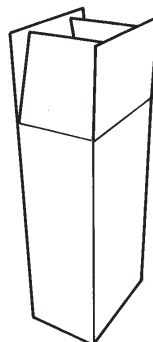
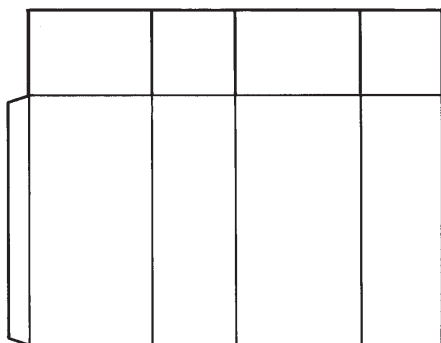
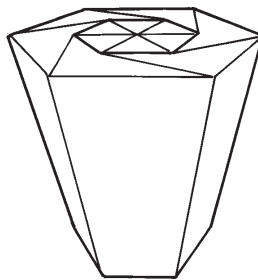


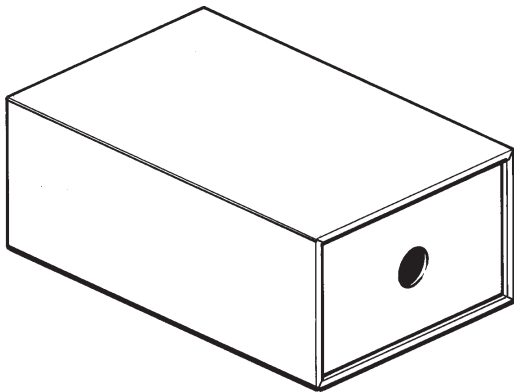
DESIGNING AND MAKING A METAMORPHIC CARTON

The card carton industry in the UK is part of a much larger multi-*billion* pound industry spread across Europe. Its products form a vital link in our product supply chain and many also function as significant consumer products in their own right. The importance of the industry is reflected by the work of the international European Carton Makers Association (ECMA) which publishes a comprehensive *taxonomy* of folding carton styles. A taxonomy is a means of organisation and classification; in this instance cartons are organised into general *classes* and then *specific variations*.

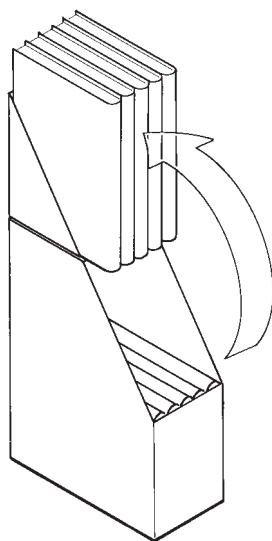
The ECMA taxonomy is a voluntary code which guides manufactures and also sets an industry standard so that manufacturers across Europe can speak a common language. The cartons described in the code range from simple to extremely complex structures. In all instances, these are developed from flat sheet material to form a rigid container.



Increasingly, paper and card are regarded as interesting structural materials - as well environmentally friendly which can be recycled. Stiff card is used widely for small consumer products such as storage containers and file-index boxes, small chests of drawers and so on.



A lot of containers used to supply goods have a dual function: for example, they contain units of confectionery for transport and can then be turned into a point of sales display stand. Something that can change its function from one use to another is called *metamorphic* (literally: changing form). The term is also sometimes shortened to *morphing* to describe the gradual transformation of images (e.g. faces) from one into another by means of computer software.



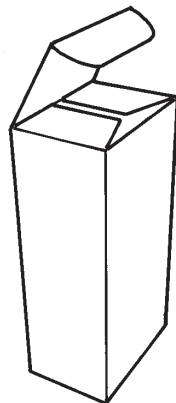
DESIGN OPPORTUNITY

Design and prototype a metamorphic carton that can be used, for example, for packaging a product and which can then be adapted for a significant *secondary* use. The product must have structural integrity -it must 'work' efficiently to resist loading in both situations- and it must be durable and easy to convert. It should also be possible to produce this product from flat sheet material and ultimately specify its outline and development for possible inclusion in the EMC code. (This requires a line drawing of the development or net and an accompanying 3D representation.)

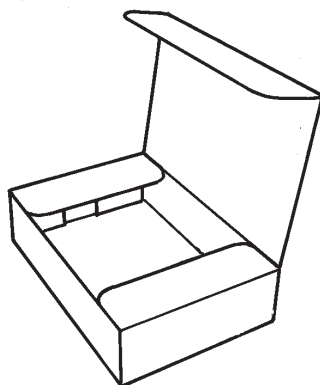
THE EMC CODE

In this code, cartons are classified into seven generic groups. The following give *abbreviated* descriptions:

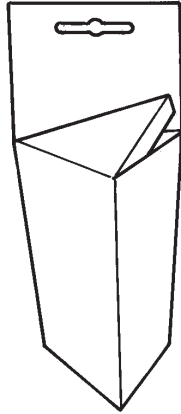
Group A: Long seamed glued folding cartons with rectangular surfaces. Square tube-type containers with a long seam; all main panels have a 90° angle between them.



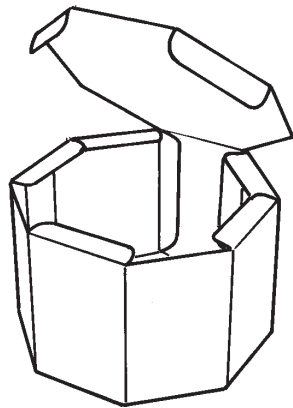
Group B: Folding cartons with rectangular surfaces, non-long seam glued. No long seam gluing is involved.



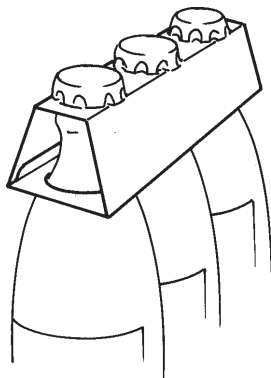
Group C: Long seam glued folding cartons with non-rectangular surfaces. A long seam is involved but at least one of the container's surfaces is non-rectangular.



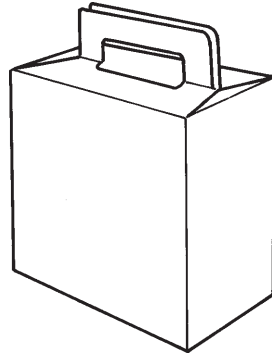
Group D: Folding cartons with non-rectangular surfaces, non-long seamed glued. No long seam is involved and at least one of the container's surfaces is non-rectangular.



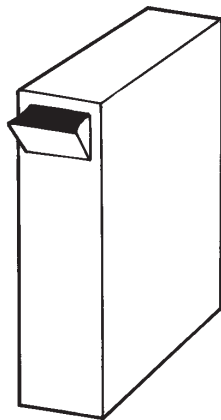
Group E: Product-integrated folding carton. Are designed to fit around specific goods. Devices designed around the container's function - e.g. a pull-out lip for pouring soap powder.



Group F: Other folding cartons - not attributable to any of the above categories.



Group X. Auxiliary devices of all groups. These include opening and closing flaps, zipper devices, pour-out devices, devices for hanging and carrying.

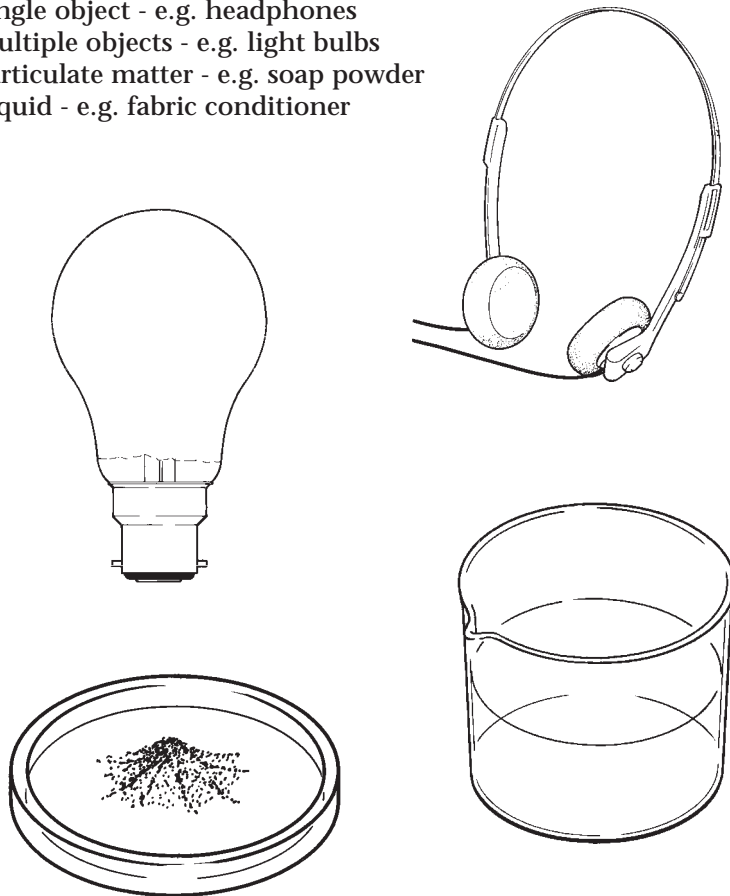


Within each category, available cartons are described with a clear 3D line drawing together with a development or net outline. Also, the packages are fully described in terms of their functional parts such as method of closure. The industry has built up a considerable specialised vocabulary to describe containers and component parts, and a glossary of the less familiar terms is given here on page 56.

DESIGN CONSIDERATIONS

The primary function of the carton will be to contain one of several different products. These can be broadly categorised, for example, as follows:

- Single object - e.g. headphones
- Multiple objects - e.g. light bulbs
- Particulate matter - e.g. soap powder
- Liquid - e.g. fabric conditioner



The nature of the goods must be carefully specified and understood; some of the overall considerations will be:

- weight**
- durability** (or fragility)
- distribution** (in container)
- need for special wall barrier** (does container have to be moisture-proof; is there a need for an inner lining bag ?)
- security** (does carton need to be tamper-proof?)

In designing the carton for its **primary function**, other considerations will include:

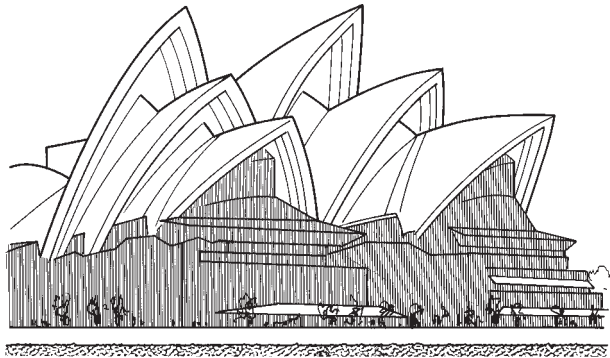
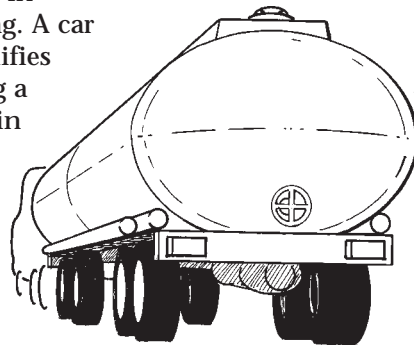
- method of filling carton
- method of sealing carton
- durability of carton
- ease of access (opening & closing)
- carton graphics

In designing the carton for its **secondary function**, other considerations will include:

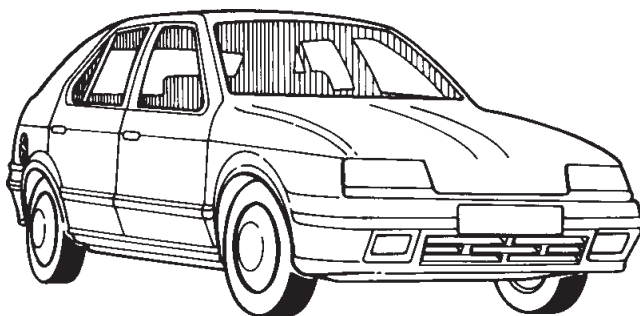
- ease of convertability
- durability for secondary use
- structural integrity for secondary use

'ENGINEERING' IN CARD

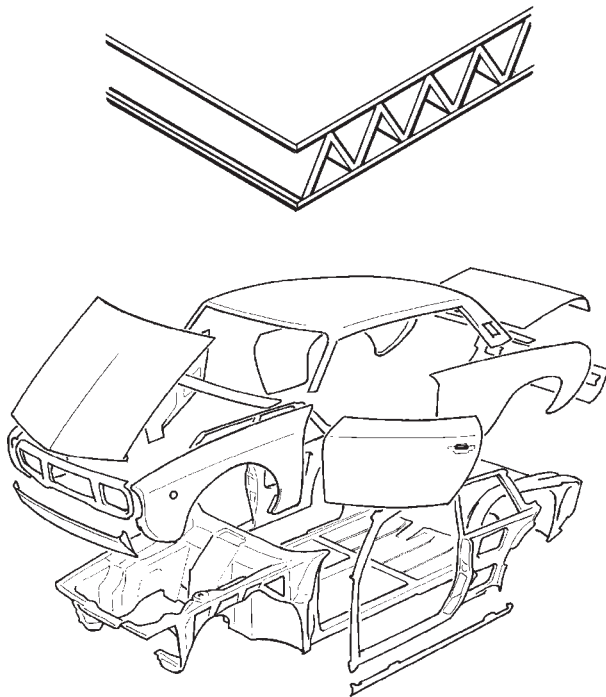
There are many parallels between the design of carton-type structures and shell structures of steel or concrete familiar - respectively - in mechanical and civil engineering. A car body shell, for example, exemplifies the basic principle of converting a non-rigid flat sheet material (thin mild steel sheet) into a stiff three dimensional shell capable of supporting considerable loads.



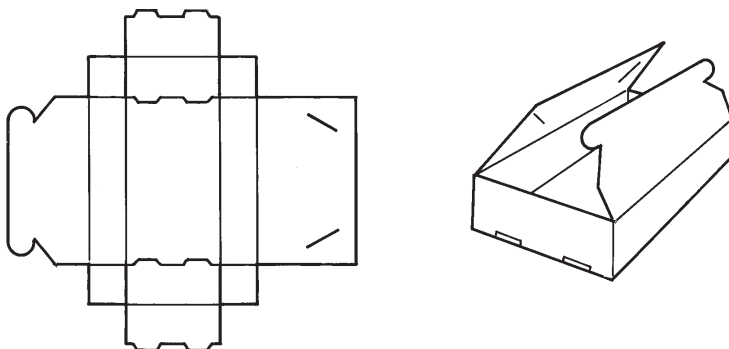
A car body shell, and similar shell structures, achieve their great strength through *compound* folding. It is the geometry of folding that confers the shape.



A simple example of geometrical folding is the familiar *fan-folding* of paper - which is actually used as a structural principle in lightweight 'honeycomb-centred' structural sheet material of the type used for aircraft interior panels. A single 90° fold is sufficient to confer minimum structural properties to a material which is otherwise compliant in sheet form. The main strength is in the region of the fold itself and for this reason a typical car body shell structure contains a maximum number of folds very close to each other.



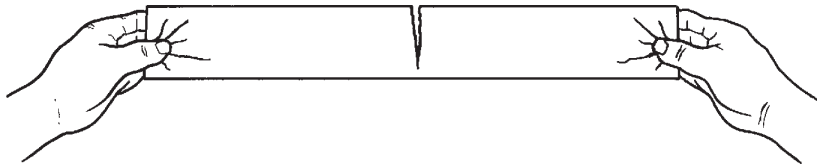
The same basic structural design and manufacturing consideration also apply to cartons. Not surprisingly, the principal resistance to loading is at the folds and even more so at the corners. Ideally, a carton is folded from only a single development or net and avoids glue joints which increase manufacturing costs.



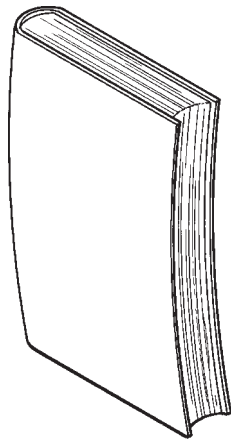
Most cartons are subject to dynamic as well as static loading. At rest, a carton has to bear its own weight and support any contents. Typically, it might also have to support several other cartons stacked for storage. Almost invariably, though, a carton is subjected to much greater *transitory* (short-term) *dynamic* loads when it is moved. An obvious example is a container sent through the post which might be thrown or dropped many times.

Some of the physical properties of cartons, including the properties of basic materials, are the subject of British Standards. For example, BS 4468 sets a reference standard for *internal tear strength* where a specified instrument measures the force needed to tear from an initial cut through to the opposite edge of a specimen (measured in mN). BS 3748 sets a reference standard for board stiffness where the force required to bend a standard sample through a deflection of 15° is measured. Again, special equipment and test criteria are given.

In general, card as a material shares many of the characteristics of composite wood-based sheet products such as chipboard, although it is far more compliant in a thin sheet. In tensile tests, tears will *propagate* (move through) from a small nick, cut or other point of weakness. This is because, the applied stress becomes concentrated on a few fibres at the tip of the tear. It is important therefore to avoid any design features which are likely to focus stresses at potentially weak points such as the sharp corners of openings.

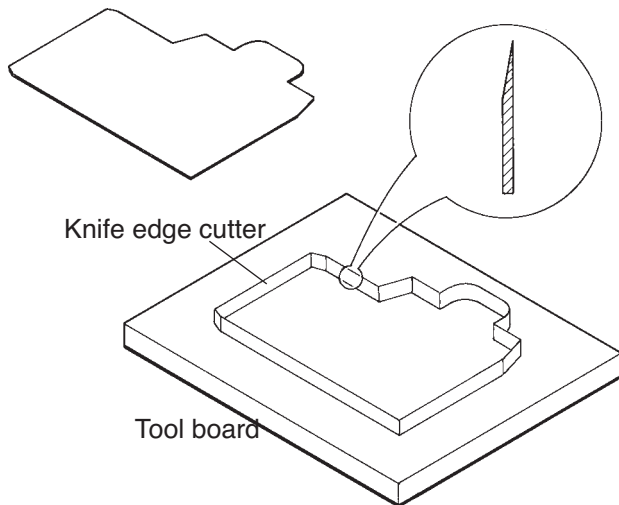


In compression, card buckles easily and requires *geometrical* support from folding or fabrication. It also deforms preferentially along lines of weakness where, for example, the card has been creased. (This is also a useful property because creases are applied to a flat sheet to ensure folding at the correct places.) It should also be noted that card tends to permanently deform or *creep* when subject to a load over a longer period that would otherwise be insufficient to cause permanent deformation. Books, for example, are often damaged by creep when they are stored incorrectly for long periods.

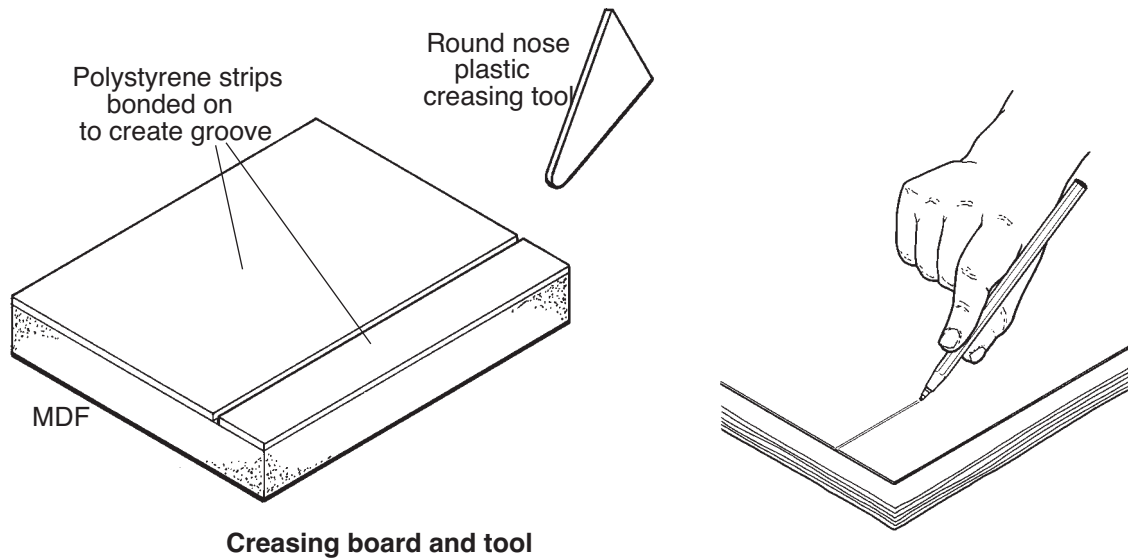


MANUFACTURING

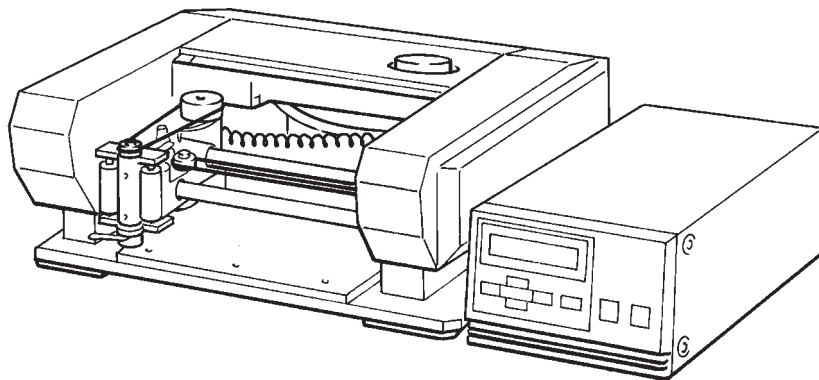
Cartons are normally manufactured by high-volume processes which perform cutting out, creasing, forming and gluing in a continuous operations. Cutting out, for example, is done with *knife-edge die* tool. This is a plate into which knife edge strip material is fastened to the required cut-out profile of the carton development. A similar (blunt-edge) tool may also be used for creasing.



In your own prototype work, a suitable guillotine, craft knife and straight edge can be used for basic cutting. It is also advisable to use or make a line creasing tool. A simple creasing tool consists of a slotted strip and a plastic edge tool which is run along the card overlying the slot. Alternatively, for thin card, an empty ballpoint pen can be run over card which is backed by a sheet of hard rubber or several sheets of newspaper.



A card development can be marked out manually or by using computer software and a suitable plotter. The Roland range of CNC plotter/cutters, which use a casting knife tool, can also be used to cut out thin card. The advantage of this method, where it is an option, is in being able very quickly to make modifications to a prototype.



ADHESIVE BONDING

For rapid prototyping, double-sided tape is probably the most convenient form of adhesive; it will also enable dissimilar materials to be joined - e.g. card to polythene or polystyrene. As well as providing permanent joints for the primary function of the carton, tape can be applied with one layer of wax paper left in place, so that the unused adhesive face is ready for use when the carton undergoes conversion to its secondary use.

When subjected to a *peel test*, a good glued joint in card will result in fibres tearing from the material itself and remaining on the glue. It is worth noting that ultra-strong variants of ordinary double sided tape are used in load bearing structural work - e.g. wing components of passenger aircraft.

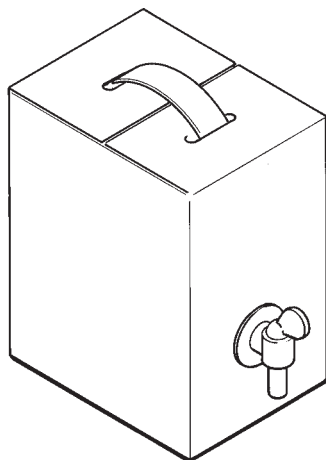


Peel test for adhesive

GLOSSARY OF CARTON TERMS

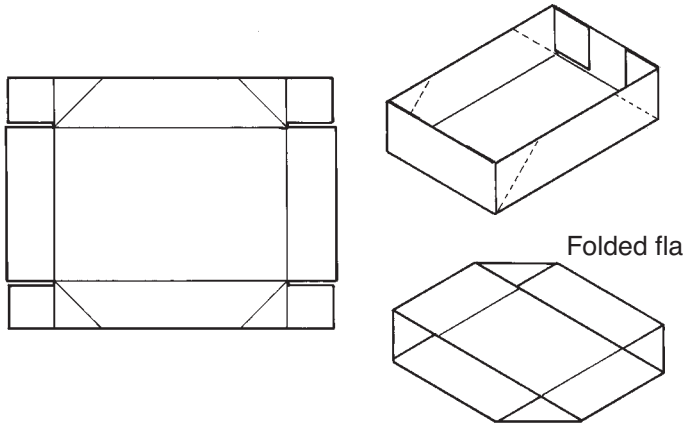
Bag in box

Carton consisting of an outer box shell containing a bag for fluid. The most common example is probably the wine box.



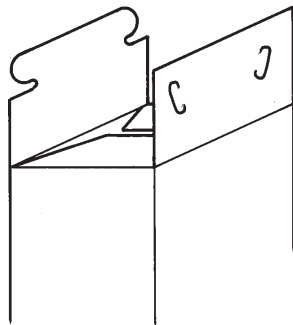
Brightwood corner

A corner construction method where a glued flap is an extension of a pre-creased panel. Four brightwood corners enable a simple box form to be collapsed flat.



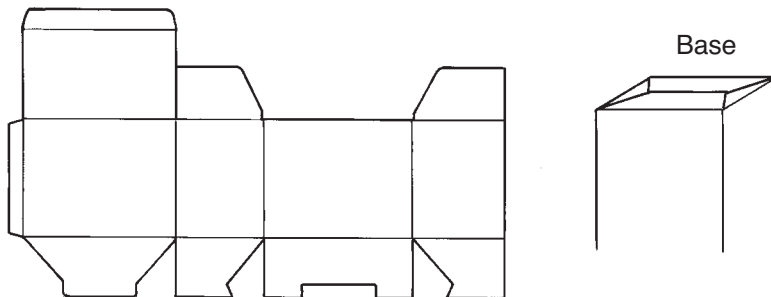
Claw lock

A common form of carton closure where pre-cut lugs engage in slits.



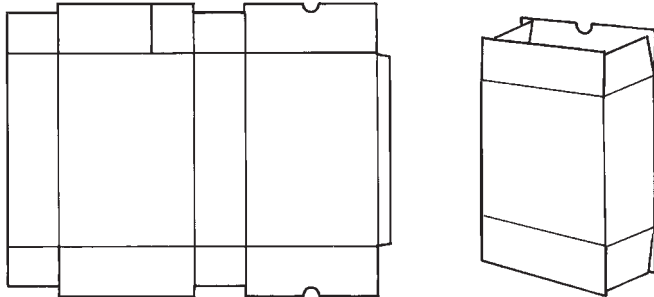
Envelope closure (or quick-fix base)

A form of carton base where the parts interlock without glue. When closed, it resembles a traditional envelope.



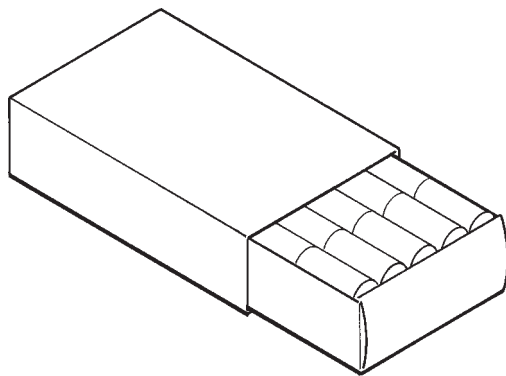
Skillet

A carton type having two subsidiary and two major ends flaps. In a skillet, one major flap is glued - e.g. the common cereal carton.



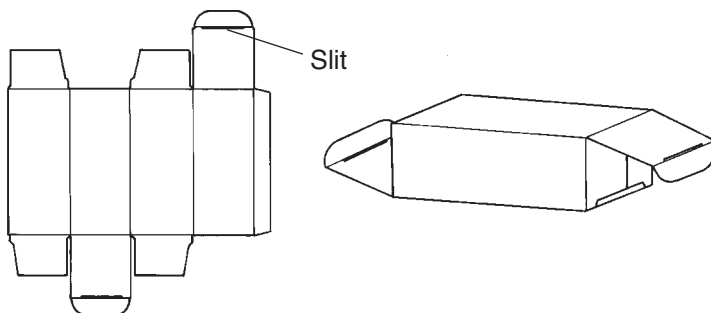
Shell and slide

A carton type having a sliding component within an outer shell - e.g. a typical cigarette packet.



Slit lock

A method of locking a carton flap where a small subsidiary flap engages in a slit in the main flap when the carton is closed.



Tuck in end carton

Probably the most common form of carton having two subsidiary flaps and a single larger tuck-in flap - e.g. used in toothpaste tube containers.