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February 2001

Design for the Environment
Gravure Partnership

The Effect of Ink Temperature On Solvent Losses and Print Quality

Background—The U.S. Environmental Protection Agency's (EPA) Design for the Environment (DfE) Program, the University of Tennessee (UT) Center for Clean Products and Clean Technologies, and Western Michigan University (WMU) partnered with the Gravure Association of America (GAA), gravure printers from the packaging and product sectors, and other industry experts to identify 1) common environmental issues for gravure printers, especially small- and medium-sized businesses in the packaging and product sectors; and 2) potential risk reduction and pollution prevention opportunities for addressing key issues.

Packaging and product gravure printers are particularly concerned about solvent losses from ink during press operations—including solvent losses from the ink sump and ink pan areas—which might be reduced by controlling ink temperatures. Smaller gravure printing operations generally use a press-side sump to pump ink to the press, where the ink may absorb heat from the ambient air or from press operations. Large publication printers generally have in-line heat exchangers and closed-loop ink delivery systems, which are not as subject to solvent losses from elevated ink temperatures. The Gravure Partnership performed a preliminary study of the effect of ink temperature on solvent losses and print quality, which is summarized below. The results suggest that packaging and product printers could reduce solvent losses, and, in some cases, improve print quality by controlling ink temperatures. Further study by the industry is needed to confirm these results.

U.S. Gravure Industry Statistics

Sector	# of plants	Avg. presses per plant
Publication*	24	6.3
Packaging	276	2.5
Product	174	2.8
Total	480	2.8
Avg. employees per plant**		<20
Annual sales ($/yr)**		>$18 billion

Data from 1987-1993 (GAA Profile Survey of the U.S. Gravure Industry).

* 2000 data from GAA.

**Data for publication, packaging and product combined.

Gravure Industry Statistics—The gravure industry comprises three main sectors: publication, packaging, and product printing. Publication gravure plants are generally large operations that tend to be more automated, with more advanced systems for addressing environmental concerns. Packaging and product gravure plants are often small- to medium-sized printing facilities with fewer employees, fewer presses, and more limited resources.

Risk Reduction Opportunities—The partnership began with a scoping phase to identify potential opportunities for packaging and product printers to reduce emissions and risk from printing operations. Project partners consulted with GAA and industry experts to develop a preliminary list of risk reduction opportunities (see box, page 2), which were then verified through site visits to gravure printers in the packaging and product sectors. DfE project leaders chose to study the effect of ink temperature on VOC emissions and printability for the following reasons:

- Ink temperature's effect on solvent losses and print quality are common problems among various packaging and product printers, in spite of different inks, number of colors, and substrate.
- By controlling ink temperature, printers might gain print quality and cost benefits as well as environmental benefits.

- Emissions from the ink sump and ink pan areas are not always captured by air pollution control equipment attached to presses.
- Reduction in the use of hazardous air pollutants (HAPs) and VOCs could reduce adverse impacts on human health and the environment (due to direct toxicity from HAPs and indirect effects of smog formation from VOCs).

Gravure Partnership Purpose—The purpose of the DfE Gravure Partnership was to 1) identify risk reduction and pollution prevention opportunities for addressing key environmental challenges in the gravure industry, 2) determine whether promising risk reduction techniques might also have cost and/or performance benefits, and 3) provide the risk, performance, and cost data to the gravure industry for further technology verification.

Following scoping, a laboratory experiment was conducted at WMU's Printing Pilot Plant to explore the relationships between ink temperatures, solvent losses, and print quality (Sosa, 1999). The results of the WMU temperature control study, presented here, provide preliminary information to the industry on the potential risk, performance, and cost benefits of ink temperature controls.

Risk Reduction Opportunities

Risk reduction opportunities identified by the DfE Gravure Partnership include:

- Volatile organic compound (VOC)/solvent emissions reduction
  - from floor cleaning
  - from press operations
- Hazardous waste generation
- Shop towel management

WMU Temperature Control Study

The WMU laboratory experiment met key objectives of the DfE Gravure Partnership by:

- Developing information on the effects of ink temperature on solvent consumption and print quality.
- Determining that technologies to moderate or control ink temperatures are a worthy subject for further investigation by the industry.

Temperature Control Study

Purpose

The purpose of the preliminary laboratory study was to evaluate the effects of temperature on solvent consumption and print quality.

Method

Two colors of nitrocellulose (Type C) ink common to packaging printers were used in 3-hour production runs on a 42", 4-color gravure press at 300 ft/min. Type C inks are generally ester or ketone inks. The solvent blend used in the temperature experiment was 50% normal propyl acetate and 50% normal propyl alcohol (by volume). Samples were taken for the two inks at three different ink temperatures: 66°F, 79°F, and 92°F. The cooler temperature was obtained by using cold water and ice to cool water circulating through copper coils submerged in the ink sump. The warmer temperature was obtained by circulating hot tap water through the copper coils. No temperature controls were used for the middle (ambient) temperature, which increased by 3°F to 5°F during the course of the 3-hour run.

During the runs, ink temperature was measured and viscosity was tested and adjusted every 5 minutes. Print quality measurements were taken every 20 minutes. Several measures of printability were obtained. (See Study Parameters Box.)

Study Parameters

Controlled conditions

Press size:	42" wide, 4-color press
Press speed:	300 ft/min
Substrate:	1.25 mil polyethylene film
Run length:	3-hour production run (samples taken every 20 minutes)
Ink type:	Type C (nitrocellulose), magenta and cyan
Solvent blend:	50% n-propyl acetate, 50% n-propyl alcohol (by volume)
Initial ink vol.:	60 lb (solvent + ink)

Variable conditions (average ink temperature)

66°F (cooled with cold water and ice)
79°F (ambient)
92°F (heated with hot water)

Measurements taken

Viscosity (adjusted every 5 minutes)
Solvent consumption
Ink consumption
Printability

- Optical density
- Gloss
- Microstructure image analysis (dot structure)
- Tonal response
- Rub resistance (Sutherland Ink Rub Tester)

Solvent and Ink Consumption Results

Colder ink needs more solvent to bring it to target viscosity, but as temperature rises, the solvents in solvent-based inks evaporate faster and require more solvent to maintain viscosity (Sosa, 1999).

- Total solvent consumption (solvent added during makeready plus solvent added during the print run) in the magenta ink increased with increasing temperature (see Figure 1).
- Total solvent consumption in the cyan ink was slightly greater at 66°F than 79°F due to the amount of solvent needed to reach target viscosity during makeready. Solvent consumption increased from 79°F to 92°F (see Figure 1).
- Total mass (ink plus solvent) consumption increased with increasing temperature: 9%-28% increase from 66°F to 79°F and 37%-56% increase from 79°F to 92°F.
- Ink use (not including solvent added during makeready or the trial) also increased as temperature rose (see Figure 2). The increase in ink consumption at higher temperatures may be due to the higher pigment to solvent ratio of warmer ink, which prints a thicker layer.

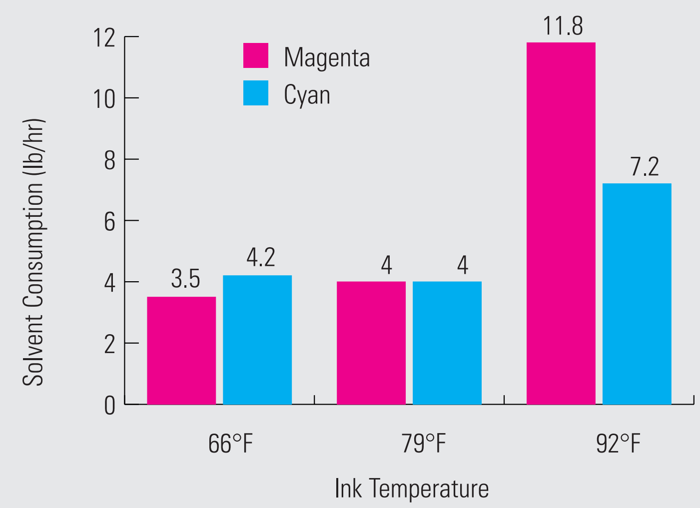
Print Quality Results

In the WMU study, printability and quality were affected as ink temperature increased, with both printed solids and tones affected (Sosa, 1999).

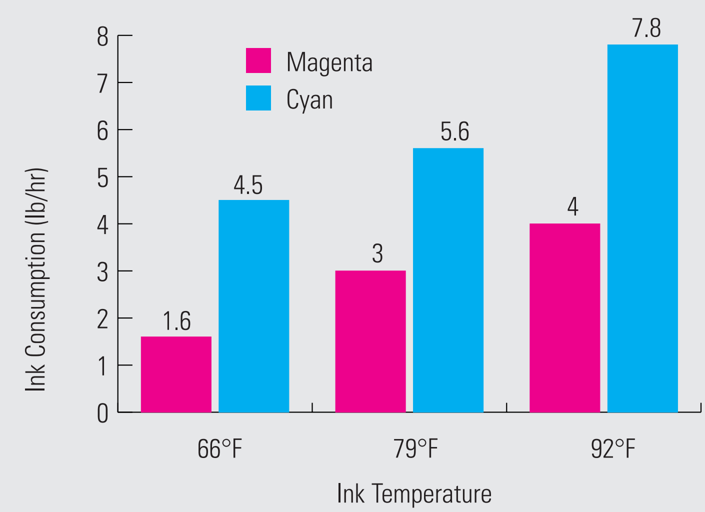
- *Reflection Density*—dropped by 0.055% of reflected light for every 5°F temperature increase from 79°F to 92°F (see Figure 3). Theoretically, ink at higher temperatures should print darker colors, but reduced reflection densities at higher ink temperatures have been reported elsewhere (Celio, 1998).

  Warmer inks evaporate faster, which can cause a wettability problem and screening. Screening is a print defect caused by uneven flow of inks between cells (GAA, 1991). In the WMU study, as ink temperature rose to 92°F the ink dried before spreading adequately on the substrate, thus reducing the overall printed solid area and the reflection density (Sosa, 1999). Printed tone steps were most affected; the finest dots did not print at all.
- *Specular gloss*—decreased by 20% from 66°F to 79°F, but increased by 3% from 79°F to 92°F (see Figure 4). Colder ink requires more solvent to reach target viscosity; lower pigment concentration leads to a thinner printed ink film. In the WMU study, the specular gloss measurements for the colder ink

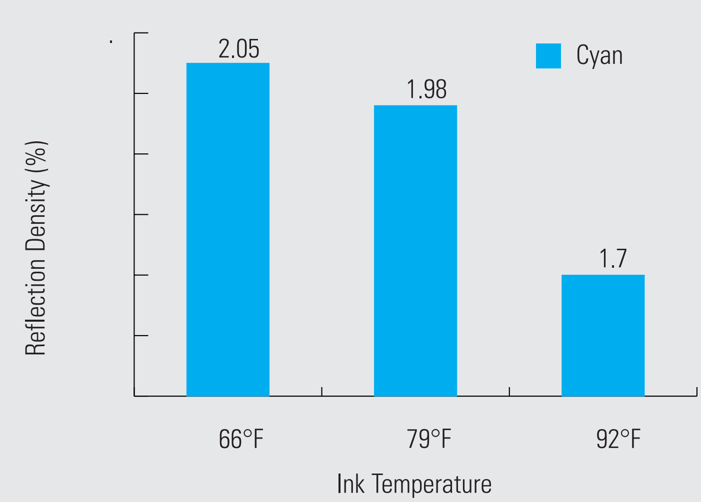
Total Solvent Consumption Figure 1



Ink Consumption Figure 2



Print Quality — Reflection Density Figure 3



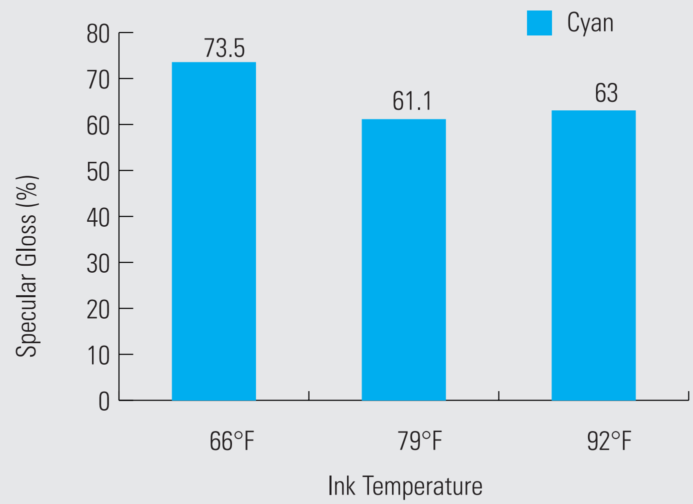
were influenced by the glossy polyethylene substrate showing through the thinner ink film. The increase in specular gloss seen from 79°F to 92°F may be due to the decreased wettability and increased screening observed at higher temperatures. Screening may have caused more light to be reflected from the polyethylene substrate.

- *Dot structure* (see Figures 5 and 6)—hot inks had deformed dot structure caused by the “donut effect.” As ink fills the engraved cells of a printing cylinder, it forms a concave shape leaving an air bubble to be trapped between the ink and the substrate. The air prevents the ink from being transferred to the middle of the printed dot and forces the ink to be spread outward, creating a “donut.” Warmer, less viscous ink produces a bigger concave meniscus as it lies in the cylinder cells, which results in more air being trapped and a larger donut. As the donut effect increases with temperature, the amount of printed image decreases and the printed dot becomes bigger (Sosa, 1999).

  Deformed dots caused by the donut effect also had bigger perimeters. As the dot perimeter increases so do the dot gain and mottle, causing a decrease in print quality. Finally, photographs taken in the solids areas confirmed the reduced wettability of the hotter ink; the white, non-printed areas of the solids rose with increasing ink temperature.
- *Haze*—not a quantifiable variable in the WMU study, but appeared to increase with decreasing temperature. Decreasing efflux time and/or doctor blade pressure may reduce haze.
- *Rub resistance*—no change in rub resistance at different temperatures. A Sutherland ink rub tester was used to rub the printed films against a white surface for a specific amount of time. The reflection density of the white surface was measured before and after the test to determine the amount of ink transferred from the printed film to the surface. The difference in the reflection densities of the hottest temperature and the coldest temperature inks were within the resolution of the densitometer.

Print Quality — Specular Gloss

Figure 4



Magenta elongated tone (25%) — 150 lines per inch

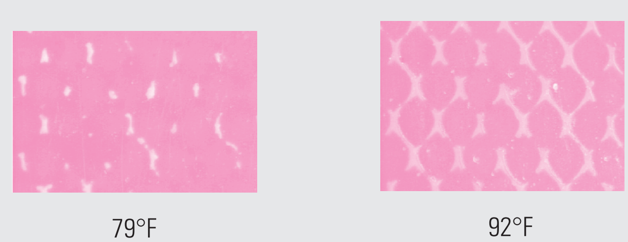
Figure 5

Cyan compressed tone (25%) — 150 lines per inch

Figure 6

Magenta solid — 150 lines per inch

Figure 7



Conclusions

The WMU study assessed the effects of three ink temperatures (66°F, 79°F, and 92°F) on solvent consumption and print quality of Type C inks under laboratory-controlled conditions. The study was designed to provide preliminary data on the potential benefits of ink temperature controls to the gravure industry for further technology verification (see box on Study Limitations). The results are promising.

- Small- and medium-sized printers in the product and packaging sector may be able to reduce solvent consumption, improve print quality, and achieve cost reductions by implementing ink temperature controls.
- Decreasing solvent consumption and solvent emissions could also reduce health risks because of reductions in potential exposures to workers or the public.
- The greatest benefits may occur when ink temperature is maintained near a typical room temperature rather than chilled to below typical room temperatures, suggesting less chilling is needed to achieve optimal results.
- Ink temperature controls might also reduce overall ink consumption (up to 20%-30%) without adversely affecting print quality, but these results need to be confirmed on different substrates and in "real world" settings.
- Ink temperature controls can also be expected to reduce solvent use (perhaps up to 50%), especially in the summer months when ambient temperatures are higher.

Potential Cost Savings—Potential savings were estimated for two scenarios using the assumptions of the model facility (see box at right) and the solvent and ink consumption results from the WMU study. Scenario 1 assumes a small printer operates at 92°F for three months and 79°F for nine months a year. Scenario 2 assumes the printer implements temperature controls to maintain a constant temperature of 79°F all year.

Conditions will vary greatly by facility; many other factors may also affect these estimates. Nonetheless, they provide a starting point for companies to estimate their own potential savings. Although these estimates do not account for the cost of cooling, any cooling solution and associated energy requirements that cost less than the estimated savings above could result in payback after the first year.

Industry Challenge—The results of the DfE Gravure Partnership suggest ink temperature controls may present

Study Limitations

- The WMU laboratory study was designed to evaluate the potential risk, performance, and cost benefits of ink temperature controls for gravure printers. The study does not establish a definitive relationship between ink temperature, solvent emissions, and print quality.
- The study evaluated the effects of ink temperature on Type C inks only. Results may differ with other ink types.
- The range of test temperatures (66°F to 92°F) was selected to represent the extreme of printing conditions that might be encountered in the industry. Smaller printers may have ink temperatures approaching the upper limit in the summer months, but these higher temperatures are not typical of year-round operating practices.
- Many ink and solvent systems used in packaging and product gravure have an affinity for pressroom air moisture, particularly at low temperatures. Moisture pickup due to low ink temperature can cause blushing and ink kick-out. The study did not directly assess the moisture pickup of the colder inks, but no blushing and ink kick-out effects were seen.

Potential Cost Savings

Parameter	Scenario 1	Scenario 2	Reductions or savings
Solvent emissions (lb/yr)	113,400	86,400	27,000
Ink consumption (lb/yr)	97,200	86,400	10,800
Annual solvent costs	$56,700	$43,200	$13,500
Annual ink costs	$388,800	$345,600	$43,200
Solvent & ink costs	**$445,500**	**$388,800**	**$56,700**

Example Model Facility

Press size:	23" wide
Printing units:	3
Annual operation time:	7200 hr/yr
Press speed:	300 ft/min
Solvent use rate:	9 lb/hr at 92°F
(per color):	4 lb/hr at 79°F
Ink use rate:	6 lb/hr at 92°F
(per color):	4 lb/hr at 79°F
Solvent cost:	$0.50/lb
Ink cost:	$4.00/lb

gravure printers with an excellent opportunity to prevent pollution at the source, while improving print quality and reducing costs. Small- and medium-sized printers that experience printing inefficiencies due to fluctuations in ink temperatures may benefit most from ink temperature controls, but no clear or commonly implemented solutions for addressing these inefficiencies yet exist. The DfE Gravure Partnership challenges the industry to confirm project findings to optimize printing operations. To meet this challenge, gravure printers could:

- Independently evaluate the effects of ink temperature on solvent and ink consumption, print quality and cost.
- Assess and/or optimize current ink temperature control options, including
  - Submerged copper coils in the ink sump, including the cost and pollution implications of frequent cleaning.
  - In-line heat exchangers on the supply line.
  - Room temperature control (air conditioning).
- Adapt a temperature control option from another industry.
- Develop a new, innovative method for controlling ink temperatures.

Questions to consider when evaluating the use of temperature control in a printing facility include:

- How will less solvent consumption affect treatment systems such as oxidizers and recovery systems?
- What is the cost of adding temperature controls on press and providing cooling water?
- How do different colors and ink types behave, noting that in this study the two Type C inks behaved differently?

References

Celio, Tino (1998). *Ink Temperature Control in Gravure Printing.* Ambril, Swtizerland: Paper presented at the annual meeting of the Gravure Association of America conference, Memphis, TN.

GAA (1991). *Tone Reproduction.* Gravure, Rochester, NY.

Sosa, Rodrigo (1999). *Effects of Temperature Control on Gravure Packaging Ink*: A Thesis Submitted to the Faculty of the Graduate College in partial fulfillment of the requirements for the Degree of Paper and Imaging Science, Western Michigan University, Kalamazoo, MI.

What is EPA's Design for the Environment Program?

EPA's Design for the Environment (DfE) Program partners with stakeholders to help businesses help the environment. DfE projects help businesses design products, processes, and management systems that are cost-effective, cleaner, and safer for workers and the public. The DfE goals are to:

- Encourage businesses to incorporate environmental information into their decision criteria.
- Effect behavior change to facilitate continuous environmental improvement.

To accomplish these goals, DfE and its partners use several approaches including cleaner technology and life-cycle assessments, environmental management systems, formulation improvement, best practices, and green supply chain initiatives.

To date, the DfE Program has brought environmental leadership to over 2 million workers at over 170,000 facilities. Small- and medium-sized businesses recognize DfE as a unique source of reliable environmental (as well as performance and cost) information that allows them to make better decisions.

How Can I Get More Information?

To learn more about EPA's DfE Program or the Gravure Partnership, contact:

EPA's DfE Program
Phone: 202-260-1678
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