to swell. The loss of the solvent by evaporation after the marking has been applied can result in shrinkage. Shrinkage can cause the ink receptive layer to pull back leaving the psa exposed. Shrinkage can also cause lifting from applications with a deep contour or lifting around corrugations. In graphics with butt seams of two panels, the shrinkage can result in the substrate being exposed or can result in light leaks with back-lit applications. Other problems that could occur would be edge curling and overlap lifting. Overlap lifting occurs when one panel with a psa is placed on top of another in a multi-panel graphic and the top panel pulls back with shrinkage. Further, retained solvent can cause the psa to increase or decrease dramatically in tack and the film to soften making application to a substrate difficult or impossible. All of the above can lead to performance problems. The question then is how can a piezo ink jet printer make these demanding graphics to the same degree of performance as made by screen printing methods.

One solution to the problem of retained solvent in a marking is to limit the amount of solvent printed. The graphic designer and/or color separator can set printing parameters with the piezo print operator in order that total ink coverage can be limited during separation. Total ink coverage here means the total percentage of the inks (CMYK) used in the darkest shadow regions of the graphic. For example, CMYK values of 60, 60, 60, and 100% produce a total ink coverage of 280%. Total ink coverage is sometimes referred to as total area coverage; total dot area; maximum CMYK; maximum ink amount; total ink limit; or total printing dot. Part of establishing the total ink coverage is determining maximum black. The black ink should be limited to the minimum level necessary to achieve a maximum density. For example, if you review a series of black patches in 1% increments from 90 to 100%, a visible difference in density usually stops being noticeable between 94 to 100% of total black.

If the total ink coverage on a color-separated image is too high for the media being used, one should use ink limiting, if possible. There are RIP softwares available that support ink limiting to reduce the total amount of ink on the media.

For example, Scotchprint® Graphic Maker Software by 3M™ manipulates the print data to reduce the amount of ink used while maintaining color balance for the best possible image quality. It does this by limiting the number of ink spots that are printed over the top of another without restricting the 100% solid colors (cyan, magenta, yellow, and black). With this particular software, ink limiting can be set for none, 100, 150, 200, or 250%.

Another major consideration in making demanding graphics by solvent-based piezo ink jet printing would be to select the correct media (ink receptive layer with a psa) for the ink, graphic, and application needed. Different media will interact differently with inks. Manufacturers can rate media for total ink coverage permitted that will still perform acceptably for the more demanding graphics (see Reference 6 as an example). Figure 4 shows test panels of two durable films printed at 300% total ink coverage and oven dried under the same conditions. The test panels consist of making overlaps, going over rivets, and making a test gash for assessing shrinkage. The film on the left is recommended for total ink coverage up to 300%. The recommended film shows no overlap lifting, no tenting around the rivets, and no shrinkage in the test gash whereas the other film exhibits lifting, tenting, and shrinkage.

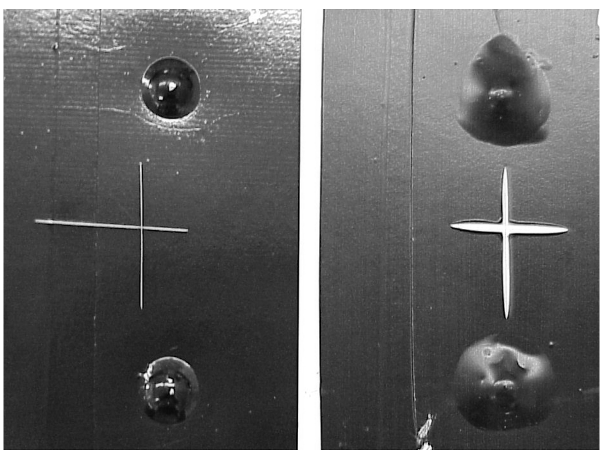

Figure 4. Test Panels of Two Films at 300% Total Ink Coverage.

The above considerations were based on the assumption that the dryer in the printer had been adjusted for the best possible drying conditions. If one still needed further drying of a marking, one could use other methods such as allowing the marking to air dry for 24 hours, pass the marking down a tunnel dryer, or to place in a batch oven as could be done with markings made with solvent-based screen printing inks.

Conclusions

Quality graphics that were just recently being generated by screen printing are now being done on a routine basis by solvent-based piezo ink jet printing. One needs to take retained solvent into account for the more demanding graphics as one would need to do also for conventional solvent-based screen printing inks. The need to eliminate retained solvents in the more demanding graphics will probably lead to the development of improved dryers on the printers and an increased use of software with ink limiting.

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Biography

Ronald R. Adkins received his B.S. in chemistry in 1970 from Northern Michigan University. He received his Ph.D. in physical chemistry from the University of Detroit in 1976 where he elucidated the chemical structure of sulfur-nitride compounds by physical and theoretical methods. He joined 3M in 1984 and has been involved in the formulation of outdoor durable screen printing and piezo ink jet inks. He does studies also in wet adhesion, pigment dispersions, and dirt resistance. He is active in ANSI/ISO and the Federation of Societies for Coatings Technology.