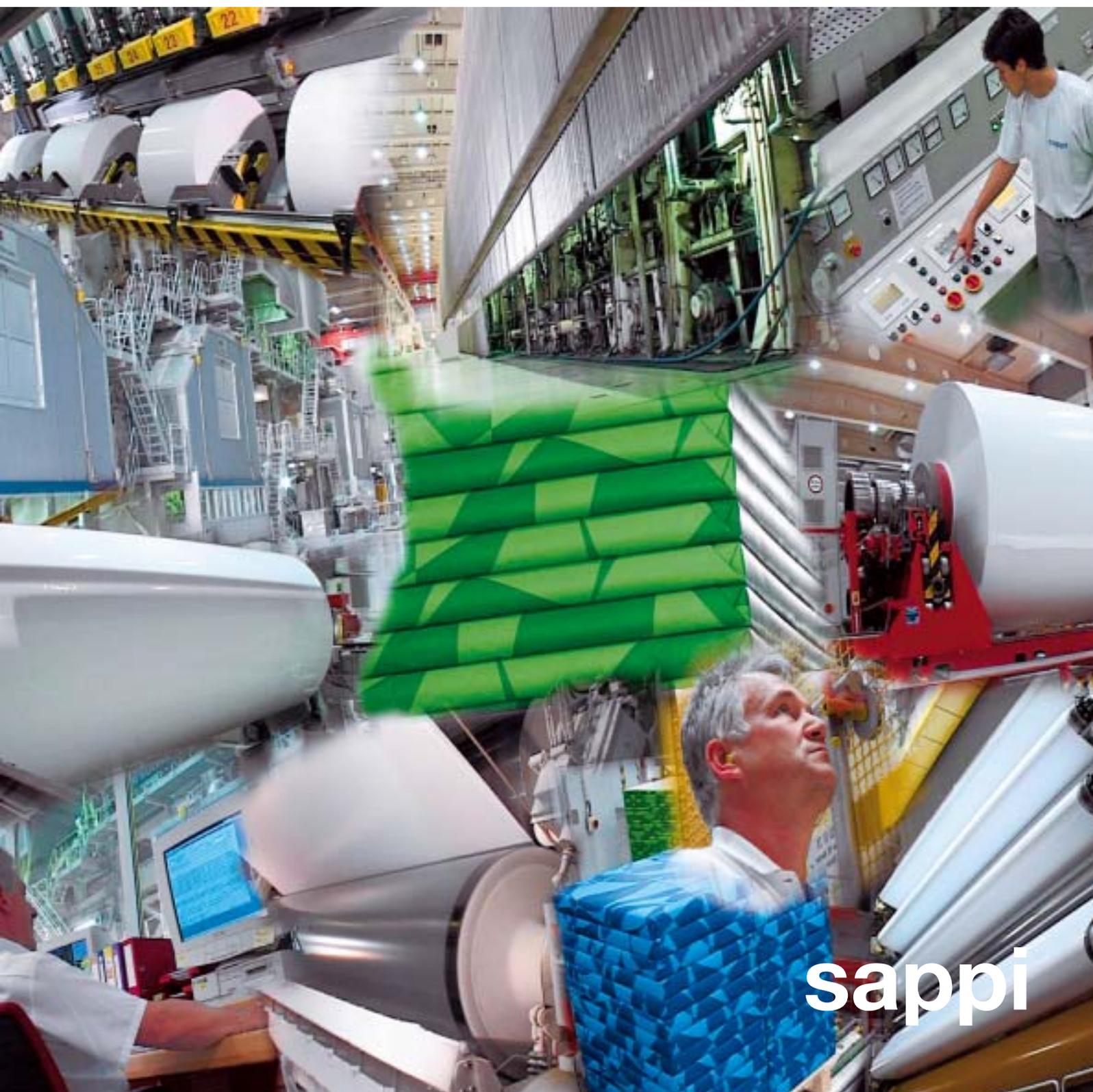


The Paper Making Process

From wood to coated paper



sappi

The Paper Making Process, the fifth technical brochure from Sappi Idea Exchange



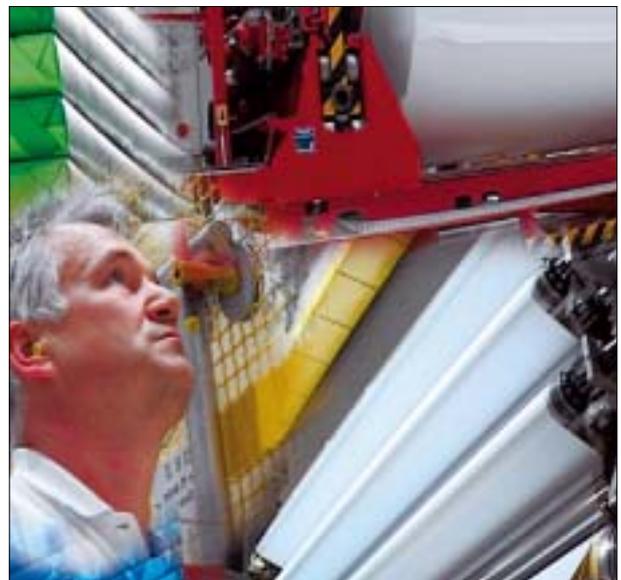
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The Paper Making Process

From wood to coated paper

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I Introduction

Though we may take it for granted, paper is always with us, documenting our world and reminding us of the limitless possibilities of life. Invented by the Chinese 2,000 years ago, paper has been used ever since as a communication medium. Initially, paper was made out of fibres from mulberry bark, papyrus, straw or cotton. Wood only emerged as the chief raw material for paper mass production as recently as the mid 19th century.

The printed page is immediate, its message cutting across cultures; a tactile experience that demands attention and creates desire. It is a passport to knowledge, a storage medium, a persuasive tool and an entertaining art form. Paper is a sustainable resource and a permanent document. It is the universal medium on which we chronicle our every-day history. Paper carries the past. It is the canvas on which we live the present and the blueprint upon which we design our future.

Paper touches the lives of every individual on this planet, and at Sappi, we never stop thinking about this fact. We are proud that Sappi is the largest and most successful producer of coated fine papers in the world. At Sappi, we are relentlessly developing new standards for the paper industry.

Drawing on centuries of experience, and the craftsmanship and expertise of its own people supported by 21st century papermaking technology, Sappi will lead the industry to ensure that this creative communication medium, paper, is the best it can be!



The interior of a historical paper mill

This brochure shows how we make this first class paper. Starting with the production of the most important raw material, wood. The pulping process converts this wood into the most appropriate type of pulp. The paper machine then converts the pulp into a thin base paper, which, at the end of the production process, is coated to give it a superb flat surface and bright shade. Following the description of this process, we will take a look at the properties used to measure the quality of paper.

II Wood production

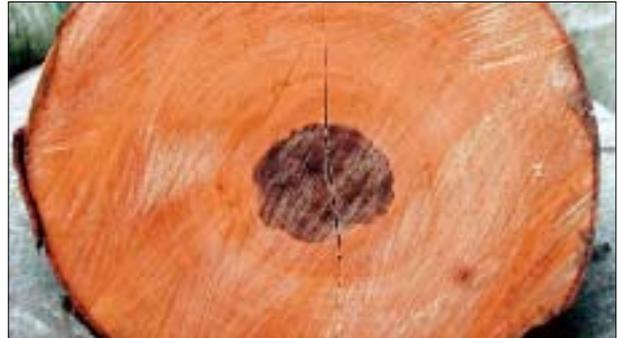
Wood as the raw material

Approximately 25,000 plants with a woody stem are registered under the term wood. However, the different varieties clearly differ in terms of usability for the production of paper.

Conifers are preferred as the fibres are longer than, for example, fibres of deciduous trees. Longer fibres form a firmer fibrous web and, hence, a firmer paper on the paper machine.

Conifers used are mainly spruce, fir and pine, whereas beech, birch, poplar and eucalyptus are the most important deciduous varieties used for paper.

A trunk of a tree is not a homogeneous body composed of identical cells. The cells differ according to type, age, season of origination and arrangement in the trunk. At the outside, there is the bark, below are the bast and the cambium, which form the growth tissue. By cell division, the cambium grows out from the centre of the tree. Growth stagnation during the winter months results in the annual rings. The trunk with its different cells which are responsible for the transport of the nutrients and the saps can be used for paper pulp, but not the bark.



Beech trunks

This means that the wood supplied to the paper mill has to be debarked before it can be used to produce one of the varieties of pulp – the base material for the production of paper. The debarked trunks are either pulped to fibres (mechanical wood pulp) or processed to chips for chemical pulp.

The wood finds its way directly to the paper mill in the form of trunks or in the form of timber mill waste (slabs, chips).



Wood trunks



Chips

III Pulp production

Pulping process

Pulping of wood can be done in two ways: mechanically or chemically.

Mechanical pulp

In the case of mechanical pulp, the wood is processed into fibre form by grinding it against a quickly rotating stone under addition of water. The yield* of this pulp amounts to approx. 95%. The result is called wood pulp or MP – mechanical pulp.

The disadvantage of this type of pulp is that the fibre is strongly damaged and that there are all sorts of impurities in the pulp mass. Mechanical wood pulp yields a high opacity, but it is not very strong. It has a yellowish colour and low light resistance.

Chemical pulp

For the production of wood pulp, the pure fibre has to be set free, which means that the lignin has to be removed as well. To achieve this, the wood chips are cooked in a chemical solution.

In case of wood pulp obtained by means of chemical pulping, we differentiate between sulphate and sulphite pulp, depending on the chemicals used. The yield of chemical pulping amounts to approximately 50%. The fibres in the resulting pulp are very clean and undamaged. The wood

pulp produced by this process is called woodfree. It is this type of pulp which is used for all Sappi fine papers.

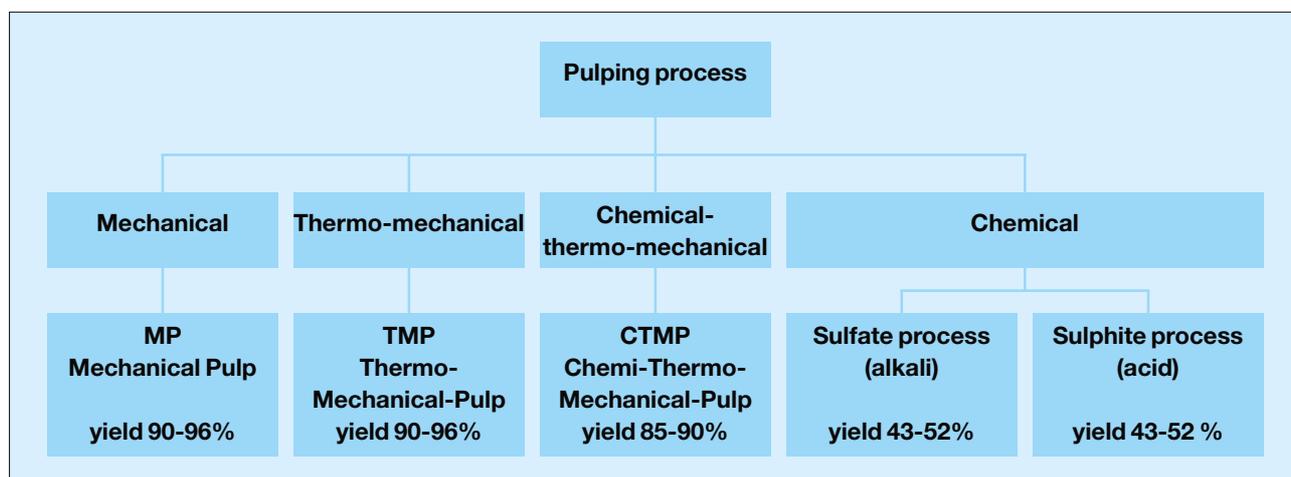
The **sulphate process** is an alkaline process. It allows for the processing of strongly resinous wood types, but this requires expensive installations and intensive use of chemicals.

The **sulphite process** utilises a cooking acid consisting of a combination of free sulphur acid and sulphur acid bound as magnesium bi-sulphite (magnesium bi-sulphite process).

In the sulphite process, the cooking liquid penetrates the wood in the longitudinal direction of the fibres, which are aligned in this same longitudinal direction in the chips. When the cooking liquid penetrates the wood, it decomposes the lignin, which, during the actual cooking process, is converted into a water-soluble substance that can be washed out. The decomposition products of the carbohydrates are included in the cooking liquid as sugar.

When the waste fluids are concentrated in order to recycle the chemicals, these sugars are processed to alcohol and ethanoic acid. In this stage, the sulphite pulp is slightly brown and therefore has to be bleached to obtain a base colour suitable for white papers. This bleaching process, in which no chlorine or chlorine compounds are used, also takes place in the pulp mill as an integrated part of the over-all operation.

The strength of sulphite pulps is less than that of sulphate pulps. Sappi uses only the magnesium bi-sulphite process in its own pulp mills. ** yield = usable part of the wood*



Intermediate pulp types:

TMP Thermo Mechanical Pulp

In this procedure, chopped waste wood is vaporised and then beaten into single fibres in refiners under vapour pressure.

CTMP Chemi-Thermo Mechanical Pulp (wood pulp)

This process consists of a combination of impregnation (mixing with a chemical pulp), cooking, refining and bleaching. The pulping yield amounts to 90%.

The fibre length and the related strength of the paper are controllable. CTMP contains a certain amount of lignin, a tenacious, tough substance from the cell wall of the wood which strongly turns yellow.

Pulp bleaching

Initially, wood pulp has a brown or brownish colour. To obtain the brightness required for white papers, it has to be bleached. During this process of bleaching, the remaining lignin is removed as well. In practical terms, bleaching is a continuation of the chemical cooking process, taking place directly afterward in the pulp mill as an integrated next step of the overall procedure. Bleaching is a complex process, consisting of several chemical process steps, with washing taking place between the various chemical treatments.

The wood pulp can be bleached with chlorine / chlorine compounds, ozone / oxygen in different forms as well as hydrogen peroxide.

Based on the negative impact of some chlorine containing decomposition products, there are, however, environmental objections against the use of chlorine and chlorine products.

For this reason, Sappi has long ago switched to chlorine-free processes.

These processes are referred to as Totally Chlorine Free (TCF).



From the unbleached to the bleached pulp

IV Paper production

Raw materials

Preparation of the fibres in the refiner

The type of refining which takes place in the refiner has a decisive influence on the properties of the paper to be produced. A refiner is a refining aggregate with rotating and



Refiner for stock preparation

stationary cutters, the so-called rotors and stators. The variable positioning of these rotors and stators in relation to each other determines whether the fibres are being cut (free stock refining) or fibrillated (wet refining). Fibrillating is a fine bleeding of the fibre ends, resulting in a close-knit connection between the individual fibres. In the final paper this, in turn, results in greater strength.

Additional raw materials for the base paper

Process materials include water, fillers, sizing substances, dyes and additives.

Fillers serve multiple purposes: they make the paper more opaque, more closed in its surface, brighter in shade as well as softer and more flexible depending on the requirement. Besides minerals, such as kaolin and china clay, the modern production process of paper makes extensive use of calcium

carbonate (chalk), which has the additional advantage of making the paper more resistant to ageing. The total percentage of fillers used can be as high as 30% of the stock. In industrial paper production, the respective quantities and density ratios are regulated by computer controlled proportioning systems. This is the only way to guarantee a uniform quality standard in the production of high-quality brand papers.

But by far the most important process material is water. For each kilo of paper approximately 100 litres of water are required. In our time, the only justification – economically as well as ecologically – for the use of such enormous quantities of water, is closed circulation and effective waste water treatment.

The Sappi paper mills have the highest expenditures for environmental protection, even when compared to the high national standards.

In the proportioning system water, stuffs and fillers are brought together in mix tubs. The so-called constant part of a paper machine constitutes the transition from pulp preparation to the headbox of the paper machine. Another element of this constant part is the sorting unit, where impurities, foreign substances and patches are removed.

Fillers:	Calcium carbonate, Clay, Titanium dioxide
Additives:	Dye, Optical brightening agent
Binders:	Latex and starch products

Paper machine

Suspension at the headbox

After dilution and sorting in the constant part, the suspension of fibres, process materials and water has to be led to the wire part uniformly distributed across the width of the paper web. In principle, the speed at which the suspension exits from the headbox onto the wire has to be equal to the speed of the wire on which the sheet is formed. To achieve this, pressure is applied to the suspension in the headbox, in order to accelerate it to the wire speed. Apart from that, turbulence is generated just before the exit point of the headbox to avoid harmful flock formation.

The suspension leaves the headbox at the discharge lip. At this point, the suspension flowing onto the wire can have a thickness of up to 18 mm.



Ehingen PM 6

Sheet formation in the wire section

Once the suspension has left the headbox and comes into contact with the wire, the paper fibres move to the wire as a result of their natural flow resistance, thus forming a layer of fibres on the wire which accumulates towards the top of the stock. At the same time, water drains away at the bottom, and this combination of processes leads to two different forms of sheet formation, depending on the freedom of motion of the fibres in the suspension: through filtration and by means of thickening.



Gratkorn PM 11

Filtration

In the case of filtration, a sharp transition is generated between the fibre layer building up on the wire and the suspension above. In this liquid phase, the pulp concentration is nearly constant and the fibres can easily move to each other in the corresponding ratio.

Thickening

In the case of thickening, there is no clear division between the generated fibre mat and the suspension. The concentration increases linearly from top to bottom and the fibres are demobilised in the suspension. At the same time, water drains out from all layers of the suspension, to be collected for reuse.

The elements with which the sheet formation can be controlled are divided in four main groups:

1. Running elements

- the endless wire
- the upper and lower wire

2. Rotating elements

- table roll
- forming roll
- suction roll
- squeeze roll
- egoutteur

3. Stationary elements

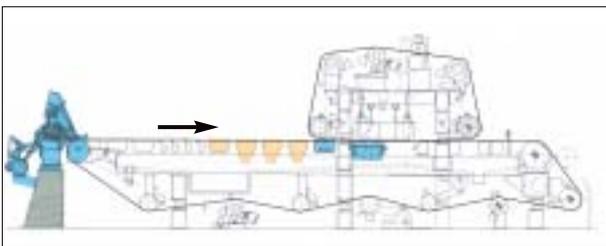
- wire table
- hydro foil
- vacu foil
- suction box

4. Mechanical elements

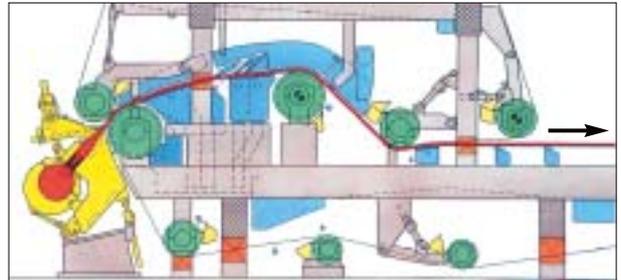
- screen adjustment of the headbox
- wire shaking

Twinformer

Sheet formation takes place in the screen part of the paper machine. It is in fact an on-going battle between filtration and re-flocculation. The wire part can have different design features. The most common design is the endless wire concept. It is a universally applicable system allowing for high flexibility with regard to basic weight and sheet properties. However, these endless wire paper machines have a serious performance limitation in that they are strictly one-sided: drainage takes place only at the bottom, not at the top. And so, new designs were considered to increase drainage efficiency. This led to the development of the so-called twinformer, where additional equipment is installed on the rods of the endless wire. The twinformer is a design which provides for drainage of the suspension to the top side as well, by means of an added upper wire and a series of suction boxes. With this additional equipment, the paper stock can now be drained on both sides – from the bottom by means of gravity, and from the top, by means of suction. Drainage time is significantly reduced, which results in a far more efficient production process, with the added advantage of reduced two-sidedness of the paper.



Twinformer



Gapformer

Gapformer

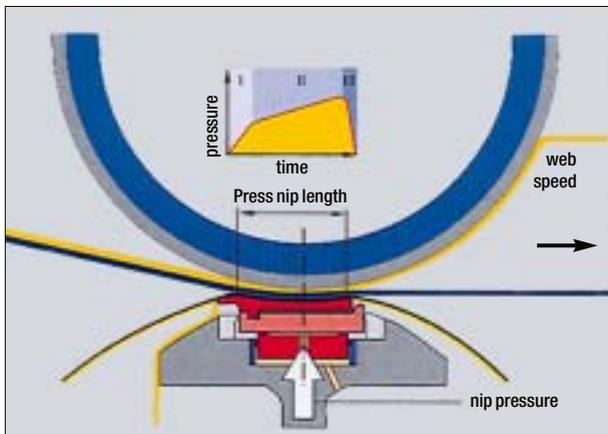
A further development in modern, high-speed paper machines are the so-called gap formers. In these formers, drainage is carried out to both sides simultaneously as the suspension is injected directly between the two wires directly from the headbox. Upon leaving the headbox, the pulp mass is immobilised in a matter of milliseconds, thus preventing later drainage elements from affecting the sheet structure which is now beginning to form. The fibre web is frozen – literally – the second it comes out of the headbox.

This process sets high demands on the quality of the headbox and the constant part.

De-watering in the press section

After formation of the sheet, a process which determines the most important sheet properties, the paper sheet has to be further drained and compressed. In this next phase, mechanical pressure exerted vertically to the sheet surface is used to further increase the proportion of dry content. In the press section, the web runs between a series of rolls which exert specifically set amounts of pressure. The water pressed out of the paper is absorbed by felts and transported off.

In recent years, shoe presses have been developed to increase the efficiency of the traditional roll presses. In these press units, one of the rolls is replaced by a hydraulically pressed shoe. This creates a bigger press nip, which makes the process more effective.



Shoe press

Dryer section

When the paper leaves the press section, it has a dry content of up to 50-55%. Now, the remaining water has to be removed by vaporisation. The most common type of paper drying is contact drying on cylinders heated with vapour. Here, the heat energy is transferred from the outside walls of the drying cylinders to the paper surface by direct contact. The dryer section consists of a succession of drying cylinders and the paper web is transported over and between these cylinders, the paper alternately making contact with the upper and the lower side. Drying takes place in different phases. In the

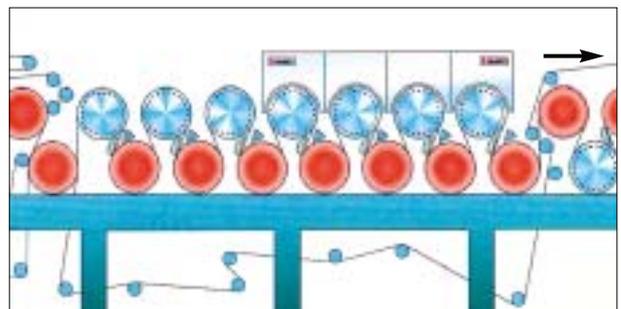
short, first phase, only heat is transferred to the paper. There is no vaporisation. This takes place during the second phase, when the wet paper starts to convey its humidity to the surrounding air. In other words, the water contained in the paper starts to evaporate. In the third phase, the paper surface has already been dried to the maximum extent, and heat transmission into the dry paper stimulates vaporisation inside the paper.

End group

After conclusion of the drying process, the paper is often subjected to glazing in machine calenders. Besides machine calenders, which use steel rolls, there are also soft calenders, consisting of paired rolls where one is made of steel and the other one is coated with a soft, plastic material. This produces a better overall glazing effect and eliminates the problem of so-called "black glazing".

At the end of the machine, the paper is taken up on steel cores, the so-called tambours. Most paper machines use pope rollers. The tambour presses against the big pope roller and takes up the paper in uniform windings and at constant circumferential speed.

In the paper machine, there are various measuring frames at different positions, continuously measuring and controlling the selected quality parameters, such as base weight, moisture and ash contents, brightness and opacity.



Drying section

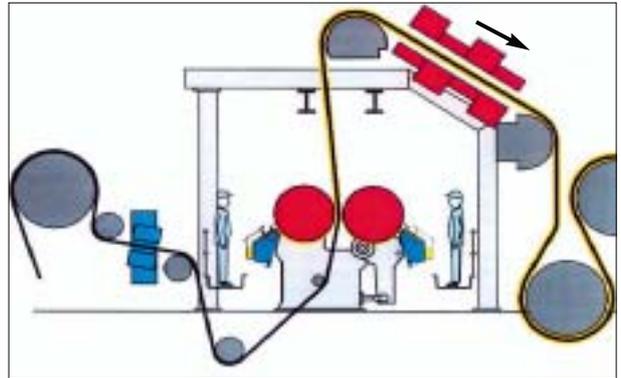
Surface treatment

Size press

The simplest form of refinement is surface treatment in the size press which is integrated in the paper machine.

Here, starch is applied to strengthen the paper surface. At the same time, this “closes” the surface of the paper, thus preventing problems like dusting or picking from occurring in the later printing process. In many cases, treatment in the size press is used to prepare the paper for the subsequent process of coating.

The size press consists of a pair of soft rolls, often coated with rubber, which press against each other as the paper web is guided through the nip between the rolls. The size solution is transferred to the paper through this nip, which also serves to control the dose of sizing being applied. In the size press, the quantity of applied pigments is limited.



Film press

Film press

As machine speed increased along with the quality demands for pigmented and machine coated papers, new multiple roll systems were developed which allowed for pre-dosing of the coating.

These modern press systems use a precisely pre-dosed film of coating, which is transferred to the paper in the nip between the application rolls. In this case, however, the coating is applied on the back side of the roll, using a design similar to that of a coating installation. These film presses run at high speed and they can operate with high concentrations in the sizing and pigmenting system.

V Coating

The benefits of coated paper

In recent decades, print media have had to meet increasingly high demands, in terms of visual aspects and in terms of printability. To meet these demands, coated papers were introduced many years ago.

Coating a paper enhances its optical and tactile characteristics – whiteness and shade, gloss and smoothness – but it also improves its printing behaviour, allowing the use of very fine screens, yielding more colour in thinner ink layers and producing more contrast in printed images.

When paper is coated, a covering layer of pigments, binding agents and process materials is applied to the surface. To achieve optimal results, all elements involved in the process must be perfectly tuned for mutual support, and this includes the coating colour, the coating method, the coating machine and its specific settings and the paper itself. One coating machine can apply multiple layers of coating, all depending on the intended use of the paper and all applications of coating requiring their own drying times. There are single coated papers, double coated papers and triple coated papers. In many cases, several methods of application are combined for an end result that benefits from each of the individual advantages.



Film coating



Blade coating

Coating machine

A primary reel, on which paper deficiencies can be removed, is superposed to the coating machine. To bridge set-up times at the coating machine, this primary reel has to operate at a higher speed than the paper machine. It has an unwinding system, designed for use of a flying splice. Next, the paper is coated. First on one side, followed by drying. Then the other side is coated and dried. For drying purposes, infrared-dryers, airfoils and drying cylinders are used. Rolls with gyratory grooves and wide plug-in reels provide safe reel guidance through the coating machine.

The heart of the coating machine, however, is the coating unit with the integrated coating aggregate. Under each coating unit, a workstation pumps up the coating mass from the preparation tanks, where the colour is mixed. These tanks, made of stainless steel, are cooled to avoid coating sticking to the walls and clot formation. The coating has to be permanently filtered and aerated to avoid deficiencies, such as blade streaks. Automatic control systems continuously monitor and adjust coating quantity and humidity of the coating.

At Sappi, different methods and techniques of coating are used. The two main coating techniques are film coating and blade coating.

In film coating and roll coating a uniform layer of coating is applied to the base paper. The surface contours of the paper remain visible. This is why the process is also known as “contour coating”.

In blade coating, an excess layer of coating is first applied to the paper, which is then partially scraped off again (“doctored”) with a steel blade. The pressure exerted by this doctor blade produces a uniform surface. The cavities of the paper are filled with coating and the fibre backs remain nearly uncovered.

Coating preparation

Coatings mainly consist of pigments (chalk, clay or talcum). In themselves, however, these are powdery substances which would be blown off the paper surface like dust. Therefore, binding agents must be used to provide adherence to each other and to the paper. Depending on the intended use of the paper and the type and structure of the pigments used, different quantities of binding agents are required. Binding agents can have a natural basis (casein or starch) or a synthetic composition (synthetic dispersions).

Process materials add specific properties to the coating. One commonly used process material is optical whitener. It converts invisible, ultraviolet light into visible bluish white light, giving an impression of true whiteness.

In the so-called “coating kitchen”, these individual components, taken from large storage silos, are mixed in stainless steel tanks. After having been thoroughly screened, naturally. Each specific coating has its own recipe, exactly prescribing the quantities of each component. To preserve consistency from preparation to preparation, the whole process of coating production is fully automated.

In the coating units, measuring frames monitor the weight of the coating being applied to the paper and the resulting gloss of the paper itself.

Usually, the coating kitchen is also responsible for preparation of the starch solution used in the size press (with or without pigmentation), which is an integrated part of the paper machine.



Supercalender

VI Finishing

Calender

Calenders are used to make the paper surface extra smooth and glossy. A calender consists of a number of rolls, where pressure and heat is applied to the passing paper. There are many different types of calenders. Some can be integrated as part of the paper machine, others are operated separately, as stand-alone installations. These separate installations, the so-called supercalenders, can include up to 16 rolls. These rolls can have different surfaces – they can have steel walls or coverings with elastic materials, depending on the desired extent of glazing.

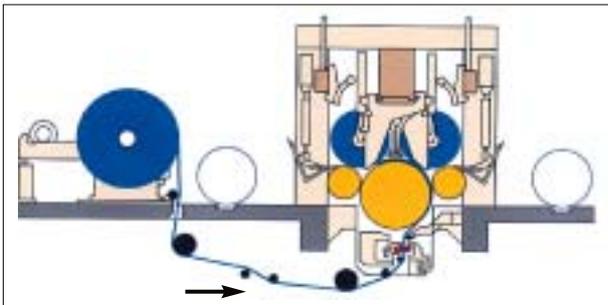
Depending on type, the paper is ready after it leaves the coating machine or the calender.

Rewinder

The function of the rewinder is to rewind the reels from one tambour to another tambour. Here, the web run can be changed, from the outer to the inner side, the reel edges may be cut and deficiencies in the paper can be removed.

Slitter rewinder

The finished paper, which on the tambour still has the full machine width, is cut to smaller reels on the slitter rewinder. Circular knives cut the tambour to reels of specified width while the tambour is being unwound. Depending on paper type, these reels are now ready for delivery to the customer, or they are transported to a cross cutter where the paper is cut to sheets.



Reel cutter

Cross cutter

In a cross cutter, the smaller reels that have been cut to size from tambours by the slitter rewinder, are cut to sheets of a specified size. Several reels can be processed simultaneously, depending on the design of the cross cutter and the “cutting weight” of the paper. The important thing here is to produce sheets with clean cutting edges, in other words, to prevent cutting dust from clinging to the edges, since this would cause problems in the printing process. The paper reels fed into the cross cutter are trimmed on both edges and separated in longitudinal direction by circular knives. The web is then cut off to the required size by the chopper knife.



Cross cutter

One important aspect is that the cutting process must be perfectly synchronised to produce the exactly right size and squareness. A conveyor belt directly after the knife section holds the sheets in position and transports them at high speed to a second conveyor belt. Here, the speed is reduced and the sheets are laid out in overlapping arrangement for further transport to the final stacked layout.

Modern cross cutters do more than just cutting. They check the quality of the paper surface, remove faulty sheets, count the sheets and insert counting strips. Some even allow for a “flying change” process of continuous operation, in which full pallets are automatically transported off and new pallets moved into position without halting the machine.

Guillotine

Guillotine type cutters are used for cutting relatively small quantities of paper in special sizes. In these cases, completely refitting the cross cutter would not be economically sensible. Guillotines are also used for the so-called four-sided trim which is necessary for certain print jobs.

VII Packing and storage

Finally, the paper is packaged for transport to the customer. The packing is important to avoid transport damages and to provide protection against moisture. Transport methods and means determine the type of packing.

Automatic reel packing machines perform the following tasks:

A bar code identifies the reel. While the reel is positioned in the centre, interior side caps are applied on both sides. Based on the sequence belonging to the bar code, a machine wraps the reel with pre-selected packing paper, using a certain number of windings and a specific type of gluing. Finally exterior side caps are added, the reel is weighed and the labels are attached. The reel then goes to the transport department via a conveyor belt.



Packing of reels

Sheetsize paper can be packed in reams or delivered as bulk-packed goods, with pallet packing only. Reams can contain 100, 250 or 500 sheets. In the case of smaller orders or special sizes, ream wrapping is carried out manually. Large stock orders in standard sizes are reamed on ream wrapping machines.

The packing material is designed according to customers' requests. Protection against damage and moisture is the main concern, but ream wrapping can be used as an advertising medium as well.



Packing of pallets

The defined packing units are taken off the stack before reaching the ream wrapping machine and transported in correct alignment to the first wrapping unit.

The packing paper is cut off, wrapped around the paper and glued in place. The packed reams are then stacked and labelled.

Pallets with sheetsize paper (reamed or bulk-packed) are wrapped vapour tight with shrinking or wrapping foil. For transport over longer distances, a covering plate is applied and the packed pallets are reinforced with loops of steel or plastic banding.

Pallets packed in vapour tight wrapping do not require a full air-conditioning when in storage. They can be stored in light and water protected areas. Paper producers and wholesalers often use high shelf stocks, in which the pallets can be stored randomly, to be picked by computer-controlled picking systems.



Automatic warehouse

VIII Paper properties

The data sheets list the most important quality characteristics of the paper.

These include:

Basis weight

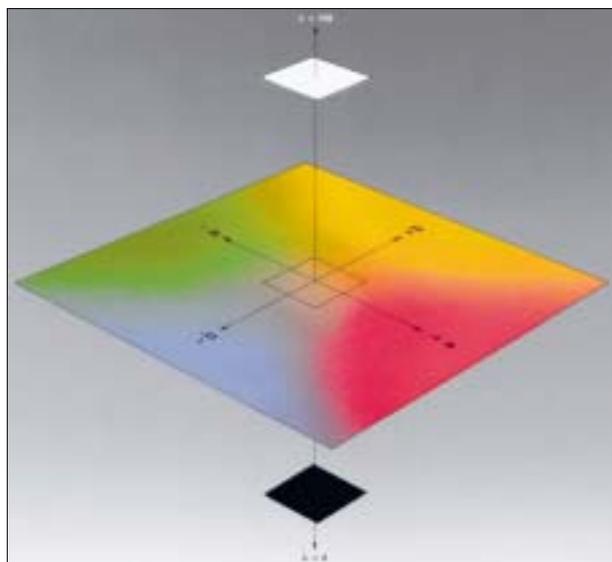
The basis weight of a paper means the weight in grams per square meter (g/m^2) under conditioned circumstances. The entire mass is the sum of fibrous materials, fillers, process materials and water.

Brightness

The brightness (ISO) is a measure for the brightness degree of the paper expressed in percent compared with the brightness standard (magnesium oxide = 100%). The higher the brightness value, the brighter the paper is.

Gloss

The gloss figure in the data sheets indicates the percentage of reflected light with a defined angle of incidence. A higher gloss leads to stronger light reflections and higher gloss values.



Colour space

PPS roughness

The geometric form of a paper surface is defined as deviation from the ideal flat level. The more the surface approaches the ideal level, the smoother the paper is. The measuring method (PPS) is based on the measurement of air leakage between the paper surface and the even measuring head. In the case of PPS roughness, the average pore depth over a defined circular area is measured. The higher the measured value is, the “rougher” the paper surface is.

Opacity

The opacity is a measure for the opacity degree of the paper, expressed in percent in relation to the reflected light. Paper which lets a lot of light through, is transparent; paper that lets little light through, is opaque. The higher the value, the more opaque the paper is.

Relative humidity

At a given temperature, there is a maximum to the amount of water vapour that the air can absorb. Relative humidity indicates the percentage of this maximum which is actually in the air (i.e. between the sheets of a stack or the windings of a reel).

pH value

The value in the data sheets defines the pH value of the surface. The pH values are indicated on a scale from 0 to 14. The value 7 marks the neutral point which corresponds to distilled water. Values below 7 refer to “increasingly acid”, values above 7 stand for “increasingly alkaline”. Papers should have a pH close to the neutral point in order to meet ideal requirements for printing and further treatment.

Specific volume

Paper thickness is expressed in micrometer (μm). To compare the thickness of papers with different basis weights, specific volume is used.

$$\text{volume} = \frac{\text{thickness } (\mu\text{m})}{\text{basis weight } (\text{g/m}^2)}$$

IX Concluding remarks

The content of this brochure is based on our technical experience in papermaking and textual building blocks from the book "Het Papierboek".

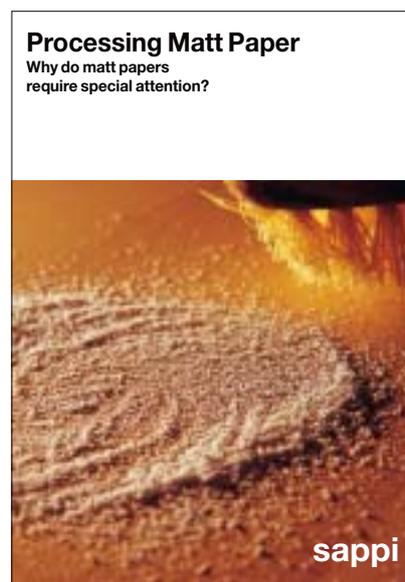
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EPN Publishers
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The Paper Making Process is one of Sappi's technical brochures. Sappi brought together this paper related knowledge to inspire our customers to be the best they can be.



The Paper Making Process video and the other technical brochures are freely available at our knowledge bank:

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