Climate and Paper

The interaction between climate and the processing of coated papers in printing and finishing

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I Introduction

The situation in paper production and printing industry

Discussions about the effect of climatic influences during storage and transport and in the process of printing and finishing, are as old as the industrial production of paper itself. Generations of experts have had to deal with the more pronounced negative effects and there are numerous publications in the field of specialist literature on measuring temperature and humidity. So it is not as if experience is lacking on the subject. Still, many of the relations have not yet been sufficiently explained. And in some cases, cause and effect remain completely obscure. In the practice of paper processing, many delusions and misunderstandings still exist, particularly with respect to the interaction between climate, paper and printing.

In modern production facilities, paper intended for sheet offset printing is prepared at a relative humidity of 50%, with a deviation tolerance of 5%. Papers intended for web offset printing have similar or slightly lower humidity values, depending on quality. These humidity properties are continuously monitored in all stages of the production process. And in order to keep the paper in optimal condition for the subsequent printing process, it is wrapped in special packaging material that protects it from climate changes in the environment. How the paper – or, more specifically, the fibre – will react to climate circumstances at the printer's or binder's facilities or at the location of the end consumer, however, is a matter beyond the control of the paper manufacturer.

As a global supplier of quality papers, Sappi has a market share of 25% in coated woodfree papers for the Western world. Sappi Fine Paper Europe manufactures coated papers in seven different mills across Europe, using state-of-the-art technology for the production of, mostly, woodfree coated papers for the printing industry. Innovation and continuous development are among our key priorities.

Gratkorn mill houses the world's largest and most advanced paper machine for woodfree coated paper. All seven of our production facilities can look back on a long tradition of paper manufacturing and several of our paper mills with integrated pulp production have led the way in new technologies for the paper industry.

Sappi Ehingen

The situation in printing and finishing industry

Normally speaking, there are few climate related problems in printing and finishing. As a result, climate only becomes an issue when printing problems, such as dot doubling, mis-registering, creasing or curling, do occur. Obviously, the likelihood of this happening, is more pronounced in seasons with extreme weather conditions – hot summers and cold winters. In these periods, improper handling – prematurely unwrapping the paper, use of paper that is too cold – or unfavourable conditions in the printer's or binder's facilities, can have disastrous consequences for the flatness and runnability of the paper.

This publication is intended to help clarify some of the more serious negative effects of climate circumstances. It offers guidelines for correct handling of coated papers, one of the pre-conditions for optimal control during the actual process of printing.

II Definition of terms

When we use the term **weather,** what we actually mean are the atmospheric conditions at a certain location at a specific point in time. When we refer to the weather during a longer period of time, we talk of the **weather situation.**

The concept **climate** is slightly more complex. It refers to the long-term weather conditions or weather situation in a certain region in terms of temperature, air humidity, air pressure, precipitation, wind direction and wind-force, cloudiness and sun hours.

Interior climate is a term used for the air condition in rooms partially or completely shutting off people and equipment from the influence of outside climate conditions. The interior climate, in other words, the climate condition of the immediately surrounding air, is decisive not only for human comfort, but also for the course of production processes and for the condition of stored goods sensitive to temperature and humidity.

In this respect, there is obviously a big difference between **conditioned** and **non-conditioned** locations. A non-conditioned location is a room or workshop where climate conditions are not artificially controlled. In a conditioned location, climate conditions are controlled by means of heating, humidifying and re-moisturing. In the case of non-conditioned locations, the influence from outside conditions is strong.

In conditioned locations, heated during the winter months, but not air-conditioned, relative air humidity is the reverse of outside air humidity. When the heating is on, during winter, inside air humidity is at a minimum. During summer, it reaches maximum levels.

Finally, there are the climate conditions in the immediate vicinity of an object, in our case a reel of paper or a stack of sheets. Here, the term **surrounding climate** is sometimes used.

Data logger, an instrument for measuring temperature and air humidity in adjustable intervals of 15 seconds to 120 minutes for the maximum duration of one year.

Data logger HygroLog-D

Air temperature

Air temperature is a unit for measuring the warmth of the air, or, technically speaking, a unit for measuring the energy of gas molecules – nitrogen and oxygen.

When air takes on heat energy, the air temperature rises. The molecules accelerate and the air volume expands.

There are two fixed points in temperature:

0 °C = the temperature at which ice melts

and

100 °C = the temperature at which water boils (at sea level).

Air humidity

Air always contains a certain amount of humidity in the form of vapour. There are two types of air humidity: absolute moisture content and relative humidity. Here are the definitions:

Absolute moisture content

The mass of vapour in a given volume of air, in other words, the amount of moisture, measured in grams, in a cubic metre of air. In terms of printing practice, absolute moisture content is of minor significance, since it does not take into account one vitally important climate component – temperature.

Condensation point temperature

When humid air cools down to a certain point, the moisture it contains starts to condense. This temperature is referred to as the condensation point. It is one of the variables used in measuring relative air humidity.

Relative air humidity

At a given temperature, air can contain only a specific amount of moisture in the form of vapour. The higher the temperature, the more moisture it can absorb. Air is called saturated when it has absorbed the maximum amount of moisture it can contain at a specific temperature. Relative humidity, then, is the proportion of absolute moisture content in relation to the highest possible moisture content at a given temperature:

$$\text{relative humidity} = \frac{\text{absolute moisture content}}{\text{maximum absolute moisture content}} \times 100\ (\%)$$

Since maximum moisture content is temperature dependent, temperature is one of the elements that determine relative humidity. As we have seen, this is not the case with absolute moisture content. The figure on page 6 shows the relations involved. Using these relations, relative air humidity can be calculated on the basis of room temperature and absolute moisture content. Reversely, absolute moisture content can be calculated on the basis of relative humidity.

Thermo-hygrograph, an instrument for measuring temperature and humidity over a period of 24 hours or 7 days.

Thermo-hygrograph in action

Humidity of materials

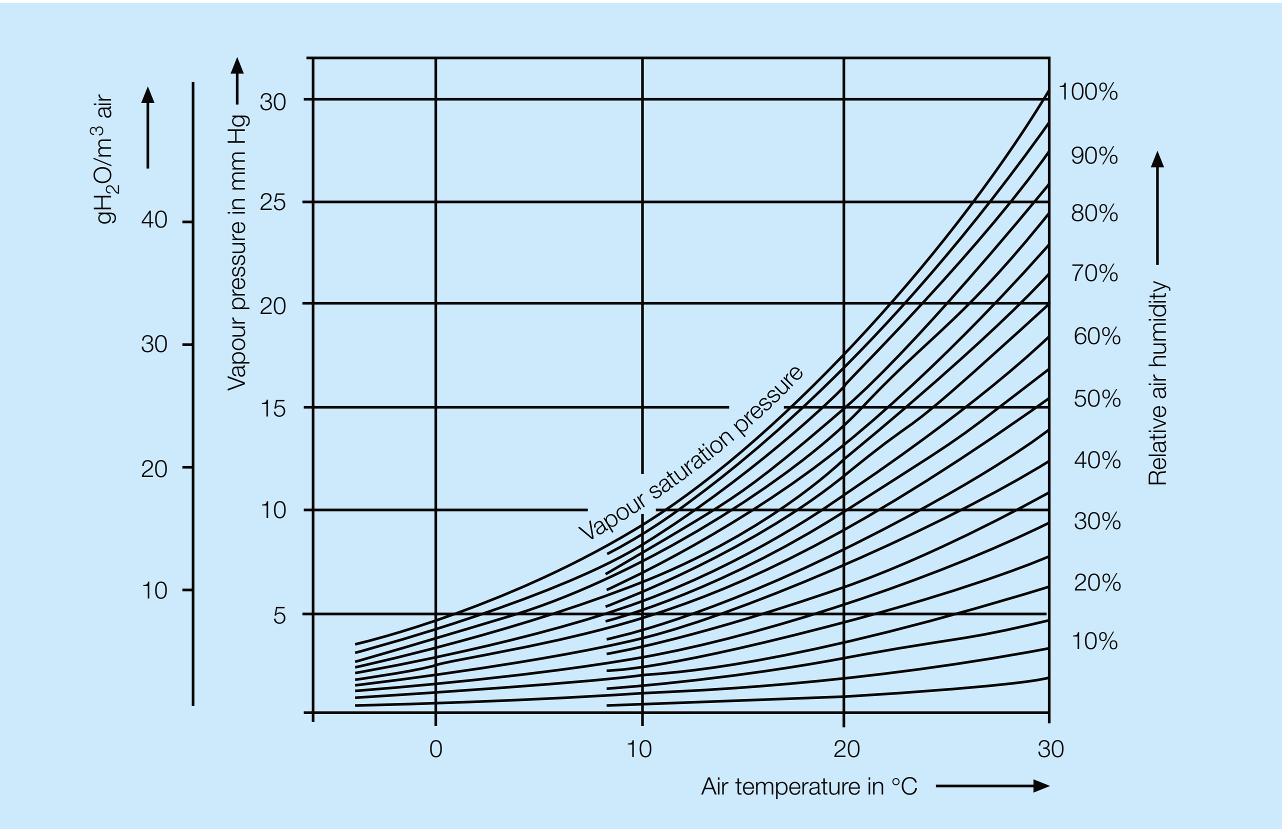
Porous materials like paper contain moisture – in the form of vapour in the larger pores and in liquid form in the minute capillaries of the paper structure. As with air, the humidity of materials can be defined in two different ways:

Absolute moisture content

Humidity measured in percentages is the proportion of moisture inside the paper, in relation to the mass of the material. In paper production, absolute moisture content is commonly used as a unit for measurements and control, but in printing and finishing, it hardly ever enters into the equation.

Humidity balance

Porous materials like paper aspire to an equilibrium – a balance – between their own humidity and the humidity of the surrounding air. This accounts for the balance in humidity that will always exist between the humidity of the air separating individual sheets of paper in a stack and the humidity of the paper itself. Humidity balance, then, is the relation between the humidity of a material and the humidity of the surrounding air. As long as both values are balanced, the paper will not absorb moisture, nor will it exude moisture. But when there is a difference in humidity levels, the paper will adapt itself to the humidity of the surrounding air by either absorbing or exuding moisture.



Relation between air humidity and temperature

III The influence of interior climate on paper flatness

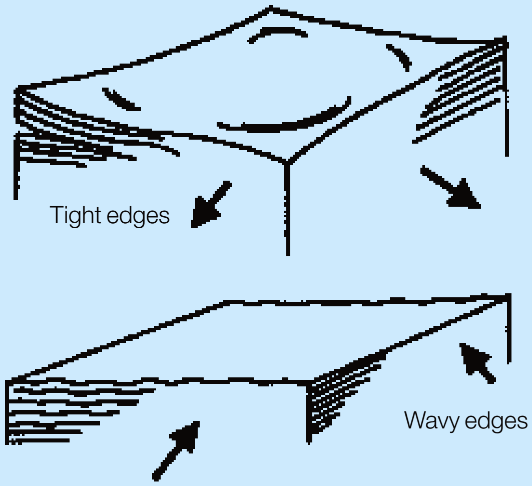
The influence of air humidity

Particularly nasty problems occur in offset printing when the paper used has certain deformations, either in the form of wavy edges or tight edges. The reason why these phenomena cause so much trouble, is the full contact between blanket cylinder and impression cylinder in the printing zone, where these deformations can lead to dot doubling, misregistering and creasing.

Wavy edges occur when the humidity of the sheets of paper in the stack is below that of the surrounding air, in other words, when excessively dry paper is subjected to average, but inevitably higher air humidity, or when normally humid paper is subjected to extremely high air humidity. This will predominantly be the case during the hot and humid months of summer in non-conditioned warehouses and printing shops, or when dampproof wrapping is not used during transport or storage in humid conditions. On the other hand, if, during winter, too cold and already unpacked paper is introduced into the warm air of the printing shop, the surrounding air temperature will sharply drop, thus causing a sudden rise in air humidity. In both cases, the edges of the sheets will absorb moisture, making them swell in relation to the centre of the sheets. The result is wavy edges.

The mutual influences of relative air humidity and stack humidity.

The arrows show the direction in which moisture is absorbed by or exuded from the stack of paper.



Exchange of humidity in a stack of paper

A sword gauge for measuring relative humidity

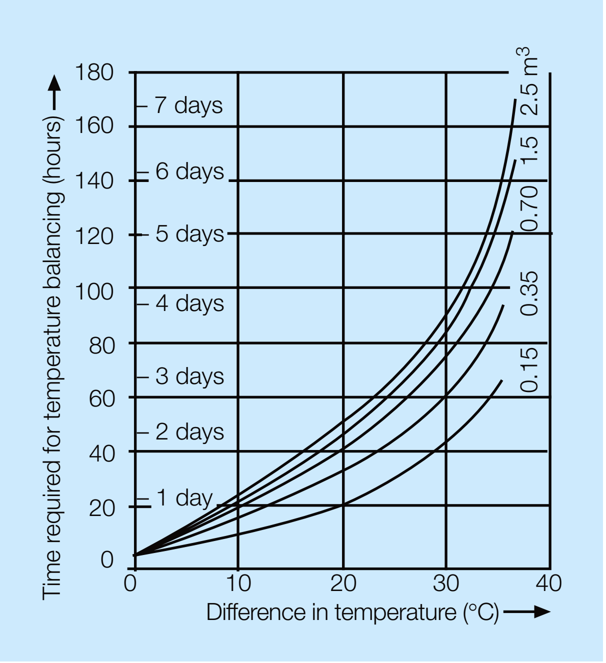
Tight edges occur when sheets of normally humid paper are subjected to exceedingly dry air humidity. In this case, moisture is absorbed from the edges of the sheets, which, as a result, shrink in relation to the centre. This will mainly occur during winter, when the relative air humidity in heated, non-conditioned or non-humidified working spaces can drop to levels as low as 20 % of the normal values. Normally, dampproof wrapping provides efficient protection against humidity influences. Obviously, to be able to offer such protection, the wrapping must be completely intact.

Deviations in humidity balance of up to 5% in either direction do not lead to wavy edge or tight edge effects. At a difference in relative humidity of 8 to 10%, however, the situation quickly becomes critical.

The influence of interior temperature

Temperature has only minor effects on stack humidity. Nevertheless, temperature remains an issue to reckon with, since it is one of the elements determining relative air humidity. This means that, in case of an observed difference in stack temperature and room temperature, the paper should remain wrapped in its dampproof packaging until this difference in temperature has been balanced out. The time this takes, will vary in individual cases, dependent on the extent of the temperature difference and the size of the stack. The figure to the right contains general guidelines.

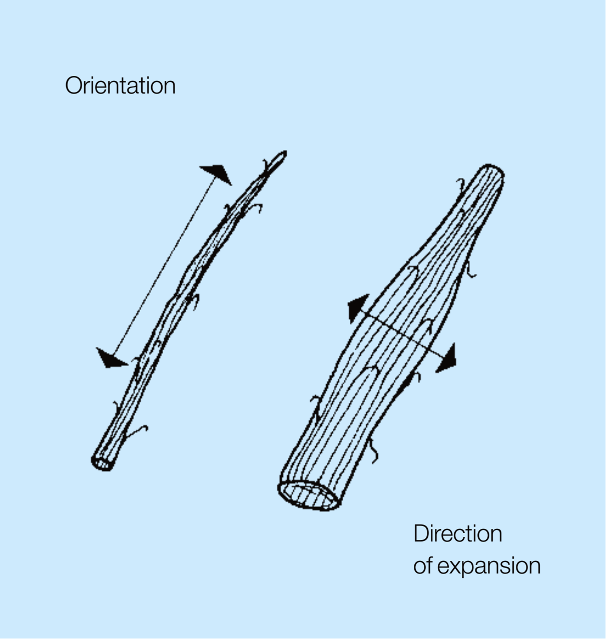
One thing to keep in mind is that different types of paper have different properties of heat conductivity. Hence, temperature balancing times can also vary with different paper types.



Relation of temperature balancing time and difference in temperature and stack size

The influence of humidity on curling tendency

The tendency to curl is closely connected to fluctuations in humidity. Curling is caused by the paper fibres expanding and shrinking in the cross direction (see figure below). When paper is moistened on one side, the fibres expand in one direction, causing the paper to curl toward the dry side. As soon as a balance in humidity within the paper structure has been restored, the effect is cancelled out – unless this is prevented by an uneven fibre distribution.



Expanding behaviour of paper fibres

The influence of stack humidity and temperature on ink drying

Exceedingly high humidity balance of the paper stack can lead to significant extension of ink drying times. Experience shows that stack humidities of up to 60% do not cause drying times to significantly go up. Above 60%, however, the effect is pronounced indeed, in some cases leading to drying periods three times as long as normal.

Extended drying times can also occur when the stack of printed paper is too cold. When printed paper is temporarily stored in a cold room (temperature dropping from 25 to 5 °C), the ink will take 10 to 15 hours longer to dry.

IV The relation between climate and technical printing problems

Vegetable fibres are the primary raw material for paper, and these fibres are sensitive to moisture. Depending on the humidity of the surrounding air, they either absorb or exude moisture.

The extent to which paper contains moisture, is largely the result of the raw materials used, but the way these raw materials have been prepared in the pulping process also has an effect. If the fibres have been intensively beaten, their surface size will have increased, and this, in turn, increases their capacity to absorb moisture.

Mineral fillers, such as calcium carbonate and kaolin, are not actively involved in any processes of moisture exchange. Therefore, papers with a large proportion of fillers contain less moisture than papers with low quantities of fillers or no fillers at all. Sizing (the application of a glue layer) has no significant effect on moisture content.

Depending on paper type, the level of moisture content can influence the general properties of a paper. For instance in terms of its tensile strength, folding resistance and surface smoothness. In general, however, the issues mentioned only lead to processing problems under exceptionally adverse conditions. This is very different in the case of two other common phenomena that do cause serious problems: static charge and dimension variations. Both can have a negative impact on the runnability of the paper, thus leading to misregistering and other disturbances of the printing process.

Dimension variations

Depending on relative air humidity, the fibres contained in the paper either absorb or exude moisture, causing them to swell or to shrink. In other words, the shape of the fibre changes, significantly so in the cross direction, much less in the machine direction. On top of this, during the process of paper production, the fibres orient themselves in the machine direction (the run direction of the wire). The combined effect of these two phenomena inherent to the production of paper, is that dimension variations are far more pronounced in the cross direction of the paper than in the machine direction.

Different types of paper can show swelling levels of 0.1 % to 0.3 % in machine direction, as opposed to 0.3 % to 0.7 % in cross direction. These are values that in the practice of printing will never be reached, but they can be measured in tests of moisture-induced expanding according to DIN / ISO 8226-1. These tests show that a change in relative air humidity of 10 % causes the paper to “grow” in a proportion of 0.1 % to 0.2 % across the width. This means that a paper of 100 centimetres across, will expand 1 to 2 millimetres – a change in dimension that will definitely lead to printing problems such as misregistering. Fortunately, most printers are aware of the issue, and take these dimension variations into account during pre-press and actual print run. Apart from that, the problem of misregistering caused by absorption of moisture has to a great extent been solved by technical innovations – such as moisturising installations, “low-fount” offset plates, the addition of alcohol to the fountain solution and, last but not least, increased printing speeds significantly reducing the “dwell time” of the paper in the printing press.

Static charge

Another problem that occurs from time to time, is sheets of paper “sticking” together. In most cases, this is due to static charges, primarily produced by friction, direct contact with other materials and sudden separation. Static charges most commonly occur when exceedingly dry paper is processed in conditions of low air humidity. A level of 40 % to 32 % humidity appears to be the critical bottom limit, both for the paper itself and for the relative humidity of the air in the workshop.

Static charges, causing sheets to stick together, can result in multiple sheets being fed into the press at the same time. Static charges can also make the cushion of air, separating two sheets in the delivery, dissolve too quickly, thus causing ink from the printed side of one sheet to set off onto the unprinted side of the next one.

V Circumstances within the printer's power to control

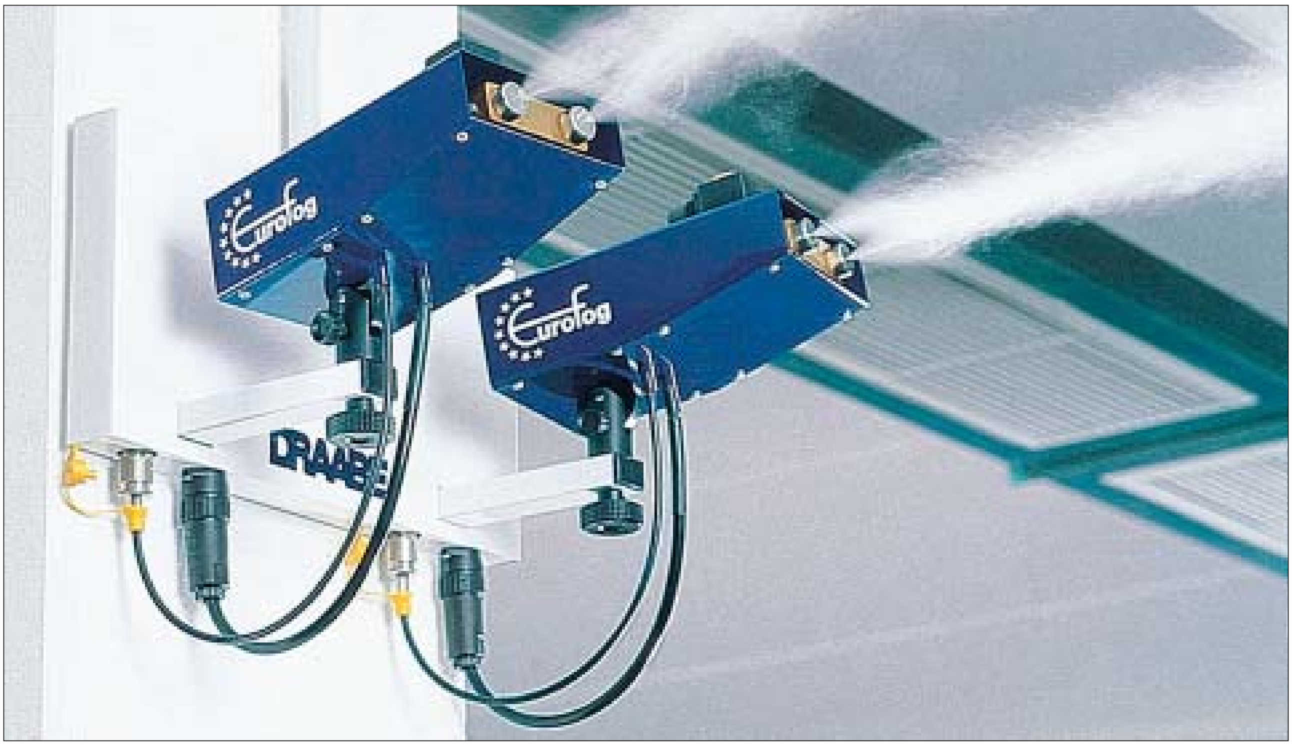
Circumstances in the workshop

Today, moisturising installations are used in practically every paper processing environment. Most of these installations are fully automatic or semi-automatic and require little or no maintenance. Particularly during winter, when relative air humidity can drop to very low levels, moisturising installations help to create optimal conditions in storage rooms and workshops. The basic design is the same in all cases: a series of spray nozzles, operating on compressed air and spreading a thin mist of water. The installation automatically maintains the required air humidity according to a set range of humidity values.

Paper handling

Especially in periods of critical climate circumstances, printers are advised to follow these guidelines:

- Paper is not an efficient heat conductor. Therefore, allow for sufficient time to let the paper adapt itself to the temperature in the workshop.
- Do not open the paper wrapping until printing is about to begin. The wrapping protects the paper from fluctuations in temperature and humidity.
- Infrared-drying, which drastically reduces the relative humidity of the paper, should be used sparingly.
- During drying, the paper should not be exposed to extremely low temperatures, as this would significantly extend drying times.
- Avoid damaging the paper wrapping and carefully re-wrap remaining pallets.



Air humidifying installation EuroFog

Two-sided printing in a printing unit

VI Special issues in web offset printing

The technique of heatset web offset printing, with its special drying process, has its own, unique requirements. In multi-colour web offset printing on coated papers, the paper web is printed on both sides and thermally dried after it leaves the last printing unit. Drying takes place at this point because an unsettled layer of ink would rub off on the turning bars, the guide bars and the former fold, causing the print to smear and preventing successful processing in the folding unit.

Heatset inks settle (or "set") when the thin-liquid binding agents evaporate. To make this happen, the printed paper web is heated in a multisection drying oven, with different temperatures in each of the different sections. Usually, the first section has the highest temperature, which is then gradually reduced in the following sections. Overall, however, very high temperatures are used, because processing takes place at high speed and the paper does not remain in the drying oven for very long. When it leaves the oven, the paper web is usually at a temperature of 100 to 130 °C, depending on paper quality, substance and ink covering.

Outline of a web offset printing press

VII Problems in web offset printing

Blistering

When the ink dries, so does the paper. In intensively printed areas, if the drying temperature is too high or if the paper is sensitive to such problems, this can lead to blistering. The sudden, extreme rise in temperature produces a build-up of water vapour in the internal structure of the paper. And because the paper is not only coated, but also printed on both sides – at certain places covered in thick layers of ink – this vapour has nowhere to go. This leads to tearing in the internal structure of the paper and blistering in the printed areas (see figures).

From a technical point of view, blistering is a direct result of ink layer thickness and high temperatures in the drying oven. Thick layers of ink reduce the air (or vapour) permeability of the paper surface and high temperatures increase the amount – and the pressure – of vapour building up in the internal structure.

The easiest and most efficient way to prevent blistering, is reducing the oven temperature. This means that printing speed will have to be reduced as well, in order to achieve sufficient settling of the ink at a lower drying temperature.

Since blistering only occurs in areas with intensive ink covering on both sides, reducing the thickness of the ink layer – by means of UCR (UnderColour Removal), for instance – can also have a positive effect. Apart from this, there are certain paper properties that affect blistering, such as the type of binding agents and coating pigments used, the amount of binding agents contained in the paper and the amount of coating used, and the degree to which the surface has been "closed" as a result of calendering. Obviously, the humidity of the paper is a very important factor as well. Usually, papers intended for web offset printing, particularly the woodfree types, have lower humidity levels than papers for sheet offset printing.

Blistering

Blistering

Breaking in the fold

Breaking in the fold is a common problem in web offset printing, particularly when mechanical papers are used. Broken or severely weakened folds can cause press stops and can make the end product unusable (see figure to the right). The main sources of breaking in the fold are the extreme temperatures the paper is subjected to in the drying oven and the pressure applied in the folding unit. The single most important thing here is to find a compromise that will allow for sufficient ink drying without causing the paper to dry out.

Breaking in the fold

In the folder, the pressure applied by the folding rolls must be carefully adapted to the thickness of the paper used.

Paper should have a certain residual strength, for which the FOGRA method suggests the following values:

Paper substance > 72 g/m²

Critical range
< 10 N/15 mm
(Breaking in the fold as a result of paper properties)

Middle range
10 N/15 mm to 15 N/15 mm
(Breaking in the fold as a result of paper properties or caused by processing issues)

Neutral range
> 15 N/15 mm
(Breaking in the fold unrelated to paper properties)

Paper substance < 72 g/m²

Critical range
< 10 N/15 mm
(Breaking in the fold as a result of paper properties)

Middle range
10 N/15 mm to 12,5 N/15 mm
(Breaking in the fold as a result of paper properties or caused by processing issues)

Neutral range
> 12,5 N/15 mm
(Breaking in the fold unrelated to paper properties)

These values apply to both machine and cross direction of the paper.

Fluting

Even today, more or less pronounced forms of "fluting" are among the typical problems in web offset printing on coated papers. The waves run parallel to the printing direction – which, in the case of web offset, is automatically the machine direction. One of the main paper characteristics that affect the severity of fluting, is the MC/CD (machine direction / cross direction) strength ratio of the paper. Strong longitudinal fibre orientation makes a paper more sensitive to fluting. Interestingly, the problem occurs most with papers of the lower substances. But the decisive factor is the printing form itself. Pages that contain intensively printed areas next to areas with hardly any or no ink at all, are particularly sensitive to severe fluting. When this happens, there is nothing that can be done in the printing process to prevent it.

Waviness observed before the paper is actually fed into the web offset press, however, is a very different issue. One method of partially preventing these so-called "tensile waves", is to reduce web tension. The problem can never be totally eliminated, since a certain amount of web tension will always be necessary to prevent creasing or misregistering.

Humidity measurements of printed paper show that, in the drying oven, practically all moisture is extracted from the paper. Humidity balance values of 10 % are common.

Fluting

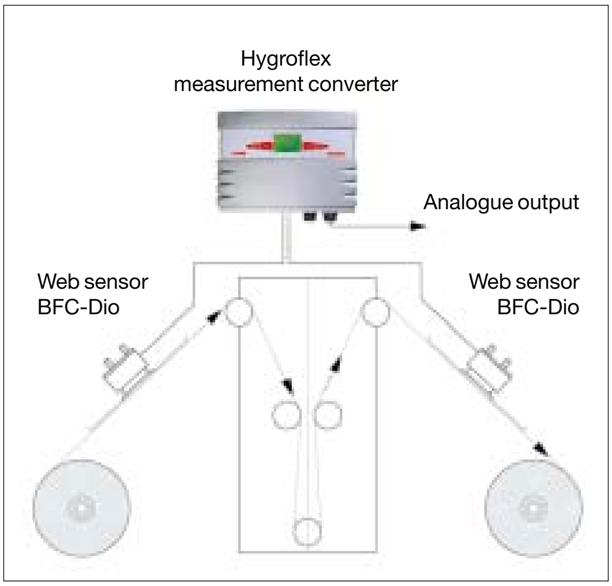
Fluting

Expanding

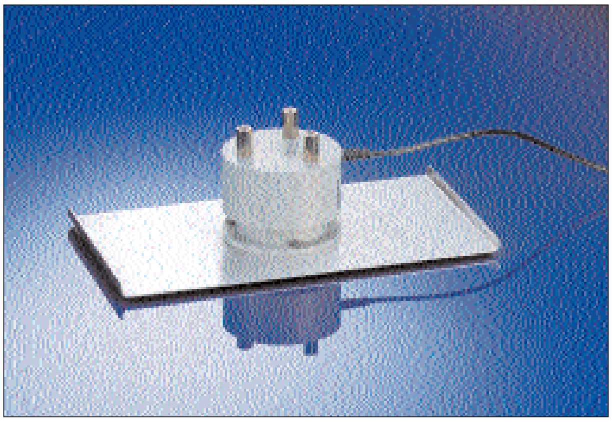
The problem of expanding or “growing” of printed paper, as seen when pages produced in web offset are combined with covers produced in sheet offset, is caused by the intensive drying of papers after they leave the drying oven. Here, so much moisture is extracted from the paper, that it inevitably shrinks to some degree, up to 0.3 to 0.7 %. After the signatures have been gathered, stitched and cut, the paper begins to adapt to the surrounding humidity once again, and starts to “grow”, causing the inside pages to extend beyond the size of the cover.

The best method for counteracting or totally eliminating this problem, is sufficient remoisturing. Remoisturing installations serve to evenly rehumidify the entire paper web after it leaves the drying oven. This also improves paper flatness and totally eliminates the risk of static charges. Remoisturing equipment can be easily installed on most existing printing presses.

Remoisturing



Web sensor



Digital web sensor for measuring humidity balance and temperature on the moving web

Remoisturing installations use digital web sensors to control humidity and temperature. The installation is placed directly above, but not touching the paper web, thus creating a limited space with a carefully regulated and measurable artificial climate in which outside influences can easily be compensated for. This way, paper quality is continuously monitored. Apart from that, these measurements supply large amounts of data that can be used as a basis for process improvements.

VIII Measuring temperature and humidity

Measuring interior temperature and room humidity

The usability of values in a diagram, describing, for instance, development of relative humidity with changing temperatures, is completely dependent on the accuracy of the measurements taken. The curve in such a diagram shows that temperature measurement in particular has to be very exact. This means that thermometers should be used which indicate half degrees and (approximations of) tenths of degrees. Exact temperature measurements are relatively easy and effortless, but the same cannot be said for measurements of absolute moisture content or relative humidity.

The practical problem with these measurements is that very small quantities of moisture have to be measured with very high accuracy. The diagram on page 6 shows that, at a temperature of around 20° C, an increase in moisture content of no more than 2 g/m^3 produces a rise in air humidity of no less than 10 %.

Measuring the moisture content of paper

Moisture content measurements are highly uncommon in the printing and finishing industries.

Here, we will only list the various measuring methods used in practice. More information can be found in FOGRA Praxis Report 50.

- The warmth-chamber method
- The infrared-drying scale
- Measurement of moisture content on the basis of microwave drying
- Measurement of moisture content on the basis of microwave absorption
- The Karl-Fischer method for measuring moisture content
- Other methods

Measuring the humidity balance of paper

In contrast to measurements of the “absolute” moisture content of printing papers, determining humidity balance is common practice in the printing and finishing industry. Humidity balance is a unit indicating the extent of equilibrium between relative humidity of paper and surrounding air. As long as these two levels of humidity are balanced, the paper will not absorb or exude moisture, which means that, in this state of humidity balance, no changes occur in the moisture determined (for instance, dimensional) properties of the paper. To determine the relative humidity or humidity balance of paper, changes are measured in the behaviour of objects or materials which – measurably – react to moisture. For instance, the length changes of animal hairs, changes in the conductivity of electrolytes or changes in the resistance of semiconductors. In the practice of paper production and processing, these methods are widely applied in measurement and control systems. The very accurate methods for calibrating such equipment are all based on measurements of condensation point temperature and determination of psychrometric differences or vaporisation coldness. FOGRA report 50 describes the working of condensation point gauges and psychrometers.

Electronic measuring equipment

Nowadays, electronic gauges with digital displays have become widely-used tools for measuring air humidity. These modern gauges combine very fast response times with ease of use and calibration. Common humidity gauges all use one of two possible methods of measurement – conductivity measurement or capacitive measurement.

Conductivity measurement uses the changes in conductivity of hygroscopic electrolytes under the influence of vapour absorption as the basic input for measurements. Capacitive hygrometers measure the capacitive changes of dielectric substances – non-conductors – under the influence of vapour absorption. In both cases, these changes occur as a result of changes in air humidity. Numerous instruments of different design are available for these measurements – sword gauges for measuring humidity in stacks of paper, surface gauges for measuring sheets and reels of paper. There are also sensors for measurements of air humidity which are consequently used to control moisturising and conditioning installations. Most of these instruments come with a set of tools for easy calibration. To carry out this calibration process, the measuring cell at the tip of the instrument is sealed air-tight. Next, a saline solution is introduced in the very small space directly under the measuring cell in order to set the air humidity. The values indicated by the tool are then compared to the values derived from the saline solution, which must always be kept at an exact, prescribed temperature.

Sword gauge

Surface gauge

IX Concluding remarks

The contents of this brochure are the result of practical experience and close collaboration with FOGRA, an organisation which has been very helpful in many ways.

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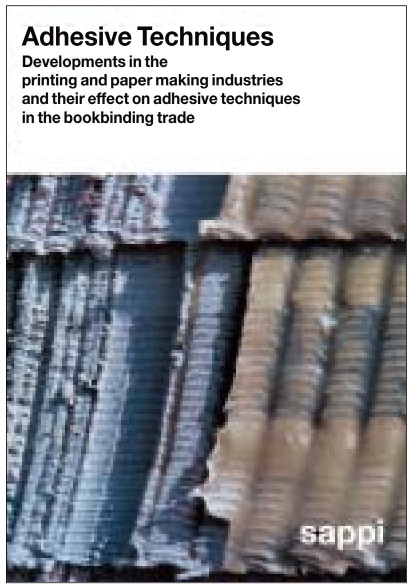

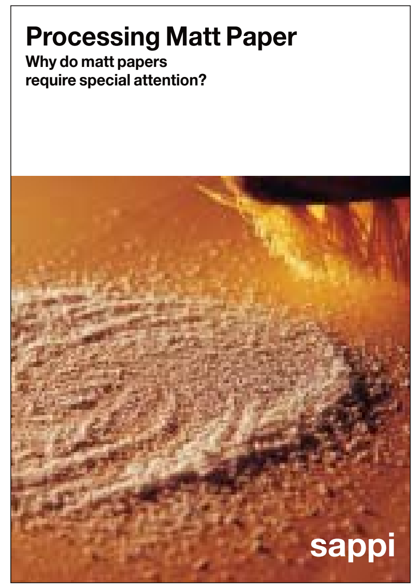

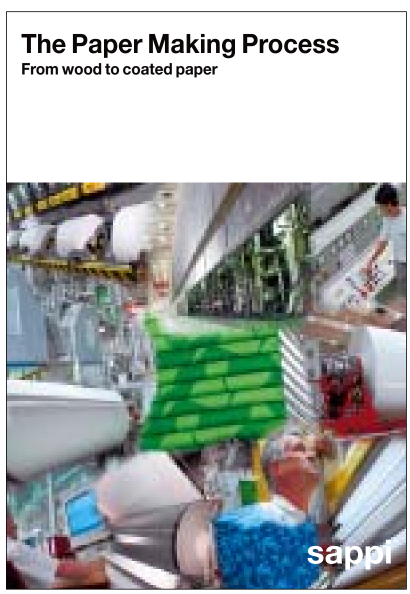

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