

Effects of Ink - Fountain Solution Interactions on Piling in Heatset Printing

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Abstract

In this study on-line measurement devices were utilized to clarify how the changes in fountain solution properties affect formation of non-image area piling during printing. On-line measurements of pH, conductivity, redox potential, temperature, and calcium content were installed to measure fountain solution quality. Chemical impurities in the fountain solution cycle are mainly due to dissolution of ink. The dissolution increases concentration of dissolved cations such as aluminum and calcium, which increases hardness and conductivity. This has implications both to the press runnability and product quality. Non-image area piling on blanket originates from the plate. Ink spreads to the non-image area of the plate and ends up on the non-image area of the blanket. A part of it continues further to the paper. On-line measurements of water, ink pigment, and ink binder were used to follow the interactions of ink and fountain solution on plate and blanket. The findings were verified by visually observing the press with triggered micro-imaging. When fountain solution feed level is correctly adjusted, the main reason for the non-image area piling is poor ink stability on the plate. High amounts of cations in fountain solution may separate ink pigment particles from the ink binder. The phenomenon is seen as ink pigment particles on the non-image area of the plate, and it is significant especially when the same fountain solution has been utilized for a long period of time.

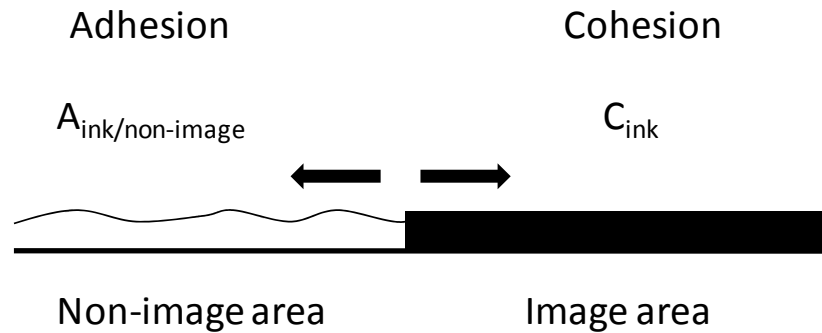
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Introduction

Non-image area piling on blanket in offset printing is traditionally considered as an unavoidable process property. The piling looks like ink and it is visible to the naked eye after several thousands of copies. This piling can cause uneven dot gain leading to ghosting or decreased dot sizes, causing finally vanishing dots. It affects both press runnability and productivity. At worst, even 10% of the efficient printing time goes to removing these accumulations from the printing blanket thus lowering the productivity. (Passoja et al., 2007)

Fountain solution is a chemical mixture of several different ingredients dissolved in water in a homogeneous phase. Its primary functions are to form an emulsion with ink, prevent the printing plate from scumming, and protect the printing machine by lubricating and cooling (Tam, 1995). Depending on the printing unit and the dampening system, the fountain solution may emulsify into the ink, either in the roll nips of the inking device before the printing plate, or on the plate surface as the fountain solution and ink come into contact with each other. While the inking rollers run over the surface of the plate, the ink absorbs a certain amount of fountain solution in the split between the roller and the plate surface. The fountain solution diffuses into the ink as droplets and an ink/fountain solution emulsion is formed. The forces between the ink and the fountain solution depend on molecular interactions between their components. These components include surface-active additives in the fountain solution such as isopropyl alcohol or non-ionic surfactants, as well as the components in the ink (MacPhee, 1993; Wickman et al., 1997).

In offset, ink transfers to the printing area of the printing plate by the principle of contact and split. This requires that the adhesion force between the ink and the plate ($A_{\text{ink/image}}$) is greater than the opposing force, i.e., the ink cohesion (C_{ink}). Ink should not transfer to the nonprinting areas. This means that adhesion ($A_{\text{ink/non-image}}$) should be smaller than ink cohesion. After transfer to printing areas, the ink should not migrate sideways. A spreading parameter, S , defines the tendency of ink to spread sideways from printing areas to non-image areas. S is the difference between ink adhesion to the non-image area and ink cohesion as Figure 1 shows. S should be negative to prevent spontaneous spreading. Water is necessary since it reduces ink adhesion to the non-image areas; it also decreases the spreading coefficient (Oittinen and Saarelma, 2000).



$$S = A_{\text{ink/non-image}} - C_{\text{ink}}$$

Figure 1. Definition of spreading coefficient.

The fountain solution should be usable with a wide range of inks and papers used in the printing press. In offset printing the fountain solution feed range, the so-called “working water window,” controls this. As the printing proceeds, the fountain solution feed should be at such a level that the surface of the plate is covered with a thin film of emulsion. The fountain solution feed rate is adjusted according to the water window, which depends on the printing ink and the absorption ability of the paper. The water window defines the appropriate fountain solution feed rate for good print quality without water-related printing problems (between toning and water marking). The water window depends on the properties of the fountain solution, ink, printing plate, and external process factors (e.g., temperature) (Lee, 1998; MacPhee, 1993).

The fountain solution conductivity is commonly used as a measure of solution purity; it is not an exact functional property of the solution. The conductivity describes the solution’s ability to conduct electricity. As ionic substances are dissolved into the fountain solution, the ions formed make the fountain solution conductive. The effect of fountain solution quality on printing performance has been discussed previously in the literature. High fountain solution conductivity (high magnesium and calcium content) is reported to disturb the offset process by generating non-inked particles in the image areas (Tosch et al., 1991). Pineaux et al. (1997) concluded that water hardness affect the behavior of the

dampening solution. They detected the relation between fountain solution hardness and print contrast.

This paper demonstrates the effects of fountain solution purity and interactions between ink and fountain solution on printing performance and print quality. New on-line monitoring equipment was used the first time to observe these phenomena. Findings about the role of the fountain solution on non-image area piling are presented.

Experimental

Fountain solution was prepared with local tap water using 3.5 V-% of Vegra Alco-damp RED 3232/869 Zi dH N additive. The fountain solution was alcohol-free having pH of 4.7. The solution can be classified as soft water, since the hardness value was below 8°dH. Fresh fountain solution refers to a fountain solution which was prepared just before the trials. The used fountain solution was acquired from the printing press after a few days usage.

Commercial thermal CTP printing plates and commercial blankets were used in this study.

High-pigment magenta ink was used in this study. Magenta ink was chosen due to the contrast requirement of micro-imaging on a blue blanket surface. Ink element composition was analyzed using a Hitachi S-3400N scanning electron microscope (SEM) with an energy-dispersive X-ray (EDS) detector.

A supercalendered (SC) paper was chosen for this study. The commercial supercalendered (SC, 56 g/m²) paper was provided from a paper mill in Finland. The paper included only clay as filler.

Printing trials were performed at KCL's heatset web offset press, Albert-Frankenthal A 101 S. The speed of the press was 5 m/s (about 40 000 copies/h). Only magenta ink was used. The target density for SC paper was 1.1. Ink transfer unit was observed. Pressmen controlled the ink and fountain solution feed on the basis of target density and print quality.

Single unit dampening system for isolated fountain solution circulation was used on upper side of the 4th unit for easier fountain solution measurements and deposit detection. It was possible to control the fountain solution temperature and keep it on a normal level (11–13 °C). The layout was planned so that there were measurement fields and enough space for all the on-line measurement devices.

In the trials, micro camera, KCL Inka, and KCL Hippo measured on-line the changes on plate and blanket surface in the 4th upper unit:

- Micro-imaging was used to capture still images of a rotating blanket and plate cylinder. The non-image area, 15% halftone area, and line images of the plate and blanket were studied. The basic principle, equipment, setup, and operating conditions of the micro-imaging system are presented in the literature by Passoja et al. (2007).
- KCL Inka measures the relative change of ink pigment, and KCL Hippo measures the relative change of water and ink binder on the non-image area of the plate and blanket before the ink transfer. KCL Hippo measures water band at 2900 nm and C-H band at 3400nm. KCL Inka measures magenta ink in region 590–600 nm. KCL Inka and KCL Hippo measurements are uncalibrated; therefore, we could only follow relative changes in ink pigment, water, and ink binder amount. The results are given as changes in absorption signal intensity.
- On-line measurements from the fountain solution tank were performed according to manufacturer's instructions using YSI-556 MPS multi-parameter probe and Consort C933 analyzer with calcium-sensitive electrode. YSI 556 MPS measures conductivity, pH, temperature, and redox potential. Consort C933 measures calcium content. In addition fixed instrumentation (temperature, pH, and conductivity) on the press was followed.

Fountain solution samples were taken during the trial runs for laboratory measurements. Elemental analysis of the fountain solution samples were performed with inductively coupled plasma atomic emission spectroscopy (ICP-AES). To determine the elements in dissolved and colloidal fraction the settleable solids were removed from the samples.

Results and Discussion

Dissolution of ions into fountain solution cycles

The dissolution of the metal ions into the fountain solution is a critical parameter for the printing process; increased dissolution increases hardness and conductivity. As mentioned in the introduction, high concentration of calcium ions in the fountain solution is known to be detrimental for the printing process. Calcium precipitates will disturb the offset process by reducing ink transfer on the inking rollers and blanket or on the plate, which leads to increased costs through production breaks, poor printing quality, increased usage of fountain solution, and/or increased use of water softeners.

Concentration of dissolved ions in the fountain solution cycle was monitored using on-line conductivity and calcium measurements. In stable conditions (same paper, ink, and fountain solution) the elements present in the ink started to concentrate into the fountain solution (Figure 2). It is seen that the linear increase in conductivity and calcium was not due to evaporation of water, since the content of elements like phosphorus and sulphur was not increasing even though these were present already in the fresh fountain solution (Table 1).

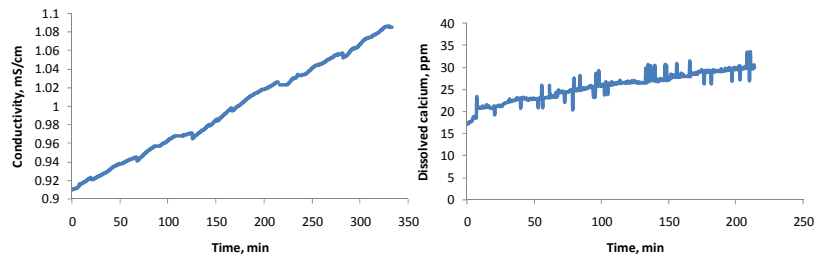


Figure 2. *The effect of dissolution of the ions into conductivity and hardness of fountain solution.*

Table 1 Concentration of elements in fountain solution during printing (total [tot] = sample taken from the press, dissolved [diss] = settleable solids removed).

Printing time, min	Mg	Al (tot)	Al (diss)	Si (tot)	Si (diss)	Ca (tot)	Ca (diss)	Fe	S	P	Co	Cu	Zn
0	5.4	2	2.0	9.7	9.7	25	25	0.2	11	67	0.1	0.5	0.03
40	5.8	3.9	3.9	13	13	25	25	0.3	11	66	0.09	0.4	0.04
65	6.0	6.9	5.0	13	14	27	27	0.4	11	66	0.09	0.4	0.04
85	6.2	8.4	6.2	15	15	29	29	0.5	11	68	0.1	0.4	0.05
90	6.1	8.1	5.2	14	14	29	28	0.4	11	67	0.09	0.4	0.04
130	6.6	11	6.1	18	15	31	31	0.5	12	68	0.1	0.4	0.05
155	6.9	14	7.1	22	17	34	34	0.6	12	68	0.1	0.4	0.06
180	7.0	14	7.7	23	17	34	34	0.7	12	68	0.09	0.4	0.06
CHANGE, %	23%	86%	74%	58%	43%	26%	26%	71%	8%	1%			
CHANGE, mg/l	1.6	12.0	5.7	13.3	7.3	9.0	9.0	0.5	1.0	1.0	0.0	-1	0.0

There was no calcium in SC paper, and thus all the increase in the amount of dissolved calcium was coming either from the ink or from the fountain solution. Since there was no increase in concentration of all the elements in the fountain solution, we can exclude the possibility that the fountain solution could have

concentrated due to evaporation. This leads to a conclusion that the increase in conductivity due to the increase of calcium was not originating from the paper. This excludes the possibility of calcium precipitations in machinery, filters, etc.

The impurities in fountain solution mostly originated from the ink and the role of paper on fountain solution quality was insignificant. The ICP-AES analysis in laboratory clarified that the content of aluminum, silicon, and calcium in the fountain solution increased during printing (Table 1). Based on an energy-dispersive X-ray spectroscopic (EDS) analysis of ink, it can be seen that these were the dominant elements in the ink in addition to carbon, oxygen, and sulphur (Figure 3).

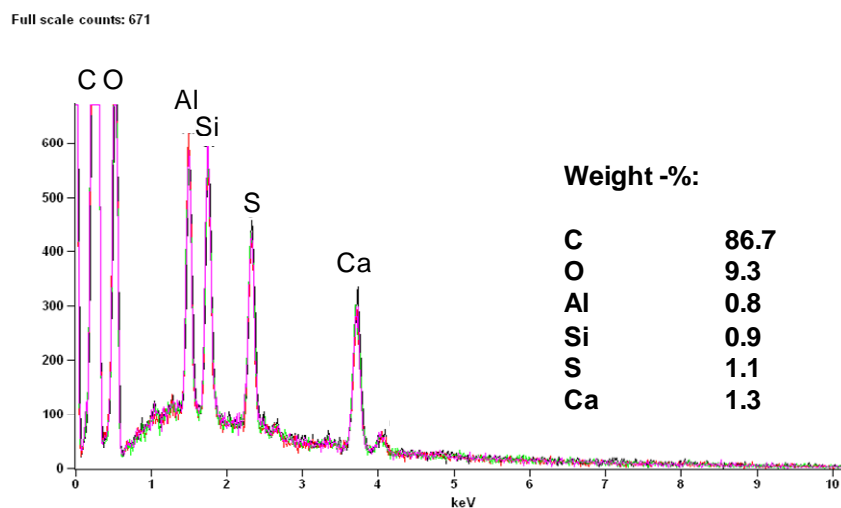
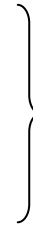


Figure 3. EDS analysis of magenta ink element composition and their weight-% in the ink.

The conductivity increase is almost fully explained by the increase of hardness and aluminum ion concentration. These explain approximately 83% of conductivity increase. The most significant factor in the conductivity increase was calcium and aluminum content increase. During the three hours printing trial in Table 1 conductivity increased approximately 7.5 mS/m. The calculation is based on eq. ionic concentrations at 25°C (Vanysek, 2008).

Increase in conductivity of individual ions explains this increase as follows:

- Calcium Increase 9 mg/l equals 2.6 mS/m
- Magnesium Increase 1.6 mg/l equals 1.1 mS/m
 Total 6.2 mS/m
- Aluminum Increase 12 mg/l equals 2.5 mS/m



Effect of fountain solution purity on printing performance

Instability of ink and fountain solution emulsion causes the appearance of some ink particles on the non-image area of the plate. Optimal fountain solution feed level is not able to prevent the phenomenon. The formation of ink particles on non-image area occurs despite the uniform fountain solution layer on the plate surface—it is not a pinhole mechanism. The ink pigment is present as individual small ink droplets, and they are expected to form by chemical mechanism between fountain solution and ink. Ink pigment particles enter the non-image area of the plate in nip contact with the inking roller. Deviation in fountain solution layer quality allows this. Dissolved impurities in fountain solution attract ink pigment particles. It is also possible that, after emulsification, the inner cohesion of ink decreases and the ink spreads more easily to the non-image area of the plate.

Used fountain solution was found to contain high amounts of multivalent cations such as calcium and aluminum. These cations easily adsorb on the surface of negatively charged particles which are present in ink and in fountain solution. High multivalent cation concentration decreases the thickness of the electrochemical double layer on the surface of the particle. The thinner the layer the easier the particles flocculate. Therefore high multivalent cation concentration makes it easier for ink and fountain solution particles to interact and form flocks with each other. This “unstable” state can cause ink (pigment) particles to spread to the non-image area. For fresh fountain solution conditions are more “stable” and ink particles remain more easily in the halftone dots. This is presented in Figure 4. The form of ink pigment molecule supports this theory. Pigment is a negatively charged salt with carboxylic (-COO⁻) group. Positively

charged cations in fountain solution attract these anions and might cause ink spots on the non-image area of the plate.

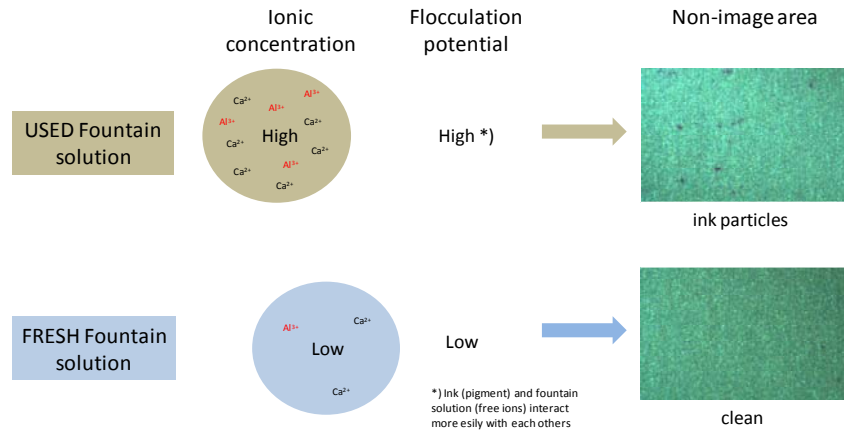


Figure 4. Non-image area piling for fresh and used fountain solutions.

Ink pigment and binder accumulation can be evaluated based on on-line measurements performed using KCL Hippo and KCL Inka devices. The devices measure ink binder and ink pigment content on the plate and blanket. The differences between the accumulation of pigment and binder can be seen on Figure 5. The binder accumulation on blanket is insensitive to fountain solution purity. The binder accumulates with the same rate for fresh and used fountain solution. The pigment accumulation on the blanket behaves rather differently. The ink pigment accumulates on blanket more when used fountain solution is used. Pigment is the component that visually causes the piling and therefore fountain solution purity is must be taken into account in production printing. Especially for used fountain solution it seems that pigment and binder separates. The separation causes non-image area piling of ink pigment.

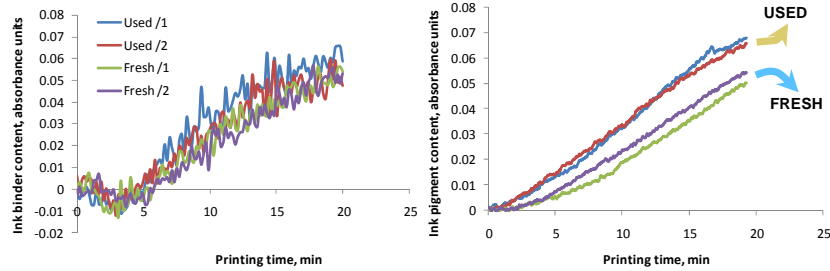


Figure 5. Accumulation of ink binder (left graph) and ink pigment (right graph) on blanket non-image area for fresh and used fountain solutions. Two curves for each fountain solution are parallel trials.

In principle, it is expected that ink binder and ink pigment should remain attached through the printing process. However, based on Figure 5, it seems that pigment and binder can separate under certain circumstances. The values in the figure are measured from the blanket, but the actual phenomenon is expected to happen already on the plate or during emulsification. The amount of binder on the non-image area of the blanket is insensitive to fountain solution quality.

Binder binds the pigment, and therefore ink pigment ends up in the same area with the binder. However, changes in fountain solution quality cause separation in ink pigment measurement opposite to ink binder measurement. With the used fountain solution it can be seen that the binder is not able to bind the pigment, but part of the pigment goes to the non-image area with the fountain solution.

The reason for different behavior of binder and ink is in their structural differences. Oil-based binders do not easily mix with water. Ink pigment particle is a negatively charged salt. Positive ions such as calcium and aluminum in fountain solution attract the pigment and compete with the binder. It is easier for the pigment to end up in the non-image area than for the binder.

Ink pigment particles appeared at random locations on the plate and disappeared during the next revolution of the plate cylinder. Due to the random behavior of the phenomenon it is obvious that the problem is not due to deviations in the plate surface quality or uneven wearing of the plate. Ink particles are transferred

to the blanket surface as a piling buildup and even further to the paper (Figure 6). This is suggested as the cause of piling build-up on the blanket.

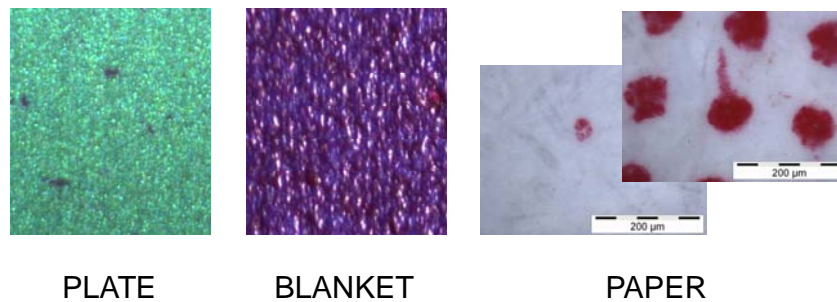


Figure 6. Ink pigment particles on non-image area of plate (left) and blanket (middle), and on non-image and half-tone area of the paper (right).

According to micro camera images, the fountain solution purity had an effect on the piling (including both ink pigment and binder) on the blanket surface. It can be seen that with used fountain solution the accumulation layer covered the blanket more evenly and the halftone dots were smaller (Figure 7). Ink particles filled the non-image area between the dots. The piling is not only ink but it also gathers components from the paper as was shown in earlier study by Passoja et al. (2007). Smaller dots on the blanket also caused differences in printed samples. The dot gain results showed that with used fountain solution the dot gain was smaller (11%) compared to dot gain with fresh fountain solution (13%) in the 15% image area.

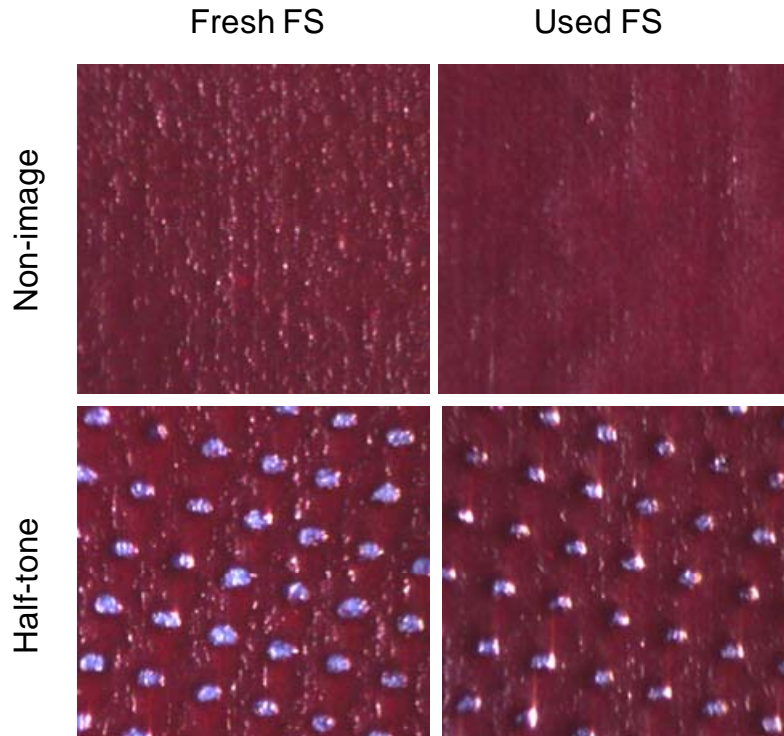


Figure 7. Piling on the blanket with fresh and used fountain solution.

Conclusions

Piling formation on the blanket surface can be explained by the instability of ink-fountain solution emulsion. Ink pigment particles are small droplets of ink that are transferred with fountain solution to the non-image area of the plate. The droplets are formed due to the flocculation caused by multivalent cations in the fountain solution cycle. The phenomenon is substantial especially with used fountain solution. The droplets are formed at random locations on the plate, transferred to the blanket and partly further to the paper.

Impurities in fountain solution originate from ink. This is noted during printing in terms of increased concentration of aluminum and calcium in the fountain solution cycle. The increased amount of ink particles in the fountain solution

cycle increased the conductivity of the fountain solution. The role of paper on the fountain solution quality was insignificant. The fountain solution purity affects piling formation on the blanket; with used fountain solution the accumulation layer covered the blanket more evenly and the halftone dots were smaller than with fresh fountain solution.

On-line tools monitor piling tendency during printing. The tools are potential for evaluating the compatibility of plate, ink, fountain solution, blanket, and paper during printing. Plate monitoring shows the instable behavior of ink emulsion and the wetting ability of the fountain solution providing means to adjust the ink-fountain solution feed levels. Furthermore, the piling tendency of the blanket can be followed during printing to optimize the washing frequency and runnability.

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