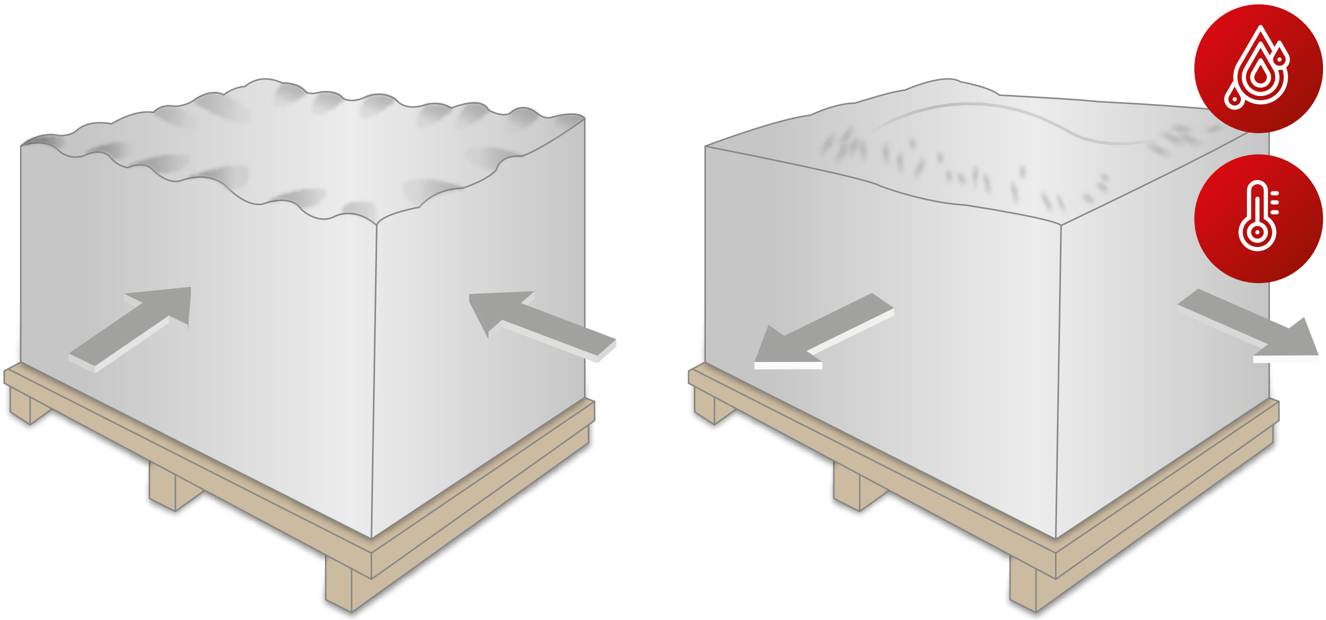
White paper

PAPER AND CLIMATE

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



Environmental conditions have a big influence on the paper and ultimately on the print quality.

Contents

Introduction	
The situation in the paper production and printing industries	2
The situation in the printing and finishing industries	2
Definition of terms	
Weather, weather situation and climate, interior climate and ambient atmosphere	2 - 3
Air temperature and air humidity, absolute and relative air humidity	3
Moisture content of materials, absolute moisture content, dew point temperature, equilibrium relative humidity	4
The influence of interior climate on paper flatness	
Influence of air humidity, wavy edges and tight edges	5
Influence of room temperature	6
Influence of humidity on curling tendency	6
Influence of stack humidity and temperature on ink drying	6
Relationship between climate & technical printing problems	
Dimensional variations	7
Static charge	7
How to improve print quality	
Climate in the print room	8
Paper handling	8
Special issues in web offset printing	9
Problems in web offset printing	
Blistering	10
Breaking in the fold	10 - 11
Fluting	12
Expanding	12
Measurement of temperature and humidity	
Measurement of room temperature and humidity	13
Measurement of the moisture content of paper	13
Measurement of the equilibrium relative humidity of paper	13
Electronic measuring instruments	14
Concluding comments	15

Introduction

The situation in the paper production and printing industries

Discussions about the effect of climatic influences during paper storage and transportation and during 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 on the need to monitor and control temperature and humidity. Despite the long experience in this subject, some relationships have still not been explained sufficiently or at all. In the practice of paper processing, many 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% ± 5% and at 40% ± 5% for web offset printing. These humidity properties are monitored continuously in all stages of the production process.

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 environmental changes. The paper manufacturer, however, has very little or no influence on how the paper gap or, more specifically, the paper fiber gap will react to environmental conditions existing at the printer's, bookbinder's or end customer's premises.

The situation in the printing and finishing industries

Under normal circumstances, there are few climate-related problems in printing and finishing. Only when printing problems such as dot doubling, mis-registering, creasing or curling occur do climate-related influences become an issue. The likelihood of this happening is more pronounced in seasons with extreme weather conditions – hot summers and coldwinters. In these periods, improper handling – premature unwrapping of the paper and use of paper that is too cold – or unfavorable conditions at the printer's or binder's premises can have disastrous consequences for the paper quality.

This white paper is intended to help clarify some of the more serious negative effects of environmental conditions and provide guidelines for correct handling of coated papers and for optimal control of the printing process.

Definition of terms

Weather, weather situation and climate

When we speak of weather, what we actually mean are the atmospheric conditions at a certain place at a specific point in time. When we refer to the weather during a period of days or weeks, we talk of the weather situation. The concept of climate is slightly more complex.

'Climate' 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, cloud cover and sun hours.

Interior climate

Interior climate is a term used for the air condition in rooms partially or completely excluding people and materials from the influence of outdoor climatic conditions. The interior i.e. the climatic condition of the air in the immediate environment, is decisive for production processes and for the storage of goods sensitive to temperature and humidity.

In this respect, there is a big difference between conditioned and non-conditioned rooms. The former is a room or workspace where climate conditions are not controlled. In a conditioned room, climate conditions are controlled by means of heating, humidification and dehumidification.

Fig. 1: HL-1D data logger

For non fully-conditioned rooms, the influence of outside conditions is strong. In conditioned rooms, which are heated, but not air-conditioned during the winter months, relative air humidity behaves inversely to the outdoor air. Very low humidity values are measured during winter when the heating is on, and the highest are reached during the summer months.

Ambient atmosphere

The term ambient atmosphere is used to describe the air conditions in the immediate vicinity of an object, e.g. a reel of paper or a stack of sheets. Figure 1 shows a data logger from the HygroLog HL-1 series, an instrument for measuring temperature and air humidity in configurable intervals of 30 seconds to 120 minutes for a maximum duration of about one year.

Air temperature

Air temperature is a measure for the thermal state of the air, or, technically speaking, for the state of the energy of the gas molecules, primarily nitrogen and oxygen. When air takes on thermal energy, its 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 moisture in the form of vapor. The air humidity is given either as absolute humidity/absolute moisture content or as relative humidity. These two terms are defined as follows:

Absolute air humidity

Absolute air humidity is the ratio of the mass of water vapor to the volume of the air, i.e. the amount of moisture in grams contained in a cubic meter of air. The absolute humidity of the air is of little significance in practice because it does not consider one vitally important influencing factor – temperature.

Digital probes for data loggers in the HygroLog HL-NT series

Dew point temperature

When humid air cools down to a certain point (dew point temperature), the moisture it contains starts to condense. This condensation of water vapor through cooling to dew point temperature forms the basis for the measurement of relative air humidity.

Relative air humidity

At any given temperature, air can only contain a certain amount of moisture in the form of vapor. The higher the temperature , the more moisture air can absorb. When it has absorbed the maximum amount of moisture it can contain at a specific temperature, air is called saturated. Relative humidity, then, is the relationship between the absolute humidity and the highest possible moisture content at a given temperature:

$$RH = \frac{\text{Absolute air humidity}}{\text{Max. possible absolute air humidity}} \times 100\ (\%)$$

Since the maximum possible humidity of the air is highly dependent on its temperature relative humidity – in contrast to absolute humidity – is also temperature dependent.

Figure 2 shows the correlations. Using it, relative air humidity can be read on the basis of a given room temperature and given absolute moisture content, or, conversely, absolute humidity at a given relative air humidity.

Moisture content of materials

Porous materials like paper contain moisture in the form of vapor in the larger pores and in the form of liquid in the minute capillaries of the paper's structure. As with air, the moisture content of materials can be defined in two different ways.

Absolute moisture content

Moisture content in percent is the mass percentage of water in paper in relation to the mass of the material. In paper production, absolute moisture content is commonly used as a unit for measurement and control, but in printing and finishing, it is of subordinate importance.

Equilibrium relative humidity (ERH)

Porous materials like paper strive to reach a state of equilibrium between their own moisture content and the humidity of the surrounding air. This means the air separating individual sheets of paper in a stack and the moisture content of the paper itself will always be in balance. Equilibrium relative humidity thus reflects the relationship between the humidity of a material and the humidity of the surrounding air. As long as both moisture contents are about the same, the paper will neither absorb moisture nor give moisture off to the surrounding air. But if the difference between the moisture contents of the paper and surrounding air is large, the paper will change by either absorbing or exuding moisture.

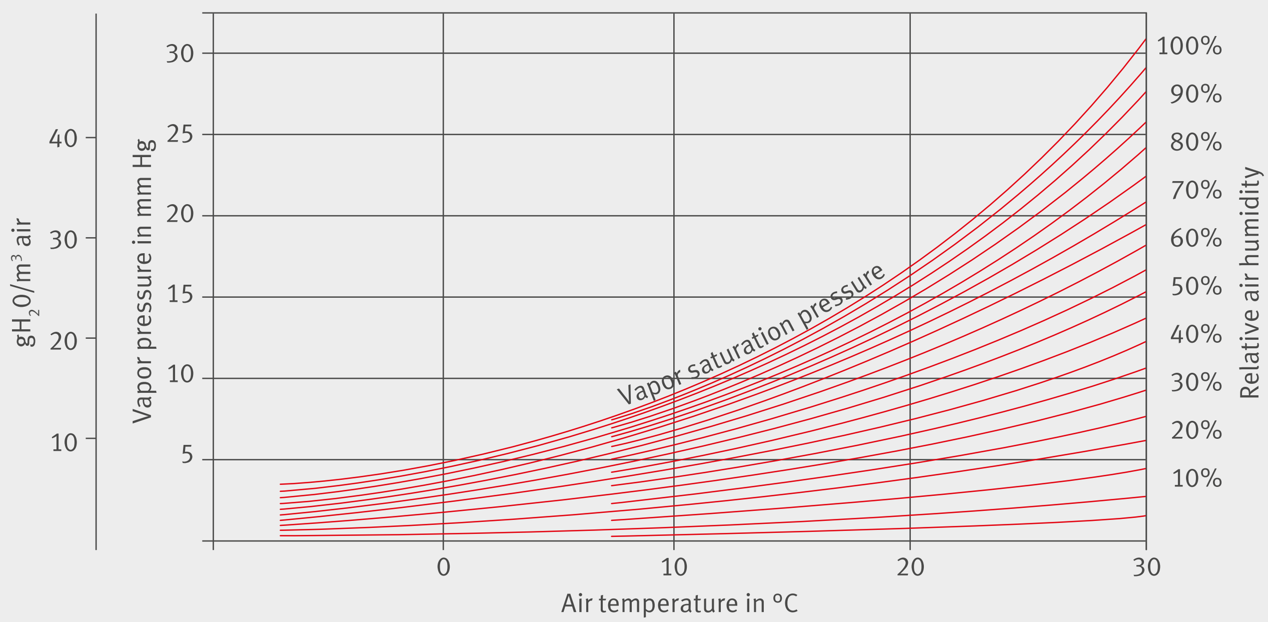


Fig. 2: Correlation between relative air humidity and temperature.

The influence of interior climate on paper flatness

The influence of air humidity

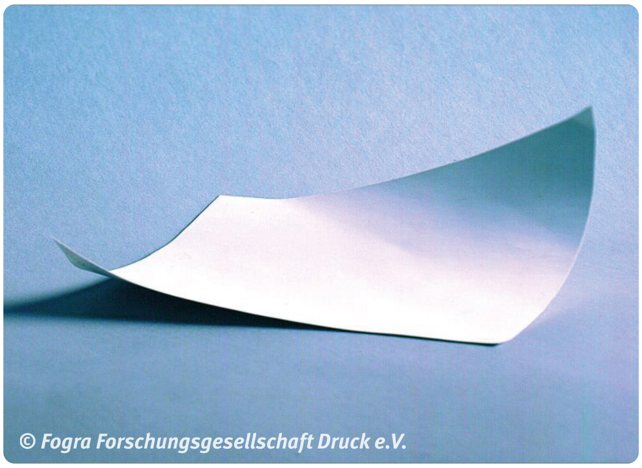
Problems can occur in offset printing when the paper is deformed, either as wavy or tight edges, because full contact between the blanket cylinder and impression cylinder in the printing zone results in deformation of the sheets, which can lead to dot doubling, mis-registering and creasing.

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 exposed to higher air humidity, or when paper with a normal equilibrium relative humidity is exposed to excessively moist surrounding air. This can occur predominantly in the hot and humid months of summer in non-conditioned warehouses and print rooms or when vapor-tight wrapping is not used during transportation or storage in humid conditions.

If, on the other hand, stacks of excessively cold paper that have already been unpacked are introduced into the warm air of a print room during winter, the surrounding air will be cooled down, thus causing a sharp increase in relative air humidity. In both cases the edges of the sheets will absorb moisture, making them swell in relation to the center of the sheets, resulting in wavy edges.

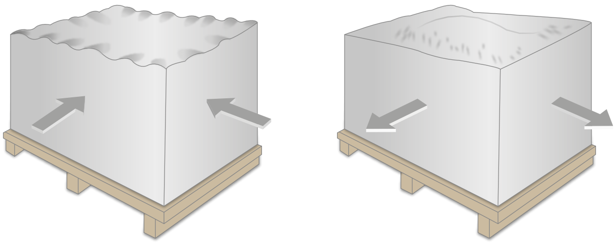
Tight edges occur when sheets of paper with a normal moisture content are exposed to dry ambient air. In this case, moisture is absorbed from the edges of the sheets, which, as a result, shrink in relation to the center. This will mainly occur during winter, when the relative air humidity in heated, non-conditioned or non-humidified working spaces can drop to levels as low as 20 % of the normal values.

Normally, vapor-tight wrapping provides efficient protection against humidity influences. The wrapping must be completely intact in order to be able to offer such protection.



Deviations in equilibrium relative humidity 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.

Figure 3 shows the mutual influences of relative room air humidity and stack humidity. The arrows show the direction in which moisture is absorbed by or exuded from the stack of paper.



Paper wavy-edge effect   Paper tight-edge effect

Fig. 3

The influence of room temperature

Temperature only has a minor influence on stack humidity. Nevertheless, it must be taken into account as it is one of the elements determining relative air humidity. This means that if there is a difference between paper stack temperature and room temperature, the paper should remain wrapped in its vapor-tight packaging until this difference in temperature has been balanced out.

How long this takes varies from case to case depending on how large the temperature difference is and the size of the paper stack. Figure 5 shows general guidelines in this regard. One thing to keep in mind, however, is that different types of paper have different heat conductivity properties. Hence, temperature balancing times can also vary with paper type.

The influence of humidity on curling tendency

The tendency of paper to curl is closely connected to fluctuations in humidity. It is also caused by the paper fibers expanding or shrinking in transverse direction (figure 4). When paper is moistened on one side, the fibers expand on this side, causing the paper to curl towards the dry side. As soon as a balance in humidity within the paper structure has been restored, this effect is canceled out – unless this is prevented by an uneven distribution of fibers.

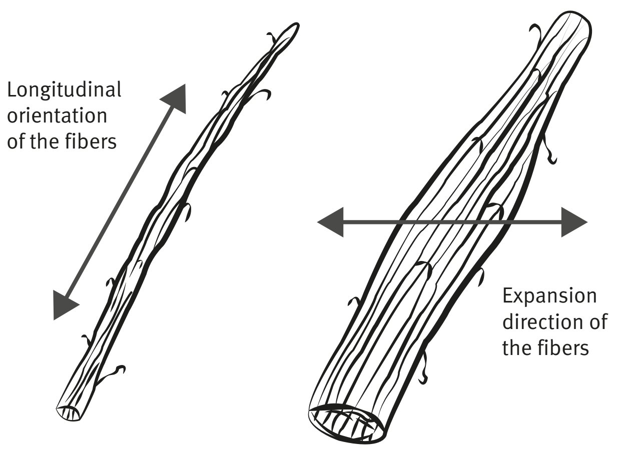


Fig. 4

The influence of stack humidity and temperature on ink drying

An excessively high equilibrium relative humidity in the paper stack can lead to a significant extension in ink drying times. Experience shows that stack humidity of up to 60 % do not cause any significant increase in ink drying times. Above 60 %, however, the effect is very pronounced, in some cases leading to drying periods three times longer than normal.

Extended drying times can also occur when the stack of printed paper is too cold. For example, when printed paper is stored temporarily in a cold room (temperature dropping from 25 to 5°C), the ink will take 10 to 50 hours longer to dry.

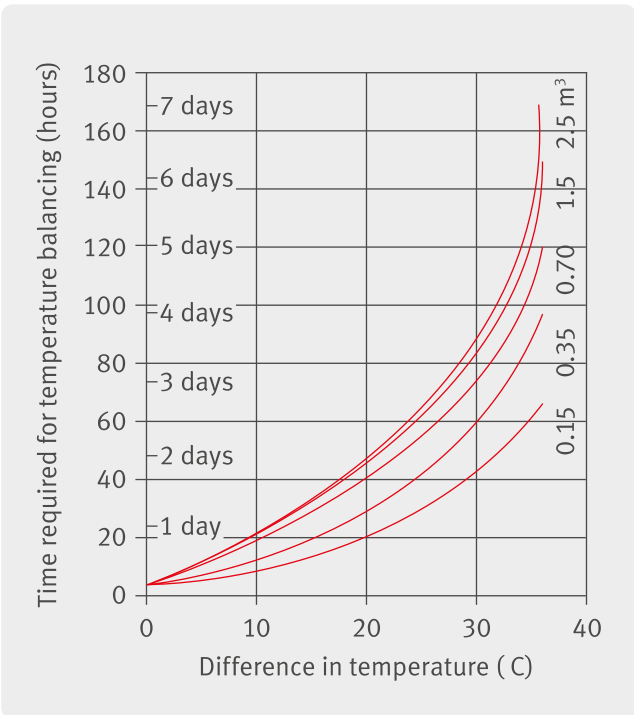


Fig. 5

The relationship between climate and technical printing problems

Vegetable fibers are the primary raw material for paper, and these fibers 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 influenced by the type of raw materials used, but the way these raw materials were prepared in the pulping process also plays a role. If the fibers were beaten intensively, 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 influence on moisture content.

Depending on the type of paper, the level of moisture content can influence the general properties of a paper. For instance, its breaking length, folding strength and surface smoothness. In general, however, the above factors only lead to processing problems under exceptionally adverse climate conditions. This is very different in the case of two other common phenomena that do cause serious problems: static charge and dimensional variations.

Mis-registering can also be attributed to poor runnability of the paper through the printing press.

Dimensional variations

Depending on the relative air humidity, the vegetable fibers contained in the paper either absorb or exude moisture, causing them to swell or to shrink. Such changes in shape occur much more strongly in the diameters of the fibers than in their lengths. In paper production, the fibers orientate themselves mainly in screen run direction. Consequently, the dimensional variations are far more pronounced in the transverse direction of the paper than in 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 transverse direction. A change in relative air humidity of 10 % results in length changes of 0.1 % to 0.2 % in transverse direction, which would mean a dimensional change of 1 mm to 2 mm in the case of a paper 100 cm across. These are values that can lead to unwanted mis-registering.

Fortunately, most printers are aware of the issue, and take these dimensional variations into account during pre-press and actual print run. Apart from that, the problem of mis-registering caused by absorption of moisture has to a great extent been solved by technical innovations – such as moisturizing installations, “low-fount” offset plates, the addition of alcohol to the fountain solution and, last but not least, higher printing speeds that significantly reduce 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. These static charges occur most commonly when exceedingly dry paper is processed in conditions of low air humidity.

A level of 40 % to 45 % humidity appears to be the critical bottom limit, both for the paper itself and for the relative humidity of the air in the print room.

The resultant charge, or the forces of attraction caused by it, can result in multiple sheets being fed into the press at the same time. Static charges can also make the cushion of air that separates two printed sheets in the delivery pile dissolve too quickly, thus causing ink from the printed side of one sheet to set off on to the unprinted side of the next one.

How to improve print quality

Climate in the pressroom

Today, moisturizing installations are used in practically every paper processing environment. They are fully automatic or semi-automatic and require little or no maintenance (figure 6). Particularly during winter, when relative air humidity can drop to very low levels, moisturizing installations help to create optimal conditions in the print and storage rooms of printing companies. The basic design is the same in all cases: a series of nozzles, operating on compressed air, spray a thin mist of water. The installation automatically maintains the required air humidity according to a set range of humidity values.

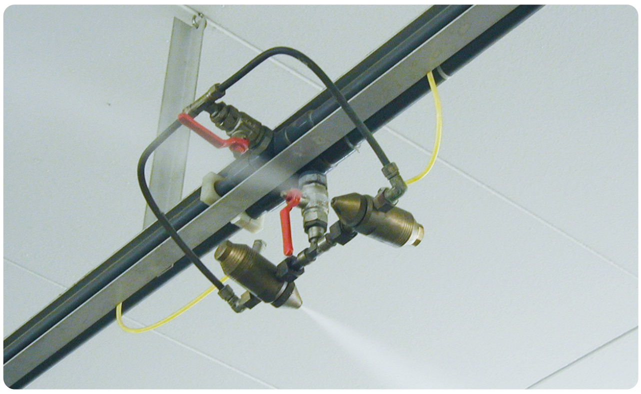


Fig. 6

Paper handling

Especially during periods of critical climate conditions, printers should follow the guidelines below when handling paper:

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

Special issues in web offset printing

In heatset web offset printing, the moisture content of the paper must be adapted to the special drying process of the printing technique (figure 7).

In multicolor web offset printing on coated papers, the paper web is printed on both sides (figure 8) and dried thermally 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 rolls and the folder former, causing the print to smear and preventing successful processing in the folding unit.

Heatset inks settle (or "set") when the thin binding agents evaporate. To make this happen, the printed paper web is heated in a multi-section 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, high air temperatures are used to dry the ink 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 usually has a temperature of 100 to 130 °C, depending on paper quality, substance and ink coverage.

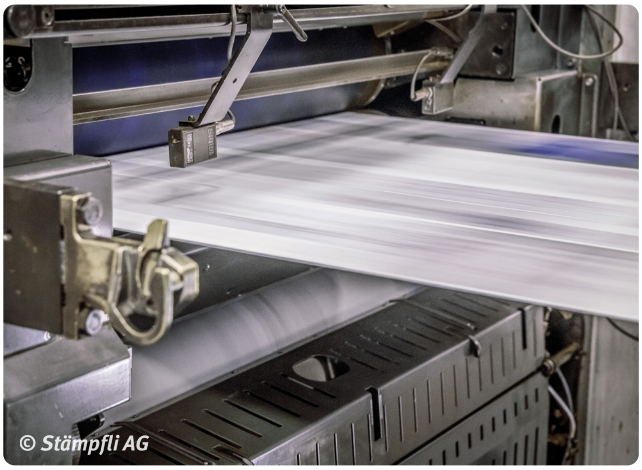


Fig. 8: Two-sided printing in a printing press

Fig. 7: Web offset printing press with drying oven

Problems in web offset printing

Blistering

When the ink dries, so does the paper. If the paper is sensitive to blistering or the drying temperature is too high, this can lead to blistering in intensively printed areas. The sudden rise in the temperature of the paper web produces a build-up of water vapor in the internal structure of the paper. Also, because the paper is not only coated, but also printed on both sides – at certain places covered in thick layers of ink – this vapor has nowhere to go.

This leads to tearing in the internal structure of the paper and blistering in the printed areas (figure 9). From a technical point of view, blistering is influenced mainly by the thickness of the ink layer and the temperature of the hot air in the drying oven. The air or vapor permeability of the paper surface drops as the thickness of the ink layer increases, while the amount and pressure of the water vapor building up in the internal structure rises as the temperature of the hot air increases.

The easiest and most efficient way to prevent blistering is clearly to reduce the temperature of the hot air. To achieve sufficient settling of the ink at a lower drying temperature, this means that printing speed will have to be reduced as well. Since blistering only occurs in areas with intensive ink coverage on both sides(figure 10), reducing the thickness of the ink layer – by means of UCR (Under Color Removal) or GCR (Gray Component Replacement), for instance – can also have a positive effect.


© Fogra Forschungsgesellschaft Druck e.V.

Fig. 9: Tearing in the internal structure of the paper

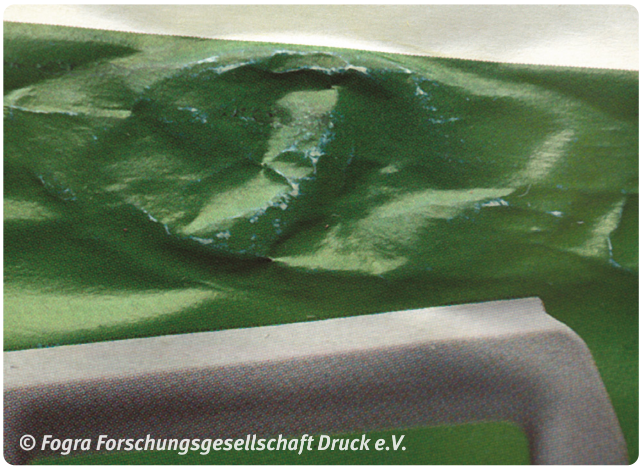

© Fogra Forschungsgesellschaft Druck e.V.

Fig. 10: Blistering

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 coating and the degree to which the surface has been “closed” as a result of calendering.

The humidity of the paper is a very important factor as well. Coated papers intended for web offset printing have less than 40 % equilibrium relative humidity.

Breaking in the fold

Breaking in the fold is a common problem in web offset printing, particularly when lightweight papers are used (figure 11). Broken or severely weakened folds can cause press stoppages and render the product unusable (figure 12). The main causes of breaking in the fold are the extreme temperatures the paper is subjected to in the drying oven and excessive pressure applied in the folding unit of the web offset press.

The temperature of the hot air should be set such that the ink is dried sufficiently without causing the paper to dry out excessively.

In the folder, the pressure applied by the folding rolls must be checked carefully and adapted to the thickness of the paper used. The paper should have a certain residual strength, for which the FOGRA method suggests the following values:

Paper substance › 72 g/m^2

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/m^2

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 residual strength values apply to both machine and transverse direction of the paper.

Fig. 11: Breaking in the fold in lightweight papers

Fig. 12: Broken folds can cause press stoppages

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 – and thus also in the running direction of the paper. One of the main paper characteristics that affect the severity of fluting is the bending stiffness in transverse direction. Papers with lower substances and strong longitudinal fiber orientation are particularly affected.

In these papers fluting originates before the paper is actually fed into the web offset press in the form of "tensile waves", which are fixed by the ink layer and subsequent drying with hot air.

Although the intensity of fluting can at most be reduced a little by reducing the tension of the web, it cannot be eliminated completely (figure 13). Humidity measurements of printed paper show that practically all moisture in the internal structure of the paper is extracted in the drying oven. Equilibrium relative humidity values lower than 10 % are common.

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.

The extreme loss in moisture leads inevitably to shrinking of the paper to some degree. When the paper begins to adapt to the surrounding humidity and absorb moisture again after, for example, stitching and cutting, it starts to grow again. When the inside pages of a print product extend beyond the size of the cover, we speak of "growing".

The best way to counteract fluting or growing and to improve the flatness of web offset products is to remoisturize sufficiently (figure 14). Remoisturizing equipment can easily be installed on most existing web offset presses. Remoisturizing installations serve to evenly rehumidify the entire paper web after it leaves the drying oven.

Fig. 13: Fluting

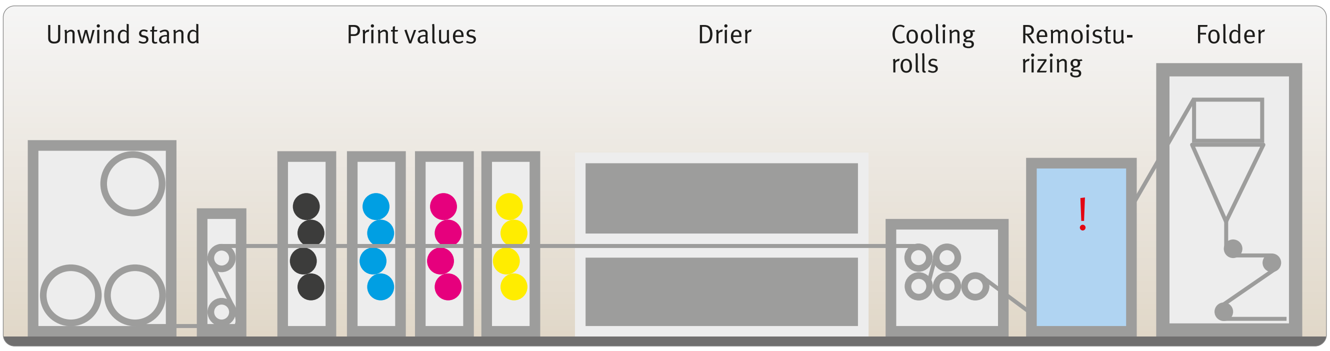


Fig. 14: Remoisturizing

Measurement of temperature and humidity

Measurement of room temperature and humidity

The usability of the values in the diagram in figure 2, describing, for example, the development of relative air humidity as temperature changes, depends on the accuracy of the measurements taken. The curve shows that temperature measurement in particular has to be very exact. This means that thermometers which indicate half degrees and allow estimation of tenths of a degree should be used.

Although exact temperature measurements are relatively easy and effortless, the same cannot be said for reliable measurements of absolute or relative air humidity.

The practical problem with all humidity measurements is that relatively small quantities of moisture have to be measured exactly.

Figure 2 shows that, at a temperature of around 20 °C, an increase in moisture content of around 2 g/m³ produces a rise in relative air humidity of about 10%.

Measurement of the moisture content of paper

Moisture content measurements are highly uncommon in the printing and finishing industries. The various measuring methods used in practice are listed below. More information can be found in FOGRA Practice Report 50.

- The oven drying 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

Measurement of the equilibrium relative humidity of paper

In contrast to measurements of the “absolute” moisture content of printing papers, determination of the equilibrium relative humidity is common practice in the printing and finishing industries.

This value indicates the extent of equilibrium between the relative humidity of the paper and surrounding air. As long as these two values are approximately the same, the paper will neither absorb nor exude moisture, which means that no changes, particularly dimensional changes, will occur in the humidity dependent properties of the paper.

To determine the relative humidity of air or the equilibrium relative humidity of paper, it is necessary to measure the change in a measurable humidity dependent parameter. Such parameters that are influenced by humidity fluctuations are, for example, the changes in length of paper fibers, the conductivity of electrolytes and the 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 methods applied for calibrating humidity measuring instruments are very accurate and based on the principle of dew point measurement and determination of psychrometric differences or vaporization coldness. FOGRA Practice Report 50 describes the working of dew point gauges and psychrometers.

Electronic measuring instruments

Electronic gauges with digital displays are widely used-tools for measuring humidity. They combine fast response times to changes in humidity with ease of use and calibration.

Common humidity gauges basically use one of two possible methods of measurement – conductivity measurement or capacitive measurement.

Conductivity measurement uses the changes in conductivity of hygroscopic electrolytes (e.g. lithium chloride) under the influence of vapor absorption as the measuring signal. Capacitive hygrometers measure the capacitive changes of dielectric substances – non conductors – under the influence of vapor absorption. This is dependent on the relative humidity of the surrounding air.

There are numerous measurement probes of different design available for these measurements:

- sword probes for measurements in stacks of paper
- surface probes for measurement of sheets and reels of paper
- probes for measurement of room air and thus for control of humidifiers and air conditioning systems.

End user calibration accessories are available for these electronic measuring instruments, the process is straightforward. To perform a calibration the sensor at the tip of the probe is sealed air-tight in the calibration device. Next, a saline solution is introduced into the very small space directly under the measuring sensor in order to provide known %RH value the air humidity.

Fig. 15: Rotronic GTS handheld measuring instrument for the paper industry

The values indicated are then compared with the values derived from humidity standard, which must always be kept at a stable temperature.

Acclimatization

The following table shows the time in hours needed for acclimatization of paper before it is unwrapped by volume (m³) and temperature difference (°C) between press room or pressroom and paper

Temperature difference / Paper per pallet	5 °C	7 °C	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C
Approx. 0.2 m^3	4 h	7 h	9 h	15 h	21 h	28 h	41 h	62 h
Approx. 0.4 m^3	7 h	12 h	17 h	26 h	36 h	41 h	64 h	92 h
Approx. 0.6 m^3	9 h	15 h	20 h	31 h	42 h	55 h	76 h	106 h
Approx. 1 m^3	12 h	18 h	23 h	33 h	48 h	63 h	84 h	120 h
Approx. 2 m^3	13 h	19 h	24 h	35 h	49 h	66 h	93 h	130 h

Concluding comments

The contents of this white paper are the result of practical experience and close collaboration with FOGRA, an organization that has been helpful in many ways, and the company Sappi Europe, a European paper producer.

FOGRA Forschungsgesellschaft Druck e.V.

The objective of Fogra Forschungsgesellschaft Druck e.V. (Fogra Graphic Technology Research Association) is to promote print engineering and its future oriented technologies in the fields of research and development, and to enable the printing industry to utilize the results of this activity.

We would like to thank FOGRA for making texts and photographic material available to us from FOGRA PraxisReport 50, "Klima, Papier und Druck" by Dipl.-Ing. (FH) Karl-Adolf Falter, 1998. **www.fogra.org**

Sappi

Sappi is an international company specializing on the distribution of wood pulp, paper pulp, paper and biorefinery solutions for customers in more than 150 countries.

We would like to thank Sappi for their close collaboration and support. **www.sappi.com**

54004E/2020-02