Paper, Ink and Press Chemistry

Exploring key print variables

Paper, Ink and Press Chemistry,
the eighth technical brochure from Sappi

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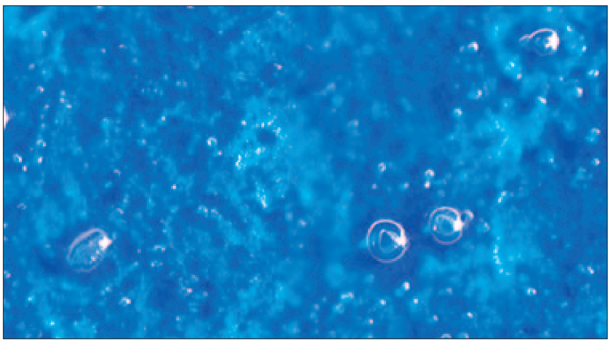


I Introduction

A final printed piece has three components: paper, ink and fountain solution emulsified in the ink. These key components are complex in composition and the process of bringing them together to satisfy a broad range of customers is extremely challenging. As a producer of one of these components, Sappi has studied the printing process and wishes to support our printing partners with this technical brochure. Its purpose is to describe paper, ink, press chemistry and their interactions.

We have learned the importance of identifying the key variables in a process and developing measurement techniques to help control these fundamental variables. We will share some of the test methods that simulate the printing process as an important component of diagnosing and controlling the process.

We start with water, often overlooked but critical to fine printing.

Water hardness	1 soft	2 average	3 hard	4 very hard
Total hardness as: *mmol alkaline-earth ions/litre	0–1.3	1.4–2.5	2.6–3.7	>3.7
German hardness °d	0–7	8–14	15-21	>21
English hardness °e	0–9	10–18	19–26	>26
French hardness °f	0–13	14–25	26–37	>37

* mmol/litre = 1/1000 of the molecular weight in grams per litre

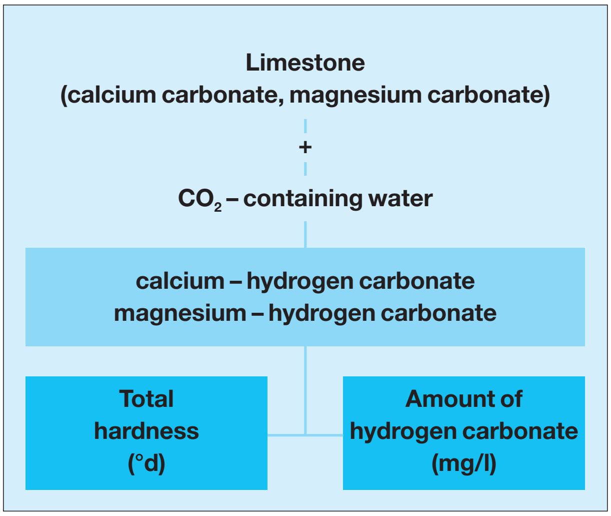
Conversion table of different standards for water hardness

II Water and water treatment

Water and water hardness

Water (H_2O) consists of hydrogen and oxygen, but as tap water it reaches the printer in different qualities and different degrees of purity, depending on its origin (groundwater or other). Even in clean rainwater, soluble gasses and dirt particles are present.

Groundwater is situated below the surface of the earth. The geological layers of the earth through which the water seeps, determine the composition of the water. As water seeps through these layers, soluble salts are absorbed, along with large amounts of carbon dioxide. The dissolving behaviour of the water depends on the types of stone it passes through. Limestone, for instance, is insoluble in clean water, but if carbon dioxide is present, the limestone is transformed into the lightly soluble calcium hydrogen carbonate.



Relation between water hardness and hydrogen carbonate

Depending on the concentration of calcium and magnesium salts, water is classified from hard to soft. Hardness is expressed in degrees. One degree German hardness (1°dH) is equal to 10 mg of calcium oxide per litre water.

Apart from this total hardness, the amount of hydrogen carbonate is important. Both parameters have a clear influence on the offset process, because hydrogen carbonate (HCO_3) is also a source of calcium carbonate.

The table above contains conversions for the different standards of water hardness.

Water conditions and the need for water processing

Water intended for the production of dampening agents for offset printing has to meet the following conditions:

hardness according to dH	8–10	= 1.428 – 1.785 mmol C_aO/l
carbonate hardness	3–4	= 0.071 – 1.428 mmol HCO_3/l = 65.33 – 87.1 mg HCO_3/l
pH-value	7.2 +/– 0.4	
conductivity	max. 320 +/- 30 µS at 20°C	
chloride upper limit	= 25 mg/l	
nitrate upper limit	= 20 mg/l	
sulphate upper limit	= 50 mg/l	

Water conditions

Whenever these conditions are not met, a water mineral processing unit is required, especially under the present circumstances, in view of the increasingly strict corrosion guidelines issued by machine manufacturers.

Water treatment

Just as we cannot drink water from every tap in the world, we cannot expect perfectly balanced water to be available for printing purposes around the globe. There are several types of water treatment methods (including de-ionisation and reverse osmosis). The choice depends on the required end quality of the water, and on the quality of the influent. Influents can be regional tap water, surface water or groundwater.

Elements and components in influent (tap) water

Components of water:

- ☐ calcium
- ☐ magnesium
- ☐ sodium
- ☐ hydrogen carbonate
- ☐ chloride
- ☐ sulphate
- ☐ nitrate
- ☐ iron
- ☐ oxygen
- ☐ carbon dioxide
- ☐ hydrogen (ion)
- ☐ bacteria
- ☐ algae
- ☐ floating substances

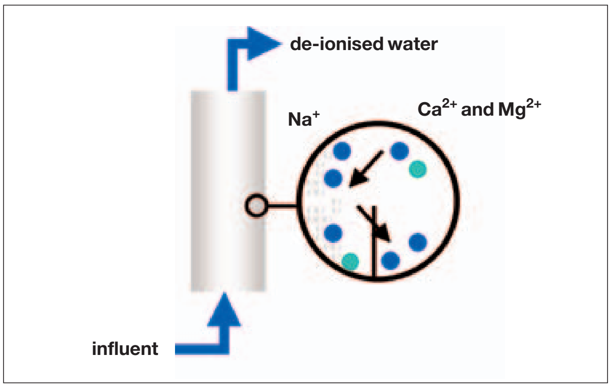
It is common to conduct a full water analysis before use in the printing process.

Certain ions that are typically present in water can react with paper coatings or ink pigments. Understanding the composition of the water source feeding the plant can explain some press problems or point to an appropriate treatment method.

Interactions between ink, fountain solution and paper can be influenced by the presence of calcium ions. The presence of calcium in magenta ink is well known, and can cause deposits on magenta ink rollers and blankets. Accumulation of calcium from paper coatings or from fountain solution can lead to scaling problems.

De-ionisation

To avoid serious scaling on ink rollers and blankets, calcium and magnesium are often reduced to a minimum by a process of ion exchange. Simply removing one of the salt forming components, will prevent scaling from taking place. De-ionised water contains sodium ions instead of calcium and magnesium, and therefore, de-ionisation is usually the first step in the water treatment process.



De-ionisation

Once calcium and magnesium have been exchanged for sodium ions, the water is filtrated to remove the other salt forming components.

Reverse osmosis

It is common knowledge that a raisin swells when put into water. The principle behind this is the equalisation of the salt concentration. The process can be reversed by pressing a salt containing solution through a semi-permeable layer. This process is called reverse osmosis. The water which passes through the layer (the exchanger), loses up to 95 % of all dissolved salts, simply because dissolved ions are too big to pass. The layer consists of a mineral compound with holes of a specific width. Small molecules pass through the holes, whereas bigger compound molecules or even cellular material are stopped.

When the influent has passed the exchanger, reverse osmosis can operate for many years before a descaling treatment is needed. In areas with very soft water qualities, it is sufficient to use nano-filtrated water. In this simpler reverse osmosis process the water is only pressed through a membrane without other treatments taking place.

Effects of water treatment

Examples	pH	Conductivity [mS/cm]	°dH	Ca^{2+} mg/l	Mg^{2+} mg/l
3% Fountain solution	4.85	2.150	–	–	–
Nano-filtrated water	6.60–7.60	< 0.100	1–3	<5	<1
Rehardened water	6.80	0.250	5	25	5
Reverse osmosis	6.50	0.030	0	0	0
De-Ionised water	7.45	0.430	0	0	0
Tap water	7.65	0.430	11	50	10

Effects of water treatment

III Fountain solutions

Since successful ink transfer requires compatible chemistry, matching ink and fountain solutions is critical. The fountain solutions must keep the printing plate clean while allowing the ink to transfer efficiently. These properties can be provided by use of a fountain solution concentrate.

In view of the huge variety of printing substrates, inks, printing circumstances and types of dampening units, differentiation in fountain solution concentrates is an absolute necessity. Today, manufacturers of fountain solution concentrates offer many different types of concentrate for the different types of presses. Ongoing changes in application conditions (new press types, new plate types, IPA-free printing, etc) will require new recipe concepts and, as a result, new and more specialised fountain solution concentrates will continue to be developed.

Composition of fountain solution concentrates

Fountain solution concentrates are aqueous mixtures of different components

- ☐ Buffer systems to adjust pH value
- ☐ Film forming hydrophilic and wetting substances
- ☐ Biocides, fungicides, for anti-microbial equipment
- ☐ Complexing agents to bind scaling components
- ☐ Anti-piling agents
- ☐ Co-solvents to keep the system homogeneous
- ☐ Anti-foam agents
- ☐ Corrosion inhibitors
- ☐ Release agents (alcohol free and alcohol reduced)

Fountain solution components are very proprietary and often customised to a specific plant. Measurements help determine their effectiveness both before and during printing. Here are the key measurements.

pH

pH is the unit of measurement for acidity or alkalinity. The letters pH stand for pondus hydrogenii (potential hydrogen). A neutral solution such as pure water has a pH value of 7. Solutions with a lower pH are called acidic, and solutions with a higher pH are called alkaline. The pH scale ranges from 0 to 14. The figures of the scale are the mathematical (negative logarithmic) expression of the hydrogen ion concentration in a water-based solution. For example, pH 4 represents a 10^4 concentration of hydrogen ions (i.e. 1 part in 10,000 parts), and pH 7 means 10^7 (1 part in 10 million parts).

pH	Examples
0	Chloric acid 1 mol/l = 36,5 g/l
1	Gastric acid
2	Cola
3	Citric fruits
4	Acid rain
5	Fountain solution Europe
6	Rainwater
7	Clear water
8	
9	
10	Soap
11	
12	
13	
14	Sodium hydroxide

Examples of pH value

Low pH (acidic) conditions cause water to be corrosive. Acids will cause pitting of concrete, dissolve metals, wrinkle vinyl, and irritate skin and eyes.

High pH (alkaline) conditions cause scaling: minerals (calcium, copper, iron etc) precipitate out of the water and those minerals will block filters and pipes.

Depending on the pH value, calcium carbonate contained in the paper will react or not react with the fountain solution. At high pH values, calcium carbonate will be stable, but at low values, there can be an interaction between paper and water.

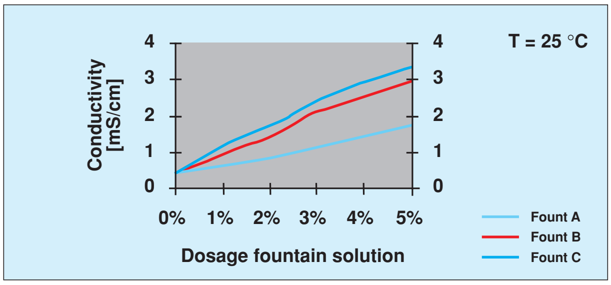
The pH value also determines whether metals are vulnerable to the fountain solution or not. At low pH values, metals will corrode.

Conductivity

Conductivity is a liquid's capacity to conduct electrically charged particles. All dissolved electrolytes in the liquid result in certain numbers of positive and negative charges. Therefore, conductivity is related to the amount and type of dissolved materials.

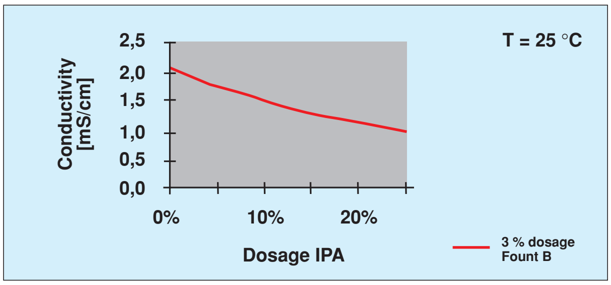
This property is used to determine the dosage of fountain solution, or assess the quality of the tap water.

The diagram below shows that conductivity versus dosage normally is a linear correlation and starts with the value of the pure solvent (tap water, reverse osmosis water). The curve depends on the type of fountain solution. An absolute conductivity value is not very significant for its quality. What is decisive, is the slope of the curve.



Conductivity versus dosage

The influence of paper on conductivity, depending on paper type, is often expressed as an increase of conductivity (5–10%) of the fountain solution caused by paper components extracted out of the top layer. However, in practice such values are always influenced by natural processes of production and consumption of the fountain solution, which means that the interaction cannot be easily expressed by way of a simple graphic. A high conductivity does not necessarily cause problems. Fountain additives with IPA replacement often have a high conductivity to start with. Increasing conductivity on press points to contaminated fountain solution, which can lead to problems due to a disturbed ink / water balance: ink piling, poor ink drying, too high dot gain, poor print quality.



Conductivity versus IPA

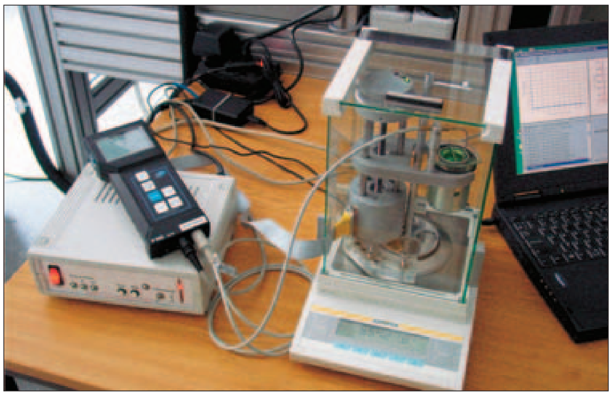
All of this means that different types of additives can result in different conductivity values at the same dosage level, without any relation to quality.

The diagram above shows a decrease of conductivity when the IPA percentage is raised.

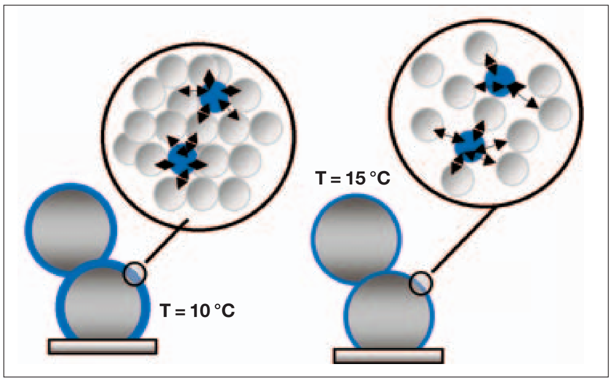
Buffers

To keep the pH on a stable level, the fountain solution must be buffered. The pH can be influenced by an interaction between fountain solution, paper and ink. For this reason, fount systems are always buffered to avoid pH fluctuations. To design pH levels and to make a stable fountain solution, a salt combination is necessary.

Correct combinations of acid in the buffer are needed for thorough plate wetting without any deposition. In order to achieve the necessary thorough plate wetting without, on the other hand, causing deposition, the buffer must contain the correct combinations of acid.



Viscosity measuring equipment



Influence of temperature on viscosity and transfer

The use of IPA

IPA (isopropyl alcohol) in varying doses has been used in sheet-fed and web offset printing for almost 25 years.

Arguments for and effects of the use of IPA

- Reduction of the surface tension in order to achieve thorough wetting of the printing plate (thin and homogeneous dampening film)
- Increase of fountain solution viscosity in order to achieve uniform fountain solution transport from the water pan to the printing plate
- Rapid evaporation of IPA generates a cooling effect
- Improvement of emulsification and stable ink / water emulsion
- Antibacterial effect
- Reduction of foaming

Arguments against the use of IPA

- Environmental damage due to the presence of VOC (Volatile Organic Compound)
- International legislation aimed at a reduction or total elimination of VOC emission
- Additional taxation in many countries
- IPA in the air is limited to max. 150 mg/m^3 MAC (= the Maximum Allowed Concentration) in many countries
- IPA in the air may cause increased physical strain (e.g. respiration difficulties)
- The ignition temperature of fountain solution with IPA is lower than 50 °C. This implies a danger of fire and explosion, especially in case of incorrect handling and technical errors
- IPA is expensive

Viscosity and its relation to fount transfer

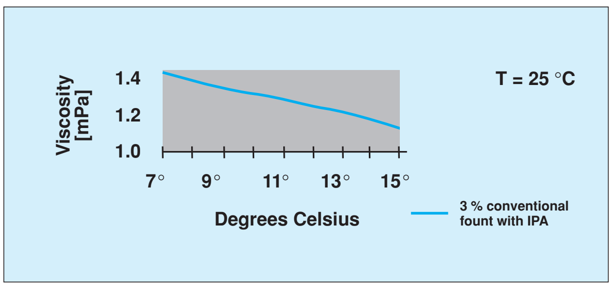
Viscosity is the degree of internal bonding of a liquid as a result of the attraction of molecules. In the same way, transfer of a liquid over a pair of rollers will be influenced strongly by internal molecular bonding. When viscosity increases, mass transfer increases as well (up to a given maximum). Therefore, in fountain solutions, there are two important parameters which influence the amount of transferred liquid:

- Temperature
- IPA dosage

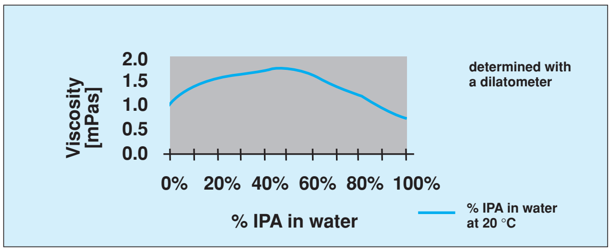
Viscosity and temperature

Temperature is a measure for the amount of molecule motion. Higher temperatures are the result of more intensive internal motion of the material and increasing intermolecular space. This in turn implies decreasing attraction of the molecules, and thus a lower viscosity.

As shown in the diagram below, higher viscosity at lower temperatures produces a thicker fluid film on rollers, which leads to better transfer over a wide range of roller speeds.



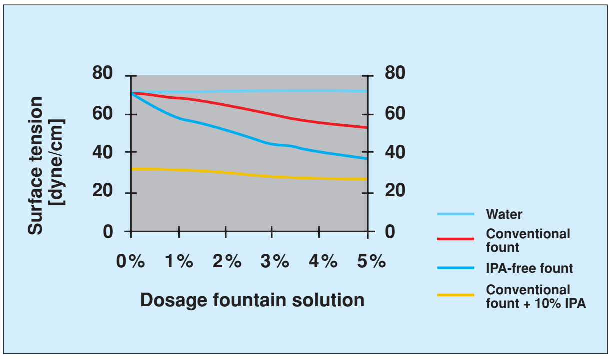
Viscosity versus temperature



Viscosity versus IPA dosage in water

Influence of IPA dosage on viscosity

One of the most remarkable effects of the use of IPA is a change in viscosity. This is caused by the formation of three-dimensional network structures in the liquid, which results in an increase of viscosity at certain dosage ranges. This means that IPA dosage also has a significant influence on the transfer behaviour of fountain solutions. Printers notice that transfer is reduced when the IPA-percentage is lowered. Depending on the quality of the fountain solution, this has to be compensated for by increasing pan roller speed. Some fount specialists recommend the use of special rollers, sometimes combined with temperature reduction to imitate the viscosity effects of IPA.



Surface tension versus dosage

Corrosion

Corrosion inhibitors in the fountain solution prevent corrosion on plate, blanket and (in sheetfed) impression cylinders. Quality fountain solutions are certified for corrosion. For many press manufacturers, this certification is a pre-condition for inclusion of corrosion damaged press parts in their warranty regulations.

Anti-piling additives

Anti-piling additives in the fountain solution counteract build-up on blankets. Due to this reduced build-up, the wash intervals decrease considerably. Also, the life cycle of plates, especially plates that have not been cured, can be significantly extended when there is no piling.

Surface tension of fountain solutions

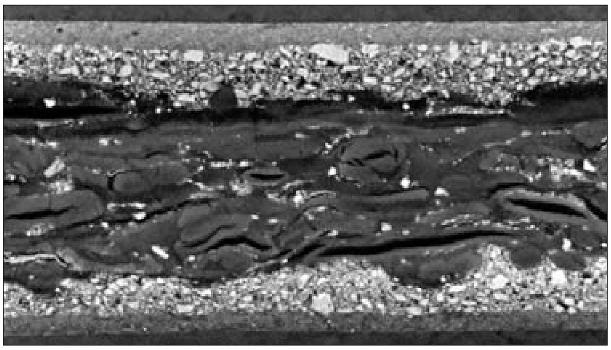
Conventional fountain solutions based on a fountain concentrate plus IPA have a surface tension of about 40 mN/m, when the percentage of IPA is 8% or higher. The surface tension is nearly identical under static and dynamic circumstances, and adding more IPA does not lower the surface tension significantly.

When fountain solutions based on a fountain concentrate without IPA are used, the surfactants in the concentrate have to take over the role of IPA.

Combined laboratory and field tests have shown that appropriate IPA-free fountain solutions have to meet the following parameters:

- In a 3% solution the surface tension must be lower than 45 mN/m at 10 Hz tested in a BP2 bubble tension meter (simulates the dynamic surface tension on high-speed presses).
- The slope of the tension curve between 1 Hz and 10 Hz must be as flat as possible to avoid printing problems due to differences in press speed.
- The BP2 curves of the 3% and 5% solutions have to be closely aligned. If not, there is a danger of overdose sensitivity.
- The BP2 test should always be combined with an inter-facial tension test. This is done by checking the contact angle of a 3% solution on an ink surface. Here as well, the fountain solution has to meet a certain value.

BP2 tests, therefore, can be indicative of the wetting of the plates. The tests reveal whether the fountain solution is able to wet the plate fast enough in thin layers at high speeds. Measuring the interfacial tension will give an indication as to the sensitivity to emulsification. These two parameters must always be tested together, because it is possible for certain fountain solutions to reach their ideal BP2 curve (lower than 45 mN/m at 10 Hz) with a 4% solution, but at this concentration, they may have insufficient contact angle.



SEM-picture of a cross section of a coated paper. The lighter areas on top and bottom are the coating layers (double coated) and the dark area is the base paper

IV Paper

Paper components

Paper, in terms of technical production, is an interwoven mat of vegetable fibres formed by deposition of these fibres from suspension in water. It is a tabular structure generated by natural agglutination and felting of fibres.

Graphic papers can be divided into two main categories: woodfree and mechanical papers, either coated or uncoated. These papers are available in different grammages and surfaces, such as glossy, silk and matt.

Woodfree papers are produced from cellulose (chemically treated woodfree fibres), whereas mechanical papers are produced from a combination of cellulose and mechanically treated fibres. The main wood types used in the paper industry are deciduous wood (beech, eucalyptus) and coniferous wood (spruce, fir, pine). Hardwood from rain forests can not be used in the paper industry. In the paper mill the pulp is beaten to a specific length and thickness depending on the required paper quality. Fillers, binders and process materials are added to form the base paper. This uncoated base paper can be calendered, at which point it is basically fit for printing. To improve the paper surface and enhance printability, further finishing techniques are applied.

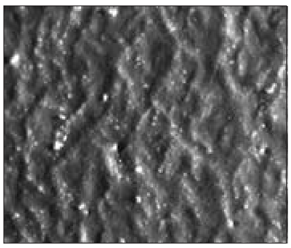
Currently, the most important finishing process for paper is coating. In the process of (machine) coating, the base paper is covered – coated – on each side with one or two, sometimes as many as three layers of a white pigment coating that consists of:

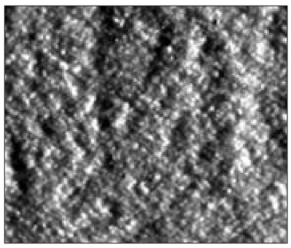
- Pigments (e.g. calcium carbonate, kaolin)
- Binders (e.g. latices, starches)
- Additives (e.g. dyes, optical brightening agents)

The function of binders is to finely distribute pigments in the coating and to bind them to the paper. Binder / coating recipes vary according to the printing process for which the end product is intended.

Coating application improves the paper surface (smoothness, shade), resulting in improved print quality. Glossy, matt and silk papers all have their own, specific coating formulations.

Depending on the required paper surface, calendering may take place.





Paper surface detail: gloss (left) and matt (right)

Paper grades
A general European paper type classification:

MF	Machine finish (newsprint)
SC	Super Calendered
ULWC	Ultra Light Weight Coated
MFC	Machine Finish Coated
WFP	Wood Free Pigmented
WFC	Wood Free Coated
WFU	Wood Free Uncoated
FCO	Film Coated Offset
LWC	Light Weight Coated
MWC	Medium Weight Coated
HWC	High Weight Coated

Paper properties

Optical properties:
Brightness: whiteness of paper
Opacity: degree of non-translucency of paper, expressed as the percentage of reflected light
Gloss: specular reflection of light on paper's surface

Physical properties:
Grammage: a paper's weight per square meter (g/m^2)
Thickness: a paper's thickness (µm)
Bulk: volumic mass (g/cm^3)

Mechanical properties:
Tensile strength: Force of rupture of a strip of paper of standard width submitted to parallel extension.
Stiffness: rigidity or resistance to bending.

Printability:
Print gloss: specular reflection of light on a printed paper.
Ink rub resistance: ability of the printed part of a paper to resist abrasion.
Pick resistance: ability of coating/fibres to resist being pulled out of the surface during printing.
Ink setting: selective penetration of ink components into the paper, leading to the immobilisation of ink on the paper.
Ink drying: hardening of the ink film deposited on paper.

V Offset printing inks

Inks for sheetfed as well as inks for heatset web offset printing are structured lithographic paste inks and generally consist of a varnish, pigment and extender, mineral oil distillate, vegetable oil and additives.

Ink composition

Varnish
The varnish is the binding agent and consists of hard resins, chemically modified wood resin and synthetic hydrocarbon resin, soft alkyd resin and a mix of vegetable oil and mineral oil distillates. The mix is cooked to dissolve and disperse the hard resin, thus forming a homogeneous varnish.

Pigments
The colorants in the inks are synthetic organic pigments, not to be confused with natural pigment or with dyes. For black ink, carbon black is used as the pigment. The amount of pigment and extenders (chalk/clay) depends on the desired colour and structure of the ink.

Mineral oil distillate and vegetable oil
For the heatset printing process it is necessary to use a diluent that can be evaporated in a hot air dryer. For this reason, a fraction or distillate of mineral oil with a boiling range of 240–290 °C is used. The function of this diluent is to act as a "carrier" for the resins and pigments and to allow the final formation of an ink film of about 1 micron thickness on paper.

Sheetfed inks are designed for drying by oxidation (skinning). Certain vegetable oils harden under the influence of oxygen from the surrounding air. The most commonly used type is linseed oil. A dryer catalyst accelerates the drying process.

Additives
Certain additives are used for the pigment grinding process or to provide specific ink properties which have an effect on the lithographic behaviour of the ink on press. Waxes are used to improve the rub resistance and slip properties of the dried ink film.

In sheetfed inks certain agents are used to create an appropriate balance between the drying properties of the printed ink film and the skinning tendency of the ink surface in an open can or ink duct.

Interaction ink / fountain solution

An emulsion is a mixture of ink and fountain solution where the fountain solution is dispersed in small, equally distributed droplets in the ink (emulsified). On press, this emulsion should not lose any of the performance characteristics of the ink itself so that tack, viscosity and proper transfer can be maintained.

Moisture percentage in the ink

One of the big questions in the lithographic process is how much water actually is present in the emulsion during the printing process. In the Duke laboratory emulsification test (low-shear stirring), the maximum water pick-up is generally between 35 and 50% or even higher, but no correlation is found with the emulsion behaviour on the plate.

One practical test (American Ink Maker), where samples were taken directly from the plate while the press was running and fountain solution and ink are in contact with each other for a micro-second under relatively high-sheer conditions, indicated a water content of 5–15% (Karl-Fischer). Another test (Fogra) showed the same values.

The most important conclusions from the American test are:
Water pick-up in lab tests is much higher than on the press.
The differences in water pick-up are dependent of colour, supplier and fountain concentrate percentage.

Interaction between ink and paper

Adherence
Adherence of ink to paper is not a uniform process. Part of the ink anchors into the paper. This means one part of the ink will absorb into the paper (coating), like water into a sponge. The other part actually adheres to the paper.

Picking
Removal of coating or fibres from the paper during printing is called picking. It occurs when the pulling force (tack) of the ink is greater than the surface strength of the (coated or uncoated) paper.

Normally, the ink grade is chosen on the basis of its tack level. The higher the tack level the easier picking can occur.

Rub resistance
Rub resistance is the ability of printed paper to withstand the effects of repeated rubbing.

The degree of rub resistance is a factor of the ink used, the type of resin contained in the ink and the additives. One of the most commonly used additives for improving rub resistance is Teflon wax, which enhances slip performance. It is used in inks for more critical papers and circumstances.

Rub resistance however, is not exclusively related to ink. The printed material plays an important role too. Glossy papers have better rub resistance than matt papers. Generally rough paper is more sensitive to rub than smooth paper. This is true for ink as well: the smoother the surface, the better the resistance.

Gloss
Gloss is a perception based on the physical, optical property of a surface to specularly reflect projected light to a more or less pronounced degree. All three phenomena mentioned above, adherence, picking and rub resistance, have a major influence on gloss.

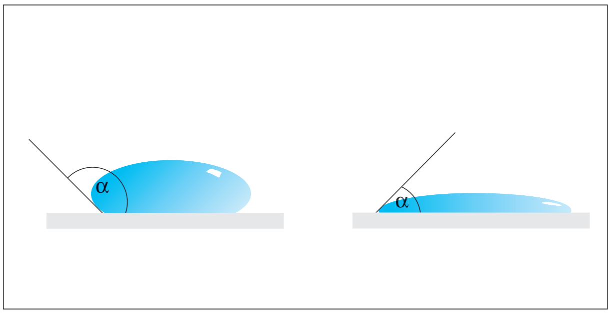
The better the lay of an ink on a paper, the higher the gloss. But the ink itself and the paper itself obviously have effects on gloss as well. On a matt paper it is less easy to achieve proper gloss by way of the ink and vice versa.

VI Interaction between fountain solution and paper

Introduction to contact angles

In most cases where a liquid droplet is applied to a solid material, an angle is formed at the point of contact between droplet and solid, the so-called wettability angle or contact angle.

This contact angle is an indication of the wetting performance of liquids applied to solids. The contact angle is measured as the angle between the base and the tangent at the point of contact between liquid and surface. This value corresponds to the surface energy level in the equilibrium system formed between liquid and solid on condition that the surface is smooth, non-porous, non-sorptive, and homogeneous. Furthermore the liquid must not react chemically with the substrate. Wetting is defined as a contact angle of 90 ° or less.



High (left) and low (right) surface tension

Contact angle measurements and wetting studies can be performed using a Dynamic Absorption Tester (DAT 1100, Fibro System AB).

Surface tension and surface free energy

Surface tension is the “contractional” force between the molecules inside the fountain solution droplet, which makes the water molecules remain attached to each other. With the Fibro DAT instrument, the surface tension can be directly measured from the shape of the fountain solution droplet. This measurement is expressed in mN/m. The surface tension is usually characterised by two components: polar (water attracting) and dispersive (water repellent).

Surface free energy, similarly, is “attractional” force which is available on the surface of a solid substrate to attract the liquid molecules. Surface free energy has two components as well: polar and dispersive.

In contrast to surface tension, surface free energy can not be directly measured, so it has to be calculated from contact angle measurements with two or more selected liquids.

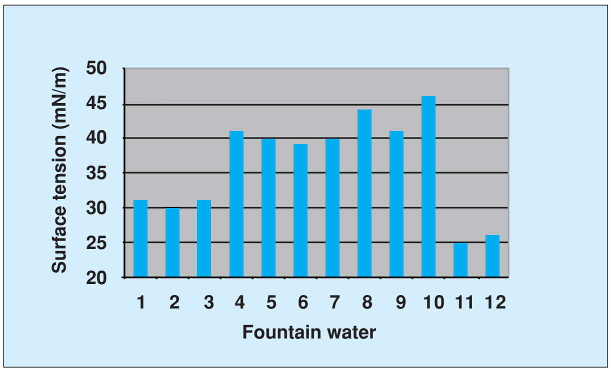
Wetting and penetration

It must be emphasised that wetting performance depends on the interaction between fountain solution and paper. Quality inks or quality papers by themselves are not enough, since fountain solution and paper have to be tailored to one another to obtain the desired performance. Even with a good match, it may be necessary to reduce the contact angle.

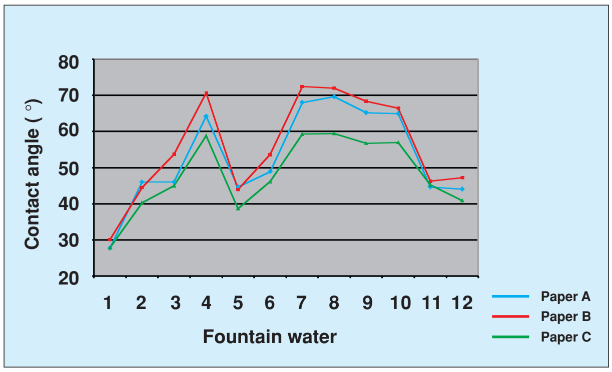
To reduce the contact angle, the surface tension of the fountain solution can be reduced (by adding isopropyl alcohol or tensides), the surface free energy can be increased (corona treatment), or a combination of both can be used.

The wetting process starts when the lowest part of the liquid drop first makes contact with the paper. The liquid starts to spread over the surface and penetrate into the porous paper. In offset printing, fountain solution is transferred to the paper from a blanket. This fountain solution must disappear from the surface before the paper enters the next printing nip. Hence, initial penetration is very important in this printing process.

Contact angles of fountain solution droplets on paper are dependent on the surface free energy, but are also influenced by the porosity of the paper and the size of the pores.



Surface tension of 12 commercial fountain solutions



Contact angle of different fountain solutions on different papers

VII Laboratory study: measurement and evaluation of fountain solutions

Study description

In order to assess the influence of different fountain solutions on paper, 12 commercial fountain solutions were tested on 3 different papers.
The method used is the Fibro DAT 1100. The fountain solutions are divided over 9 heatset fountain solutions and 3 sheetfed fountain solutions, some conventional (isopropyl alcohol based) and some non-conventional (tenside based).

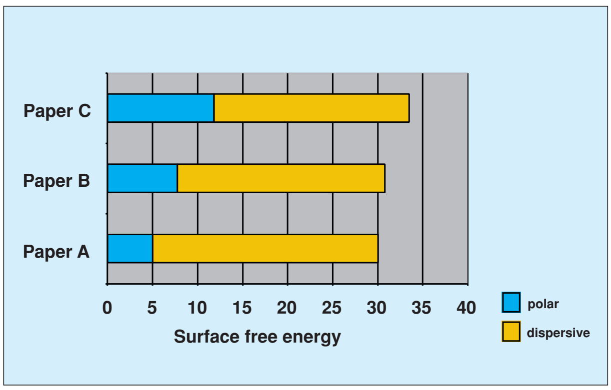
IPA-free fountain solutions generally have a lower surface tension in comparison to conventional fountain solutions. Each combination of paper and fountain solution has a specific contact angle. Thus, paper C has the lowest contact angle (best wettability) with all tested fountain solutions and fountain solution 1 has the lowest contact angle (best wettability) with all tested papers.

Ink repellence

If the flow rate of fountain solution is high and/or the paper has poor water-absorbing characteristics, the film of fountain solution on the surface of the paper results in repulsion of the ink in the following printing unit. Depending on the extent of the repulsion, solid areas can show an uneven printout and large screen areas can also be affected.

It is important to have laboratory methods for evaluation of ink repellence, which correlate well with printing results in practice. These methods are particularly useful for complaint investigations, paper development and for the determination of the influence of printing conditions and fountain solution composition.
For the 12 different fountain solutions and the 3 papers we used the AIC II/5 test and the spot test.

The AIC II/5 test is carried out using the IGT test-printing machine. Dampening is performed using an engraved steel roller dampened with fountain solution. The engraved roller allows the application of up to 0.7 g/m² of fountain solution. The printing ink used is a special low tack picking test ink and the print speed is 1.5 m/sec. The printing unit of the AIC II/5 unit is situated below the dampening unit, which allows the first section of the paper strip to be printed dry. The second section of the paper strip is printed after dampening and is designated as the first interval. There is a time interval of 0.05 seconds between wetting and printing. The last section of the strip is printed after an interval of 1.0 second after dampening. This section is designated as the second interval. The printing densities of the solid area (dry printing) and the first and second intervals are measured. The mean

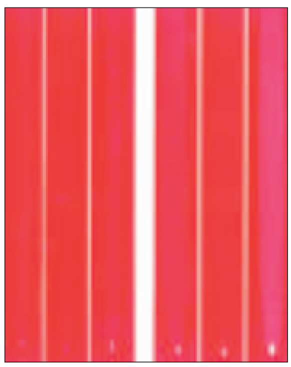


Surface free energy (polar and dispersive) of the papers

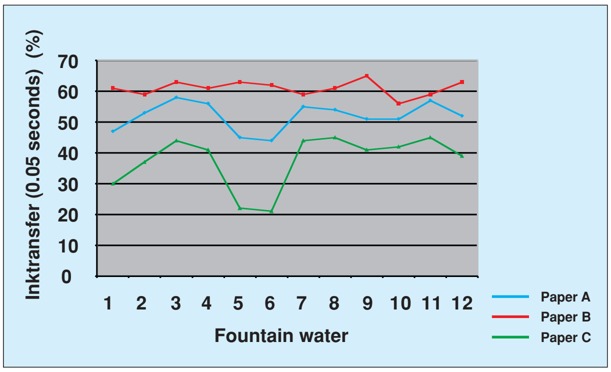
Fountain water 2 Fountain water 6

AIC-Test: 3 paper samples (A, B, C) tested with 2 fountain waters

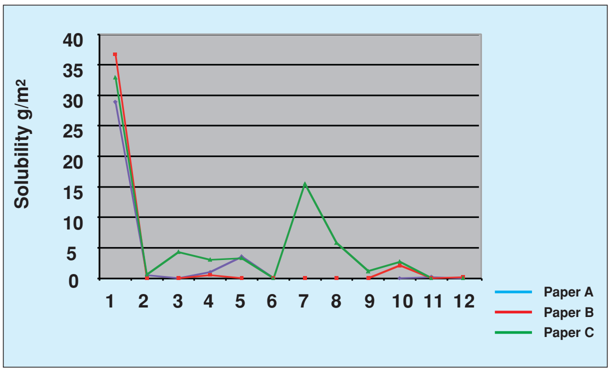
Fountain water 2 Fountain water 6



Spot test



Ink repellence of the three papers (A, B and C) with different fountain solutions Paper C is more sensitive for solubility of coating.



Adam's Wet Rub test of the three papers (A, B and C) with different fountain solutions. All three papers show a high solubility degree with fountain solution 1. Paper C is more sensitive for solubility of the coating than paper A and B.

value of each of the two dampening intervals is expressed as a percentage of the mean value for the solid area. The higher these values are, the lower is the ink repellence of the paper.

The spot test is carried out using the Prüfbau printing machine. A drop of 5µl fountain solution is applied on the paper sample by means of a micro-pipette and the paper sample is immediately printed with the Huber picking test ink 408001 at a speed of 1 m/sec. The ink densities in the pre-wetted and dry printed areas are measured. The ink density in the pre-wetted area is expressed as a percentage of the ink density in the dry printed area. The higher the resulting value is, the lower is the ink repellence of the paper.

The higher the contact angle is, the lower is the sensitivity for ink repellence. This is confirmed with the ink repellence test on the IGT AIC II/5 and the spot test on the Prüfbau. So paper C has the lowest contact angle with all tested fountain solutions, which results in a higher sensitivity for ink repellence (see graph above). In comparison with the other papers (A and B), paper C has a lower contact angle (good wettability), but a slower penetration. A slower penetration of the fountain solution could lead to a higher sensitivity for wet pick (weakening of the coating layer).

Wet pick is tested on the Prüfbau printing machine. The paper is pre-wetted with the fountain solution and directly printed with an aluminium roller (special picking test ink). With interval times of 10 seconds, the printed paper is brought into contact against the same printing roller until picking in the pre-wetted area is noticed.

Another test to investigate the paper – fountain solution interaction is the Adam's Wet Rub test. The Adam's Wet Rub tester is used to determine the solubility degree of coating of offset papers when brought into contact with fountain solution. 30 ml Fountain solution is placed in the sample pan. A paper strip is put on the idler with double-sided tape. The paper strip on the idler is rubbed for 20 seconds against a rubber roller, turning in the sample pan with fountain solution.

Afterwards the fountain solution in the sample pan is decanted into a beaker and evaporated in an oven at 105 °C. The residue is weighed and expressed in g/m^2.

Conclusions

Ink repellence improves at a higher contact angle with fountain solution. A higher contact angle means a worse wettability of the paper surface. In comparison with paper A and B, paper C has a low contact angle (good wettability) but a slower penetration (porosity, pore size). A higher penetration of the fountain solution can lead to a higher sensitivity for wet pick (weakening of the coating layer). Penetration is controlled by properties such as:

- surface energy
- paper roughness
- surface tension of fountain solution

Specific combinations of fountain solution and paper surface produce a higher solubility of the coating. The differences between the fountain solutions are larger than expected, and the same is true for the interaction with the paper. Each fountain solution and each paper has its own characteristics, which makes the combination of fountain solution, ink and paper more complex.

Offset printing is a technology that is clearly determined by interfacial processes, of both a physical and a chemical nature. The fact that homogeneous phases (e.g. pure water) are hardly ever involved in this process and that more often than not it is a matter of mixed phases (e.g. water in which other substances have been dissolved) or even compound phases (e.g. printing ink, a dispersion of solid and fluid content) makes understanding how the various partners involved in this process interact more difficult.

VIII Practical examples & solutions

Ink / water balance

When too little fountain solution is fed, the non-printing area of the plate will accept ink, and the print will start scumming. At too high levels of fountain solution, the ink is washed away from the printing area. It is up to the printer to find the correct amount of ink and fountain solution fed to the printing plate. This is called the ink / water balance. An ink that can easily absorb an overdosed amount of fountain solution is said to have a wider “water window”.

Parameters that are of influence are:
- Paper / ink combination
- Water absorptivity of the ink
- Plate type
- Fountain solution chemistry
- Press ink- and dampening roller settings
- Temperatures

Interaction fountain solution / paper

Almost all of today’s printing techniques are based on interactions between liquid and solid materials. These interactions can be divided into wetting, spreading and penetration or absorption, which occurs when a liquid is transported into a porous structure.

The paper is wetted not only by the emulsified ink, but by the fountain solution as well and the film of fountain solution that remains on the paper may cause problems with ink repellence in multicolour printing. It is important that the fountain solution rapidly penetrates the paper before it comes into contact with the ink in the subsequent printing unit. This penetration is not forced but spontaneous and is therefore controlled by paper properties such as solid surface free energy, pore structure, surface roughness and surface tension of the fountain solution.

A well-established trend is the use of environment-friendly materials, for example the replacement of IPA with a surfactant in fountain solutions. Such procedures, however, make it more difficult to control the interaction between paper and fountain solution as well as the interaction between paper and ink.

Possible printing problems when the pH value of fountain solution is low:
- Prolonged ink drying time
- Poor solidification of the ink film (which influences rub resistance)
- Increased wear of printing plates
- Roller stripping (ink does not spread evenly across roller surface due to surface not accepting ink)

Possible printing problems when the pH value of fountain solution is high:
- Emulsification of ink and build-up on ink rollers
- Saponification of the ink (the ink goes into the water)
- Plates will not clean up on starts

Glazing of blanket / ink and dampening rollers

This can have several causes:
- DH (German hardness) of the water too high
- Insufficient amount of calcium binder in the fountain solution concentrate
- Too low fountain solution pH
- Interaction paper – ink – fountain solution

Piling

In general terms we can distinguish between two types of piling: positive piling and negative piling.

Positive piling

Positive piling is characterised by ink build-up on the blanket, within an image or at the edge of an image. When piling occurs within the image, the cause is often to be found in a disturbed ink/water balance. This disturbance may be caused by a too high dampening feed (especially at low ink supply/consumption), or a fountain additive which is not adapted to the ink.

Piling at the edge of an image (always at the back edge), is caused by edge pick. This in its turn may be caused by insufficient pick resistance of the substrate, too high ink tack, too much printing tension, blankets with poor release properties, or insufficient dampening feed.

Negative piling

Negative piling is characterised by ink build-up on the blanket in non-image areas. In heatset web offset printing, this type of piling is often the cause of web breaks. After a press stop for washing the blankets, the built-up substance can become sticky and cause a web break at start-up.

Several technical research institutions have investigated the causes of negative piling, but a solution has not yet been found.

Ink repellence

This phenomenon is usually characterised by a cloudy printed image. The problem occurs when, during printing, the thin film of fountain solution on the paper has not disappeared before the subsequent colour is printed. Because ink is repelled from this film, the subsequent colour will show a cloudy print.

A quick way to establish whether the problem really is ink repellence is switching off the colour(s) prior to the poorly printing colour. If the print result improves, ink repellence is the cause. Decreasing the dampening feed on units prior to the poorly printing colour will solve the problem or at least improve the result.

Possible causes for ink repellence are: too slow water absorption of the substrate, too high dampening feed, or a fountain solution containing components which are absorbed (too) slowly into the substrate.

Backtrap mottling

In offset printing, it is normal that a portion of the original ink film on the paper is redeposited or "backtrapped" on the downstream blankets. Backtrap mottling occurs when the absorption of the ink vehicle is not uniform. Instead of a uniform ink film back split, the downstream blankets split the ink unevenly to the point where a mottled print is noticeable. A quick way to establish whether mottled print is really caused by backtrap mottling, is switching off the colours after the poorly printing colour. If the screens print well again, backtrap mottling is probably the cause of the problem.

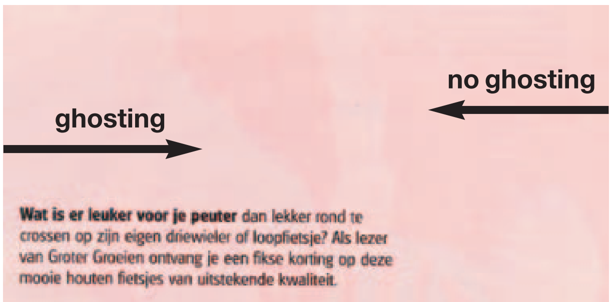
A slower ink or a different type of blanket may improve the result, but usually changing the colour sequence (problem colour further downstream) is the only effective solution.

Paper plays a major part in the backtrap mottling problem.

Poor ink drying

Poor ink drying can have several causes:

- A fountain solution concentrate that has a negative influence on ink drying
- A disturbed ink/water balance (ink tends to emulsify)
- An overdose of fountain solution or of ink drying additives (in the case of inks drying by oxidation)
- Too low fountain solution pH
- Ink or paper has poor drying properties

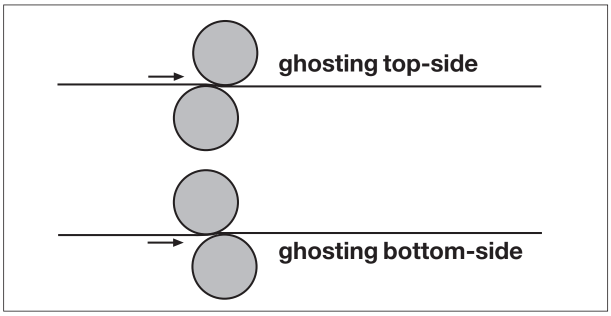


Mechanical ghosting (web offset)

This phenomenon is characterised by diminishing dots in screen areas which have heavy ink coverage on the opposite side of the paper. The contours of the heavy coverage image become visible in the screen. After blanket washing the problem is gone, but not for long: sometimes it re-appears after no more than 3,000 copies.

Putting the ghosting colour out of register and immediately back into register will make the problem disappear temporarily. Several press manufacturers have developed software which makes the fixed plate cylinder slowly describe a pattern, and the other colours follow suit (auto-cycle). This has the same effect as manual cylinder adjustment.

The position of the blanket cylinders determines the ghosting side:



The fundamental cause of ghosting is still unknown. There have been cases where the problem was solved by changing a blanket on the ghosting unit. In other cases printing with lower tack inks solved the problem. Some printers think that web tension plays a part. Many more ideas have been put forward, but to this day, there is no final solution.

Chemical ghosting (sheetfed offset)

The phenomenon of ghosting may occur under certain circumstances when two layers of ink, which have been applied at different times, dry on top of each other in an oxidative way. The appearance of ghosting is unpredictable, and is caused by a concurrence of several unfavourable circumstances. It may also disappear without any apparent reason. The problem is very complex and remains unpredictable, despite the amount of research that has been performed.

We can distinguish between two types of chemical ghosting: contact appearance at printed areas, and yellowing effect at unprinted areas.

It is often thought that migration of the ink through the sheet, from one side to the other, plays a part in contact appearance at printed areas, but this is not the case. There is a direct surface-to-surface reaction between the sheets in the stack after the first printing pass (recto). While the ink is drying through both absorption and oxidation, substances are released which influence the surface tension of the verso side of the sheet directly on top. This changes the ink transfer to this side during the second pass. The resulting effect is often a difference in gloss.

The following measures may prevent ghosting effects:
- □ Avoid mixing different ink brands
- □ Refrain from using ink additives, particularly drying additives
- □ Print the side with heaviest ink coverage in the first pass
- □ Avoid exposing printed stacks to extremely high or low temperatures
- □ In case of subsequent finishing, dispersion varnish is preferable over oil-based varnish

In some cases varnishing the printed surface with a special varnish (several layers if necessary) can reduce the phenomenon to an acceptable level. Airing the sheets several times, and extending the time between printing passes can sometimes offer a solution as well.

Yellowing effect at unprinted areas is also caused by substances that are released during the drying process. These substances are absorbed into the sheet directly on top, and cause yellowing of the paper.

Dot gain

The degree of dot gain is an important factor in good print quality. If there is too much dot gain, the screen dot will print too wide, which in turn requires printing with a too low density. A frequent problem is screens printing too wide to reach the colour intensity of a solid. Assuming that the dot size on the plate is correct, this can have several causes: too high dampening feed, a poor ink / water balance (emulsification), (too) low tack ink, or too much pressure between plate and blanket. In general, uncoated papers have a high dot gain.

IV Closing remarks

Offset printing is still a very complex process. If one of the links in the chain is not performing optimally, it can seriously compromise the end result.

Good co-operation between manufacturers of presses, ink, paper and fountain solution remains all-important.

We thank these companies for their contribution to this brochure:

ProScience, Weert
(The Netherlands)

Vegra GmbH, Aschau Am Inn (Germany)

Flint-Schmidt, 's-Gravenzande
(The Netherlands)

Text and editing:
Corry Olejniczak, Bert Vanlaer and Maurice van Duuren

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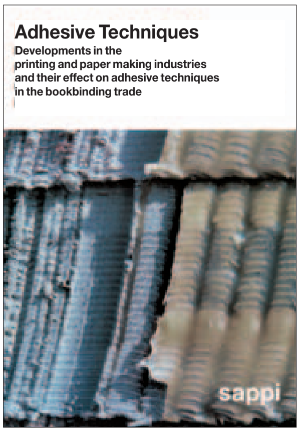

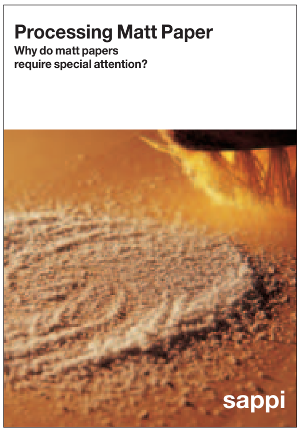

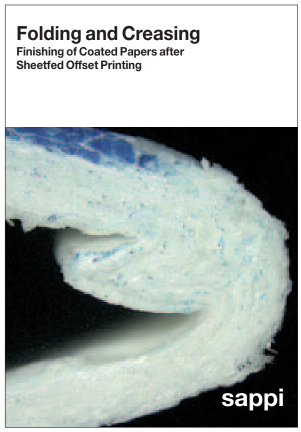

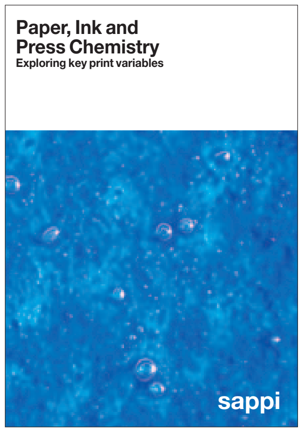

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Sappi Fine Paper Europe
Sappi Europe SA
154 Chausseé de la Hulpe
B-1170 Brussels
Tel + 32 2 676 97 36
Fax + 32 2 676 96 65

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