The Effect of Applying Various Temperatures on the Sheetfed Press on the Resulting Print Quality

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Keywords
Temperature, Print quality, Tone value increase,
Color difference, Ink properties

Abstract

Although various laboratory experiments have shown significant changes in the ink rheological properties when the temperature varied, few studies have been carried out to check the quality of print at different temperatures. EFPG and GATF carried out a joint research project to observe this.

Tests were conducted on a sheetfed press equipped with a temperature control system in order to print at different temperatures. The print quality was evaluated in terms of densitometry (solid ink density, tone value increase, print contrast,...) and colorimetry (spectral reflectance curves, CIELAB, gray balance,...). Moreover, the rheological properties of the inks used were studied. The following study presents the effects of temperature on the print quality and establishes that a temperature range exists which allows the best compromise between print quality and runnability.

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Introduction

Usually, in offset lithography, the temperature fluctuates between 25°C and 35°C during a press run. It is often observed that a temperature close to 25°C gives a better quality. In this study, we want to carry out tests on a temperature-controlled sheetfed offset press. The goal is to determine whether printing at a "low" temperature improves the resulting quality and to try to interpret the differences that may be observed on the press by studying the rheological properties of the inks used.

This article will start with a bibliographic review about printing at different temperatures. Then it will present the tools needed to carry out the project. It will also describe how the printing tests were carried out and what kinds of data were collected from the printing runs. After this, we will present the effects of various temperatures in the press unit on the resulting printing quality. Finally, the consumable properties will be studied in order to possibly explain the results obtained on the press.

Bibliographic review

Consistency of temperature on a printing press

Temperature is a key factor in the offset process. Thus, before carrying out experiments on the effects of applying different temperatures in a sheetfed press, it is important to know which temperatures to study and whether it is possible to reach these temperatures and be sure that they are stabilized. Pineaux et al. (2000) observed significant shifts in the temperature between the beginning and the end of a print run on a heatset web press. They noticed that two hours were necessary to reach a stable temperature. Moreover, Bohan et al. (1997) showed that temperatures taken on different places on a sheetfed offset press varied considerably in a short time. Thus, before starting this study about the effects of printing at different temperatures on a sheet fed press, it was determined whether more or less steady temperatures could be reached. However, sheetfed print runs are usually much shorter than those encountered in web offset printing. A typical running time varies between fifteen minutes and two hours; this parameter will be taken into account.

Moreover, even if the press utilizes a powerful and efficient cooling system, its different rollers will not reach the same temperature. The Technical Report published by the Web Offset Association on "Temperature effects in heatset offset web printing" (1998) showed that often the cooling system, which generates large changes in the temperature of ink rollers and in the water solution pan, produces much smaller changes in the surface temperatures of the plates and blankets. The temperature variations for plates and blankets are attributed to the evaporation of fountain solution from the latter and from the inking system. The report also mentions that the "water window" (range of dampening solution that can be emulsified with good print rendering) decreases when either the ink vibrator surface or the fountain solution temperatures increased. Thus, the temperatures of the rollers would have to be carefully checked on the sheet fed press. For this, a hand-held pyrometer was used to check the temperature levels in different areas of the press.

Effects of temperature on ink properties

Three student final projects at EFPG (internal documents, 1996, 1998 and 1999) showed that all inks have specific behaviors when the temperature varies. Rheological properties and tack can be affected by the temperature variation.

Effects of temperature on print quality measurements

One of these student projects showed that the temperature had an effect on dot gain. Conversely, the Web Offset Association's Technical Report about "Temperature effects in heatset offset web printing" (1998) showed that the temperature had no effect on dot gain.

The previously cited projects also noticed that printing at different temperatures implied variations in colorimetric data (for example, a^*, b^* may vary).

This bibliographic review showed the different points to deal with this study:

- To check temperature parameters during the tests
- To observe the print quality obtained
- To study the ink properties at various temperatures

I. Experimental

The goal of the project was to measure differences in print quality when printing at the following temperatures: 18°C, 22°C, 26°C and 30°C. The temperature of 26°C is the normal printing temperature at GATF. This is why we chose to select the other temperatures below and above 26°C, with a four-degree shift.

Tests on press - Necessary tools:

- The press:

The sheetfed press used was a 2000 Heidelberg Speedmaster SM 102 located at the GATF in Sewickley, PA, USA. Each unit has four ink form rollers and the dampening unit was used in the direct mode.

A Technotrans cooling system injects cooling liquid in different rollers *(Figure 1)*. First the liquid goes through the ink fountain roller, and then it goes into three ink distributor cylinders. The second cylinder is in contact with the third and the last ink form rollers and the last one is in contact with the first and the second ink form rollers.

A thermal KPG Electra CTP plate was used for the tests. The total coverage areas of the first plates (from run 1 to 7) were 56% for black, cyan and magenta and 55% for yellow. For the second plates (run 8), it was 58% for black, magenta and yellow and 57% for cyan. These results can be used to calculate the ink thickness as described by J. Lind and J. Mac Phee (1991).

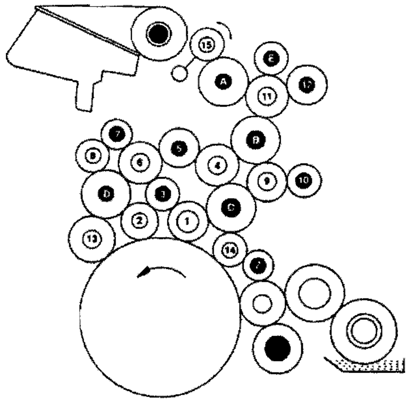


Figure 1: Roller layout (from Heidelberg Speedmaster SM 102 operator's manual). The temperature of the fountain roller and that of rollers A, D and C are controlled. Roller "z" was not used during testing (direct dampening).

- Printing temperatures:

During the print runs, the "printing temperature" was measured on the last ink form roller with a Rayteck IR pyrometer in order to check that there were no significant variations. For the tests, four printing temperatures were chosen: 18°C, 22°C, 26°C and 30°C.

During each of the eight runs, the temperature of the last ink form roller was measured. The experimental temperatures did not overlap. Steady temperatures were easier to achieve at 22 and 26°C: they remained within a 2°C range around the target temperatures, whereas the errors at 18°C and 30°C were ± 1.5°C. These two intermediate temperatures (22°C and 26°C) were close to the ambient pressroom temperature, which varied between 22 and 23°C.

- Materials:

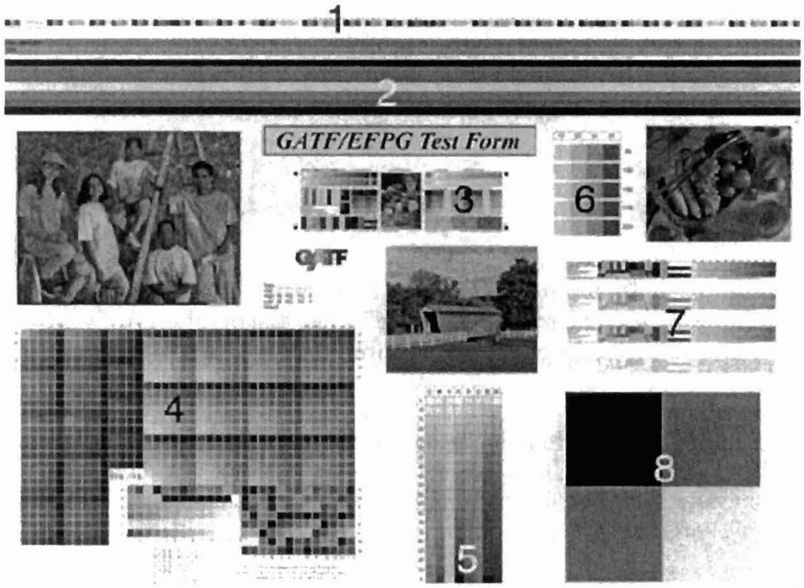
The inks used for these experiments were INX OSF Vision Black, Cyan, Magenta and Yellow. The paper used was 80 g/m² Lustro Gloss, a coated paper donated by SAPPI. It is a 120g/m² paper with a bulk of 0.8 cm³/g. Its Bekk smoothness is very high: 1200s. The Cobb 1 min, which qualifies the absorption of water, is 30 g/m².

Procedure for print runs:

The print sequence was black, cyan, magenta and yellow. The wet density targets were: Black=1.85, Cyan=1.45, Magenta=1.55, Yellow=1.00. Each run was printed at 10,000 sheets per hour (industrial speed) and 1,000 sheets were printed. Each time we ran an ink consumption test, 2,000 sheets were used. 20 random sheets were removed from each print run.

Print quality measurements:

The quality of printed sheets was evaluated using different measurements. Thus the test forme (figure 2) had to display all the targets and control bars for the following purposes. Here is the layout of the test form and its different targets.



1: Control bar
2: Take-off bar
3: Proof comparator
4: IT 8 / 7.3 target
5: Tone scales
6: Dot size comparator
7: Plate control target
8: Mottle patches or solid blocks

Figure 2: Test forme

- Densitometric measurements:

A reflection densitometer (X-Rite Spectrodensitometer 500 series and an X-Rite ATS System, Auto-Tracking Spectrophotometer Software) was used. It was calibrated to status T which is the density response standard for the graphic arts in the United States *(T-Ref, Graphic Communications Association, Alexandria, VA, USA).*

With the X-Rite Spectrodensitometer, variations in the densitometric values during each print run were observed out of the 20 sheets removed from each print run are taken). With the ATS system, the control bars were scanned to obtain a mean, a standard deviation, as well as the minimum and maximum values.

- Colorimetric measurements

A spectrophotometer (X-Rite Spectrodensitometer 500 series and a Gretag SPM 55) was used with a geometry of 0/45°. It measures the spectral reflectance of printing samples by illuminating the sample and measuring the percent reflectance at each wavelength throughout the entire visible spectrum. We measured:

- L^*, a^*, b^* data (CIELAB) (figure 2, targets 2, 4 and 5).
- Spectral reflectance curves (figure 2, targets 2 and 4).
- Gray balance (figure 2, targets 2).

- Image analysis

For each print run, the overprint areas were observed using image analysis. An Agfa Fotolook 2.5.1 software was used. Solid patches were observed with an enlargement of 50 and midtones with an enlargement of 100.

Ink property measurement

The project also studied the inks used during the printing tests.

- Ink consumption:

During the print runs, the ink consumption was measured at two different temperatures to check the possible influence of temperature. The ink consumption procedure was the one described by Lind and MacPhee (1991).

- Rheological properties

A Carrimed CSL^2 500 rheometer with a cone-plate geometry (2 cm diameter and 4° angle) was used for flow and oscillation experiments. For the flow experiments, the shear rate varied and the stress was measured at 14, 18, 22, 26, 30 and 34 °C.

The viscosity was measured at 10 s^{-1} (rheometer limit). However, Barnes (1989) mentions that a typical shear rate on a press varies from 10^{-2} to 10^5 s^{-1}. Eyring's equation gives viscosity as a function of temperature:

$$\eta = A \times \exp\left(\frac{E_a}{R \times T}\right)$$

where η is the viscosity measured at 10 s^{-1}, A is a constant depending on the frequency of intermolecular vibration, T is the temperature in K, R is the gas constant (R=8.32 $J.mol^{-1}.K^{-1}$), and E_a is the activation energy of flow in $J.mol^{-1}$.

The oscillatory flow experiments were conducted on the same cone-plate rheometer, within the appropriate stress and frequency ranges. Preliminary experiments were performed in order to establish the linear viscoelasticity domain. Oscillation frequencies were scanned in a logarithmic mode, from 0.1 to 20 Hz (rheometer limit), at 18, 22, 26 and 30°C. The storage modulus (G') and loss modulus (G") were measured. The loss tangent (tan δ) and dynamic viscosity (η') were calculated.

- Tack:

The Inkometer was used to determine the tack and stability of offset printing inks. The measurements were taken at 1200 rpm during 10 minutes at 32.2°C using 1.32 cc of ink.
The measurements were also taken on a Tack-O-scope at 150 m/min during 10 minutes at 14, 18, 22, 26 and 30°C, using 0.6 cc of ink.

II. Results and Discussion

A. Printing Quality Measurements

- **Density** (tone scales on the test forme)

The purpose was to have the same solid ink density settings for all the printing runs at different temperatures. The GRACoL guidelines (2000) points out that average print run variations can reach ± 0.10 for solid ink density. The SWOP recommendation is to have a standard deviation lower than ± 0.07.

verage SID	Run 1 (22°C)	Run 2 (26°C)	Run 3 (30°C)	Run 4 (18°C)	Run 5 (22°C)	Run 6 (26°C)	Run 7 (30°C)	Run 8 (18°C)	Tar gets
lack	1.64	1.65	1.56	1.44	1.63	1.54	1.59	1.68	1.85
Std dev	0.03	0.04	0.04	0.14	0.03	0.02	0.03	0.11	0.07
yan	1.28	1.25	1.25	1.23	1.30	1.26	1.25	1.43	1.45
Std dev	0.04	0.04	0.06	0.05	0.03	0.03	0.04	0.08	0.07
lagenta	1.38	1.39	1.34	1.19	1.37	1.36	1.35	1.55	1.55
Std dev	0.03	0.04	0.05	0.17	0.03	0.02	0.04	0.06	0.07
ellow	0.94	0.89	0.89	0.89	0.95	0.98	0.97	0.89	1.00
Std dev	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.02	0.07

Table 1: Average solid ink densities and standard deviations for each print run.

For the yellow ink (table 1), the density remains steady during each run and closest to the target density. But all densities for the other colors are less than the corresponding target densities. As a matter of fact, target densities dealt with wet ink but densitometric measurements were made after drying. The drying changed the optical properties of the ink (change in the structure of the binder). For black, cyan and magenta colors, densities remain steady during each run at 22, 26 and 30°C, except for the first sheets of run 1, 2 and 3.

On the other hand, at 18°C, densities drop during the whole run and standard deviations often reach 0.07 to 0.10 (which is significant). Moreover, at this printing temperature, we observed stripping on the ink fountain cylinder. Areas without ink were visible on each fountain cylinder, as the corresponding ink could not wet the latter. This can explain the density variations and decreases at this temperature.

- **Tone value Increase (TVI)** (tone scales on the test forme)

According to the GRACoL printing guidelines (2000), for good quality printing on a gloss coated paper (printed at 175 lpi like in the GRACoL #1 coated category), the expected total dot gain should be 22% for black, 20 % for cyan and magenta and 18 % for yellow. Moreover for good printing, it is recommended that the total dot gain value should not differ by more than a total of 3% in opposite directions from their target values. The results presented here are obtained with the Spectrodensitometer.

Figure 3 (black) shows that only the 22 and 30°C TVI averages (± standard deviation) remain in the range recommended by GRACoL (lower and upper limits). For this reason, they can be considered good printing temperatures. Nevertheless, the TVI at 18 and 26°C are close to the recommended range but show larger standard deviations.

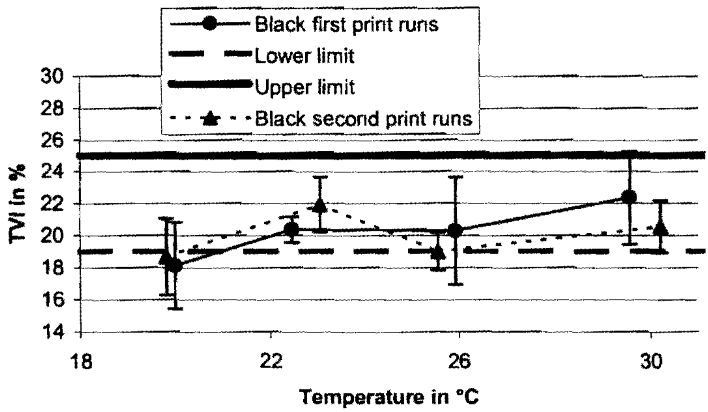


Figure 3: Variation of 50% TVI averages (± standard deviations) as a function of printing temperature for black.

In figure 4 (cyan), only the 22 and 26°C TVI averages (± standard deviation) remain within the GRACoL range. The TVI averages at 18°C are just below the range and the 30°C TVI values are too much scattered.

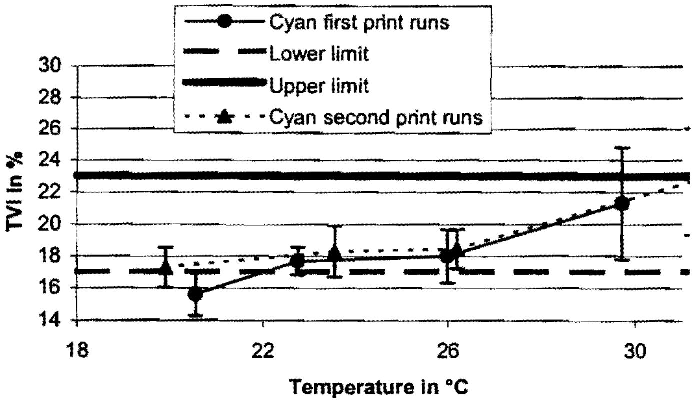


Figure 4: Variation of 50% TVI averages (± standard deviations) as a function of printing temperature for cyan.

In figure 5 (magenta), only the 22 and 26°C TVI averages (± standard deviation) remain within the GRACoL range.

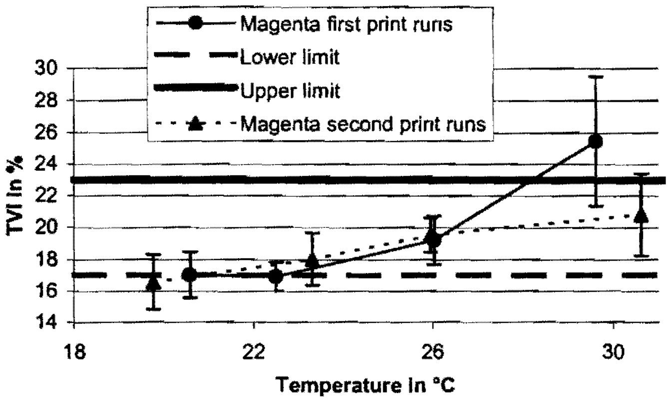


Figure 5: Variation of 50% TVI averages (± standard deviations) as a function of printing temperature for magenta.

For the yellow ink, (see figure 6), the 18 and 22°C TVI averages (± standard deviation) remain within the GRACoL range. The 30°C values are all above the upper limit.

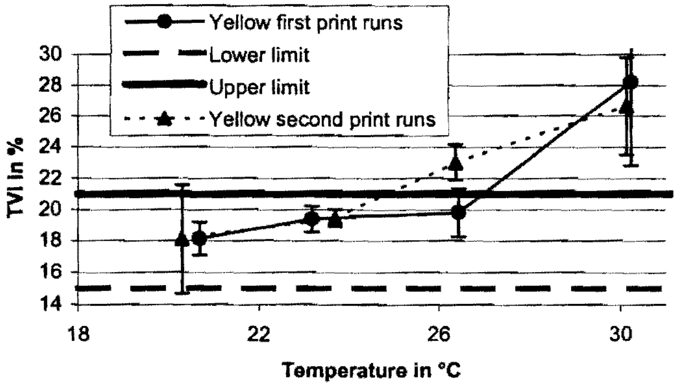


Figure 6: Variation of 50% TVI averages (± standard deviations) as a function of printing temperature for yellow.

Yellow and magenta appear to be the most affected by the temperature. Their tone value increases show a significant difference between 18°C and 30°C. Just as the 50% tone values increase, the 75% tone values increase with the printing temperature. Moreover, on figures 5, 6, 7 and 8, the standard deviations are higher at 18 and 30°C. This can be explained because 18 and 30°C are temperatures far from the ambient temperature. Thus they were difficult to keep steady, and could affect the printing quality.

As far as TVI is considered, 22°C is the best temperature to obtain good quality: small standard deviations, meeting GRACoL specifications.

- **Contrast**

For print contrast, GRACoL specifications (2000) suggest a print contrast range between 40 and 45% for the black, between 35 and 40% for the cyan and the magenta, and between 30 and 35% for the yellow. In figure 7, the black and cyan print contrasts remain within their range for all experimental temperatures, except 30°C. The magenta contrast does not meet the specifications at 18°C and 30°. As to the yellow, the print contrast deteriorates above 26°C.

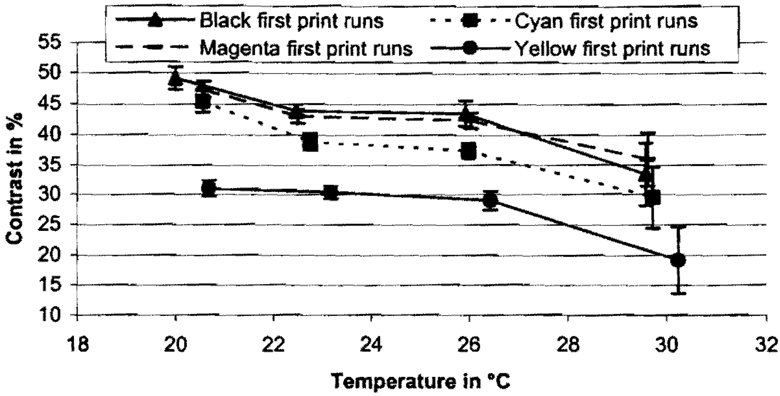


Figure 7: Variation of print contrast averages (± standard deviations) as a function of printing temperature.

- **Trapping**

Table 2 shows that the different temperatures studied induce practically no trapping variation.

Average trapping (%)	Run 4 (18°C)	Run 1 (22°C)	Run 5 (22°C)	Run 6 (26°C)	Run 2 (26°C)	Run 3 (30°C)	Run 7 (30°C)
Blue	67	69	68	70	71	70	69
Std dev.	2.1	2.8	3.5	2.2	1.6	1.4	1.4
Green	86	86	86	88	87	86	85
Std Dev.	0.9	2.3	1.0	1.3	0.7	1.0	2.1
Red	80	79	77	77	74	77	76
Std Dev.	3.8	2.3	1.5	1.1	1.3	1.5	2.1

Table 2: Average trapping and standard deviations for each print run.

Image analysis gives more information about the trapping quality. It seems that even if trapping remains steady in solids, the trapping quality of midtones changes with temperature.

First, in figure 8, a tone value increase can be observed. White areas are reduced when the temperature increases. Moreover, on these 50% tone pictures, lots of artifacts can be observed at 30°C: the printing looks dirty.

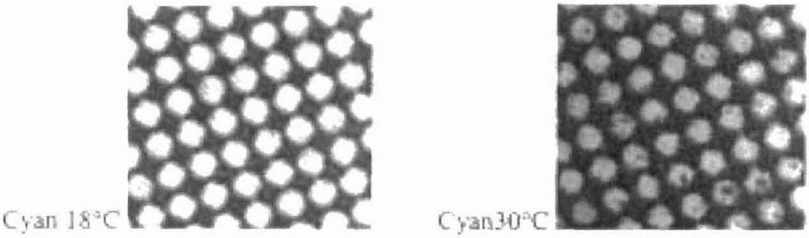


Figure 8: 50% cyan halftones at 18°C and 30°C.

Secondly, in figure 9, for the blue trap, an image analysis shows that as the temperature increases, the number of magenta dots increases. This could mean that magenta does not print well on the cyan when the temperature increases.

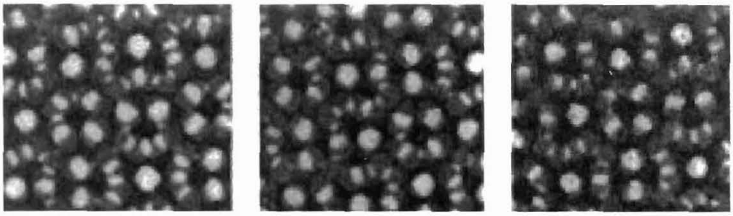


Figure 9: Blue trap in midtones at 22, 26 and 30°C

Then, even if the measured trap data do not change, the trapping quality appears better at lower temperatures, probably due to higher tacks.

- **CIELAB Colorimetry**

The variations of L^*, a^* and b^* as a function of the printing temperature are presented. No significant variation can be noticed.

ΔE values were calculated using 22°C as the reference temperature, because it appeared to be the best printing temperature for good densitometric results.

Average printing temperature in °C	ΔE						
	Black	Cyan	Magenta	Yellow	Blue	Green	Red
19.9	3.6	1.8	5.5	0.4	2.9	3.8	3.2
26.0	2.2	1.6	8.5	4.7	7.7	3.4	5.1
30.5	2.3	2.0	6.5	2.0	6.7	2.0	3.2

Table 3: ΔE (solid patch) values for different colors and printing temperatures.

Printing at different temperatures leads to colorimetric differences. In table 3, magenta, blue, green and red colors show higher ΔE values (from 2.0 to 8.5) than other colors. These color differences are high enough to be perceived by human eyes. Moreover, in most cases, ΔE is lower between 22°C and 18°C than it is at other temperatures.

- **Gray Balance**

With the L^*, a^*, b^* measurements, it is possible to evaluate whether the gray balance is good. L^* must remain between 50 and 60, whereas a^* and b^* must be as close as possible to 0. The results are presented in table 4.

Printing temperature in °C	Gray 50% black			Gray 50% cyan, 39% magenta, 39% yellow			ΔE
	L^*	a^*	b^*	L^*	a^*	b^*	
19.9	58.5	-0.1	-1.5	57.0	-1.6	-1.8	2.2
20.5	61.1	-0.1	-2.2	58.1	-0.9	-1.6	3.2
22.7	59.6	-0.1	-1.65	59.1	-1.9	-0.3	2.2
23.4	57.4	-0.2	-1.75	55.7	-2.1	0.3	3.3
26.0	58.1	-0.2	-1.8	55.6	-1.4	2.7	5.3
26.1	58.8	-0.2	-1.6	56.4	-1.1	0.7	3.4
29.8	58.0	-0.2	-1.6	55.0	-0.8	0.8	3.9
30.5	55.0	-0.2	-1.5	54.1	-1.9	-0.0	2.5

Table 4: average L^*, a^*, b^* values for grays at different printing temperatures.

The 50% black grays tend towards the blue. All data are close. The three-color gray data are more scattered. They tend towards the green. Moreover, when the printing temperature increases, the value of b^* tends to be higher and evolves towards the yellow. Previously, densitometric results showed that the yellow TVI was most affected by the temperature. This higher TVI explains the tendency towards the yellow for the b^* measurements.

Applying different printing temperatures seems to have little effect on the colorimetric properties: L^*, a^*, b^* do not vary. The only significant effects come from the densitometric results. The 22°C printing temperature offers the best compromise in terms of TVI for each color. Moreover, print contrast is better at lower temperatures. However, the temperature does not affect the trap values but seems to affect the quality of trapping.

B. Inks Properties

- **Ink behavior**

At 22 and 26 °C, the inks reached the expected temperatures easily. However, to get the printing temperature of 30°C, the cooling liquid had to flow through the sheetfed press at 36°C. The make-ready was longer than for previous temperatures and the densities varied more.

To print at 18°C, the cooling liquid had to go through the sheetfed press at 10°C. Pressmen had many difficulties to set densities and the latter dropped during the whole runs (we had agreed that the press operator was not to adjust densities during the experiments). Moreover, we observed stripping on the ink fountain cylinder. The magenta and cyan units were the most affected.

- **Ink consumption**

Ink consumptions were measured at 22°C and 30°C.

Color unit	22°C	30°C
Black	85	8
Cyan	98	95
Magenta	91	111
Yellow	124	122

Table 5: Ink consumption in grams at 22 and 30°C.

Table 5 shows that there are no real differences in terms of ink consumption when we change the printing temperature.

- **Rheological properties**

Rheological properties have a direct effect on ink transfer and thus on print quality. In order to characterize the inks, flow and oscillation experiments were carried out. With the flow curves, it appears that when the temperature increases, the viscosity and the thixotropy decrease. At low shear rates, a slipping phenomenon was observed.

The power law model is the most adapted to describe the behavior of these inks:

$\sigma = K \times \dot{\gamma}^{n}$ where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency ($Pa.s^n$), n is the power law index.

Temperature in °C	Yellow		Magenta		Cyan		Black	
	K ($Pa.s^n$)	n	K ($Pa.s^n$)	n	K ($Pa.s^n$)	n	K ($Pa.s^n$)	n
14	386.3	0.80	220.7	1.11	453.1	0.84	509.1	0.72
18	263.8	0.81	349.6	0.81	346	0.81	279.5	0.83
22	245.9	0.76	232.6	0.84	276.4	0.82	178.7	0.85
26	130.6	0.79	215.1	0.81	195.3	0.82	114.7	0.86
30	91.53	0.78	152.5	0.80	129.3	0.81	91.58	0.83
34	74.59	0.73	112.5	0.78	93.29	0.80	62.75	0.85

Table 6: Variation of K and n for different inks at different temperatures.

As the temperature increases, the consistency of each ink decreases (see table 6). The power law index decreases for cyan and magenta when the temperature increases, which means that the flow behavior becomes more and more shear thinning. We can therefore expect the ink transfer to deteriorate as the temperature increases: poor uniformity and a higher tone value increase.

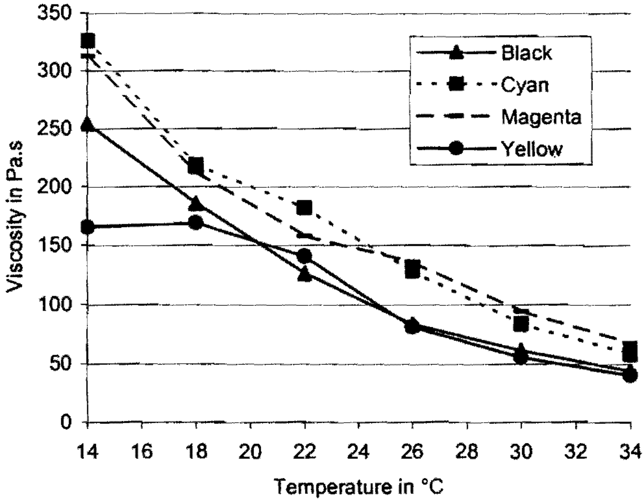


Figure 10: Variations of viscosity as a function of temperature ($10 s^{-1}$ shear rate).

The variations of viscosity as a function of temperature were plotted at $10\ s^{-1}$ (figure 10). When the temperatures increases, the viscosity decreases from 330 down to 60 Pa.s for the cyan and from 170 down to 40 Pa.s for the yellow. For all temperatures, cyan is more viscous than magenta, black and yellow. However, as the temperatures increase, the viscosity differences between inks decrease.

The activation energy of flow indicates how sensitive to temperature the ink viscosity is. The activation energies were calculated and are displayed in table 7. Blayo (1993) measured their values around 80 kmol/J for quickset inks.

Color	Activation energy in kmol/J
Black	65.7
Cyan	62.1
Magenta	54.0
Yellow	57.1

Table 7: Activation energies of flow of the tested inks.

The inks used for the printing tests seem less sensitive to temperature than what could be expected. This explains why the variations in colorimetric results remained low when the temperatures varied.

However, results here contradict densitometric results. Indeed, as far as the 50% TVI is concerned, magenta and yellow were the most sensitive to the temperature. However, they show the lowest calculated activation energies and should therefore be less sensitive to temperature variations. We must here recall that the activation energy is calculated at 10 s^{-1}, whereas on a sheetfed press the shear rates are higher (10^{-2} to 10^{5} s^{-1}, Barnes (1989)).

Oscillation experiments were also carried out. The storage and loss moduli (G' and G") increase and the dynamic viscosity (η') decreases when the oscillation frequency increases. It is also pointed out that the storage modulus and the dynamic viscosity decrease when the temperature increases. Thus, during a cycle, when the temperature increases, less energy is stored or released. From elsewhere, the storage modulus is higher for magenta than for cyan, yellow and black.

For the variations of the loss tangent, it was noticed that as the frequency increases, tan δ tends towards 1, thus improving the elastic behavior. Moreover, a decrease in the temperature also improves the elastic behavior. A more elastic behavior implies a better rendering of the dots.

Finally, it seems that magenta is the only color whose behavior does not tend towards a better elasticity. The degradation in the trapping quality of magenta halftones could result from this (see fig. 9). Moreover, it can be noticed that the behaviors of other inks are closer at 18°C than 30°C. Tan δ decreases towards 1 faster for yellow than for black and cyan.

- **Tack**

The Inkometer results present in figure 11 show that the inks used had a steady tack. A little increase is observed during the 10 minutes period. The Tack-o-Scope results display the same tendency.

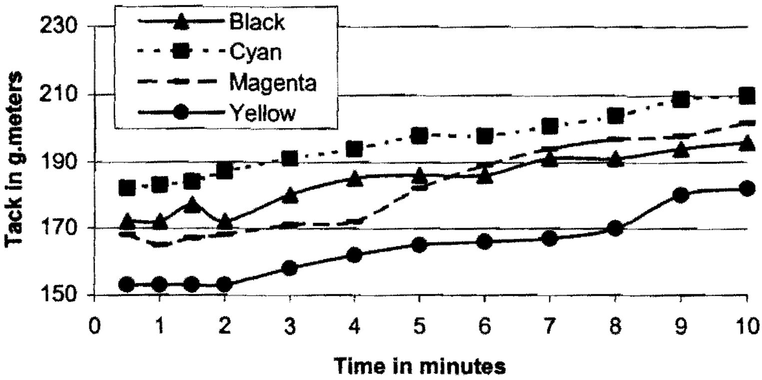


Figure 11: Variations of tack (Inkometer) during 10 minutes at 32.2°C.

Out of these experiments, we considered the tack measured at 1 min on the Tack-o-Scope. Figure 12 shows its variation for the different colors.

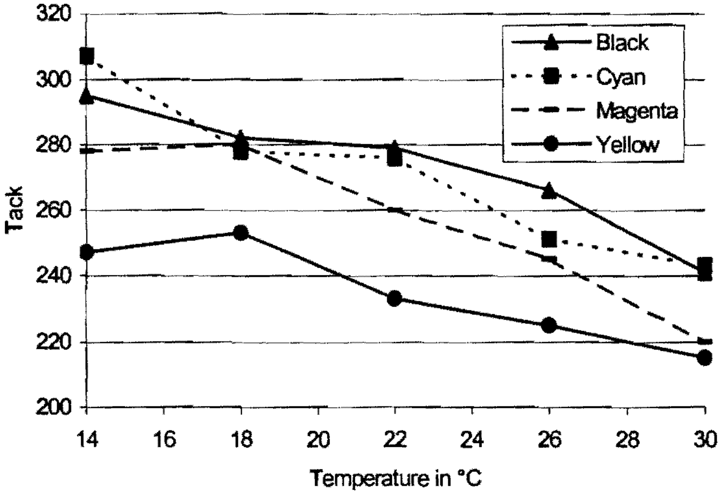


Figure 12: Variations of tack (1 min) as a function of printing temperature.

The tack drops when the temperature increases. Tack values of cyan and magenta are the most affected by the variations in temperature. These results are different from those obtained for viscosity.

The study of inks properties showed that cyan and magenta were the most sensitive inks as far as viscosity, tack, tangent of loss angle were considered. If the activation energy of flow was considered, black and cyan were the most sensitive.

Regarding the densitometric and colorimetric results, the magenta and the yellow colors were the most affected by printing at different temperatures.

Thus, we found a correlation between the print quality results and the ink properties for the magenta only. Cyan was very sensitive to the temperature in the lab but induced low variations in print quality. Cyan is known for its stability on press. The print quality varied a lot with the yellow ink when temperature varied, but the ink properties measured in the laboratory did not show such sensitivity to the temperature.

Conclusion

Temperatures have an effect on the print quality. The print runs at different temperatures showed differences in terms of printing quality.
Concerning densitometric results, TVI is the most affected value when the temperature changes. Moreover, differences in the trapping quality were observed in halftones. The temperature of 22°C appears as the best compromise in terms of densitometric results. The magenta and yellow inks were the most affected by the temperature changes.

Concerning the colorimetric results, ΔE was calculated for CIELAB measurements. This calculation showed that printing at different temperatures could give important differences in terms of color (ΔE>2).

The temperature also affects the ink behavior. Rheological properties and tack showed that some inks (here, magenta and cyan) are most affected than others by temperatures changes.

These observations lead to possible interpretations or to need for further investigations. Indeed, it appears that the last two inks in the press sequence (magenta and yellow) are the most affected as far as print quality is concerned. We cannot exclude the possibility that their position on press has something to do with the variations in print quality:
- they are printed on a "wet" paper (the paper has already received some dampening solution two times before being printed in magenta and three times before being printed in yellow),
- the paper temperature itself may have varied between the first unit and the last one,
- the tack of these last inks is slightly lower than the tack of the black and cyan inks.

Therefore, the same type of tests on press should be carried out with a change in the color sequence (for instance yellow, magenta, cyan and black).

Moreover it was noticed that a rise of the temperature lowers both tack and viscosity. Nieminen (1992) showed that both tack and viscosity affect emulsification. We may therefore hold a possible explanation for the poor level and quality of trapping. Indeed, we reached a trapping level of 60 to 80% (rather than the 90% expected) and the photomicrographs showed a degradation of the dots shapes at 30°C. Therefore, the emulsification process must be studied more thoroughly to confirm the link between these two phenomena. Different methods of emulsification could be applied in the laboratory (Litho-Lab™...).

More experiments with different inks series would complete this study and confirm these results. However, this project showed that printing temperature cannot be neglected since it may definitely affect print quality.

Moreover, only short print runs were made, so that it was not possible to check potential differences in the process runnability as a function of the temperature in the long run (easy make-ready, fewer clean-ups ...).

Finally, the gain achieved in print quality should not cost the printer more because the electrical power consumed to set the cooling liquid at 18, 22, 26 or 30°C is almost the same and should not affect the energy costs much.

Acknowledgements

The authors wish to thank the Graphic Arts Technical Foundation, as well as Mr. Bussière and the board members of the foundation "Oeuvre des Retraités et des Orphelins du Livre" for their active support of this project.

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