4. Printing and converting performance

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Paperboard converting

Paperboard has the ability to achieve or exceed the same excellent image reproduction as for the best fine papers. Paperboard offers equal possibilities to achieve new, challenging shapes as competing packaging materials. However, increasing demands on performance of the material in various converting processes have become evident when speeds in both printing processes and post-press converting have increased. Additionally, the acceptance level for impurities or slight deviations in quality in the final product has dropped noticeably as a result of both end-user demands and the use of modern quality control equipment in the various converting machines.

Productivity is the material’s and defined process’s ability to meet the defined goals and is difficult to define quantitatively since expectations differ from company to company. The same paperboard in the same type of machine but for a different end use can have higher or lower results in terms of productivity. Productivity can be measured in many ways, in both fixed and relative numbers, and for a whole plant or per specific machine:

- Number of man hours spent per converted sheet.
- Overall equipment effectiveness, capacity utilisation.
- Number of approved converted sheets per man hour.
- Amount of waste.

The material and its properties will have an effect on all of the above parameters in terms of the material’s ability to withstand increased mechanical stress during higher converting speeds and from higher demands on ink-surface interactivity, and to function without interruptions in converting due to inconsistency of these properties.

The increasing demands in the brand promotion process for graphic design and the use of non-print surface enhancement are creating innovative shapes and multi-sensory experiences for the consumer or user who handles the product.

An understanding of the interaction between paperboard properties and converting efficiency is essential for designers and converters, since the ultimate design of the product together with the choice of paperboard will impact on crucial conversion factors like printability, flatness, and creasing/folding properties. Considering all the variables, it is probably true to say that consistency in the behaviour of the paperboard product is the key to high efficiency.

Printing presses and post-print converting machinery will accept a wide range of paperboard types at decent levels of productivity. However, tolerance for irregularities in critical parameters is diminishing as speeds and complexity rise. Critical parameters where consistency is important for high productivity include:

- Ink-surface interaction for uniform ink- and glue setting and drying.
- Dimensional stability for correct register and accurate die-cutting.
- Flatness for efficient feeding and glue seam alignment.
- Clean edges and surfaces to avoid unnecessary cleaning interruptions.
- Correct folding action for quick carton erection and subsequent glue seam alignment for accuracy in shape, which promotes high speeds during the carton filling stages.

The following sections describe the features that support both high-quality and trouble-free production for the most common processes.
**Excellent print quality**

It is essential that paperboard for graphical applications should provide excellent print quality. To achieve this, the paperboard must meet stringent requirements in terms of its appearance and performance during the printing process. The ability of the board to fulfill these requirements is referred to as printability. High print quality is, in the main, characterised by uniform print results, high ink gloss and true colour reproduction.

**Uniform print results**

To achieve uniform print in both half and full tones it is essential that both the ink transfer and ink setting are adequate. Good ink transfer from the ink carrying plate to the paperboard is essential. A uniform surface tension enables sufficient wetting of the surface by the ink. This is particularly important in flexo applications, digital printing (liquid toner), or when printing on extruded plastic surface or surfaces coated in some other manner prior to printing.

Uniform ink setting is important regardless of the printing process used. This is achieved by ensuring the uniform absorption of oil and/or water (depending on the ink vehicle). For oil-based inks in conventional offset printing the uniform absorption of both water and oil is required as ink transfer can be obstructed by the presence of fountain water on the substrate surface. In offset printing irregularities in ink setting can cause mottle or back trap mottle.

To achieve uniform ink transfer and setting it is important that the paperboard has a coating layer with an even thickness; this is of particular importance for blade coating, and a high degree of uniformity. A rough baseboard surface prior to coating causes local variations in coat weight that lead in turn to variations in calendering and glazing. A well-controlled coating operation contributes to uniform print results by ensuring a monitored coat weight and a controlled coating composition.

**High ink gloss**

High ink gloss is a property of a very flat, levelled ink film. This is true for any ink film and should not be confused with the term “high gloss inks.” Having a coating with uniform absorption properties is crucial. With a very smooth paperboard surface, the ink levelling will be more rapid and occur more easily. Because a thicker ink film can fill cavities in the paperboard surface, the thicker the ink film the more likely the ink is to form a smooth surface. It is for this reason that the thick ink films in screen printing often result in higher ink gloss.
The key to high ink gloss often lies in allowing the ink film to level out into a flat surface before setting. This means allowing the ink to stay “wet” for a little longer. It should be noted that good ink setting requires rapid absorption and so the levels of ink gloss achieved are to some extent limited by the necessity of achieving satisfactory ink setting. The composition of the paperboard’s coating is the principal factor affecting the speed of ink drying. A coating with large pores absorbs ink more slowly and thus supports better ink levelling.

True colour reproduction
The factors that have the greatest impact on true colour reproduction are ink density, dot gain (mechanical and optical), and the magnitude of the colour gamut that it is possible to obtain with a given set of inks.

- The ink density is directly connected to the amount of ink pigments transferred to the paperboard surface. In some cases the result depends on the water and oil absorption of the coating layer. Too much moisture on the paperboard surface may result in poor ink transfer for an oil-based ink (this is known as ink refusal). This moisture may be due to condensed water from a cold paperboard pallet, or excess fountain water from a previous printing unit, or excess fountain water that has not emulsified correctly with the ink.

- Dot gain can be discussed as both mechanical dot gain and optical dot gain. In offset printing most of the mechanical dot gain occurs before the ink hits the substrate surface and therefore variations in the paperboard’s coated surface contribute little to variations in mechanical dot gain. However in flexo applications or digital printing (liquid toner) the surface tension and permeability of the paperboard surface could cause the ink to spread more or less on the surface or inside the coating/baseboard structure.
• Optical dot gain is influenced by the light absorption of the coating and baseboard and their light-scattering properties. Good surface smoothness is also thought to have a positive effect on optical dot gain, but this has not been conclusively demonstrated.
• The reproducible colour gamut depends primarily on the ink quality, ink layer thickness, and ink density achieved. Other factors that affect the colour gamut are high ink gloss and the optical properties of the paperboard surface. For the secondary and following colours the ink trapping properties are crucial. Good clean trapping will enable the reproduction of a larger colour gamut; it is essential that as much of the secondary and following inks as possible is transferred in an even pattern on top of the first ink with no irregularities in ink density. The ink setting properties and ink tack of the various ink layers influence each other; for this reason the colour sequence may be important.

Runnability and efficiency
Good runnability comprises the different factors that let the jobs run efficiently through the press and finishing equipment with low down time and low material waste. Multi-ply paperboard has many important features that support cost-effective printing and finishing operations, as well as the total quality image of the finished products. The prime building block for efficient converting of the paperboard is a product which behaves consistently in both printing and post-press converting. Consistency makes the product predictable, which means in many cases shorter make-ready. Reliability will also play a role to maintain expected production rates from batch to batch year in and year out.

In-feed and operation
How quickly the in-feeder can be set up and how well the substrate runs are factors that affect the total economy of a print- or converting job. The factors that mainly determine how quickly the job can be set up and processed are efficient feeding, flat sheets, dimensional stability, and dust-free stock.

Efficient feeding
The main paperboard properties that affect consistent feeding from pallet to pallet or reel to reel are friction, uniform thickness and paperboard flatness/shape (of which the latter is described in the section below). The friction originates from several different sources but the main factors are the surface chemistry and the surface topography.

The sheets may adhere to each other due to electrostatic attraction. This is mostly applicable to thinner paper, but may occur with lower grammages of paperboard. The best way to prevent electrostatic charges from being built up is not to let the paperboard dry out too much. If the surface is somewhat rough, you risk mechanical interlocking between the sheets to obstruct the feeding. On the other hand, too smooth a surface will present a larger contact area between the sheets, which might enhance the interlocking caused by surface chemistry. This effect could be compared to the force that makes it hard to separate two glass plates that are piled together.
Flat sheets
The flatness of the sheet affects the press speed and sometimes even the print result itself. Flatness irregularities are described as twist or curl. Both will cause difficulties in feeding and running the press or finishing machine. The best way to avoid twist or curl is to maintain the original moisture content of the paperboard.

Flatness is a decisive property of paperboard and will affect the efficiency of operation through the full conversion chain. During the paperboard manufacturing process control of curl and twist is a very complex process and starts in the forming of the multi-ply structure at the wet end of the board machine, where the following factors contribute to minimising inbound stress in the sheet:
• fibre composition in the respective layers of the multi-ply construction
• fibre orientation
• fines content
• controlled removal of water and rewetting
• controlled drying of the web
• web draws in the drying section.

A balance in these properties will produce a flat sheet and will minimise the risk of uneven tensions caused by hygro-dimensional changes. The release of tension could occur later in the printing or finishing processes and result in distortion of the sheet.

Dimensional stability
In multi-step processing (or even in multi-colour printing) it is important to use a substrate with excellent dimensional stability. The substrate is exposed to many different forces that might stress the structure in such a way that the sheet changes its dimensions. The forces might come from hygro-expansion due to moisture exposure or from mechanical stress imposed on the sheet during the printing or finishing operations, either one or both. Different paperboard types are more or less prone to distortion under climate changes.

Dust-free stock
To achieve an efficient operation in the printing or finishing machine requires a substrate free from dust or fibrous debris. To minimise dust or debris (mainly coming from the sheet edges) the areas to focus on are pulp processing and the retention of smaller fibres.
• Clean edges depend substantially on the fibres’ ability to bond with each other. Fibres from chemical pulp are flexible and interface easily with other fibres to form a strong network. For mechanical pulp the refining process plays a central role in increasing the binding abilities of the fibre network. Refining generates larger contact areas between the individual fibres. Fine-tuning of this process ensures a well-bonded network.
• With the help of retention chemicals the small parts of fibres (fines) are kept inside the sheet. This provides more contact points in the fibre network and helps to bind the fibres together. Fibre retention is essential for both mechanical and chemical pulp.

Ink application
Paperboard features that are especially important for the ink application are good surface strength and good plybond.

Good surface strength
In offset litho printing the inks have a very high tack. To resist the forces in the printing nip and to prevent coating picking, the coating must be well attached to the baseboard surface. A good bond between coating and baseboard is promoted by the following paperboard properties.
• To provide a strong bond to the coating, the fibres in the baseboard surface should adhere well to each other. If the fibres are not sufficiently bound together the coating can come off, taking some of the top fibres with it as well (this is known as pull outs). The good bond between the fibres is promoted by good fines retention. Uniform surface sizing of the baseboard is a strong base for the coating. Weaker spots may otherwise be torn off in the printing nip.
• Good internal bonding in the coating layer is a vital factor. This is not only an internal coating issue, but can also be influenced by the baseboard. Variations in the baseboard surface porosity may cause binder migration in the coating layer and thereby variations in the internal strength.
Good plybond

Good plybond is primarily applicable to offset litho printing, since the tacky inks impose a high force on the substrate. This force is a combination of pulling and shearing in the exit of the printing nip, which may cause delamination. Unlike coating picking, which may occur in the interface between the coating layer and the baseboard surface, delamination occurs within the baseboard structure, either within a ply or between different plies, often close to the surface.

Delamination is least of all desirable in the printing process, so the plybond must be sufficiently strong. However, in the creasing, folding and embossing operations delamination is necessary, so the plybond must not be too strong either. Therefore the properties of the baseboard need to be very well balanced.

Good plybond depends on the forming of a strong and elastic network inside the baseboard. This is influenced by the fibre characteristics and the formation of the sheet. The use of virgin fibres with different tensile strength, stiffness, shape and bonding abilities affects the strength of the final fibre network. The basis for producing a fibre network with the right strength is the use of virgin fibres in itself, together with controlled sheet forming on the paperboard machine.

Quick turn around and reverse side printing

To achieve high print speed and good economy it is important to be able to turn the sheet around and print the reverse side as soon as possible after the first print run. The most important factor for quick reverse side printing is ink drying. Too much ink, or the wrong pH in the fountain water may decrease the drying speed.

Since different ink types are designed to dry in different ways, the drying is influenced by various surface properties. Therefore it is vital to match the ink type carefully to

![Diagram showing ink absorption and evaporation](image-url)
the surface properties of the paperboard. With offset ink for coated surfaces the ink must set fast enough to enable the drying process. Smaller pores in the coating absorb the low viscosity part of the ink oils quicker and the total pore volume will affect the speed of ink setting.

No set-off
To minimise the risk of set-off, fast ink setting and drying are crucial. The absorption properties correspond to the ones mentioned in the point above. Other paperboard properties that influence the set-off are surface smoothness and low density.

- The surface smoothness is a matter of matching the surface properties correctly on both the print side and the reverse side. On a rough surface, set-off from the “peaks” in the surface topography may occur. On a very smooth surface, on the other hand, the large contact area between the sheets may increase the risk of set-off. Particularly in this case it is extremely important to match the ink type carefully to the surface properties of the paperboard.
- A high density substrate, such as a thick, wood-free paper, will result in higher pressure on the underlying sheets in the delivery stack, compared to a high bulk paperboard. Given the same height of delivery stacks in a sheet-fed printing press, a high bulk substrate such as graphic paperboard decreases the risk of set-off.

Make the most of the finishing options
Graphic paperboard is a forgiving material. This becomes particularly obvious when it is time for the finishing operations. Below the strong, smooth, white surface lie all the strengths required for carrying out the most demanding applications. Whether it is just adding a varnish to highlight the graphic presentation or using the most advanced designs in multi-step processes, a predictable, good result will follow.

Runnability in general
Good runnability in the various finishing operations relies on the same factors as those described above in the section “In-feed and operation” and additionally on good rub resistance and no rub-off.

Good rub resistance
It is essential for an ink or varnish film to be durable and preserved through the finishing operations and when handling the finished products. Factors that influence rub resistance are ink type and surface abrasiveness.

- The best way to achieve good rub resistance is to choose an ink with a somewhat higher content of wax. As explained earlier, matching the ink type properly to the absorption properties of the substrate surface is of prime importance.
- A smooth surface contributes to a good rub resistance by having less peaks in the surface topography. Hence loss of ink or varnish in the finishing operations can be avoided. The surface abrasiveness is also thought to be influenced by the coating formulation and choice of coating pigment.

No rub-off
The ink pigments should be well bound to the surface and not come off during the finishing operations. It is – once again – a matter of careful matching of the ink type to the substrate absorption properties. The surface should not absorb the ink binder, leaving the pigments...
somewhat less bound to the surface. This can be the case when using a substrate with too high or quick ink absorption, a problem that is primarily controlled by coating pore size and total pore volume.

A wide range of finishing options

The multi-ply construction and the surface characteristics of paperboard products facilitate a wide range of finishing options. However, the finishing techniques are very different. Therefore the runnability aspects in connection with the different sections are described in the chapter Finishing techniques.

In general terms, the following paperboard features allows the printer to make the most of the finishing options.

• Strength and toughness are measurable as tensile strength, tearing resistance, delamination strength, and compression strength. These properties are decisive for achieving sophisticated designs such as embossing and complex structural shapes.
• Creasing and folding abilities depend on a complex combination of factors such as tensile strength, compression strength, delamination strength, bending resistance, flatness, and dimensional stability. They are decisive for the paperboard's ability to “forgive” the permanent deformation of deep and narrow creases, and to retain the intended shape of folds.
• Flatness and dimensional stability are decisive for excellent results in the finishing operations. The choice and composition of raw materials and carefully controlled manufacturing processes result in a paperboard that retains its flatness and dimensional stability throughout all operations. But since paperboard is a hygroscopic material, it should not be exposed to conditions that affect its moisture content. Please refer to the chapter Handling paperboard for information on how to prevent moisture problems.
Clean edges and surfaces

Clean edges and surfaces and their impact on the printing process can be simply defined in terms of:

- Their ability to be free from dust and fibrous debris particles that may detach and adhere to the printing press plate or blanket, thus causing premature stoppages for wash-ups.
- The presence of such material interfering with the print impression may cause break-up of the screen definition, apply ink in non-printed areas, or cause spots in solid prints (hickies).
- Such stoppages adversely impact on press efficiency and in extreme situations can cause immediate rejection of the material being processed.

The ability to provide paperboard with clean edges and surfaces is a prime consideration when the printer is assessing material for optimum process efficiency. Any loose particles in the form of solid or fibrous material, etc. on the paperboard edges or surfaces may transfer to the printing blanket, plate or cylinder during the printing operation and result in print defects. In extreme cases exceptionally large pieces may even result in damage to the press blanket in offset litho.

Edge cleanliness is as important as surface cleanliness, since debris can break away during sheeting, stacking or printing operations and become attached to the printing blanket in offset litho. Edge debris can sometimes be characterised by the build-up of debris on the press blanket in the contact areas adjacent to the sheet edges.

It is possible to identify different types of edge and surface debris. Some types of surface debris are clearly not edge related. It is also possible to identify the difference between slit (machine direction) or chop (cross direction) edge debris.

Edge- and surface-related debris can usually be categorised under the following headings:

- **Edge debris (slit and chop):**
  - loose fibres
  - fibre clumps (usually chemical pulp in origin)
  - shive (usually mechanical pulp in origin)
  - dust
- **Surface debris:**
  - edge debris (see above)
  - coating particles
  - miscellaneous process particles
  - miscellaneous contraries.

Debris of the above type is not necessarily differentiated by the printer, whose prime requirement is for press efficiency with any excessive presence of the above being unacceptable. The build-up of unwanted particles on the press blanket and printing plate will gradually result in a break-up of the screen definition, print spots in non-printed areas or cause hickies and other blemishes in text and solid prints.

Once debris has built up on the printing press there is no alternative except to shut down the press and clean the plates and blankets. This not only incurs lost time but also increases waste when the press is restarted and colour balance restored.

The minimisation and elimination of the above debris types is therefore an essential factor for good press performance and the faithful reproduction of the print design, which may ultimately impact on the consumer’s decision whether or not to buy.

While the need for the paperboard manufacturer to provide clean and debris-free products is recognised, much has been done in recent years to eliminate dust and debris etc. immediately prior to the printing operation. The development of vacuum extraction systems, usually in combination with ionising bars to eliminate static, has led to enormous improvements to the length of print runs.
This does not, however, mean that there is no room for further improvement. The printer knows what improvements have been achieved by the introduction of these systems, but the emphasis is still on the paperboard supplier to provide clean material so that the printer can maintain the expected high levels of through-put.

As far as the paperboard production process is concerned, the introduction of extensive vacuum- and dust-removal systems at all stages of the finishing process has become an important element in achieving the ultimate goal of a totally clean product. Such vacuum systems are commonplace and sometimes used in combination with antistatic.

It is, however, important to stress that as with on-press systems the paperboard must be clean to start with in order to obtain the optimum ultimate performance. In this respect it is essential that careful attention is paid to knife design, quality, and alignment and to the adjustment of chop to ensure that unwanted debris is not generated in the first instance.

<table>
<thead>
<tr>
<th>Type of edge and surface debris</th>
<th>Origin and effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chop edge</td>
<td>Particles with one straight edge and one torn edge. Other fibrous material and coating may also be attached.</td>
</tr>
<tr>
<td>Shives</td>
<td>Hard bundles of unseparated mechanical fibres with a characteristic cross-grained structure.</td>
</tr>
<tr>
<td>Slit edge</td>
<td>Fibrous, wavy trim material from the slitting process.</td>
</tr>
<tr>
<td>Coating particles</td>
<td>Flat pieces of coating, generally quite small, that have, for example, become detached from build-ups on rolls in the coating section of the paperboard machine.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>This debris can originate from a variety of materials used in the paperboard manufacturing process, e.g. synthetic rope fibre, calender debris.</td>
</tr>
</tbody>
</table>
In all processes emphasis must be placed on the slitting and sheeting operations with the optimum application of only the best debris removal systems. With today’s modern slitting and sheeting operations, which are able to offer a minimum of manual handling, a further reduction in the generation of unwanted dust and debris in the final product has been made possible.

During subsequent die-cutting and creasing operations the generation of dust and debris (or swarf) must also be avoided by use of the correct and properly set tooling. Sharp, properly set and maintained knives are, therefore, a prerequisite for well-cut, clean edges.

**Characteristics of clean edges and surfaces**

**Assessment of clean edges and surfaces**

An optimum paperboard product is one that is totally clean. The amount of debris must therefore be almost zero to assess a paperboard as good with respect to clean edges and surfaces.

There is no officially recognised method for the measurement of edge or surface cleanliness.

Despite the absence of a recognised test procedure it is possible to quantify the cleanliness of both edges and surfaces. In simple terms the visual assessment of slit and chop edge quality can provide an early indication of a potential problem.

It should be noted, however, that visible edge debris does not necessarily indicate loose edge debris. Where a potential problem is indicated, further examination is necessary to identify the likely impact on press operation.

Quantification of loose edge debris can be achieved by the vacuum removal of material from pallet edges. This is done by using a specially adapted vacuum head which incorporates a black filter cloth supported by a wide mesh holder. Material removed can then be compared visually using a rating scale.

The presence of surface debris is most easily quantified by rolling a soft polyurethane roller on the paperboard surface and physically counting the number of particles removed over a specified area.

Both edge and surface assessment methods need to be performed under carefully controlled conditions and repeated to obtain statistical significance.

Material removed can be further classified and quantified according to type by microscopic examination. The table on the previous page describes and illustrates some of the types of particles referred to in the first part of this section.

As far as the printing operation is concerned the performance of a paperboard is measured by the time which elapses between blanket washes, or the length of print runs. This can, however, depend on the detail of screen definition required and also on the positioning of any obvious blemishes, which can sometimes be removed without a complete blanket wash or stoppage.

**Different paperboard ply constructions**

Solid Bleached Board has the advantage that loose fibres and dust are least likely to be generated as a result of the use of long, strong chemical fibres and also pulp and surface treatments. Folding Box Board, where mechanical pulp is sandwiched between chemical pulp layers, also utilises pulps and surface treatments to minimise debris generation but does have a greater potential for debris release.

FBB therefore requires close attention to slit and chop quality.

During the die-cutting and creasing operation, different types of paperboard will react differently. Strong high-density paperboards require sharp, well-set knives to cut through but give very clean, well bound edges with low risk of dust and debris. Stiff but lower density paperboards are less sensitive to knife sharpness, but because the fibres are less bound the risk of debris generation is higher and therefore knife sharpness remains crucial. Many recycled fibre boards have a high mineral content. This makes them difficult to cut efficiently whilst maintaining good quality edges.

**Key properties**

**Impact on loose particles**

The optimisation of the finishing operation and the efficiency of debris removal systems have the greatest impact on the ability to achieve clean edges and surfaces. However, the paperboard construction can also play a role. Construction features that may affect the degree of bonding or fixing of fibres within the paperboard sheet include:

- the chemical/mechanical pulp ratio
- the fibre length or fibre treatment
- the surface and “forming end” treatment processes.

However, in general the key to the prevention of debris is still to pay close attention to the slitting and sheeting operations where the potential for debris generation is at its highest.
Handling paperboard

When working with multi-ply paperboard and handling it properly, the reward will be a material with superior properties in all areas of manufacture. The multi-ply construction is the basis of many of the excellent characteristics that help to achieve the best quality and runnability in the printing and finishing operations. The multi-ply construction also requires a few special – but very important – precautions when it comes to handling.

Board, moisture, and flatness
Paperboard is sensitive to changes in humidity. The main factor for retaining the original characteristics of the paperboard throughout all production steps is to maintain its original moisture content. Paperboard is manufactured to be flat in a defined environment of 50% relative humidity at 20 °C. Exposure to variations of humidity will result in a change of paperboard shape or dimensions. Drying out will make the paperboard more brittle.

Prior to printing/converting
A relative humidity of 45–60% at a temperature of about 20 °C in the production areas is recommended to prevent curl and/or misregister. Leave the moisture proof wrapping on the pallet or reel up to the point where the paperboard is to be converted. The wrapper ensures protection against moisture changes, but only as long as it is undamaged. The moisture-proof wrapping must also not be removed until the paperboard has attained the temperature of the converting environment. Recommended warming-up times are given in the following table.

When cold paperboard is exposed to a warm environment the air adjacent to the board can be cooled below its dew point (point of condensation) and this moisture is then absorbed by the board. The time for the temperature equilibrium to be established varies depending on the temperature difference and the weight of the board (pallet or reel).

After printing/converting
Paperboard in sheet form should be rewrapped with moisture-proof material after printing. The printing process can cause a reduction in the paperboard’s moisture content, especially when the sheet has been IR or UV dried. In this case if the temperature of the pile reaches more than 60 °C and the paperboard is not properly protected, then the result could be a loss of moisture to the environment during cooling. Rewrapping is particularly important in order to ensure good register when the paperboard is printed in two or more passes through the printing press. It is also important to wrap in this way to achieve good register between the print and the next process, e.g. cutting and creasing, guillotining or bookbinding. Paperboard products should be wrapped in moisture-resistant material after conversion and prior to shipment to the customer (end user) or to further conversion operations.

Keeping the equilibrium moisture and thereby the flatness and stability is important for the converting line efficiency. Printing presses and packaging lines can only be tuned to a degree to accommodate curled, twisted or brittle material. The most sensitive operations where a well-balanced and flat paperboard plays a vital role are:

- in-feed in a printing press or post press operations
- sheet transport between print units
- delivery/stacking in a neat pile to accommodate efficient post-press converting
- register between print units, both sheet-fed and reel-fed
- accuracy and register in die-cutting and embossing
- consistent result from creasing operations
- predictable and undisturbed runs in a folding/gluing operation
- accuracy in final carton shape or cover alignment in bookbinding
- uninterrupted carton erection prior to filling.

Handling during operation
Multi-ply paperboard needs to be handled with caution or it can easily be damaged. One particular damage is the cigar rolls (or roll backs) caused by the rolling-up of the top layer of a sheet. Should you need to restack the paperboard, avoid sliding stacks of paperboard across the edges of the rest of the pile; this may tear the surface and create cigar rolls. This risk is evident when using ream-wrapped material.

<table>
<thead>
<tr>
<th>Pallet or reel weight (kg)</th>
<th>Temperature differences board – printing room (print room temp. about 20 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>10 °C 2 days 20 °C 2 days 30 °C 3 days</td>
</tr>
<tr>
<td>800</td>
<td>10 °C 2 days 20 °C 3 days 4 days</td>
</tr>
<tr>
<td>1200</td>
<td>10 °C 2 days 20 °C 4 days 5 days</td>
</tr>
</tbody>
</table>
Precautions should also be taken when guillotining material, when sliding the paperboard stack over a worn cutting stick may damage the bottom sheet in the same manner.

The problem of cigar rolls can be prevented entirely if the board is stacked directly on the pallet at the board mill and the pallet is then directly fed into the printing press, then cigar rolls will not be seen.

To prevent damage to the effects of a corona surface treatment it is important to avoid contact of any kind with the surface of the extruded/laminated board prior to conversion.

**Storage and age**

Paperboard manufactured from virgin fibres will change little over time when properly stored, i.e. stored at the correct temperature and equilibrium moisture. Virgin fibre paperboard, when stored in such a way, will show little or no change in mechanical properties and only marginal change in surface or optical properties; these changes are more noticeable in FBB products when compared to SBB products. In general the above applies to converted creased blanks in store, however, particular attention must be paid to tight stacking and protective wrapping of flat stored blanks to ensure the moisture equilibrium is maintained and avoid shape distortion.

Iggesund Paperboard recommends a maximum of 1 (one) year time limit, from delivery, for paperboard in store and 6 (six) months for all corona-treated material.
Offset lithography

With paperboard all available printing techniques may be used to achieve at least the same high-class graphic presentation as when using high quality graphic paper. The good printability and high print quality, together with the many different finishing options and the superior finishing results, imply many good reasons for using paperboard as first choice.

When printing paperboard there are a few things to keep in mind – things that are not always obvious if you are used to paper. This chapter will highlight some of them. The stiffness and bulk – the favourable thickness/grammage relationship – are the most significant characteristics which make paperboard superior in many respects. However, the effects can come as a surprise if one is not used to working with paperboard. Another main difference to consider is the multi-ply construction of paperboard.

Offset lithography

Offset lithography is perhaps the most commonly used method – or rather a set of methods – to print paperboard. Offset provides very high print quality and is commercially attractive for a wide range of run lengths. With the plate given, the print result follows from a complex interaction between ink, fountain solution (in conventional/litho offset), blanket, paperboard characteristics, and drying mechanisms, together with the pressure, temperature, and press speed. Thin paperboard can be printed in the same type of presses that are used for printing paper. However, the best way to print thicker or stiffer paperboard is in a designated press. In this type of press the cylinders and sheet transport systems are adapted to thicker and stiffer substrates.

With their double-size impression cylinders and specially adapted sheet guidance systems these presses are well suited for thicker or stiffer substrates.

If a considerably thicker substrate is printed in an ordinary press, without changes in blanket and plate packing, the thicker substrate adds to the diameter of the impression cylinder, making it appear larger than the diameter of the blanket cylinder. Hence the blanket cylinder and the impression cylinder will have different circumferential speeds, inducing stress on the paperboard. If the ink is too tacky the paperboard will stick to the blanket longer in the printing nip and be released from the blanket with an increased release angle. A higher release angle causes larger forces on the sheet. This might lead to linting or picking and, in extreme cases, possibly also blistering or delamination.

Paperboard handling in offset printing

The multi-ply construction of graphic paperboard has several strong advantages over a single-ply paperboard, but it should be handled somewhat differently. To avoid problems when printing graphic paperboard, there are a few things to consider.

Delamination

The main risk with multi-ply paperboard is delamination. If the paperboard is handled too roughly, the different layers in the multi-ply construction might be separated from each other.
To avoid this problem, please keep the following few points in mind.

- Do not apply higher pressure than necessary between the blanket cylinder and the impression cylinder.
- Do not use significantly tackier inks than normal. Spot colours are known to be tackier than the process colours/Euroscale inks.
- Be careful when the press is cold. Start it up slowly to get the ink viscosity right before running it full speed “Monday morning effect”.
- Reduce the press speed, if necessary. Slowing down the press will reduce the force acting on the paperboard.
- Use quick release blankets. This will reduce the force on the board.
- Avoid manual cutting of the sheets. If the cuts are not 100% correct they might induce stresses in the sheets that in turn might cause the different layers to separate from each other.

High ink tack
Too high ink tack may cause delamination. If the ink vehicle penetrates very quickly into a very absorbing substrate, the tack build-up of the ink may be high. If it is too high, the substrate may delaminate when leaving the printing nip. Adding suitable gel or varnish to the tacky ink (recommended by the ink supplier) is a way to slow the ink setting and prevent delamination.

Blisters
One very special defect – although a very rare one – is the blisters that might occur when IR drying with the IR lamps set at maximum. Too much heat may cause the moisture in the paperboard to turn into steam inside the paperboard layers. Since the steam has a larger volume than the moisture, it will cause blisters on the paperboard. This is why paperboard in general is not suited for heat-set offset applications.

Anti-set-off spray powder
Spray powder is recommended to reduce the risk of set-off. But to avoid problems in later production steps the use of spray powder should always be minimised. Please consult with the people responsible for the subsequent steps before increasing spray powder amount or particle size significantly.

There are many suppliers of spray powder and a number of powder types with several modifications to the particles. The main particle categories are calcium based, sugar based, and starch based. Starch based particles may also come in a modified form as microencapsulated in silicone.

The choice of particle origin is not influenced much by paperboard type. However, the use of highly abrasive, large sized particles when using very glossy products is not recommended, since this may cause micro-scratches on the printed surface.

Offset lithography

The forces inflicted on the paperboard after the printing nip are a combination of pull in the Z-direction and shear.

The choice of granular diameter is influenced by the paperboard properties. Ranging from the very fine 15 μm particle to the very coarse 70 μm particle, the choice mainly depends on ink and varnish coverage, substrate surface smoothness, and delivery pile pressure. For fully double-side coated products with a very light ink coverage, and low delivery stack, as small as between 25 and 30 μm particles may be appropriate. To ensure low set-off for only single-coated backside, uncoated reverse, large sheet size, high delivery pile, or fully varnished surface the particle size (or quantity) should be increased.

Alternative offset printing techniques

There are a number of alternative offset lithographic printing techniques, of which UV offset, waterless offset, Direct Imaging presses, and hybrid offset presses are briefly described below.

UV offset printing
UV offset printing means using inks that cure (dry) by exposure to ultra violet light, not by oxidation and absorption like conventional inks. The press has powerful UV lamps mounted in it, and the inks contain a chemical compound (a photo-initiator) that causes a chain reaction when exposed to the UV light. This reaction changes the structure of the ink film from fluid to solid in a split second. In other words, there is very little absorption of ink into the substrate.

The strongest advantage with UV offset is that the inks dry immediately after being exposed to the UV light. The printed sheets can be handled directly after being printed. The inks also have excellent stability on press and excellent gloss.

A common problem, however, is poor adhesion of the printed ink film due to its shrinking during curing, in some cases to a point where it is a problem in post-press handling. The strong UV lamps can also cause the substrate to yellow somewhat, which is why it is important not to use more energy than needed to cure the ink. A high density substrate requires more energy than one with lower density.
Waterless offset printing

In waterless offset printing the plates are different from the conventional offset plate. The non-image areas are held free from ink by the specific surface tension of the plate, not by the assistance of water. Aside from this, there is no fundamental difference between conventional offset and waterless offset.

However, since the fountain water has a big part in the conventional offset process, a waterless system needs to be built up of different, or modified, components (inks, additives, and press). It is possible to print waterless by mounting waterless printing plates in a conventional offset press and not use the dampening units. But to be 100% successful it is desirable to have better control of the process. The press should be equipped with water-cooled rollers in order to keep the temperature of the press at the right level. This is important because the inks are highly temperature sensitive and will drop in viscosity with increasing temperature.

Waterless offset means faster make-ready. An often reported benefit is also lower dot gain and sharper dots. This enables the use of finer screen rulings than on a conventional offset press. Some also report shorter drying times, since there is no water emulsified with the ink.

All paperboards are well suited for waterless offset printing and will give excellent print quality. However there are some things to note and understand about this printing method and how it should be set up when working with multi-ply paperboard.

The main area to focus on is the inks. For waterless offset they are normally formulated to have higher viscosity and higher working tack than conventional inks. Since there is no water emulsified with the ink it will not decrease as much in tack as a conventional ink on press. This could mean a higher working tack than desired. The ink will also tack up much more quickly than an emulsified ink during a press stop. Even at shorter standstills it might be necessary to spray the rollers with a stay-open compound to keep the ink from tacking up. If the operator is not aware of these factors and does not take appropriate steps to control them, high ink tack may cause delamination.

Hybrid offset presses

Hybrid offset presses are offset presses with additional equipment using other techniques, such as flexo or digital printing.

- Offset and flexo: This is an offset press equipped with a flexo unit at the end. The flexo unit is often used for applying water-based varnish but can also be used for special inks. One example is to print a special spot colour with fluorescent ink. Another example is printing metallic inks, which greatly benefit from being applied in a flexo unit, since the flexo technique allows the pigment particles to be larger than in offset ink. The larger particle size increases the metallic shine.

- Offset and digital: Offset presses can also have digital printing equipment mounted. Today there are offset presses with ink jet units to print very simple designs, e.g. bar codes or dates. In the future it is likely that these hybrids will become increasingly popular. As the speed and quality of digital printing techniques increase, combinations of offset and digital presses will be further developed. This will make it possible to combine true individualisation of each print with the high and consistent quality of offset printing.
Flexography

Unlike the indirect offset lithographic technique, flexography is a direct printing technique, rather similar to stamping. The image is transferred directly from the plate to the paperboard. Besides being used for colour printing, flexo is often used for varnishing with special inks or printing metal inks. In order to achieve high finish in metal inks, the whiteness and smoothness typical of graphic paperboard are particularly important. Even more important is the clean and debris-free paperboard surface. The fact that the fibres in graphic paperboard bind very well – or extremely well – together minimises the risk that debris should force the press to be stopped in order to clean the plates.

Printing plates
In flexo printing the plate itself is the compressible component in the printing unit. The soft printing plate has one major drawback in that it causes quite a high dot gain compared to offset printing. In general a hard polymer plate is required to minimise the dot gain, while a softer plate gives higher print density in full tone areas.

The impression between the anilox roll and the plate cylinder, and between the plate and substrate, should be as light as possible; this is called a kiss impression. If the pressure is too high, halo and squeeze-out will be produced. To fully match the capability of high definition jobs and the new hard polymer plates a paperboard with a very smooth surface and uniform thickness is needed.

One development for achieving minimum dot size is to use very thin plates, which are backed up from the reverse side with a compressible under-layer, when mounted on the plate cylinder. It is important that the thickness of the plate is uniform over the whole area. The thickness should not deviate more than ±0.02 to 0.03 mm. According to some printers, the issue of plate thickness can be controversial. Many flexo printers therefore experiment with different plate and ink combinations to achieve optimal print results.

Flexo inks
The flexo inks are low-viscosity inks, characterised as fluids. There are solvent-based, water-based, and UV-curable inks. The solvent-based inks have more or less been replaced by water-based inks when printing on paper and paperboard, mainly for environmental reasons. Since it is not possible to print wet-on-wet, the flexo press is equipped with intermediate dryers or UV lamps between every inking unit. Heated air is used for drying solvent- and water-based inks.
Screen printing

There are two different screen printing methods: the flat bed method and the rotation method, of which the former is most common for printing graphic paperboard. Screen printing is particularly suitable for substrates that are too stiff to be printed in other presses. Some screen presses are also capable of printing much larger sheets than normal presses. These factors make screen printing ideal for producing large paperboard displays.

Paperboard has some clear advantages in screen printing. A substrate with low amounts of dust and debris is important in all printing methods, but in screen printing it will have more direct effects on the production economy and perhaps also indirect effects in print quality. Spots in the printed image from loose fibres will eventually force the press to be stopped for cleaning. As a result production time will be lost and the mesh may also be clogged with partly dried ink, distorting the hues and image details.

The smooth coating is also a highly important advantage, since it will not absorb much excessive ink. Screen inks are expensive and screen printing produces a much thicker ink layer. This, of course, makes it more resistant to scratches after a good drying period. Also the ink layer retains its hue and/or saturation better when exposed to sunlight, compared to other printing methods. Ink jet in large format is gradually moving in to replace screen printing for certain applications.
Digital printing and direct imaging technologies

Digital printing is an umbrella term used to describe all systems which use any one of a number of technical solutions to replace the traditional pre-press stage in which physical image carriers such as cylinders or plates are created for multiple prints. There is a difference between direct imaging technologies and masterless technologies. What they have in common is that the printing matter or image carrier is created inside the printing unit. However, digital printing in the true sense of the word only occurs when a digital image file replaces a physical image carrier as the master which enables variable data to be printed.

**Direct imaging of a print master, film or plate, in the printing unit**

The majority of these print engines are working with a re-imageable master directly from data files, not for each revolution of the printing cylinder, but for each new job. As they usually do not handle variable data throughout the print run, in a sense they are not primarily digital printing systems. They are mostly used for small- to medium-length repetitive print runs where the advantage lies in the machines fast make-ready time. Inking systems have much in common with other established printing techniques. As a result, demands on the paperboard’s surface characteristics are much the same as for conventional offset printing.

**Masterless printing systems**

With these print units the print master is truly the digital file and the image is created and positioned on demand for each sheet/revolution. These systems are usually based on dry- or liquid toner, electrophotography or drop-on-demand ink jet. The inking systems for these print engines differ greatly from conventional printing systems and place different demands on paperboard performance.

A few of the masterless printing methods have been around for years. The most frequently used are electrophotography with powder toner, thermography and ink jet in its simplest form. The development of computer capacity as well as fine-tuned imaging devices and ink jet head design has led to improvements in quality and speed. In turn, these have made possible the step from office print to industrial production. The introduction of liquid toner in electrophotography and UV-resistant inks in ink jet has led to further quality advantages and numerous new end uses.

**Paperboard in digital printing**

Due to the multitude of available technologies it is difficult to give specific recommendations. For all methods using electrical charges the moisture level of the substrate needs to be controlled, as a lower level has proved to give better results. For liquid toners and liquid inks, the surface chemistry and porosity play an important role in enabling sharp image reproduction and good ink adhesion. For end uses like displays, cards and covers in smaller volumes, paperboard is used successfully in various print engines. Consistency in thickness is an important feature in the feeding of the sheets as well as in the consistent transformation of toner and ink. Stiff paperboard might not be suitable for use if there are tight turns of the feeding paths in the machine. The finishing or converting equipment may also be too weak to process stiff and tough paperboard.

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![The large format ink jet printing principle widely used for displays](image1)

![Three general types of drop ejection in ink jet, either directly through piezo-electric crystals or indirectly through acoustic pressures](image2)
Gravure printing

Gravure printing is normally a reel-fed printing method although sheet-fed machines exist in small numbers. Gravure is used mainly for large runs for magazines and directories on thinner paper. However, a significant number of applications are run on paperboard for high volume packaging such as cigarette cartons and large volume confectionery/liquid packaging. The presses used for printing packaging applications are different from the publication presses in two ways: they are narrower and print units are almost exclusively set up in a straight sequence horizontally (magazine printers can have print units set up vertically). The advantages of gravure printing lie in the high, consistent and continuously reproducible print result. Further, the advantage of fast ink drying (by evaporation) contributes to an immediate post-finishing of the printed goods. The process is ideally suited to situations where there is a range of print designs but a constant carton construction and size.

Description of the gravure printing technique

The gravure printing process uses a metal cylinder with the image engraved or etched on to the surface in the form of a pattern with cavities, called “cells”. The gravure cylinder surface varies depending on the engraving or etching system. The surface can be made of either copper protected by a final chrome finish or zinc. The cylinder rotates through an ink pan where the cells pick up ink. The excess ink on non-image areas is scraped off the cylinder by a doctor blade before the ink is transferred directly to the paperboard surface. The inks are based on low viscosity solvents or water. After each ink unit, the ink is dried using high velocity air nozzle dryers in hoods, which are either heated or not depending on the application and ink system.

The transfer of ink from the cylinder can be aided by electrostatically charging the impression roller. This is called Electrostatic Assistance (ESA) and is particularly used when half tones are being printed. However, ESA cannot be used with printing inks that have metallic pigments which are conductive. In this case, the printability properties of the paperboard must be sufficient for printing without ESA. In many cases where metallic inks are used the ESA can be run on the units prior to the metallic ink being applied, for instance in the case of pictorial health warnings on tobacco applications. Similarly, ESA cannot be used on foil/metallised polyester-laminated boards.

Gravure in practice

Due to the high volumes and high speed in the gravure printing machines the operation is demanding when it comes to reel presentation. There must be tight tolerance in width, clean edges, well aligned cores and high quality joins (if any joins are present). Issues relating to web tension and dimensional stability are critical for achieving...
good register in printing and finishing. They therefore require consistent properties with regards to the tensile strength and stiffness of the paperboard. The choice of paperboard will affect the natural abilities for dimensional stability (see the section on flatness and dimensional stability).

The hardness of the cylinder also demands a smooth surface for best contact and ink transfer since the cylinder does not adapt to the surface structure in the same way as, for instance, a rubber blanket in offset printing. The thickness of the paperboard must be consistent. This also means that the gravure method is relatively more sensitive to surface defects like blade lines and indentations than other methods. The failure in ink transfer results in missing dots.

In food packaging, the paperboard's solvent retention properties affect the speed at which the cartons can be wrapped without having to “air” the pallet to achieve acceptable levels of solvents trapped in the board. Factors governing the degree of solvent retention include the specific ink system used, plus well-managed and well-controlled dryers that are in good condition.

Freedom from visual defects is clearly of crucial importance and a high proportion of modern presses are equipped with a unit that will scan for print defects (including those caused by the board) and reject defective cartons. Clearly, the paperboard’s freedom from any surface defects, whether visual or physical is a key property.

**Key paperboard characteristics**

- thickness
- tensile strength
- stiffness
- surface smoothness
- flatness and dimensional stability
- moisture level in the board to control solvent retention.

**Finishing in gravure printing**

In gravure printing most products are finished up to the point of blanks inline. This means that varnishing, embossing, die-cutting and, at times, foil blocking, is done at the end of the press with rotary or flat bed tooling.

Misregister can occur not only in the printing process itself but also in all subsequent finishing stages.
Creasing and die-cutting at these high speeds therefore require consistent properties in terms of thickness, tensile strength and plybond in order to avoid variations in crease performance and registration between creases and embossings.

Due to the high tooling costs for rotary converting, the issue of tool wear in die-cutting is an important factor to which the paperboard properties can contribute to some extent. Composition of the coating may provide more or less abrasion and lubrication and the baseboard finish will to some extent also affect the resistance to cutting.

Rotary cutting can be done in two ways: crush cut, in which the knife meets a flat impression cylinder, and dual knife cut, in which two knives separate the paperboard, one from above and one from below. The latter is the more common approach in high volume tobacco applications and has the advantage of minimising the number of adjustments that must be made to the tooling during production, resulting in consistency of creasing, etc.

Rotary conversion also has the advantage that no “nicks” are required to hold the cartons together to take them forward to separation of the blanks.

Some web-fed gravure printing presses are fitted with flat-bed cutting and creasing equipment. This is most suitable for plants that print small to medium runs in which the variation of layout/shape size in the process and possibly also the shorter make-ready of the flat-bed technique offers advantages. It is possible to incorporate a foiling unit at this stage; however, this is often done by sheeting the printed web and doing the foiling as a separate process.

**Key paperboard characteristics for print finishing**
- thickness
- tensile strength
- stiffness
- surface smoothness
- flatness and dimensional stability
- freedom from surface defects.
Hot foil stamping

Hot foil stamping is a finishing method used to give texts and patterns an eye-catching appearance. The foil can have a glossy or matt finish with a coloured, metallic or holographic appearance. The size of the area that can be covered varies from very small details, such as letters, to large, solid areas.

The hot foil stamping operation
The foil is carried on a heat-resistant film. During the operation the paperboard and the foil are kept parallel. A heated matrix, which is fitted to the stamping plate or cylinder, relieves the foil from the carrier and makes it adhere to the paperboard.

Since the carrier film reacts with the foil due to the pressure and heat of the stamping process, the composition of the paperboard surface is essential to provide good runnability and satisfactory bonding of the foil. The paperboard surface must be very smooth and free from impurities and spray powder. The size of the area which can be hot foil stamped varies from small, such as lettering, to large areas.

If the foil covers a relief pattern, hot foil stamping is performed at the same time as embossing to minimise the risk of misregister between the relief and the foil.

Recommendations
For the best visual appearance of the foil, it is important to have a clean and very smooth paperboard surface with a minimum of interfering surface irregularities, since these are strongly accentuated when foiled. The tool’s ability to conduct heat and the smoothness of the tool surface are equally important factors. To produce the best gloss during longer runs, the surface of the tool should be polished.

![Diagram of hot foil stamping and embossing at the same time](image)

![The composition of hot foil stamping films](image)
Key paperboard characteristics
For the best visual appearance of the foil, a smooth surface with a minimum of interfering surface structure is important, since surface irregularities are strongly accentuated when foiled.

Key properties
Key paperboard features when performing hot foil stamping:
- smoothness
- surface structure
- adhesion
- surface strength
- flatness and dimensional stability at the specified moisture content.

Problem | Cause
--- | ---
Poor foil adhesion | • Insufficient heat
Air blisters under the foil | • Excessive heat
Foil lacquer matt | • Paperboard surface not smooth enough
Irregularities in foil lacquer | • Excessive pressure

Hot foil stamping in practice
The following factors are essential for good hot foil stamping:
- foil type
- time of pressure (seconds)
- pressure (bar)
- temperature (°C).

Testing the hot foil stamping result
Visual inspection of the result, including comparison with proofs.
Embossing

Quality embossing, blind or foil embossing, preprinted metal foil, and holograms add the touch of class needed for the promotion of luxury products such as greeting cards, covers, folders, etc.

Even though all types of paperboard can be embossed, there are restrictions due to the construction and composition of the paperboard. The paperboard has to be strong and tough, but rigid and elastic at the same time. The finer the detail and the deeper the depth of embossing needed, the fewer types of paperboard grades there are available that will successfully fulfil the requirements.

Metallic foil can be used independently in foil printing or holograms or in combination with embossing for promotional reasons. Stamping foils have an effective metallic finish that make an immediate and striking impact.

If the relief pattern is to be covered with metallic stamping foil, the two operations are carried out simultaneously to minimise the risk of misregister between the relief and the foil.

Embossing means the shaping of paperboard into well-defined permanent relief patterns. If the paperboard is dense and strong, embossing can be done with complicated patterns and with pronounced relief. Often the embossed surface is printed or foiled. If the relief is raised, it is defined as positive. If the relief is impressed, it is negative.

The possible patterns obtained by embossing are almost limitless. Some types of relief are shown in the illustration here.

Embossing can also be applied as a pattern covering the entire surface, for example paperboard embossed with a linen structure.

Please refer to the fold-out at the end of this manual for an example of embossing.

Description of the embossing method

The embossing stamp (or die) is specially produced for every embossing operation. The paperboard grade and the relief shape and depth are of major importance for the stamp construction.

The embossing operation is carried out with heat and pressure to make the relief precise and permanent. The embossing tool is a thin metal sheet with the surface shaped as the relief pattern and the make-ready with the inverted pattern. The embossing stamp pushes the paperboard into the groove of the make-ready, which is located under the paperboard, and embosses a permanent relief.
Embossing

A relief pattern can be 0.15 to 2.5 mm high or deep. If hot foil stamping is performed at the same time, the relief can be 0.25 to 0.60 mm. By using both raised and immersed reliefs in the same pattern, a visual effect of a greater depth will be obtained.

**Key paperboard characteristics**

The impression from the tool will be accurate, precise and permanent if a strong and dense paperboard is used. The paperboard must allow a high degree of elongation without cracking but also retain permanent deformation after the impression. This is known as having good formability.

Paperboard with a uniform density throughout the different layers contributes to the quality of the embossing. The strength and elongation of the paperboard permit complicated patterns and large deformations without any visible damage.

**Different paperboard ply constructions**

Good formability is enhanced by the length of the fibres in the paperboard and their ability to bond together. In this respect, the ideal paperboard should consist of chemically processed long fibres. High elasticity of the coating is also important to avoid surface cracking. For this reason, Solid Bleached Board can reproduce advanced designs with relief exceeding the thickness of the paperboard. Folding Box Board is also capable of giving embossing results which meet design needs.

**Key properties**

Key paperboard features for embossing operations are:

- strength
- elongation
- toughness
- moisture content
- thickness
- density.

<table>
<thead>
<tr>
<th>Material</th>
<th>Production technique</th>
<th>Durability</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>Engraved</td>
<td>++++</td>
<td>Multi-level</td>
</tr>
<tr>
<td>Copper</td>
<td>Etched</td>
<td>+++</td>
<td>Mostly single level</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Engraved</td>
<td>++</td>
<td>Limited multi-level</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Etched</td>
<td>++</td>
<td>Only single level</td>
</tr>
</tbody>
</table>

![Relief patterns](image)
Embossing in practice

If the relief has only small differences in levels, the machine speed can be higher. There will also be fewer problems with stacking and further converting the embossed sheets. Embossing of plastic-coated or laminated paperboard must be carefully tested.

The paperboard moisture content is essential for good formability. It is therefore important to prevent the paperboard drying out.

The tool preparation is usually specific to a particular paperboard grade. This means that it is very difficult to use the tool with other grades.

To achieve the best results we recommend that you always give your tool supplier a sample of the substrate you intend to use. When producing the tool there are a number of factors to take into account. The run length will determine the choice of material for the stamp. The grade and grammage of paperboard will determine the design of the make-ready.

FBB-type paperboard (Folding Box Board) is somewhat more compressible than SBB-type (Solid Bleached Board) and will therefore absorb some of the pressure within its structure. The make-ready needs to compensate for this, i.e. it needs to be properly adjusted to both the compressibility and the thickness of the substrate.

Therefore please note that we recommend you purchase the make-ready as well as the stamp from your tool supplier rather than use a do-it-yourself material (e.g. a make-ready board or a moulded make-ready from a one- or two-component paste). A do-it-yourself make-ready will only withstand short run lengths. Even more important, it will not provide the required precision, that is, you will not be able to adjust the make-ready properly to the board.

Testing the embossing result

The embossing result is subjectively evaluated regarding defects, cracks, etc. See below.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>The blanks tear during the embossing operation.</td>
<td>• Paperboard too dry.</td>
</tr>
<tr>
<td></td>
<td>• Combination of paperboard strength/flexibility and embossing height is incorrect.</td>
</tr>
<tr>
<td>The pigment coating cracks and peels off during embossing.</td>
<td>• Coating adhesion insufficient.</td>
</tr>
<tr>
<td></td>
<td>• Coating too dry or the surface structure is too rough.</td>
</tr>
<tr>
<td></td>
<td>• Coating too weak or too brittle.</td>
</tr>
</tbody>
</table>
Die-cutting and creasing

In the conversion of paperboard the die-cutting and creasing operations are usually performed simultaneously in the flat-bed die-cutting station, which can be off-line or in-line with the printing press. In-line processing dominates for cigarette cartons; most other carton work is done off-line. Die-cutting and creasing are frequently combined with embossing.

To achieve a consistent, accurate result, it is important to choose the right tools, machine settings, types of paperboard and conditions for the paperboard. Detailed technical information on tool design, machinery and settings is available through established suppliers of machines and tools. Less information, however, is available regarding the interactions between the machinery, tools and paperboard.

Key paperboard characteristics

It is important to recognise the differences between the different types of paperboards, mainly Solid Bleached Board (SBB), Folding Box Board (FBB) and White Lined Chipboard (WLC). All grades can be cut and creased but to achieve the best result for each application it is important to fine-tune the treatment to give the desired result. Due to the type and individual properties of the different paperboard grades, die-cutting, creasing and embossing can be performed to different levels of achievement.

Common to all paperboards is the fact that results differ depending on the grain direction, moisture content and thickness, amount and type of surface treatment (pigment, plastic, or metal foil coatings).

Runnability through the die-cutting and creasing station is important. The paperboard web or sheet should be efficiently cut and creased, partly separated and rapidly pushed (or pulled) away. To run satisfactorily, the machine settings are vital. The moisture content, shape and dimensions of the web/sheet and cut blanks are important. The partly cut sheet must have enough integrity to be transported to the stripping unit. Even minor variations and disturbances can cause a breakage and jam the whole production line. After the type of paperboard, consistency in moisture and thickness are the next two most important factors.

Die-cutting

A good cut should be clean and free from loose fibres and particles. This will give accurate and clean edges and avoid contamination problems during further processing of the paperboard or in the packaging operation.

Die-cut blanks remain linked to one another by nicks. To prevent unwanted separation of the sheet during the transfer to subsequent stations, the strength of specific nicks is of great importance for a high production rate. At the same time it is important that the paperboard blanks can be easily separated in the stripping operation, which removes the paperboard waste. Having an optimum nick quality is necessary in order to achieve the best result regarding these two contradictory needs and to obtain a clean and clear cut.

Description of the die-cutting tool

The die consists of the cutting and creasing rules. When performing the die-cutting operation, the die reciprocates up and down towards the paperboard, which is placed on the make-ready. After one cycle the cut paperboard sheet is removed and a new one is fed into the machine.

Please refer to the fold-out at the end of this manual for an example of die-cutting.
The task of the ejection rubber is to hold the sheet in a fixed position during cutting and to eject the paperboard blanks from the cutting die.

A nick is obtained by making a notch into the cutting rule. The geometry of the nicks (shape and size) varies and depends mainly on the type of paperboard used. The height of the notch should be slightly higher than the paperboard thickness.

Key paperboard characteristics
Chemical fibres in the paperboard give strength and efficient bonding, which gives a cut with clean edges. Due to its strength, chemical fibre-based paperboard therefore allows smaller nicks. The different strength properties in the machine direction compared to the cross direction are important in the design of nicks. Generally nicks are two times stronger in the machine direction than in the cross direction.

To achieve clean, debris-free edges it is important to have the correct cutting conditions. Due to its strength, toughness, and density, paperboard requires sharp, well-adjusted knives and good control of the die-cutting machine. The high force required to cut through has to be well controlled to minimise what is called the “overshoot” of the moving die. Otherwise the knives will hit the counter plate too hard which will quickly damage the knives and degrade the quality of the cut edges.

The most important strength properties of the paperboard are tearing and tensile strength. The nick strength is proportional to tensile strength and grammage. The moisture content level is essential for both runnability and quality during the die-cutting process. Too high a level will make the paperboard strong, tougher and more difficult to cut. Too low a moisture level will make the paperboard more brittle and difficult to safely transfer. Difficulties in cutting through can be caused by the paperboard thickness, moisture variation, or tool wear and adjustments.

When cutting sheets into carton blanks it is important to achieve the desired shape to feed the blanks properly. Depending on the moisture equilibrium and the possibility of tension being released during cutting, the blanks can be curved or twisted into shapes that disrupt the converting and packing operations.

Moisture content variations and dimensional variations cause misregister between the printed image, cuts, creases, and embossed impressions.

The wear of die-cutting tools is not well understood. Coating and fibre composition, inks and varnishes may have an influence.
Die-cutting in practice

Tool preparation
All cutting rules must be of the same height to cut through the entire thickness of the paperboard across the die. Fine-tuning the level of each cutting rule is important but complicated. Patching up, as it is called, in one area of the sheet might induce disturbances in other areas. Machinery suppliers will be able to provide more specific information on this topic. The nick strength depends on factors such as:
- paperboard grain direction
- method of making notches
- rubbering of cutting die
- nick dimensions
- arrangements of nicks
- number of nicks
- humidity of the paperboard
- type of fibre.

The ideal position for the nicks is in line with the gripper force. The flaps of a blank should be linked with another blank by two nicks placed as far apart as possible. Nicks should not be made on glue flaps. Nicks are produced by grinding a notch in the cutting rule with a grinding wheel.

The dimensions of nicks should be as small as possible. Generally, the width of the nicks varies from 0.4 mm to 1.0 mm depending on the strength of the paperboard.

It is important that the climate is controlled in order to keep the paperboard moisture content unchanged. Variations in moisture content will cause dimensional changes due to shrinkage and expansion, which will cause misregister. Constant moisture is also important to avoid distorting the shapes of sheets or blanks, which could otherwise interfere with the cutting tools and cause machine stops. The toughness of the paperboard varies with moisture. High moisture makes the paperboard difficult to cut and the blanks tough to separate, and low moisture makes the paperboard brittle and may cause unwanted blank separation.

Rubbering of the cutting die

The rubbering of the cutting die plays a very important role for the quality of the final result. Correctly done the rubbering also supports productivity by allowing higher speeds and minimizing the risk of stops due to waste coming loose in the machine or sheets not ejecting properly from the die.

In the cutting operation the rubbers fix and secure the sheet before and during the cutting and help to strip the cut material from the sheet. All die rules around the outer edges of the design should be rubbered with “closed” rubber types. These will trap and compress air within the design and help to eject the sheet from the cutting die.

To avoid unwanted stress on the nicks the notches should not be ground through the rubbers. This would put extra stress on the nicks during the cutting operation and may decrease their strength by up to 30%, risking premature breaking.

Recommendations

Rubbers for blank separating rules with notches: The rubber is generally positioned between 1.0 and 2.0 mm from the cutting rule in order to prevent breakage of nicks. The use of profile rubber (shape-designed to distribute the stress in the compression stage in a more accurate way) has proven to give better results: stronger nicks, fewer pressure marks, and a more accurate fixing of the paperboard during the cutting operation.

A very hard profile rubber (7 mm wide) is recommended. Please note: If undesired pressure marks should occur, reduce the hardness and if possible increase the width.

Rubbers for rules without notches: The rubbers for such an area serve only to eject the sheet after it has been die-cut. The most important paperboard property in this context is good elasticity. The rubber should be compressible to at least 50% of its normal height.

The grinding of notches must not damage the supporting rubbering

The hardness and profile of the supporting material vary depending on whether its function involves fixing the paperboard during cutting or ejecting the blank after cutting. Both cork and different types and hardnesses of rubber are used.
Rubbers for paperboard printed on both sides: When die-cutting a paperboard which has been printed on both sides it is important to increase the hardness of the rubber. In this way ink flaking on the reverse side is avoided. This is especially important when using a UV curable (hard) ink or varnish.

A cork rubber or a hard elastomer is recommended. The rubber profile should be mounted as close as possible to the cutting rule.

The ram punching operation
Ram punching is a powerful cutting technique used to cut numerous amounts of small shapes such as labels, envelopes and cards. Unlike die-cutting, which cuts one sheet at a time, ram punching is used to cut through a pile of substrate. This means, of course, that ram punching and creasing cannot be performed simultaneously.

Ram punching is often used to cut paper but can also be successfully used with multi-ply paperboard to cut simple shapes. To avoid waste, the paperboard is first cut down in an ordinary cutting machine to fit the size of the intended shape, leaving a margin of 5 to 10 mm.

The ram punching tool consists of a punch mounted on a jig. To prevent edge delamination and other damage, counter pressure, i.e. that a hydraulic piston is used to press the paperboard pile against the punch is recommended. Under demanding conditions the choice of a suitable varnish that can lubricate the knife may also prevent edge damage.

A high density paperboard such as SBB is more suitable for ram punching operations than other paperboard types.
Die-cutting and creasing

The laser cutting operation
Laser cutting is by far the most elaborate and exclusive cutting method. It allows very small details and very complex designs. The operating principle is rather simple. The original design is etched through a copper template, which is positioned over the paperboard sheet. A sharply focused laser beam runs back and forth over the template and wherever there are etched areas, the laser beam vaporises the paperboard.

The paperboard used in laser cutting should be as lightly coated as possible for two reasons. The first is that the lighter the coating is, the faster the laser cutting works. The second is that the operation leaves a slightly brownish discolouration on the reverse side of the paperboard, and this is more noticeable on a heavily coated paperboard. This discoloration can be covered by printing, but it may also be considered as a part of the design.

Since the sheets are fed into the laser cutting machine with the print side down, a protective varnish to avoid scratches on the print is recommended. The use of paperboard thicker than approximately 500 μm should be avoided, due to limitations in the laser cutting process. Please contact a supplier for advice and if possible a test.

The benefits and limitations of multi-ply paperboard products in laser cutting are shown in the following table.

<table>
<thead>
<tr>
<th>Paperboard type</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding Box Board, FBB</td>
<td>Low density compared to thickness means less energy is needed for cutting (economical production).</td>
<td>Lower strength than SBB</td>
</tr>
<tr>
<td></td>
<td>Single-sided coated FBB causes less discolouration from the coating. The amount of coating compared to thickness is smaller than for alternative grades with coating on both sides.</td>
<td></td>
</tr>
<tr>
<td>Solid Bleached Board, SBB</td>
<td>The strong network in SBB baseboard allows a design with finer details (better strength in the most fragile designs than alternative grades).</td>
<td>Two-side fully coated SBB gives more discolouration, since the coating amount is higher compared to the thickness than for single-side coated paperboard.</td>
</tr>
</tbody>
</table>

Coated wood-free paper has higher coating/baseboard ratio and usually contains fillers (for opacity). Comparatively more energy is therefore needed to cut the same thickness (longer production time). Due to the high amount of coating and fillers, the discolouration is also more pronounced than for paperboard.

WLC contains impurities from recycled material. This may cause a discolouration closer to black than light brown. Depending on the type of WLC, lower tearing resistance and tensile strength may also limit the ability to produce a highly detailed design.

General recommendations
The interactions between the machines, cutting tools and paperboard differ depending on the cutting method, the design, the previous surface treatment (e.g. lamination), and the choice of paperboard product for the intended application.

- Generally, flatness and dimensional stability are vital for achieving high runnability. Moisture content is equally crucial. Too high level of moisture will make the paperboard too strong to cut, while too low moisture level will make the paperboard too brittle.
- Strength is always required from the paperboard for good runnability and good formability. The most important strength properties are tearing resistance and tensile strength.
- If white cut edges are required, paperboard made solely from bleached chemical pulp must be used.
Creasing
Creasing is an operation which facilitates the folding operation. During creasing the paperboard is weakened along well defined folding lines, which then act as hinges for folding packaging and graphical products. It is very difficult to fold paperboard with a good result without creasing. The surface plies will crack and/or the folding line will be undefined. When converting paper (less than 180 g/m²) the folding operation is often performed without any surface preparation. Paperboard with a grammage above 600 g/m² requires more than one crease or must be scored before folding.

To achieve a perfect crease the relationship between its width and depth is of great importance.

Creasing is carried out using a thin strip of steel with a round smooth edge and an accurately cut groove in a thin hard material known as the make-ready (matrix or counter-die). The creasing rule pushes the paperboard into the groove of the make-ready, located under the paperboard, creating a permanent crease.

The creasing tool’s construction and performance are essential elements in obtaining a satisfactory result.

Description of the creasing tool
The creasing rules are fitted into the die. When performing the creasing operation, the die reciprocates up and down towards the paperboard, which is placed on the make-ready. After one cycle the creased paperboard sheet is removed and a new one is fed into the machine.

The thickness of the creasing rule, the groove width, the make-ready thickness, and the paperboard thickness must correspond to each other. Different types of paperboard require different tool geometries.

Creasing – a deformation
The paperboard is creased by being pressed into a channel or groove in the make-ready. The forces created deform the paperboard in a predetermined way and the deformation is permanent. The result is a reduction in the bending resistance of the crease. The paperboard is therefore weaker along the crease than elsewhere. During the creasing operation, the paperboard sheet is bent in four narrow zones and in each of these the paperboard must endure high tensile forces or compression forces.

When converting extremely thick material the use of double creases is normal procedure.
To calculate the creasing parameters the following formulae may be used:

- Crease depth \( h_1 = t + t_n - (H - H_r) \)
- Penetration \( h = H - (H_r + t_n) \) \text{(DIN)}
- The height of the creasing rule \( H_r = H - t_n \) \text{(DIN)}

If the penetration is \( = 0 \) mm then the crease depth \( = \) paperboard thickness.
If the penetration is \( > 0 \) mm then the crease depth \( < \) paperboard thickness.
If the penetration is \( < 0 \) mm then the crease depth \( > \) paperboard thickness.

According to the DIN standard, penetration equal to the thickness of the paperboard is denoted as \( \pm 0 \). The penetration is denoted as \( + \) when the crease depth is less than the paperboard thickness and \( - \) when it is more than the paperboard thickness. Unfortunately there is not a universal agreement about the notation \( + \) and \( - \) as applied to penetration. Iggesund Paperboard uses the same notation as that described in the DIN standard.

It is not always possible to have a make-ready or counter-die of exactly the same thickness as that of the paperboard. As a general rule, choose the next larger thickness e.g., 0.40 mm for a 0.35 mm paperboard.

The width of the creasing rule is typically 0.70 mm in the thickness range 0.20 – 0.55 mm and 1.05 mm for paperboard thicknesses above 0.55 mm.

The groove width is generally 1.5 \( \times \) the thickness of the paperboard plus the width of the creasing rule. The groove width should be narrower if the crease is performed in the machine direction (MD).

Different paperboard ply constructions
Most paperboards are made of several plies. The fibre composition and physical properties vary considerably between different types of paperboard. To get well-defined creases and accurate folding with low folding resistance the crease should be deep and narrow. During creasing and subsequent folding the paperboard is subjected to severe stresses and deformations.

For successful creasing the paperboard must have strong surface plies and coating layers. Another important feature is the attainment of a good hinge. Ideally, the paperboard should delaminate into a finite number of thin unbroken plies throughout the thickness of the paperboard.

Due to the wide range of paperboards and their different physical properties, the graphical or packaging demands on creasing should be carefully matched to a suitable paperboard. Equally important is the adaptation of the creasing tools to the type of paperboard.

Key properties
Since the creasing operation causes a mechanical deformation, the measurable strength properties such as tensile strength, compression strength, elongation, and elasticity are important.

Creasing in practice
Tool preparation
The creasing rule width, the groove width and the make-ready thickness should be determined with regard to the paperboard type, the paperboard thickness and the direction of the creases (MD or CD).
The following factors are essential for good creasing:
• the height and width of the creasing rule
• the thickness of the make-ready
• the groove width
• the accuracy and hardness of the make-ready
• the pressure of the die-cutter.

It is more difficult to produce a perfect crease parallel to the machine direction (MD) than it is parallel to the cross direction (CD). In demanding cases MD creases should be defined separately. If there are many creases, especially close to each other, it is advisable to have them parallel to the CD of the paperboard.

The operating accuracy of the creasing tool is important in order to correctly locate creases. An incorrectly located crease will give a poor appearance, especially when the carton is printed.

**Thickness**
Thickness, not grammage, is an important variable for the design of the creasing tools. If the paperboard thickness is changed, even within the same type of paperboard, the tools should be adjusted (according to the formula in the section “Description of the creasing tool”). It is important to distinguish thickness from grammage. Different types of paperboard have different thickness/grammage relationships and different physical properties. To obtain a good result the tools should be designed according to the paperboard type and thickness chosen.

**Paperboard type**
For each type of paperboard, there are recommendations which will help to obtain the best result when creasing. See the Product Catalogue for further information.

**Testing crease result**
The effectiveness or inadequacy of a crease should be checked by bending at an angle of 90° or 180° depending on whether the blanks are to be erected and glued or are to be glued for flat delivery.

Creases are subjectively evaluated regarding defects, cracks, etc. For good results the folding factor, explained later in this chapter, should be above 50%.

<table>
<thead>
<tr>
<th>Paperboard type</th>
<th>Paperboard characteristics</th>
<th>Creasing results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Bleached Board</td>
<td>Dense, strong, and tough paperboard. Strong plies throughout to withstand demanding creasing.</td>
<td>Develops well defined permanent creases easily. Gives creases with low folding resistance and good foldability over a wide range of crease geometries. Accepts very narrow and deep creases without damage.</td>
</tr>
<tr>
<td>Folding Box Board</td>
<td>Low density, stiff paperboard. Strong surface plies to withstand the crease stress and deformation.</td>
<td>Develops well defined creases. The compressible interior gives less permanence of the crease as defined by the tools. The high stiffness in relation to the folding resistance gives good foldability.</td>
</tr>
<tr>
<td>White Lined Chipboard</td>
<td>Dense, intermediate to low strength and stiffness. Stronger surface plies to accept moderate creasing.</td>
<td>Develops creases provided the tools are matched with the chosen paperboard. The physical properties and pulp composition vary to a large extent. It is not possible to give typical values.</td>
</tr>
</tbody>
</table>
Scoring

The bookbinding industry is developing in many fields. Demands on shorter make-ready time, shorter runs and higher speed makes the traditional creasing technique less profitable. The use of inline scoring in the binder for both soft cover production and saddle stitching as well as for folders is the prevailing technique.

Description of the scoring operation

The paper or paperboard travels through a set of counter rotating tools with a male and female part which press a permanent groove into the substrate.

In the folding station the substrate travels through the tools mounted on shafts before going through the knife folding unit.

In the cover station for a saddle stitcher the cover is gripped and fed around a rotating drum with a male scoring wheel.

In the cover station for the perfect binder the covers are fed through two sets of shafts with tools. Tools for spine grooves as well as decorative grooves for front and back covers are fitted in an opposing manner.

The female wheel can be of three main types;
- A soft rubber counterpart which does not have a groove and which relies on the compressibility of the surface to be sufficient for developing the permanent deformation in the substrate.
- A metal surface with milled groove in fixed dimension.
- Two adjustable parts in metal, which enables the adjustment of the female groove width.

In the first case, the only adjustment that can be made during production is a pressure adjustment, which is done by pressing the male tool down harder into the substrate. In the second case, pressure can be increased up to the point where you risk cutting into the substrate. The width of the groove can be adjusted by fitting a new female tool with a different groove dimension. In the third case, both the pressure (depth of indentation) and the width of groove can be adjusted independently by using levers in the machine.

Folding performance

A study of SBB 240–260 g/m² and FBB 200–240 g/m² in 2008, identified the most important differences between traditional creasing and scoring with regard to the performance of the creased material.

Settings

The tool geometry for the scoring tools in this study were as follows: The width of the male scoring tool was set to 0.7mm which corresponded to the width of the creasing rule.
The width of the female groove was approximately 0.6 mm wider for the scoring tool compared to the groove of the make-ready used in the creasing study according to the manufacturer’s recommendations.

**Depth of the crease (h)**

In the case of both SBB and FBB products, the depth of the groove of the scored material was found to be 25–30% shallower when scoring with h=0 penetration by the male tool. However, when the penetration was increased by 20% the SBB developed an equally deep groove as when properly creased but the FBB samples were still 15% shallower than the creased material. This can probably be attributed to the higher density of the SBB. In contrast, the compressibility of the FBB paperboard requires higher pressure to develop a permanent deformation of the same depth.
Width of groove
The width of the groove inside the bulge was recorded (see the illustration above) and here the scored material showed a wider result than the creased material. The SBB samples were approximately 20% wider and the FBB was 15% wider. Increasing the pressure to a positive penetration did not affect the width of the groove significantly.

To summarise, the result of scoring can be expected to be shallower and wider than the result of creasing. An example of the effect this has on the folding resistance (moment) is illustrated by the graph on the previous page. The FBB paperboard and SBB paperboard show equal resistance to folding at 90° despite the difference in their base weight. The resistance is approximately 25% higher for the scored samples at 90° due primarily to the incomplete bulge geometry of the scored material. The remaining resistance after folding 90° drops and has been recorded over a 15 second period. This is an important property to monitor, since this corresponds to the clamping period in a perfect binder where the force with which the paperboard wants to spring back after clamping risks the integrity of the glue seam. Once again the moment to which the paperboard wants to spring back after 15 seconds is 25% higher for the scored material compared to the creased material.

Scoring in practice
The main difference between traditional scoring and carton blank creasing is the direction of the score. Whereas the bulge is always directed inwards into the fold in carton creasing, scoring for books and brochures is mainly done the opposite way. There are two reasons for this. First, the technique is mainly used for thinner fine paper where the prospect of creating a well-defined delamination within the structure to facilitate a good fold with low resistance is low due to its monolayer construction and high internal bond.

Second, there are clear practical reasons in three different cases:
• When folding the bulge would, if turned the “correct” way, obstruct the accuracy of the folding knife in the folder when the bulge is pushed between the folding rollers. This leads to misregister and variations through the run.
• If the bulge develops towards the insert of the magazine, the alignment of the insert in relation to the cover could be obstructed. This leads to misregister between artwork which spreads over both cover and insert and reduces the ability to have a controlled and consistent operation.
• When applying the cover onto the insert in a perfect binder, the bulge will obstruct either the tight fit of the spine or the integrity of the side glue seam on the face and back page.

The traditional direction of a crease with the bead facing inwards in a fold may obstruct proper folding in a knife folding operation

Creasing the cover from the face side will produce a bead that may obstruct the alignment of the cover with the insert

The traditional way of creasing and folding paperboard might obstruct tight fitting of a book cover
**Key paperboard properties**
It is evident that traditional creasing results in a deeper and narrower crease which improves the folding performance. When scoring, you need to adjust the tooling and settings to negative penetration (according to the DIN standard) and you need to select or set the width of the female tool to an absolute minimum without inflicting a cut in the surface.

**Key paperboard properties for foldability in scoring**
- Strength and toughness in the MD and CD, tensile strength, compression strength, elongation and elasticity
- Stiffness in the MD and CD
- A strong and elastic coating.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause and remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>The outside of the paperboard cracks during folding.</td>
<td>Too high stress along the edges of the crease. Widen the groove or reduce the height of the make-ready.</td>
</tr>
<tr>
<td>The sides of the erected box bulge out.</td>
<td>The grooves on the make-ready are too wide. Increase the height of the creasing rule. To correct the creasing, remake the make-ready. The folding resistance is too great.</td>
</tr>
<tr>
<td>Irregular creases, the paperboard folds either to the left or to the right of the crease.</td>
<td>The grooves on the make-ready are too wide. Increase the height of the creasing rule. To correct the creasing, remake the make-ready. The folding resistance is too great</td>
</tr>
<tr>
<td>The liner splits.</td>
<td>Insufficient penetration or depth of crease. The groove width too narrow. The paperboard is too dry.</td>
</tr>
<tr>
<td>Crumpled roll (or bead)</td>
<td>Insufficient penetration. The groove width is too wide, possibly due to a worn matrix.</td>
</tr>
<tr>
<td>Cutting through</td>
<td>Poor alignment of the rule with the groove.</td>
</tr>
<tr>
<td>Back splitting</td>
<td>Bottoming of the bead in the groove as a result of an insufficiently thick matrix, or debris in the groove.</td>
</tr>
<tr>
<td>Bursting</td>
<td>Localised splitting of the crease due to the presence of debris etc. in the groove.</td>
</tr>
<tr>
<td>Shattering (Cobbing)</td>
<td>Tears in the reverse side adjacent to the cut edges. Prevent this by using a hard ejection rubber set approximately 1 mm from the knife.</td>
</tr>
</tbody>
</table>
Creasability and foldability

The purpose of creasing is to make well-defined folding lines, which facilitate the folding operation and provide the conditions for the paperboard product to obtain its intended shape and function. The ideal crease should perform like a perfect hinge when folded. This cannot be fully achieved, but the challenge is to come as close to such a hinge function as possible.

Creasability and foldability are two closely related and very important properties:
• for obtaining the intended carton shape and function
• when designing creative shapes, in both graphical and packaging applications
• for packaging line efficiency and runnability
• for achieving box compression strength and stacking performance.

The application determines the creasability and foldability demands. These demands can arise from production, carton shape, size or function.

The paperboard choice

Paperboard catalogues and brochures often contain the manufacturer's subjective opinion about the paperboard creasability and foldability, for example “good” or “very good”. Structure, construction, type of pulp, and basic measurable properties provide the paperboard with its creasability and foldability. The judgement “good” or “very good” must be based on facts about these properties.

The paperboard choice is important but the construction of the creasing tool and its performance are equally important for achieving a satisfactory result.

The paperboard’s stiffness and strength properties contribute to the folding result. Folding Box Board is generally stiffer than Solid Bleached Board, for a given grammage, which instead has better strength properties. Foldability is a question of stiffness and strength, related to the application demands.

The following text deals only with the aspects to be considered when creasing and folding basic grades of paperboard. The additional considerations for plastic- or metal-laminated paperboard are not discussed.

In most cases the paperboard consists of a number of fibre plies and layers of coating. The individual characteristics of the different plies and the paperboard construction as a whole have a great influence on the creasability and foldability. The multi-ply construction makes an important contribution to creasability and foldability.

The demands on creasability and foldability vary with the application. Folding Box Board (mechanical pulp with chemical pulp in the surface plies) and Solid Bleached Board (pure chemical pulp) can together satisfy a wide range of different demands.

Solid Bleached Board has advantages when the requirements for precision and machine speed are high and when the carton shape demands deep and narrow creases. This is especially so if the creases are located very close to each other in small areas, when creasing with narrow radii, and if the crease angles are small. Since the creasing operation causes a mechanical deformation, the measurable strength properties such as tensile strength, compression strength, elongation, and elasticity are vital.
Creasability characteristics
Creasability is explained as:
• The paperboard’s ability to permit deep and narrow creases. Folding such a paperboard is easy and the result will be well-defined edges and corners.
• The paperboard’s ability to adapt to the crease rule shape and retain the desired geometry of the crease. Accuracy and precision in the crease shape and location are important. The folding operation is difficult to perform if the crease is too shallow or wide.
• The paperboard’s ability to be folded is measured by the folding factor. The higher the folding factor attained without the surfaces cracking, the better the creasability and runnability in converting and packaging machines.
• The paperboard’s ability to “forgive”. A forgiving paperboard is less sensitive to variations in the creasing conditions (width, depth, and thickness), for example, due to the tools becoming blunt. The paperboard will be more reliable in the converting machines. The compression strength of paperboard in general is 2–3 times less than the tensile strength. The material will collapse where the compression forces start to appear, but the surface plies are unaffected and retain their tensile strength. This course of events is desirable. The areas with compression are initially delaminated into several thin layers within the paperboard and the plies separate. During the subsequent folding operation the delamination will fully develop and the surface plies where the tensile strength is unaffected create the hinge.

It is obvious that creasing is a severe treatment. The surface plies of the paperboard, including the pigment coating, must be strong enough to withstand the required forces and elongations. Deep and narrow creases are difficult to perform. The surface plies may crack either when the crease depth limit of the material is exceeded, or during folding.

The criteria for good creasability become more obvious if the folding factor as a function of the creasing depth or width is shown in an illustration. The end points of each graph represent either a badly defined crease or cracking of surfaces (deep creases).

Assessment of creasability
An objective evaluation of the creasability of various paperboards is performed by calculating the folding factor after creasing. The bending moment (M) is measured before and after creasing. The folding factor (F), also called moment reduction, is calculated using the following formula:

\[ F = \frac{M_{\text{creased}} - M_{\text{creased}}}{M_{\text{uncreased}}} \times 100\% \]

Folding factor = 0 ⇒ uncreased paperboard
Folding factor = 100 % ⇒ perfect hinge

The criteria for good creasability become more obvious if the folding factor as a function of the creasing depth or width is shown in an illustration. The end points of each graph represent either a badly defined crease or cracking of surfaces (deep creases).

The following conclusions can be made:
Good creasability is characterised by:
• A high folding factor attained at low creasing depths.
• A further increase in creasing depth will result in only a small change in the folding factor (as horizontal a curve as possible).
• The material should not be too sensitive to surface cracking during creasing or folding and bending, i.e. it should allow a wide range of depths/widths.

A straight and horizontal line in the illustration is optimum. In practice, the creasing tools become blunt, and
Creasability and foldability

variations occur in the settings of the creasing depth and the machinery. Thus, a paperboard that gives small changes in folding factor due to alterations in depth is forgiving as its creasability is only marginally affected by changes in the machinery and make-ready. Cracking in either of the two surface plies usually occurs when the creasing depth is increased. Therefore, a paperboard that can take as deep creasing as possible is desirable.

In paperboard with poor creasability, the folding factor is very dependent on the creasing depth, and cracking occurs as soon as the depth is exceeded.

A 3D illustration can be used to show the relation between folding resistance, crease width, and crease depth.

The exact shape, symmetry, and position of the creases have become more important as packaging applications increasingly require greater reliability and efficiency.

The final shape of the crease, i.e., its width and depth, is not only defined by the creasing tool geometry but also by the type of paperboard and its ability to adapt to the geometry of the tool. Another important observation is that the dynamic character of the creasing operation means that different board grades require different dwell times or impression times to ensure satisfactory creases are developed, i.e., some boards can be run faster than others.

Symmetry is important, especially for smaller sized cartons and cartons with very high demands on accurate shape and dimensions. If the creases are asymmetrical, the folded corner will not look as intended, and it can, depending on the degree of asymmetry, give incorrect alignment. These cartons might have a negatively affected appearance or even cause stoppages in the packaging line.

The geometric positions of edges and creases are also important for similar reasons. In this case the tolerances of the tools and the consistency of the paperboard’s dimensional movements also play a key role.

Different paperboard ply constructions

Pulp quality and composition as well as the paperboard construction have a great influence on the creasability of the paperboard.

The use of multi-ply paperboard is one important criterion for good creasability. Complete delamination of the inner plies is desirable to achieve the hinge when folding.

The following illustration shows an example of the creasability of three different multi-ply sheets. A sheet made of mechanical pulp with a surface ply of bleached chemical pulp (A), an I-beam construction with mechanical pulp in the middle plies and bleached chemical pulp in the top and bottom plies (B), and finally a multi-ply and homogeneous sheet made of bleached chemical pulp (C).

The differences in creasability are significant. A radical improvement in the creasability is gained when mechanical pulp is used together with two plies of bleached chemical pulp in an I-beam construction of the paperboard (B) instead of the paperboard with only a top surface ply (A). By redistributing the surface ply to both sides of the sheet, a wider creasing range and better folding factor are acquired. This proves the importance of strong surface plies. The best creasability performance is achieved with a multi-ply paperboard made of dense and strong chemical pulp (C).

To summarise, the use of chemical pulp alone or in combination with mechanical pulp gives advantages in creasability as shown in the illustration above. It is also important to note that paperboard is a visco-elastic material, which means that all the properties mentioned are time-dependent.

As stated previously, the dwell time during creasing and the type of paperboard both significantly affect the fold quality. Chemical pulp has advantages over time as its properties are more stable and it preserves the shape of
the creases from gradually deteriorating. Chemical pulp also more accurately conforms to the tool geometry. This contributes to consistent performance in conversion and packaging.

**Key properties**

For the creasing operation the following paperboard properties are crucial:

- elasticity and elongation
- tensile strength
- compression strength
- bending moment/resistance
- delamination strength
- flatness and dimensional stability.

Elasticity (also referred to as the tensile stiffness or E-modulus), tensile strength and elongation are three important physical parameters of the surface plies. When the paperboard is creased it is stretched in four small zones. When the creased zone is folded, high tensile strength and elongation are important to avoid cracking of the surface. Equally important are the compressive forces (also in four small zones), which develop an initial compressive failure and delamination of the interior of the paperboard. The interlaminar strength (delamination strength) should be within a given range, not too high or too low, to allow delamination during creasing but to keep the paperboard intact during other operations and use. The best crease result is achieved when the paperboard is delaminated into as many thin but undamaged plies as possible.

The flatness and dimensional stability of the paperboard sheet are of vital importance to the precision of the creasing operation. Otherwise, variations in paperboard flatness and stability add to the margin of error for tools and machinery, with a resulting negative effect either on the creasing result or on the intended appearance of the carton.

**Measuring equipment**

Examples of laboratory systems available for measuring crease quality are: the Lorentzen & Wettre (L&W) Creasability Tester, the Marbach Crease Bend Tester and the Pira Creasability and Creasebend Tester.

The L&W Creasability Tester permits three folding angles (5°, 90°, and 160°) and has three available bending speeds (5°/s, 90°/s, and 900°/s). Bending stiffness, bending coefficient and bending moment for creased and uncreased specimens are examples of properties measured by the L&W Tester. The folding ratio is calculated as the energy required to fold creased and uncreased samples × 100%.
The Marbach system is very similar to the L&W system but uses the following formula:

\[ F = \frac{S_B - S_F}{S_B} \]

- \( S_B \) = bending resistance on rupture of uncreased sample
- \( S_F \) = folding resistance on folding of creased sample

**Crease recovery resistance (CRR)**

The spring back force of a folded and creased sample can be analysed using a crease stiffness tester; this is often referred to as crease recovery resistance (CRR) and in some way characterises the paperboard’s creasability.

Crease stiffness testers are available from different manufacturers and can either provide a simple measurement of the crease stiffness (e.g. Pira style) or give a detailed analysis of force generated compared to bending angle during the folding of the crease (e.g. L&W style).

For all testers the basic principle of the method is the same. A paperboard sample is creased to a specific geometry according to thickness and prepared to a given size. The sample is then clamped in position into the tester so that the board surface, indented with the impression of the crease, touches the load cell (see previous page). The clamp is rotated through 90° and maintained at this angle for 15 seconds after which the crease stiffness measurement is taken. With Pira style testers the clamp is rotated manually by the operator and a single value is obtained for crease stiffness after 15 seconds. With L&W style testers the rotation of the clamp is performed at a constant user-defined speed by the test machine and the measurement of the force is continual. The forces can be recalculated as torques and plotted against bending angle to generate a resistance to folding plot. The resistance to folding plot can be useful to understand how different boards behave. For example, the angle at which the elastic limit is passed and subsequently the substance starts to delaminate can be identified on the curve, shown in figure 2 at position 1. The point at which the CRR is measured, i.e. after 15 seconds at 90°, is also indicated on the curve, at position 2.

**Torque vs. bending angle.** At 1 delamination of the board starts and at 2 the torque will be after relaxation 15 seconds.
An understanding of CRR and board stiffness is important if cartons are to be run well on high speed packing lines. The board stiffness is important to protect the contents being packed. However, the CRR cannot be too high or the faces of the carton will bow and look unattractive or variations in spring back force will disrupt the runnability. The difference in folding speed (degrees/second) will differ greatly with the intended folding and erecting methods, ranging from a slow folding carton side-seam gluing line to an extremely rapid hot melt case erecting line with a forming cavity and plunger, typical for confectionary boxes. Analysis of CRR characteristics allows the paperboard manufacturer to design products which can be run effectively in high speed applications.

**Creasability and foldability**

Foldability also contributes to runnability in packaging machines and to the quality of the end product. Foldability is vital in converting, when paperboard blanks are folded in order to create a glued side seam and when the package is erected, formed and finally sealed. Improper performance due to poor foldability can cause production stoppages and unnecessary material waste. Bulging sides and flap spring-back can be signs of poor foldability.

Foldability is achieved by ensuring good creasability – low bending resistance in the creased zone – combined with high stiffness. The low bending resistance in the crease is a guarantee of low spring-back, and together with stiffness prevents bulging of the carton side walls.

A creased blank is usually folded to 90° or 180°. Sometimes prefolding is done to reduce the bending resistance further. Side seam glued cartons have two creases folded to 180° and during erection are folded back to 90°. In this case it is also important to have a low folding resistance, i.e. carton opening force.

**Foldability characteristics**

Good foldability is explained as:

- the ability of a creased blank to form a carton or graphical product with the desired shape and dimensions
- minimal spring-back force.

Good and poor foldability

Foldability as a function of creasing depth

The folding resistance reduces by 10% when there is an order of magnitude increase in folding time
To achieve reliable folding it is important to maintain a high and consistent ratio between bending stiffness and folding resistance (i.e. high folding factor). If not, the result will be varying degrees of curved/distorted panels.

Paperboard is a visco-elastic material. This means that the higher the folding speed the higher the folding resistance. Measurements made on different types of paperboard show the following typical behaviour.

Assessment of foldability

The foldability of different paperboard types can be evaluated by knowing the ratio between the bending stiffness and the bending moment of the crease. By definition, this ratio determines the radius of curvature of the panels around the fold. The greater the radius of curvature the less the panels bulge.

\[
\text{Foldability} = \frac{\text{Bending stiffness}}{\text{Bending moment}} = \frac{S_b}{M_{\text{creased}}}
\]

A crease with a low bending resistance has low values for the bending moment of the crease. The equation indicates that a paperboard with a high stiffness and a low bending resistance is preferable. A paperboard permitting deep creases without damage to the surface plies provides good foldability.

Differences in CD and MD

The orientation of the fibres in the machine direction of the paperboard sheet complicates the creasability and foldability. The creasability of a crease parallel to the cross direction (CD) is always better than the creasability of a crease parallel to the machine direction (MD).

It is more difficult to make creases parallel to the main fibre orientation. The differences in creasability in the CD and MD and the bending stiffness in these respective directions influence the total foldability of cartons or other folded paperboard products.

Sometimes the terms short grain (creases parallel to the CD) and long grain (parallel to the MD) are used.

This illustration shows a malfunction in folding. Although the sheet is creased to facilitate folding, the sheet folds beside the crease. The creases made in the MD, 1), do not have a sufficiently high ratio of:

\[
\frac{\text{Bending stiffness}}{\text{Bending moment}_{\text{creased}}}
\]

The flap therefore becomes arched. Consequently, when the next flap is folded, 2), the creases in the CD are arched as well. This increases the crease’s bending resistance to such an extent that it exceeds the bending resistance of the uncreased paperboard. The flap acts as if it is not creased at all and creates an undefined bend. This may lead to folding beside the crease. This different folding performance between the MD and CD direction must be optimised for demanding applications, i.e. deeper MD creases.

Different paperboard ply constructions

The requirements for foldability in this respect can be based on the same discussion as for creasability.

Key properties

Key paperboard properties for foldability are:

- strength and toughness in the MD and CD
- stiffness in the MD and CD
- strong elastic coating.
During the folding operation, the inner structure of the paperboard should delaminate into as many thin plies as possible without each individual ply breaking. The forces applied to the creasing zone during folding are very much like those created during creasing. The paperboard’s internal strength must be high enough for the paperboard to remain intact, except when and where creased and folded. When folded it should separate into a large number of individual layers to act as a hinge.

All the key strength characteristics for creasing are also important during the folding operation. As the above discussions indicate and the equation for foldability states, stiffness is vital in addition to the strength characteristics. So far we have concentrated on the physical characteristics of the paperboard’s fibre material. In addition to the fibres, the coating (usually a pigment coating) must also be strong and elastic. The coating might otherwise crack and destroy the appearance of the printed package.

**Measuring equipment**
The bending apparatus used for measuring the folding factor for creasability can also be used in this context.
Gluing

The gluing or sealing of a carton is the last link in a long chain of operations for converting paperboard into a functional and attractive package. The last link must be as good as the others. Gluing is not difficult but negligence in performing it can be very costly.

Side-seam gluing involves applying glue to a side flap, pressing it to a side panel and maintaining the pressure until the glue seam has set. The glued blanks are then usually packed into boxes in such a way that a certain pressure over the glue seam is maintained. The blanks are allowed to dry in the boxes. This production procedure must be extremely well controlled so that unexpected trouble is prevented. The glue should be well proven for the particular type of construction, and the application of glue should be controlled.

Side-seam gluing with hot melt glue requires precise machine settings. The glue seam must be fully developed after the application of pressure.

For end-fed cartons that are sealed with water-based glue, it is important that the glue seam sets quickly and the wet-strength of the paperboard is sufficient to hold the end flap in position until the glue seam has dried. Hot melt glue seams do not need this additional requirement because the bond strength is obtained by rapid cooling.

Top-fed cartons that are erected in the machine may be mechanically locked or glued. Heat sealing is predominant for plastic-coated paperboard in the erecting unit. The closure of the package is very often done with hot melt glue because the counter-pressure in the contact areas for the gluing is often insufficient for heat sealing.

The temperature of the product also affects the gluing operation.

### Glue type

<table>
<thead>
<tr>
<th>Glue type</th>
<th>Description</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-soluble glues starch/protein</td>
<td>The glue is a starch or protein solution which may contain rubber additives.</td>
<td>Uncoated and pigment-coated surfaces in relatively slow operations when pressure time is sufficient to develop the bond.</td>
</tr>
<tr>
<td>Dispersion glues or white glues</td>
<td>Contains small plastic particles dispersed in water with various additives to soften, to wet, and to provide tack.</td>
<td>General use for slow to medium speed operations. The white glues are reasonably cheap and the consumption is low. Also used to some extent for one-side PE-coated paperboard.</td>
</tr>
<tr>
<td>Hot melt adhesives</td>
<td>Consists of thermoplastic material and additives such as resin, wax, and antioxidants. The application temperature is 100–200 °C depending on formulation.</td>
<td>Very widely used in high-speed operations for almost all types of surfaces and when pressure time or counter-pressure is insufficient for other bonding. Low heat resistance.</td>
</tr>
</tbody>
</table>
The type of glue is important. It must suit the paperboard and the machine. The glue must not have an odour or affect the packed product. The glue must be able to adhere to the paperboard and must develop tackiness and sufficient bond strength within the brief period of time that pressure is applied to the glue seam. Most glue suppliers offer detailed advice. They are familiar with the different paperboard types, the most common gluing and packaging machines and glue applicator systems.

The applicator applies the correct amount of glue with precision and is available in various types. Open time must not be too long and pressure time must be long enough. Important facts to consider when gluing are:

- The glue must wet and adhere to the substrate.
- There must be enough glue to form a bond but not so much that it squeezes out.
- The glue must be applied in the right place.
- The pressure must be maintained until the bond is strong enough.

**Description of gluing methods**
The glue is applied to the first paperboard surface with an applicator. The glue wets the surface and starts setting. The second paperboard surface is applied under pressure and a bond forms. If the glue is water based the paperboard first absorbs water, enabling the glue to set. Hot melt glues are cooled to solidify.

Open time is the time between the glue application and the application of the second surface. The open time depends on the packaging machine and will affect the selection of glue and amount of glue required. It may even affect the choice of applicator and application pattern. Let’s take an example. Hot melt glue is used. However, the existing wheel applicator puts on too thin a layer which tends to solidify before pressure can be applied. An attempt is therefore made to increase the amount of glue. This results, however, in an uneven and tailing (stringing) application. A nozzle applicator should instead be selected. This applicator applies a controlled pattern of glue which retains the heat longer, thereby sealing correctly.

Pressure time must be sufficient for the bond to develop before pressure is released.

**Glue type**
The type of glue must suit the paperboard and the machine. The substrate is of key importance because it governs the type of glue. Most glue suppliers offer detailed advice.

A glue must usually meet the following requirements:

- The glue must be reliable with almost any available application technique.
- The glue must maintain a satisfactory bond on all paperboard products.
- The applicator must be easy to clean.
- The glue in combination with the technique employed must not add odorous or toxic substances that could impair the quality of food or other sensitive products.
- The glue must endure the environment of the product, for example in hot or deep freeze applications.

**Glue applicator**
The task of the applicator is to apply the correct amount of glue in the right place. The glue may be applied in various patterns depending on the application and the applicator.

The designer of a package needs to know what will be packed, so that the design will meet all needs through to the consumer. One example is a top-fed carton filled with a product that offers no resistance, so counter-pressure for the sealing must be provided. The most common methods of applying a suitable amount of glue are described below.
Finger applicator is a matrix of fingers which are dipped into a glue pot. The fingers are lifted and a carton blank is brought into position. The fingers are brought down into contact with the blank and a pattern of glue is transferred.

This type of applicator is used in slow machinery for gluing cartons. The equipment is robust but needs continuous surveillance to make sure that glue is transferred by all fingers successfully. The amount of glue tends to vary so this type of applicator system is regarded today as more or less obsolete.

Wheel applicator is a rotating wheel which is dipped into a glue pot so it is continuously covered by an amount of water-based or hot melt glue. The glue is transferred to a blank that passes in contact with the wheel. This is a sturdy and very popular type of applicator.

The main drawback is the difficulty in controlling the amount of glue. The scraper tends to clog, so the glue layer becomes too thin, resulting in either a weak glue seam or the operator setting the scraper for an excessively thick glue seam. This applicator is best for white glue.

Nozzle applicator which pumps the glue from a storage tank to a nozzle provided with a high speed valve. The amount of glue can be set very accurately and the equipment can apply a predetermined pattern of glue in lines or dots. This is the most expensive type of applicator. It offers precise glue metering and glue pattern and has a built-in function control, so in the end it will usually pay for itself, due to its consistency and reliability.

Key paperboard characteristics
The gluing or bond forming is usually the last operation performed on a package or graphical product, so here the function is critical. The paperboard must be suitable for the technique in question and the built-in properties must be predictable, both within an order, and between orders. This means that once the glue is selected and the machine is adjusted, the machine will only need routine supervision to ensure safe functioning.

The paperboard ply construction is of great importance because it governs the creasability. High elongation-to-break in the surface will permit the use of deep and narrow creases with low spring-back force after folding. This in turn facilitates good gluing because the carton’s side flaps will not place an excessive load on the newly formed glue seam, so it can dry and develop final strength with full surface contact in the glue seam.

Key properties
Since the gluing operation is influenced by the surface ply, the surface strength properties are critical.

The importance of the design

Hard product offers counter-pressure

Soft product or partial fill offers no counter-pressure

The crease resistance in the glue flap needs to be balanced as both a too high or a too low resistance may give a weak seam
Gluing paperboard to other materials
Fitting a window on a paperboard blank involves gluing cellulose acetate or oriented polypropylene film to the reverse side of the paperboard. Usually a tacky dispersion glue is used, but hot melts are also employed. It is important to select a suitable glue that really sticks to the film and does not absorb into the paperboard thus reducing the bond strength. The glue must dry completely before the next operation and must remain flexible and tough. The glue must be suitable and the applicator must give a precise amount of glue: too little and the window will not stick, too much and the blanks will distort and may require an extended period to dry.

Process settings
Every single procedure in the gluing process must be documented so that settings can be repeated. It may be hazardous to change glues without careful testing. The same applies for mixing glues. Minimise the number of glues used. The optimum is of course to use only one type of glue.

The glue is applied to the most difficult surface in order to first to obtain the best gluing result. Since the glue is in a tacky state during the open time it is important that the environment is constant with regard to temperature and ventilation so that the tack remains predictable.

The glue seam will become stronger if it is applied adjacent to an edge and far from a crease.

Process features
The following factors are essential for good gluing:
• the amount of glue
• the open time
• the pressure and pressure time.

The pressure and temperature are essential for good sealing.

Gluing of plastic coated paperboard
A plastic coating is “a solid oil” and has a surface chemistry as such. An untreated PE surface will have a surface tension of about 30 dynes/cm and will not be wetted by emulsion glue, because the surface tension is too high due to the water content. In order to glue a one-side PE-coated paperboard with emulsion glue it must be corona treated to make the surface layer more polar with a higher surface tension than the glue.

The corona-treated surface has to be handled with great care so the one-side PE coating is not abraded or contaminated, which would cause the surface tension to fall below 40–41 dynes/cm. Gluing is actually more demanding with regard to surface tension than printing on a PE surface. If printing causes problems, it will be obvious as soon as the ink has dried, but problems with dispersion gluing are less obvious and faults may only show up after packaging.

If in any doubt whatsoever about the predictability of side seam gluing of a one-side PE-coated paperboard, the safe way out is to select hot melt gluing at a small extra cost, rather than to take any risk.

Cold glue
Cold glue requires one absorbent surface for best functionality. For the non-absorbent surface (e.g. the plastic coating), it is essential that surface tension is high enough for the glue to wet it. Normally the surface energy on the plastic coating is too low because of the chemical nature of the plastic. Therefore the plastic coating must always be modified by an oxidising treatment such as an electrical corona discharge or similar, to give the plastic a more polar nature by the introduction of oxygen into the surface molecules.

Plastic-coated paperboard has a limited lifespan and is sensitive to handling, storing and mechanical damage.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
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</table>
| Brittle glue seam | • Too little glue  
| | • Too short a time for setting under pressure |
| The glue seam opens up (glue on only one paperboard surface) | • Too low pressure  
| | • Too little glue  
| | • Application temperature too low (hot melt)  
| | • Open time too long |
| The glue seam opens up (glue on both paperboard surfaces) | • Too much glue  
| | • Too short pressure time  
| | • Application temperature too high (hot melt)  
| | • Open time too short |
| Cartons stuck together after side-seam gluing | • Too much glue – squeezing out from side seam  
| | • Skewed glue seam  
| | • Glue line too close to edge of carton |
Gluing

Hot melt
After heat sealing (see the separate section on this topic), hot melt is the alternative method of sealing a two-side plastic-coated paperboard. This is because the functionality of the hot melt method is not dependent on the presence of a corona discharge. On a two-side plastic-coated board, the corona discharge is normally applied on the side intended to be printed, to allow the ink to wet to the surface. It is not recommended to add corona discharge on both sides as the risk for blocking is unavoidable.

Testing the glue result
Maintenance of gluing equipment is very important because if a failure occurs here, the production chain stops and the product may be ruined.

In the converter’s plant, gluing is a major part of the operation and is usually given great attention. However, risks do exist, like clogging of an applicator so that it does not apply the correct amount of glue.

The packer’s operation is different: the production of the consumer product is the main focus of interest. The packaging line is often leased and is given only periodic maintenance. It is expected to run with minimum attention. This is not a satisfactory situation; all machines need continuous care by skilled personnel to ensure a safe and reliable function. For example hot melt glues may be overheated for long time periods, causing them to oxidise, even carbonise, with the result that they lose adhesive strength.

Test performance
A finger laboratory
A common way to evaluate a glue seam is to cut the carton into approximately 20 mm wide strips over the glue seam. The strips must be in temperature- and moisture equilibrium with the surroundings before testing. Separate the strips and grasp each one in turn between the index finger and thumb of both hands.

Now, very slowly roll the glue seam apart across its direction. If this can be done repeatedly with several glue seams without rupturing the paperboard, this glue seam/hot melt seam may well break open during transport or when the pack is handled frozen. Something is wrong. Go back to the process and check all the critical points.

If on the other hand, all the glued strips fail in a manner that continues into the paperboard and results in fibre tear, the glue seam will probably prove satisfactory.

The situation corresponds to a favourable ratio between the glue seam strength and the internal strength of the substrate. The adhesive itself is the strongest part of the bond.
Binding in practice – the last link

Binding is the last link in the chain of operations which transform the paperboard into attractive and functional covers for brochures, annual reports, manuals, books, or magazines. This last link must be as strong as the others when it comes to the choice of paperboard product with respect to the binding methods at hand.

The most common binding methods for paperboard covers are saddle stitching, wire binding, glue binding, thread binding, and fadensiegel binding. In all of them, the fibre direction in the binding operation is essential. The folds of the cover (as well as the insert) must always be parallel to the fibre direction. This is necessary to achieve a durable bond, narrow and permanent fold lines and low folding resistance, and to avoid waviness of the binding. A fully bleached paperboard provides the best results under difficult binding conditions, thanks to its long and strong fibres.

Saddle stitching
Saddle stitching is normally used for brochures, annual reports, magazines and booklets. The binding operation consists of creasing, folding and stitching. The folds must not crack as a result of the creasing and folding operations nor during subsequent use. This is particularly important if there is printing over the folds. Saddle-stitched productions put a lot of strain on that small piece of paperboard that holds the cover to the insert by the staple. By choosing a paperboard made from virgin fibres, the risk of the cover becoming detached from the insert with use over time is minimised.

Thread stitching
Thread stitching is the classic high-quality binding method. The sheets of the insert are stitched together in bundles with a linen thread. The block of bundles is glued directly to the back of the cover. When this binding method is used for paperbacks, it provides stability, durability and a high-quality appearance.

Wire-O binding
It is important to use virgin fibre paperboard with wire-O binding, which is often used for booklets and manuals. One practical advantage of this type of binding is that the printed insert can lay open when required. However, if the paperboard is too weak the cover can rip and fall off after intensive usage.

Glue binding
Glue binding, or perfect binding, is often used for booklets and paperbacks. Book covers need to be especially stable and durable. Depending on the thickness of the insert, creasing and folding can be carried out in various ways to improve both the function and the appearance of the cover.

To achieve an attractive cover with distinct fold lines, a strong and sturdy paperboard with a smooth surface is required. However, to achieve a durable bond, the reverse side should be uncoated or the glue will not adhere easily. If the surface of the cover needs to be smooth and glossy on both sides, special precautions are required. When using UV varnish a glue area should be spared for better adhesion.

Fadensiegel binding
Fadensiegel binding could be regarded as a combination of thread binding and glue binding. It resembles thread binding but is less expensive. It gives extra stability, durability and a high-quality appearance to the covers of printed materials such as large textbooks. The sheets are stitched together with a special plastic thread. The threads are melted and the insert block is glued directly to the back of the cover.
A covered wire-O binding, gives a printable spine for easy identification in the bookshelf.
There are various ways to crease and fold book covers.

An example of thread stitching.

Glue binding adheres better to an uncoated reverse side. Extra creases on the front and back enhances the appeal and quality.
The cover gluing operation
Gluing is not difficult but negligence in performing it can be costly. Either glue binding (where the sheets are folded, bundled and then milled to adhere better), or thread or fadensiegel binding (where the sheets are stitched, folded and bundled then the insert is glued directly to the back of the cover) can be used.

Types of surface
The result and type of glue needed depend on the type of surface to be glued.
The surfaces can be classified into three different types:
• Easy surface – uncoated or lightly coated.
• Demanding surface – fully coated, printed surface.
• Difficult surface – UV-varnished, film laminated or PE-coated surface.

Types of glue
The most common types of glue for bookbinding are cold glues:
• Polyvinyl acetate (PVA) for easy surfaces.
• Ethylvinyl acrylate (EVA) for easy, demanding or difficult surfaces.
• Co-polymers for difficult surfaces.

Important factors
Important factors to consider when gluing are:
• The glue must wet and adhere to the substrate.
• The glue must be applied in the right place.
• There must be enough glue to form a good bond but not too much so that it squeezes out.
• The open time must not be too long.
• The pressure must be maintained until the bond is strong enough.
• The glue must meet the demands of the binding machine regarding correct temperatures and rest time before the book is removed from the machine.

Three-knife trimming
Trimming is important to ensure a good cutting result without risking delamination of the edges. Parameters to be closely controlled are the pressure on the book, the knife sharpness and lubrication, and the wear of the plastic counterpart.

Key paperboard features
The paperboard features required for achieving successful binding are strength and resilience, consistency in flatness and stability, and good cutting, creasing, folding and gluing properties.

Recommendations
The paperboard properties generally required to achieve successful binding are uniform strength, consistency of flatness and stability, and good cutting, creasing, folding, and (when applicable) surface properties suitable for gluing. When using saddle stitching or wire binding, the strength is especially important. Saddle stitched operations put a lot of strain on the small piece of paperboard that holds the cover to the insert by the staple. When glue binding, a paperboard with an uncoated reverse side is the most suitable choice.
Heat sealing

Plastic on paperboard (i.e. plastic-coated board) can be used as a gluing medium, heat sealing, instead of adding an extra string of glue. What is needed is a source of heat, a pressure unit and time for the plastic to cool down without being stressed.

The heat can be applied directly to the polymer prior to sealing by using hot air or a gas flame in line with the erecting of the package. The heat can also be applied by pressure bars if they are heated by induction or ultrasonic means.

In most applications it is sufficient to have a plastic coating on one side of the board in order to achieve a good heat seal. Plastic coating on both sides will lead to a better seal. The properties of the plastic or technical/physical limitations in the plastic coating line can make two-sided coating unsuitable.

Heat sealing is well suited for high speed operations. In addition, there is no need to buy an adhesive or to clean the sealing line. These factors alone may be sufficient reason to use a plastic-coated paperboard.

Heat sealing characteristics

The sealability of a plastic coating lies in its ability to act as its own bond-forming agent without any extra hot melt adhesive. This property adds value at no extra cost. A bond can be rapidly formed by melting the plastic coating and pressing the two bonding surfaces together while the plastic resolidifies. A good seal will give full fibre tear.

Surface characteristics

Heat sealing works on most plastic coatings and plastic coating surfaces. The chemical nature of the different plastics will require different setting conditions in the heat sealing line. Some plastics are easier to heat seal than others because they require less energy (in the form of temperature, time or pressure). Using an electrical corona discharge can improve the heat sealing result but is often not an absolute necessity.

Essential requirements for successful heat sealing:
- The plastic coating must be molten when brought in contact with the second surface.
- There must be enough plastic to form a bond.
- The pressure must be maintained until the plastic has cooled and solidified.

Description of heat sealing methods

Because plastic-coated paperboard is heat sealed no extra glue is added. The thin plastic coating is melted to a tacky state in the seal area and the other paperboard surface is applied under pressure, which is held until the seal has cooled enough to solidify. The most common methods used to obtain a seal are described below. Otherwise, special precautions when choosing the glue are necessary.

Hot bar sealers are electrically heated jaws that are pressed over the plastic-coated areas to be sealed. The main use is in erecting tools for top-fed cartons made from plastic-coated paperboard. Bar sealers are convenient to use and easy to maintain. The drawback may be that they can cause visible markings on the board.

Hot wheel sealers have a gas flame-heated wheel that is brought in contact with the seal as it moves past the wheel. They offer the same advantages and disadvantages as bar sealers.
Heat sealing

Hot air sealers melt the plastic with a jet of gas flame-heated or electrically heated air. The molten, sticky areas are then clamped by Teflon-coated (or similar) jaws or by a roller nip. Hot air sealers are convenient but the equipment tends to be noisy and to heat the surroundings.

Radiation sealers work like hot air sealers except that the heating is done by precision-mounted heating elements. They are less noisy and do not emit so much excess heat. A limitation is that the heating elements must usually be made for one specific package size.

Gas flame sealers are very similar to hot air sealers, the difference being that gas flames are used instead of hot air jets. They are less noisy and emit less excess heat but require the installation of a gas system.

High frequency sealers are similar to hot bar sealers, the difference being that the energy is transferred as dielectric losses in the packaging material from a high frequency voltage applied across the jaws, which turns them into a capacitor. The heat is created inside the material much like the heating in a microwave oven. The technique offers a high-speed precision function.

Ultrasonic sealers are similar to high frequency sealers but here the heating is caused by mechanical friction losses inside the packaging material, which is clamped between a vibrating jaw and an anvil.

Testing and troubleshooting
As for all other conversion steps, regular testing is essential to ensure the desired heat sealing result. The procedure should be well documented with regard to test frequency and test method. Note that different heat sealing methods and different heat sealing applications may require different kinds of test methods. It is very important that all pre-testing in the sealing and the packaging line is done with the packaging material intended to be used for the full scale run. This includes using the same printing and varnishing techniques as intended and the correct grade of plastic coating. Extra treatments and plastic additives can affect the heat sealing characteristics and must therefore be evaluated in advance to avoid unexpected problems.

All these heat sealing methods are based on using a certain amount of energy (in the form of heat, time and pressure) to bond two surfaces together. Even a small deviation in the energy applied can result in insufficient heat sealing and severe problems in subsequent conversion stages. The temperature readings in particular can deviate from the actual temperature of the heated bar or hot air jet. Good maintenance is crucial in this respect.

Side-seam heat sealing requires precise machine settings. The glue seam is fully developed after the application of pressure and the cartons must be cooled so that residual heat does not make them stick together. Heat sealing is usually used in the erecting units for plastic-coated paperboard.

Sealing in practice
A graphical representation showing combinations of time and temperature used in a hot bar sealer, giving a fibre tear seal at constant seal pressure, helps to describe the conditions necessary for a good seal result. It is easy to see how different plastic coatings affect the seal test behavior.

Testing the seal result
The maintenance of sealing equipment is very important because if a failure occurs here, the production chain stops and the product may be ruined. This may be caused, for example, by the ageing of a heating element so that the hot air produced is not hot enough.
<table>
<thead>
<tr>
<th>Change in parameter</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher melting point</td>
<td>The seal area moves up to the right of the reference area.</td>
</tr>
<tr>
<td>Higher melt flow index (low viscous melt)</td>
<td>The seal area moves down and to the left of the reference area. The seal area also becomes narrower.</td>
</tr>
<tr>
<td>Corona treatment</td>
<td>The seal area moves down and to the left of the reference area because the corona treatment lowers the melting point of the surface and increases hot tack.</td>
</tr>
<tr>
<td>Sealing a corona treated surface to a non-treated surface</td>
<td>The seal area corresponds to the non-treated surface area because the non-treated surface area requires more heat.</td>
</tr>
</tbody>
</table>
The packaging operation

The packaging operation comprises all the activities which are involved in combining a product with its packaging on what is known as the packaging line.

The packaging line is set up in order to meet the speed and overall quantities of the product to be packed and may range from manual operation up to high speed fully automatic operation.

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The packaging operation also includes the storage and handling of the packaging prior to its use on the packaging line and in the assembly of transit packages for storage and distribution.

The packaging line efficiency is dependent on the machine, or method in the case of a manually operated line, the product, the operators, and the quality of the packaging material. The two most important tasks to fulfil on the packaging line are to minimise the number of damaged packages and to maximise the output.

Packaging based on primary fibre paperboard gives the best performance, uniformity and consistency. The packaging producer should be aware of the cost implications of packaging efficiency as it can have an important influence on the overall packaging cost.

Description of the packaging line
On the packaging line the sequence of operations is:

- Feeding from a box or magazine.
- Forming or erecting flat blanks or side-seam glued blanks depending on the structural design – forming may involve gluing, heat sealing or locking.
- Filling, i.e. inserting the product.
- Closing the carton by gluing, heat sealing or tucking of flaps depending on the structural design.

Cartons are supplied to the packaging line as flat blanks or folded side-seam glued cartons with open ends. The feeding of the blanks depends on the design of the packaging line.

The flat blanks are erected either by a special tool with a block-like shape, which presses down on the blank to form the base and sides of the carton, or by folding around a mandrel, i.e. a former. If the blanks are side-seam glued cartons, then either the opposite folded creases are squeezed and vacuumised suction devisees are applied to adjacent panels as the blank is moved from magazine to conveyer, or a tool is inserted flat and turned through 90° to open the carton.

The filling operation can be carried out on the horizontal plane or on the vertical plane. The nature of the product determines the filling method. The carton may be closed at one end prior to product loading, as is the case with vertical product loading. The closing operation might be by tuck-in flaps, gluing the flaps or heat sealing, or tab insertion and locking. For extra protection, the package might be overwrapped with a plastic film.

The unit packages are check weighed to ensure product accuracy. If the product is a foodstuff a metal detection procedure is common. The unit packages are then loaded into a transit package and the packaging operation is usually completed by palletisation.
A cigarette packaging machine typically runs at speeds of 350 to 1000 packs per minute, requiring a paperboard with perfect performance in flatness, gluing properties and friction.
Folding
The folding operation is dependent on the creases. For rectangular shaped cartons the curvature of the panels and flaps should be minimised. This is achieved by maximum creasing to minimise the residual bending resistance combined with adequate paperboard stiffness. Curved panels affect the dimensions and shapes and can cause packaging machine disturbances by exceeding geometrical tolerances. Curved panels will have a significantly increased bending resistance due to their shape. Curved panels usually have a negative impact on the final appearance of the carton.

The folding resistance of a curved panel increases dramatically with curvature. Calculations on curved panels give results as shown below. It can be seen that even limited curvature induces increased resistance to bending and will risk failure in the packaging machine due to bending beside the crease.

A study performed by Packforsk (now Innventia), has shown that problems caused by curvature depend on the conditions in the packaging machine. Heavy, rigid and supporting products combined with fixed (well-clamped) panels are more critical to curvature. A looser clamping or lighter, more fluid product is less critical since the box is allowed to self-compensate for some of the problems caused by curvature.

The moment of inertia is proportional to stiffness.
The packaging operation

The conclusions of the study were that packaging machine settings are vital. For example, the degree of clamping is one of the most important factors. The clamping can be firm, which means that the free length of the clamped panels, L, is short. The folding result with firm clamping depends on the curvature of the flap \((1/R)\) and the width of the flap.

Looser clamping is less critical and gives better folding results. The properties of the paperboard and the quality of the creases have a major influence on the result. In practice the clamping is usually neither firm nor loose. When folding after filling the carton, the presence of the product can improve the folding operation.

By changing the free length of the clamped panel different clamping conditions were simulated.

Firm clamping gives folds that are only dependent on flap width and curvature. Paperboard stiffness and crease quality are insignificant. The forbidden region gives unsatisfactory folds.

Situations with loose clamping are less critical to curvature. Crease quality and paperboard stiffness affect the degree of flap bowing.

Two examples of poor folding.
The most common problem results when the folding does not occur along the pre-marked crease.

In graphical applications the finishing operation includes the folding operation. Graphical products are mostly book covers, catalogues, etc., so the folding angle is often 180°.

Packaging line efficiency
Packaging line efficiency is expressed by the actual output compared with the expected output.

In determining the expected output in a given time it is important to establish a rate of packaging based on the real time available for packaging. This means that set up times, routine maintenance time etc. are eliminated from the overall production time used in the calculation.

During the time available for packaging it is important to record the reasons for stoppages and periods of slower production speed. It is then possible over a period of time to identify problems which need attention, particularly problems that may be packaging material related. Such studies frequently reveal problems associated with machine settings and in the handling and storage of packaging materials prior to use.

A material audit is a useful additional routine method of checking. In this procedure the quantity of packaging material issued to the machine is compared with the number of saleable packages delivered from the machine over a given period.

High efficiency in the packaging operation reduces overall packaging costs. It should be remembered that low efficiency not only means wasted cartons. Often of much greater cost significance is wasted product, wasted machine time, and losses in market share due to late and short deliveries. All these factors should be taken into account.

Key paperboard characteristics
The key paperboard characteristics required for packaging line efficiency are mainly related to strength, creasability, foldability, glueability, sealability, flatness, and dimensional stability. Variability in these properties and in the relevant structural design features of cartons and other forms of packaging based on paperboard can cause disturbances in the optimum settings necessary to achieve efficient performance in the packaging operation.

Uniformity of all relevant properties within an order and consistency in these properties from order to order is very important for good efficiency (which is also referred to as good runnability).

Uniformity in these properties is a feature of multi-ply paperboard such as Solid Bleached Board and Folding Box Board. This is because these types of paperboard are based on primary fibre of known composition and treatment, processed on fully automated paperboard machines.

Key properties
Key features for performing the packaging operation:
- grammage
- thickness
- flatness and dimensional stability
- moisture content
- stiffness and stiffness ratio
- plybond
- creasing and folding efficiency
- glueability or heat sealability for plastic-coated paperboard
- water absorption
- tensile strength
- tear strength
- delamination strength
- clean edges and surfaces
- freedom from hazardous contamination.

Packaging in practice
Adequate packaging and protection of cartons prior to use on the packaging line is necessary to avoid physical shape distortion. This protection is essential for efficient feeding, erection and carton presentation. Moisture-proof wrapping should be used by the cartonmaker when flatness, shape, and dimensional stability are critical. Extremes of temperature and humidity should be avoided.

It is very important to allow cartons to achieve temperature equilibrium with the environment of the packaging room before the cartons are unwrapped. The time required to achieve this depends on the type of packaging used to supply the cartons, or carton blanks, and the difference in temperature between the store and the packaging room. If the cartons are colder than the packaging room when they are unwrapped, moisture may condense on the cartons causing shape distortion and loss of stiffness. See the chapter General technical information in the Product Catalogue for information about warm-up times.

When cartons remain unused at the end of an order or day’s work, it is important to re-wrap them with moisture-resistant material. The paperboard is manufactured to a set moisture content to match the expected relative humidity (45–60% RH, at 20-22 °C). Any significant difference between the packaging room climate and the cartons will affect the moisture content upwards or downwards causing changes in dimension and shape.

The following factors are essential for good packaging:
- The packaging line must have design features which make it suitable for handling the design and size of the cartons involved.
- Adjustment of the variable settings is particularly relevant on machines which undergo regular carton size changes. Visual guides and accurate pre-setting techniques are now available.
- Regular attention must be paid to the mechanical maintenance and cleanliness of the packaging line.
- The training, skill and motivation of the operating and engineering staff are critically important to good efficiency.
## Packaging features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional accuracy</td>
<td>It is important that every carton blank used on the packaging line accurately conforms to the specification drawing and has an identical profile. This is best achieved by laser cutting of dies (forms) and routing of counter dies (make-readies).</td>
</tr>
<tr>
<td>Creasing</td>
<td>It is important to use optimum creasing conditions (rule thickness, width and depth of groove) to ensure consistent folding in packaging. If the folding resistance is too high in relation to the paperboard stiffness it can result in panel bowing and poor runnability. Each paperboard type requires its own specific tool settings to give the best result.</td>
</tr>
<tr>
<td>Frictional properties</td>
<td>Ink and varnish specifications significantly influence print rub and surface slip.</td>
</tr>
<tr>
<td>Cutting</td>
<td>Sharp clean cutting with the absence of swarf and shattering on the backs of the paperboard.</td>
</tr>
<tr>
<td>Flatness</td>
<td>This feature is particularly relevant to cartons which are supplied flat to the packaging line. This feature can be influenced by printing (print-induced curl).</td>
</tr>
<tr>
<td>Correct alignment of glued side seam</td>
<td>Relevant to cartons which are side seamed by the cartonmaker. The glue flap must not be tapered or skewed as this will distort the carton.</td>
</tr>
<tr>
<td>Correct application of glue on side-seam glued cartons</td>
<td>The right amount of glue must be correctly positioned. Otherwise glue may squeeze out either on the inside of the carton preventing opening, or on the outside causing adjacent cartons to stick together.</td>
</tr>
<tr>
<td>Strength of perforations</td>
<td>Perforations must be neither too heavy so that they open during packaging, transit and merchandising, nor be so light that the customer cannot open the package.</td>
</tr>
<tr>
<td>Carton opening force</td>
<td>This is relevant in cartons side seamed by the cartonmaker and refers to the ease of opening the carton on the packaging line. It is controlled by the creasing, by pre-folding of the unfolded creases and by the pressure applied to the folded creases by the draw rolls on the gluing machine. The opening force measured directly at the gluer is critical, because subsequent tightness of packaging and storage conditions will cause this force to increase with time. It can be checked by measuring the height of a fixed number of cartons (the “bounce” feature). It is recommended that the storage of side-seamed cartons should not exceed three months for optimum packaging line efficiency.</td>
</tr>
<tr>
<td>Overwrapping</td>
<td>Where cartons are overwrapped with clear or printed film, the film must not stick to the printed or varnished surface under the heat-sealed areas.</td>
</tr>
<tr>
<td>Special requirements</td>
<td>In addition to the properties of paperboard and features of paperboard packaging already discussed, there are additional requirements. These can be due to either the nature of the product being packed, the packaging environment, or some aspect of distribution and use which require additional extrusions, laminations or other functional coatings in combination with the paperboard, e.g. for frozen foods and ovenable applications. These additional treatments have implications for the packaging operation in terms of erection, forming, or sealing.</td>
</tr>
</tbody>
</table>
Deep drawing or thermo forming

Deep drawing is a long-proven and highly developed technology used to shape plates, trays and similar products from paperboard. However, it places very high demands on the paperboard. Deep drawing is also used for other materials such as paper and metal (aluminium).

Provided that the paperboard is very strong and consistent in all relevant parameters, deep drawing is today a most economical way of producing functional and attractive consumer food packs in large volumes. Very high production rates, which contribute to low production costs, are possible.

Printing the paperboard before deep drawing adds consumer appeal. The deep drawing process gives an unlimited choice of sizes. Deep drawing also offers great freedom in shape, for example rounded containers and multi-cavity constructions, which makes it possible to produce paperboard plates with shapes similar to those of conventional tableware.

Deep drawing is often performed with a plastic-coated paperboard. A range of plastic coatings is available to suit all types of applications. The most common application is the use of PE/PP-coated paperboard for paper plates. However, another interesting development is the use of PET-coated paperboard for deep-drawn/pressed single and multi-cavity trays for:

- Pizza – to be baked on the tray
- Pastry – baked or to be baked in the mould
- Ready-made meals in single or multi-cavity packages for microwave or convection oven heating.

A container produced with deep drawing can use several closure possibilities:

- A plastic-coated paperboard top, which is sealed onto the flange. The cover is often scored to facilitate opening.
- A transparent plastic film is sealed to the flange. The seal is often of the peel-seal type.
- A transparent snap-on lid, which can be used as a reclosure.

Description of the deep drawing tool and method

Deep drawing means the shaping of paperboard into rigid, hollow shapes, sometimes with several cavities. Paperboard properties like tear strength and high elongation-to-break determine the depth of forming.

A paperboard container often has a flange to facilitate the use of the tray. The flange will also increase the stiffness, which is important since stiffness is reduced in the creased and shaped areas.

The raw material for deep drawing is often a one-side plastic-coated paperboard. The printing operation is reel fed and the paperboard is rewound after printing.

Depending on the depth of the tray, the forming process is performed in one or two steps.

A normal plate is about 25 mm deep. The forming process requires only one step and no premoistening is necessary. The maximum depth is about 45–50 mm and must be carried out in two steps. In the illustration a plate is shown as a one-step forming operation.
Deep drawing or thermo forming

The paperboard is cut into round blanks, which are fed into the machine. In this case the press operation lasts for two seconds and the tool has a temperature of 80 °C. A ready-made plate is pushed out of the tool and a new paperboard blank is fed in.

In a two-step operation, the second tool is heated to lock the shape (compare with ironing a shirt). During pre-moisturing the paperboard is softened by adding water up to about 13% total moisture. The reels are well wrapped in plastic during the maturing period until cutting, creasing and deep drawing operations are performed.

Finally the edges are trimmed to provide neat and even edges on the flange.

**Key paperboard characteristics**

Different paperboard constructions behave in different ways during deep drawing. The following general conclusions about deep drawing and two common types of boards can be made:

- If the paperboard is pigment coated, the coat weight should be low to minimise the tendency for surface cracking during the forming operation. The coating formulation should be such as to give good release of the product from the heated forming tool.

**Key properties**

Since the deep drawing operation performs a mechanical deformation the following strength properties are vital:
- strong, tough paperboard with high elongation-to-break
- high tear strength
- hygiene and low odour
- very good adhesion of plastic coating.

**Thickness**

The thermoforming process depends on three main parameters: pressure, dwell time in the pressing stage and sufficient heat transfer. These parameters can be adjusted individually but are interdependent. Paperboard

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**Paperboard type**

| Solid Bleached Board (pure chemical pulp) | Suitable for all kinds of deep drawing operations, even deep shapes. |
| Folding Box Board (mechanical pulp in centre ply) | Most suitable for shallow shapes, otherwise delamination might occur. |
characteristics play an important role in ensuring good heat transfer because good contact between the tools and the paperboard is essential; this is achieved by maintaining uniform thickness throughout the run. Because tools are manufactured to match the thickness specification of the chosen material, it is difficult to change to a different material thickness without also changing the tools. When an inappropriate material thickness results in poor heat transfer, the operator may be forced to increase one of the other two parameters (pressure or dwell time). However, the resulting thermoforming may be sub-optimal due to the inappropriate material thickness.

Deep drawing in practice
Consistency in strength properties and moisture content from one consignment to the next is important so that machine settings can be adjusted according to documented experience.

Converters specialising in deep drawing invest in high-speed machinery and exchange tools for 20–40 different sizes.

The following factors are essential for good deep drawing:
- No coating or light coating on the outside for minimum surface cracking.
- An optimised container design to obtain maximum stability.

Testing the deep drawing result
The deep drawing result is subjectively evaluated for defects, cracks etc. (see below).

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>The blanks tear during the deep drawing operation.</td>
<td>Too brittle or too dry blanks due to a variation of moisture content. They must be remoistened to give a satisfactory result.</td>
</tr>
<tr>
<td>Finished articles warp during drying in storage.</td>
<td>Blanks too moist.</td>
</tr>
<tr>
<td>The pigment coating cracks and partly peels during forming.</td>
<td>A brittle pigment coating has been used.</td>
</tr>
</tbody>
</table>
Terms and concepts

Anisotropy
The property of being directionally dependent. For paperboard this usually refers to the difference in strength- and stiffness properties depending on for which sheet direction (MD or CD) they are assessed.

Biodegradable
A broad term which usually describes matter that can be broken down either through an aerobic (composting) process or an anaerobic (digestion) process into its organic parts. Inorganic materials, either alone or in compounds with organic materials, will not biodegrade. The term “biodegradable” is not very well defined with regard to the expected quality of the degraded matter, nor is any specific time frame required. This means that many organic products can claim to be biodegradable because in a broad sense they will eventually degrade over time in a variety of ambient environments.

Biogenic energy
Energy which is fuelled by constituents derived from the life processes of either plants or other living organisms.

Biomass
A renewable energy source derived from living materials in contrast to one derived from geological processes. Usually the term describes wood-, plant- and waste residues used in incineration as a replacement for fossil fuel. Biomass is also used in biochemical energy plants such as anaerobic digestion plants.

Blank (carton)
A die-cut specimen of a carton or box which has not yet been glued, erected and filled.

Broke
Also referred to as “mill broke”. During the manufacturing process, waste paper or paperboard is recovered and repulped for reuse in new paperboard. This waste paper or board is called “broke”. A sort of in-house recycled fibre, broke can contain coating particles, dye and fillers.

Carbon dioxide
The chemical compound CO₂, which naturally occurs in the atmosphere. In a natural process called photosynthesis, carbon dioxide is absorbed by plants, algae and bacteria and transformed into carbohydrates (energy) and oxygen with the help of sunlight and water. Carbon dioxide is a greenhouse gas. The combustion of fossil fuels, e.g. oil and natural gas, releases the fossil carbon dioxide stored in the fuel. The composting or combustion of biomass also releases carbon dioxide. However, in the latter case, almost the same amount of carbon dioxide as that released is absorbed by photosynthesis during the growth of the equivalent amount of biomass.

Compostable
A term describing matter which will biodegrade in a composting process (aerobic degradation). All compostable products are biodegradable by default but the opposite is not necessarily true. “Compostable” often refers to the standards defining expected performance in an industrial composting facility, such as the American standard ASTM 6400 and EN 13432. The standards define within which time frame the products should degrade to a certain fragment size and quality, and also place clear limits on the ecotoxicity and heavy metal content of the final compost.

Continuous cooking process
The chemical pulping process which feeds a continuous stream of chipped wood through a digester. The fibres are detached from each other by dissolving the lignin in a liquor consisting of a solution of caustic soda and sodium sulphide. The chips travel vertically through the digesting tower while gradually being dissolved. At the bottom of the tower the fibres are pumped to subsequent bleaching steps and then further to the board machine. The opposite way to perform chemical pulping is the batch process, in which large batches are cooked in a container and then ejected before a new batch is loaded.

Defibration
The process of separating wood fibres from each other. The two main processes are mechanical or chemical defibration (pulping).

De-inking
The process of removing printing ink and other impurities when preparing recycled fibre from printed waste paper for a new papermaking process. The most common technique is to add caustic soda to the pulp in the pulping process and then remove the freed ink and other smaller particles by the flotation technique, whereby the small ink particles and impurities attach themselves to air bubbles induced into the low consistency stock. The term DIP (de-inked pulp) is commonly used. Other important steps in recycled pulp production are high consistency cleaning and screening in multiple steps.
Dot gain
The phenomena in printing whereby halftone dots in screened images appear or become larger than intended on the finished printed surface compared to the original screened image. Also known as Tone Value Increase (TVI).

Filler
Pigments such as clay or titanium dioxide added to the pulp to improve the opacity of thin papers.

Fines
Smaller fragments of fibres which have come loose in the chipping and defibration process. Fines from chemical pulping and mechanical pulping have very different characteristics.

Grain direction
The grain direction of a paperboard sheet is the same as the dominant fibre direction. This is parallel to the machine direction (MD) in the paperboard-making process.

Halo (flexo printing)
The halo effect in flexographic printing describes the increased ink amount around the perimeter of the printed image. This is a result of ink being pressed out over the edge of the raised printing form when the form is pressed against the substrate.

I-beam principle
An I-beam is a construction element, (usually a steel beam) which has been designed to resist a large load and is strong compared to how much of its mass bears the load. The cross section of such a beam resembles the capital letter "I". An I-beam has wide horizontal flanges to absorb tensile- and compression forces and a vertical web, or waist, to resist shear forces. Stress from the bending force will be highest furthest from the neutral length axis, that is, at the flanges. By concentrating the bulk of stress-absorbing material at this point it is possible to minimise the need for material closer to the neutral axis. In paperboard making this is done by using strong and dense chemical pulp in outer layers as "flanges" and weaker, bulkier pulp (either mechanical or recycled) in between the layers making up the "web".

Ink density
A unit describing the amount of ink being transferred from the printing press to the surface of the paper or paperboard. Ink density is an optical unit with a logarithmic scale. When measuring density, the amount of light absorbed by the ink within a defined area is evaluated against a reference value from either a standard reflecting calibration tile or unprinted paper of the same sort. The different colours – cyan, magenta and yellow – can be measured using red, green and blue filters in the densitometer. Density can also be calculated using reflective data from a spectrophotometer.

Ink trap
The measurable property describing the amount of ink transferred onto a previously printed ink film. The amount of ink transferred onto another ink is measured with a densitometer. The value is compared to the density the ink would have if printed onto plain paper. The ink trap amount is described in percent. Ink trapping characteristics are governed by the setting speed of the first ink to be laid down. This setting speed influences the tack build-up in the first ink. When the first ink film has high tack (i.e. resistance to ink splitting), the second ink to be laid down on top of the first one will transfer more easily, and the main ink split when exiting the printing nip will thus occur in the second ink film. Tack development can be influenced by both the ink manufacturer and the coating characteristics of the paper or paperboard.

Integrated process
An integrated mill has both pulp production and paperboard manufacturing at the same site and often in a continuous pulping process. The level of integration can be elevated by integrating other processes, such as a sawmill, and bioenergy solutions.

Makeready
The term can have two different meanings. "Makeready time" or "makeready procedures" refer to all the preparation steps required to set up and adjust a paper converting machine, printing press or finishing equipment. In a different context, "the makeready" refers to the counter die used in the die-cutting operation.

Market pulp
Market pulp refers to pulp sold on the pulp market in bale or sheet form by pulp producers to paper, paperboard mills or other fibre-forming industries, such as those making formed trays, etc.

Migration
Migration in the context of food packaging describes the extent to which foreign substances transfer to the packed food from the surrounding materials. The sources of such foreign substances can be packaging materials, inks, glue or other added materials. Different types of food vary in their susceptibility to migration, depending mainly on their moisture- and fat content. Substances with a molecular mass over 1,000 Dalton or molecule chains larger than 24 carbon atoms are unlikely to migrate from a material over to food.
Mono material
A packaging material which consists mainly of one type of material, such as paper, aluminium, tin or glass. The term is used in the context of licence fees for various European collection, sorting and recycling systems. The fees for mono materials are considerably lower (up to five-fold/kg) than for composite materials. The threshold for being considered as a mono material varies slightly, but the most stringent level is used by the German Duales System Deutschland GmbH (DSD). This states that the packaging must consist of a minimum of 95% of one of the main packaging materials. This rules out some plastic coated paperboard, in which typically 15-20 g/m² of plastic (PE/PET/PP) is extrusion coated onto a paperboard with a grammage of between 240 to 300 g/m². However, liquid packaging board (LPB) has received special dispensation and has its own licence threshold, which is lower than that for normal composites.

Multi-layer
Multi-layer or multi-ply paperboard is a board constructed from more than one fibre layer. The layers are pressed together in a wet state directly in the board machine. The different layers can consist of different types of pulp and have different ratios between their long and short fibres.

Pulping
Pulping describes the process of converting the chipped logs to individual, separated fibres, i.e. defibration.

Refining
Refining occurs at two stages of the paperboard-making process. In mechanical pulp production, the wood chips are fed into a refiner to be ground to separate the fibres from each other. The process can be aided by steam or chemicals to promote defibration. The second stage of refining occurs during stock preparation just before the board machine. A series of low consistency refiners beat the fibres gently to enlarge the fibre contact area, which in turn increases the stock’s bonding abilities and sheet-forming ability but lowers its bulk.

Register
Register describes the degree of precision with which subsequent printing and converting steps can align with each other relative to the design. The term “misregister” is used when this alignment varies throughout one batch or run. Misregister can occur for many reasons, such as vibrations in machines, or poor hygro-stability or flatness in the paperboard sheet.

Renewable resource
A renewable resource is one which naturally regenerates itself within a reasonable period of time. These resources are part of our normal ecosystem. The term is often used in discussions about renewable energy.

Safety (product)
“Safety” in this context refers to the suitability of the paperboard for its intended use, with particular reference to meeting food safety regulations when the food is in direct contact with the paperboard surface.

Secondary packaging
Secondary packaging is used to contain a number of grouped unit packages (primary packages) merely in order to display the unit packages until their purchase or to simplify shelf replenishment. Secondary packaging can always be removed without changing the characteristics and function of the unit packages. Secondary packaging is often made of paperboard or corrugated board. When secondary packaging plays a significant promotional role, it is often referred to as display outers.

Slit and chop
These terms refer to the two main cutting directions when sheeting a paperboard web from a reel. The cut made in the unwinding direction (which is also the machine direction) is called the slit. The cut made across the web perpendicular to the machine direction at certain intervals is called the chop. The slit is thus always parallel to the fibre direction and the chop perpendicular to the fibre direction.

Stock
The stock is the final stage of the pulp before it is pumped onto the wire mesh to form the sheet. In contrast to pulp, which is normally a single type of fibre produced by one defibration process, stock can consist of a blend of different fibres (this composition is called “the furnish”) plus additives as colouring additives and retention chemicals to retain fines in the paperboard structure, thus promoting strength. The fibres may also at this stage have been refined.

Swarf
Swarf refers to the shavings or chips from the edges of a material which has been exposed to mechanical converting operations such as die-cutting or punching. This occurs mainly with paperboards which have been coated with metallised film or foil, but can also occur with very hard coatings such as UV varnishes.

Transport packaging
Also called tertiary packaging, transport packaging facilitates the safe and efficient transportation of grouped sales units with or without secondary packaging. The dominant material is corrugated board, although it is possible to replace corrugated transport packaging with stiffer secondary packaging plus shrink wrap or stretch film on a pallet load.
Unit package
This is also known as primary packaging or sales packaging. A unit package contains one sales unit at the point of purchase by the consumer. Unit packaging is made of a variety of materials such as paperboard, glass, plastic, tin or aluminium.

Virgin fibre
Also called primary wood fibre, virgin fibre is the fresh fibre produced from harvested forests as opposed to recycled fibre.

Wet end
The wet end refers to the wire section of the board machine where the stock is pumped onto a mesh to form the fibre network. The wet end stops where the press section starts. At the wet end, the water content of the stock is reduced from approximately 98% to 80% by means of drainage.

Yield
The term "yield" describes how much pulp can be produced from a defined amount of timber. The yield from mechanical pulping is typically 85 to 95%, while from chemical pulping it is about 45%. The lower yield from chemical pulping is due to the delignification process that removes the lignin in the pulp. The lignin is then used as a biofuel in the process of recovering the cooking chemicals.