THE USE OF WATER BASE INKS IN THE FLEXIBLE PACKAGING INDUSTRY

James C. Hook*

ABSTRACT-Today many companies are turning to water base inks for many good reasons. Water base inks are not as hazardous, have a high quality look, save money in inks and solvents and, according to my research, are more durable under different packaging situations. I printed a solvent base and water base ink on two different types of polyester packaging film and tested for ink durability. I did this by abusing the printed piece under conditions a flexible package might endure. The results were that under most conditions water base inks were just as good or better than solvent base inks.

As of today, most of the printing done for the flexible packaging industry is done by flexography. Most of the printers in this industry are also straying away from solvent base inks and are successfully using water base inks.

In the past, almost 100% of printing was done using solvent base inks. Drying temperatures were not high, print quality was high, most substrates could be printed on, and press operators felt that the colors looked better. The printing industry used solvent base inks for years, with rare substitutes, until the late 1970's when the government passed the Clean Air Act Amendments of 1977. This act gave the Environmental Protection Agency authority to regulate and enforce the amount of volatile organic compounds (VOC's which are vapors) that may be dispersed into the air. The printing inks and solvents used at this time exceeded the amount of VOC's set by the EPA and in the late 70's printing companies looked for alternatives to get around this problem. If a shop was measured to exceed this limit a heavy fine would be imposed. Also at this time the members of the National Association of Printing Ink Manufacturers (NAPIM) were looking for alternatives to save their companies. This is why the ink makers have come far distances with water base inks.

VOC's are not the only problem now associated with solvent base inks. The EPA has also put restrictions on what goes into our land, air and water. Any substance that can contaminate and harm any animal or being is considered a hazardous waste. These inks and reducing solvents are considered hazardous waste, therefore they can't be poured down the drain and must be disposed of properly. The waste must be put into drums and shipped to a waste treatment center, which can be a large cost to the company.

A different potential high cost is the way these VOC's will be kept from dispersing into the air. An early idea was the use of incinerators to catch the vapors before they were released into the air. This would be fine but the costs far outweigh the advantages. The vapors would still have to be dealt with away from the press and these incinerators are high in cost and the energy could be used for something more efficient like keeping the pressroom at a comfortable temperature. (Bean, 20)

A final major problem with solvent base inks is storage and transportation. All of the equipment used in and around these inks and solvents must be explosion proof. This eliminates all electric machinery and/or any other equipment that has the chance of giving off a spark. This problem is easily solved, but at a cost, by using air powered equipment.

*Clemson University

Water base inks can be the answer to most of these problems. As the name implies, water is the carrier of the ink and "...water is abundant, inexpensive, tasteless, colorless, odorless, and non-toxic. It does not catch fire and it does not pollute. Additionally, equipment can be washed up easily, there is less swelling of rubber and plastic plates and rollers, and less likelihood of color bleeding into overprint and laminating varnishes." (Winokur, 27) Along with this statement, there are a few other promising aspects of water base ink. Health problems of the crew are lowered with the absence of toxic fumes, viscosity is more stable during the press run, and water base ink saves some costs for thinners, reducers and the ink itself because a thinner layer is laid down on the substrate. Transportation, building, and storage costs will be less because of the reduction of an explosion. A major advantage of water base ink in food packaging is that the ink will not bleed into the overprints and laminations, eliminating taste and odor problems that would transfer to the food. (Bean, 20)

Since water base ink sounds so wonderful, why doesn't 100% of the flexible packaging industries use it? Water base does have some major drawbacks. One is that it takes more energy to dry. Solvent base inks take anywhere from 144-367Btu/Lb. of energy to dry on-line, while water base inks usually take 972 Btu/Lb. A company does not have to pay for incinerators to catch fumes, but they must pay for higher energy in the heaters. (AIM, 22)

The surface tension of solvents is lower than of water. Solvents range anywhere from 20.3-24.3 dynes/cm while water is at 72.8 dynes/cm. The higher the dyne means that more ink will bead up and not stick to the substrate. (AIM, 22) The only way for water base ink to stick to film is with the help of a wetting agent.

Although the viscosity is very stable during the press run, a small change will cause a large shift in the color of the printed piece. Also in the ink barrel, water base inks have a tendancy to foam and bubble up causing ink inconsistencies. A different problem with water base ink is that the press has to be cleaned immediately after the job run or else the ink will quickly harden on the plates. (Bean, 20) This is not a problem during the run.

At this point it would be a good idea to look into the makeup of water base ink. According to chemist Carleton Ellis, a water base ink is made up of "...a mixture of water, water-soluble solvent, a natural resin, alkaline reacting compound, and a dispersing agent." (Ellis, 276) This was the original "recipe" when water base ink was only used for corrugated boxes and absorbent paper. The ink was totally solvent-free because all of the drying was by absorption into the non-coated papers. Today a water base ink may have up to 40% solvents in it. Now water base inks are also considered hazardous waste and have to be disposed of properly.

Water base inks have three different types of resins. A water soluble or reducible resin totally dissolves in water. Colloidal dispersions or solubilized resins are the most common type of resin. These break down into tiny molecule size particles. An emulsion or aqueous solution resin is in two parts where one is totally broken down and dispersed into the other one which stays in a small particle form. (Burke, 44)

There are also six types of vehicles that can be used for water base inks. The first is alkali soluble acrylic copolymers, which are very expensive but have the best all around quality. This type of vehicle excels in flexibility and water resistance. Acidic resin esters are the second type and are a grade lower than the first, but they are less expensive. This is the vehicle that is used the most in the makeup of water base inks. Shellacs are the third type of vehicle. They are expensive but only have a fair film flexibility and water resistance. The fourth type is a modified shellac. This is basically a shellac that has been styrenized, which improves flexibility, water resistance and adhesion. The price of this vehicle is similar to the first type. The fifth is acidic styrene copolymers which is very similar to the second type in quality and price. The final type of vehicle is proteins. This is a carry over from the old days, It does have a very high resistance to heat, grease, and oil, but its high viscosity needs modification by low viscosity resins. (Winokur, 27)

Now that we know what water base ink is made of and reasons why companies are switching to the ink, it is time to test a waterbase ink head to head with a solvent base ink on a material used in flexible packaging. I did a comparison of the two inks by abusing the printed pieces and checking the ink adhesion. I used a coated and an uncoated polyester film and printed magenta and black solvent base ink and cyan and yellow water base ink on the films. The printing was done by flexography.

Press conditions were as follows:

Solvent base on uncoated
speed = 200 fpm, dryer temp = 185 degrees F
viscosities using #3 Zahn cup
magenta = 25, black = 30
green ink adhesion = 100%

Solvent base on coated
speed = 200 fpm, dryer temp = 185 degrees F
viscosities using #3 Zahn cup
magenta = 27, black = 30
green ink adhesion = 100%

Water base on uncoated
speed = 100 fpm, dryer temp = 245 degrees F
viscosities using #3 Zahn cup
magenta = 25, black = 30
green ink adhesion = 5%

Water base on coated
speed = 100 fpm, dryer temp = 245 degrees F
viscosities using #3 Zahn cup
yellow = 25, cyan = 25
green ink adhesion = 100%

The following tests were then applied:

Crinkle adhesion test
Scratch resistance test
Heat resistance test
Boiling water resistance test
Ice water resistance test
Freeze-thaw resistance test (FTA)

Ink adhesion will be rated by the following table:

0 - 25%	=	VERY POOR
26 - 60%	=	POOR
61 - 80%	=	GOOD
81 - 90%	=	VERY GOOD
91 - 100%	=	EXCELLENT

RESULTS

1. Crinkle adhesion test - to test the flexibility of the ink.
Procedure: Grab the printed film approximately 1/2 inch apart and crinkle film in a rotating motion ten times. Take tape test.
   1. Solvent base on uncoated = 80% adhesion = GOOD
   2. Solvent base on coated = 65% adhesion = GOOD
   3. Water base on uncoated = 5% adhesion = VERY POOR
   4. Water base on coated = 85% adhesion = VERY GOOD

2. Scratch resistance test - to test the scratch resistance of the ink.
Procedure: Place printed sample on flat, smooth surface and quickly scratch the sample with back of fingernail 30 times.
   1. 50% adhesion = POOR
   2. 95% adhesion = EXCELLENT
   3. 100% adhesion = EXCELLENT
   4. 100% adhesion = EXCELLENT

3. Heat resistance test - to test the heat seal resistance of the ink.
Procedure: Preset iron to desired temperature. Drag iron across printed surface three times.

300 degrees F

   1. 80% adhesion w/ major smearing = VERY POOR
   2. 85% adhesion w/ major smearing = VERY POOR
   3. 90% adhesion w/ no smearing = VERY GOOD
   4. 95% adhesion w/ no smearing = EXCELLENT

350 degrees F

   1. NOT TESTED
   2. NOT TESTED
   3. 80% adhesion w/ minor smearing = VERY GOOD
   4. 90% adhesion w/ minor smearing = VERY GOOD

*Note - at 350 degrees F, film started to distort and melt.

4. Boiling water resistance test - to test if the ink can withstand boiling water.
Procedure: Immerse strips of printed sample into boiling water for five minutes.
   1. 85% adhesion w/ minor smearing = VERY GOOD
   2. 90% adhesion w/ minor smearing = VERY GOOD
   3. 95% adhesion w/ minor smearing = EXCELLENT
   4. 50% adhesion w/ major smearing = POOR

5. Ice water resistance test - to test if the ink can tolerate cold, wet freezer conditions.
Procedure: Immerse printed sample in ice water for three hours, wipe dry and give crinkle adhesion test.

1. 20% adhesion = VERY POOR
2. 35% adhesion = VERY POOR
3. 5% adhesion = VERY POOR
4. 60% adhesion = POOR

6. Freeze-thaw resistance test - to test if the ink can tolerate the freezing and thawing of a package.
Procedure: Immerse printed samples in a beaker of water. Freeze for hours. Let thaw in room temperature and give crinkle adhesion test.

1. 20% adhesion = VERY POOR
2. 50% adhesion = POOR
3. 25% adhesion = VERY POOR
4. 95% adhesion = EXCELLENT

AN OVERVIEW OF THE TEST RESULTS

	SOLVENT BASE		WATER BASE	
TEST	UNCOATED	COATED	UNCOATED	COATED
1	POOR	EXCELLENT	EXCELLENT	EXCELLENT
2	GOOD	GOOD	VERY POOR	VERY GOOD
3	VERY POOR	VERY POOR	VERY GOOD	EXCELLENT
4	VERY GOOD	VERY GOOD	VERY GOOD	VERY POOR
5	VERY POOR	VERY POOR	VERY POOR	POOR
6	VERY POOR	POOR	VERY POOR	EXCELLENT
	POOR	GOOD	GOOD	VERY GOOD

It must be stressed that these were small scale testing procedures with household items instead of highly technical testing equipment. Even at a small scale, water base ink tested does seem to be a better ink than solvent base ink tested in many areas of film packaging except when the product is primarily in water. This research would have to be taken to a higher level of validity to be accepted as the standard for the flexible packaging industry. It does set some simple guidelines to what ink can tolerate, withstand, or in some cases, fail certain conditions the ink might endure on a package.

The results of this test show the progress of water base inks in the last ten years. But with all the progress only about 40% of all flexible package sales are of water base inks. (Lustig #1, 38) Is it that water base ink is inferior? Obviously not, according to my testing and other's before it. Most companies who have not converted are afraid to take the chance of changing, but they are falling behind in the industry. The growth rate of water inks to solvent inks is astonishing. In the years 1985-1988, the total growth of flexographic flexible pakaging was 4.5%. Water base ink printing grew by 32.8%, while solvent base ink printing dropped by 3.9%. The growth can also be seen in this statistic; in 1985, again in flexo only, water base inks constituted 17.3% of flexible packaging while solvent base had 82.7%. In 1988 it was 35.6% for water base and 64.4% for solvent base. (AIM, 23)

What is the future of water base inks? Besides the growth, there have been more recent government restrictions that should promote the further growth of it. Title III of the Superfund Amendments and Reauthorization Act (SARA) now require printers to keep special inventories. Printing companies must now keep strict records of inks and other materials that OSHA considers hazardous. To expand on this act, section 313 of SARA requires large volume printers to report releases of inks and solvents to the air, water, or land. (Lustig #1, 38)

Along with the government, new items are bound to make the use of water base inks rise. Infrared and radio frequency dryers are now drying water base inks without the energy needed by a conventional dryer. The infrared dryer sends out many different wavelengths of heat to the substrate. The dryer can "tune" to the wavelength the water absorbs best to dry. Since this "tuning" is possible, the dryer can run at high temperatures without drying out the substrate. If this new dryer is used correctly, a substrate with four layers of wet ink running at a press speed of 1000 fpm can be dried through one of these that is only eight inches long. (Sterne, 28)

If all of these trends hold to form, and ink manufacturers continue to make quality water base inks as they have in the past ten years, the makeup of the printing industry will change. There should not be any more major printing companies using solvent base ink in twenty years. After all, the government is going to get more stringent with our natural resources. In my opinion, the ink companies of NAPIM will perfect the water base ink to the point of having close to zero amount of solvents in the ink, and the printing quality will be higher than it ever was before.

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