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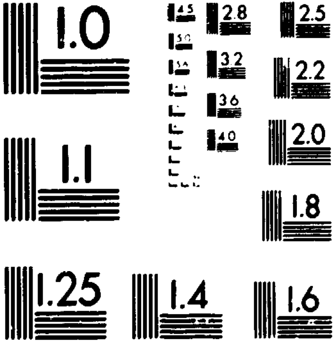

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PACKAGING AND PLASTICS*

by

Desmond A. Dean**

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PACKAGING AND PLASTICS

Packaging may be defined as the economical means of providing protection, presentation, identification/information, convenience and containment of a PRODUCT during storage, carriage, display and use until such time as the product is removed or used. Fulfilling these functions in the broadest sense will inevitably produce a compromise as emphasis on each of these factors will vary according to the product being packed. The type of packaging material used will also affect this compromise and a subject such as plastics in packaging may be influenced by any of the following:

1. The type of product and the characteristics of the product which can benefit from the use of plastic.

2. The basic characteristics of plastic which can be exploited to the general benefit of packaging.

3. The plastic materials which are most economical to use. This normally includes polystyrene, polyethylene, polypropylene and polyvinylchloride but costs vary from country to country.

4. The negative features of plastic, some of which may now be historical, but must at least be acknowledged and borne in mind if the more overwhelming positive features are to be optimised.

5. The conversion process associated with containers, components, films and laminations by which the use of plastic can be extended. These may be related to trends in design, processing and decoration methods.

6. The possible cost advantages of plastics when compared with other alternative materials such as glass, metal or paper-based materials.

7. The pack characteristics. A technological study of the types of pack and packaging systems available.

8. The environmental issues which may relate to reuse, recycling, the general conservation of energy and problems arising from disposal and possible pollution.

9. Consumer habits and product trends.

The steady growth of plastic packaging not only depends on a balance of all the above points, but on on-going awareness how each may change with time. However, most of these factors interact one with the other, hence many of the various examples of plastic in packaging which follow cannot be necessarily isolated as typical of one group. Virtually all products now benefit from the use of plastics and examples can be taken from food, pharmaceutical, chemical, agricultural, household, hardware, toiletry and cosmetic etc., products.

Plastics are found in primary packaging (those items which immediately enclose the product), secondary packaging (those items which add to the presentation and assist in the protection of the pack during warehousing and distribution) and any ancillary items which add to the convenience or the administration of the product. Indirect uses of plastics should also be included, e.g., hot melt adhesives, self adhesive and heat seal labels, shrink and stretch labels, certain adhesives used in laminations, all of which are plastic based. however, before expanding on the broad usage of plastic and specific trends it would be advisable to identify some of the longer standing negative features, as occasionally these may be restrictive to the use of plastic.Because of their historical nature some may be overlooked. These are listed as follows:-

Permeability - all plastics are to some degree permeable to gases and moisture - hence poorer barrier materials may be unsuitable for even lowly moisture or gas sensitive materials.

Limited light exclusion - plastics, unless thick and highly pigmented (carbon black is the most effective) tend to provide only limited screening to light. The addition of U.V absorbers may be used as an alternative to pigmentation.

Environmental stress cracking - normally applies to certain grades of low density polyethylene which under stress (in-built or applied) and in contact with certain groups of chemical substances (wetting agents, detergents, some essential oils) known as stress cracking agents, may give rise to stress cracking.

Electrostatic Attraction - usually of dirt, dust and fibres which in turn may increase the risk of microbiological contamination. Pick up varies according to the nature of the plastic and can be normally reduced by antistatic additives, earthing, ionic discharge or avoiding handling under dry conditions.

Panelling or Cavition - whereby a plastic container may partially collapse or indent. It may occur for a number of reasons, i.e.,

1. Hot fill leading to a partial vacuum after closuring.

2. "Compression" during capping which leads to a partial vacuum (note this may occur momentarily and only be confirmed by a high speed camera).

3. Adsorption of gases from container headspace - usually related to oxygen.

4. Atmosphere and air space changes, e.g. under conditions of steam autoclaving (sometimes called dimpling).

5. Adsorption and absorption at the inner container wall - leading to swelling or expansion of the wall thus causing distortion.

Poor Impact Resistance

The earlier belief that plastics are unbreakable only broadly applies to selected materials. Plastics such as polystyrene and PVC will crack on impact (say 1 metre drop) unless either modified in some way or produced by a process which improves impact strength (e.g., orientation).

Clarity or Transparency

Only a few plastics have high clarity (like glass). Many tend to be translucent and therefore may not display the product to advantage. Orientation may be useful in improving clarity.

Key of the Print - Pretreatments

Some plastics are difficult to print unless the surface is 'oxidised' or pretreated to improve the key. This treatment can be achieved by:

(i) Flaming.
(ii) High voltage corona discharge.
(iii) Chemical agent, e.g., hydrogen peroxide.
or
(iv) The use of a coating.

Compression and Distortion

As a light- weight material many plastic based materials may become distorted by top pressure as found under conditions of stacking. It may therefore be necessary to increase the compression strength of the outer packaging. Designing a primary pack with strengthening features (rings/ribs also overcome such problems.

Adsorption, Absorption and Migration

A two-way exchange can occur between a plastic material and a product, i.e., a constituent from the product can be lost onto, into or through a plastic or a constituent from the plastic can be removed into the product by extraction migration or even contract abrasion. This may be relevant to foods, toiletries and cosmetics and in particular pharmaceuticals. In the latter case loss of part or all a preservative system may render a product microbiologically ineffective. Migration of constituents from a plastic into a product must be checked for safety (toxicity/irritancy), changes to flavour or odour, or product changes due to chemical interaction. Some plastics (e.g., LDPE) are particularly permeable to organic odours, hence product flavourings, perfumes may be lost and external contact with odourous substances may pass through to the product.

Odour - Flavour Changes

Odour and flavour changes can occur due to the permeation of external substances, loss or changes in product constituents , and natural odours associated with plastics and their constituents. LDPE for example has a typical wax - like aroma which may become recognisable as an off flavour or taint. Although plastic like odour or flavours were at one time considered unacceptable this situatuion is slowly changing to one of limited acceptability.

Low Density (compared with glass which has a density of 2.25 - 2.5).

This may lead to problems on production lines which are not properly designed to handle plastics, i.e., instability, mushrooming, etc. The majority of plastics (if not reinforced) have a density below 1.5.

Poor Design

Weakness in plastics related to breakage, distortion, indentation, panelling etc., may all be related to poor design which in turn may give rise to uneven wall distribution. Angular, square sections will inevitably cause design weaknesses and hence well radiused shapes, radiused angles plus special strengthening features may need consideration. Design features may have to vary according to the conversion process chosen.

Examples of how some of these adverse affects can be overcome include:-

1. A hygroscopic pharmaceutical in moisture permeable PVC blister was additionally packed in foil sachet overwrap which provided a five year shelf life until such time as product was removed. The PVC provides adequate protection even against a high RH, during the then short in use period.

2. A veterinary product was packed in a collapsible multidose LDPE flask which allowed pack to collapse as doses were withdrawn via special syringe.

Again the addition of a foil sachet was essential, as this prevented loss of preservative, moisture and the ingress of oxygen which could cause product deterioration.

3. A pharmaceutical product which was packed in a squeeze (LPDE) bottle suffered loss of a volatile preservative system. A blister overwrap with peelable backing retained the preservative system, reduced moisture loss and acted as a tamper evident feature.

The writer considers it essential that problem areas in plastic packaging are clearly identified, as a problem recognised is usually half way to having a problem solved. The above therefore provides a check-list of what could occur. It is equally important to have a check-list on the advantages of plastic since many of these features are so 'obvious' that they can also be overlooked.

POSITIVE FEATURES OF PLASTIC

Light Weight

The fact that the majority of plastic lie within a density of 0.8 - 2.0 (glass 2.25 - 2.5) and may be moulded in relatively thin sections can significantly reduce distributions costs for the delivery of raw materials, supply of packaging 'material' and the distribution of the packed item. Ref: The Role of Plastics in the Export and Packaging of Pharmaceuticals by D A Dean, published in Plastics and Rubber, Materials and Applications, February 1977.

Lower Volume

A plastic container will occupy less volume than the equivalent glass bottle (a glass bottle and a PVC bottle of the same external dimensions will hold approximately 75 ml and 100 ml liquid respectively. The advantage may be less with metal but this is largely depends on the process used to produce the metal container.

Lower volumes can significantly reduce the space required to store and distribute both the empty and filled container. This can be even more improved where plastic materials are delivered as reels (form, fill, seal operations i.e, blister packaging) or as granules for manufacture into containers immediately prior to a production line operation (selected examples - Rommelag Bottlepack equipment that forms, fills and seals a liquid into a container on one machine).

Flexibility

Many plastics (thermoplastics) exhibit degrees of flexibility which can be exploited, i.e., squeezing to aid product expulsion, to reduce or adsorb impact or shock, collapsibility (to avoid air being drawn in during use, e.g., bag in box for paint, plasticised PVC bags for blood or IV solutions). Many other areas can be quoted where flexibility adds to the presentation, e.g., overwraps or bags for vegetables, clothing, confectionery etc., many of which have become so accepted that they virtually go un-noticed. Plastic liners for drums are another useful example.

Water Resistence Associated with Low Water Permeability

Since most plastics are water repellent plastics can be used for external storage (sacks of fertiliser) or as a protective overwrap to pallets (shrink, stretch or prestretched wraps). Such systems will also increase the stacking strength of fibreboard (protected from moisture extremes from the atmoshere) and further restrict moisture loss or gain between the product and the outside atmosphere. Internal plastic coatings or loose linings in fibreboard, metal containers etc., also enables wet goods, such as frozen fish, to be handled more economically and without risk of interaction with the external material.

Low Toxicity/Irritancy Risks

Although much has been written on the migratory nature of certain constituents in plastics (e.g., plasticisers from PVC and DEHP in particular) there are few reported cases where migratory constituents have caused difficulties. For example, the vinyl chloride monomer (VCM) saga whilst clearly establishing the dangers of high monomer concentrations at the polymer plant, risks from any packaging usage have remained extremely low. Today Europe and the USA work at a VCM limit of less than 1 ppm for any packaging usage. Many constituents in plastic tend to be non migratory unless a specific solvent is the contact material. Constituents such as antistatic additives, lubricants and slip additives etc., which are only effective if they are present at the surface of the plastic although removable by abrasion as well as extraction are normally only present at low levels. Provided plastic formulations are chosen with recognised food grade approved constituents, risks associated with toxicity/irritancy are usually minimal. Special clearance procedures are obviously advised for plastics containing blood or I.V solutions since these products are administered directly into the blood stream. Extra test procedures are also advised for eye and injectable preparations. Pigments likely to be toxic, based on for example lead, cadmium , arsenic etc., are now avoided for foods, pharmaceuticals, cosmetics, toiletries and toys. Moulding processes may dictate the presence of certain processing aids.

Versatile Moulding and Design Capabilities

The fact that plastics can be fabricated and moulded by a wide range of processes (injection, reaction injection moulding (RIM), injection blow and stretch blow, extrusion blow and stretch blow, rotational moulding, thermoforming, cold forming etc.,) gives flexibility in both design, output and quality capabilities. It is also frequently possible to make shapes and configurations in one piece whereas a similar design in metal could involve several fabrication processes plus an additional assembly stage.

Versatility in Decoration

Decorative appeal can be added to plastic by various means, i.e., labelling by paper, plastic and shrink or stretch labels; printing by offset lithography, dry offset letter-press, hot die stamping, (silk) screen, therimage and letraset, cliche' or tampon, gravure, flexography, jet and laser printing and such in-mould operations as embossing, debossing and transfer printing. Each process may have some limitations - for example gravure, flexography, offset litho and silk screen can be used on film or sheet based materials printed in the flat or from a reel. The fact that the cliche' or tampon process can actually print in three dimensions has seen a substantial expansion to this process.

Pretreatment or applying a surface wash or lacquer-type coating prior to printing has also given rise to fewer problems from poor ink key. Protective coatings may also be used after printing, to improve resistance to abrasion, increase product resistance and reduce of moisture/gas permeation. (more recent examples include PVdC coated PET bottles).

Improved Moisture Vapour and Gas Barrier Properties

As indicated earlier all plastics are to some degree permeable to moisture and gases (note permeability of gases is ussually of the ratio 1:4:20: for nitrogen:oxygen:carbon:dioxide (i.e. carbon dioxide shows the highest permeability). Improved control of wall thickness and the more selective use of materials and processes has meant that more products can be packed in plastic provided the turnover/shelf-life is acceptable to the product. It should be noted that a good moisture barrier material may not necessarily be a good gas barrier material. Moisture barrier properties for some plastics are given rough comparative figures below.

Aclar	(polymonochlorotrifluoroethylene) (PCTFE) $ 20,000 per tonne (trade name Allied Chemical Company)	0.01
PVdc	(polyvinylidene chloride) copolymer $2,500 per tonne	0.1
HDPE	(high density polyethylene) $ 900 - $ 1,250 per tonne	1.0
PP	(polypropylene - homopolymer and copolymer) $ 900 - 1,250 per tonne	1.2 - 1.5
LDPE	(low density polyethylene) $ 900 - 1,250 per tonne	3.0

PVC (polyvinyl chloride unplasticised) 8.0
$ 900 - $ 1,250 per tonne

PET (polyester) 8.0
$1500 - $1800 per tonne

PS (polystyrene) 60.0
$ 900 - $ 1,250 per tonne

Prices quoted as per Europe early 1984.

Aclar, PVdc, PVC and HDPE have good oxygen barrier properties whilst LDPE, PP and PS are considerably inferior. Aclar (Allied Chemical Co) although the most inert and impermeable plastic is also the most expensive. Other than a coating for pharmaceutical blister packs it has few commercially viable packaging applications. The total economics recommending the use of any one plastic are dependent on many additional factors, i.e., density, moulding cycle, (temperature/cooling), moulding process, design, capital expenditure etc., as no decision should be taken on polymer price alone. Barrier properies can usually be improved by coatings, co-extrusions etc. but at an additional cost.

Versatility in Appearance - colour, clarity, opacity, texture etc. Plastics can be produced which are clear, completely opaque, have metal finishes (metallised), opalescent, marbled etc, with a whole range of textures from high gloss, matt, artificial leather etc. Light penetration can be restricted by pigmentation (carbon black being the most effective), dyes and the use of UV absorbers. Metallisation may be used for decorative effect or to reduce permeability to moisture. Metallisation can be a relatively variable process hence the barrier properties achieved have to be critically evaluated. A metallised PET, coated with LDPE to give additional scuff and flexing resisistance can offer barrier properties approaching that of 9 um foil. Scuff and flexing resistance can be poor if a protective layer is not included. Metallised materials are finding success in bag-in-the-box applications (e.g., paints), and in sachets and flow wraps. Opaque materials are available in a wide range of colours. White opaque may be obtained by the use of fillers such as chalk or talc, whiteners (titanium dioxide 1 - 3% level) and modified by optical brighteners (e.g., ultamarine).

Colouring can be carried out by precompounding, dry colouring, liquid and solid master batching and concentrates or high let-down master batching. Fillers, depending on their affinity for moisture can either increase or reduce moisture permeation. This also applies to other constitiuents; for example plasticisation of PVC can cause a significant increase in moisture permeation.

Versatility in Material Modification to Assist Certain Properties

Examples:-

Stackability and stability (will not slide so readily) can be improved with plastic sacks if an anti-slip additive is incorporated into the material. Reel fed form fill seal operations can be improved if friction and drag (possibly leading to stretch) is reduced by the addition of a slip additive. Circumstances could however be envisaged where the above two features are in conflict with each other.

The incorporation of lubricants into the polymer can assist a moulding operation and lead to less rejects or generally improve the overall quality of the item being moulded.

Reuse of Clean Scrap i.e., Regrind

Scrap from moulding processes (e.g., tops and tails from extrusion blown bottles, sprue and runners from injeccion mouldings), if handled cleanly can be recycled provided it is permitted and has not been subjected to excessive (e.g., overheating) conditions. Regrind up to a defined level, e.g., 20% is frequently allowed. The moulder should however obtain permission for the 'user' and have it written into any specification.

Product Resistance

Although plastics cannot be described as inert and lack the high level of compatibility enjoyed by glass, plastics exist which can be used for a majority of products (for example plastic petrol tanks are curently becoming a distinct trend).

Few problems exist with many aqueous-based products provided they are not strongly acid or alkaline. Greater selection has to be exercised with organic-type solvents, volatile oils and synthetics generally. Vegetable oils, for example, which are widely sold in PVC would not be suitable for storage in LDPE where both oxidation and penetration of the oil through the container could occur.

Easily Altered or Modified so that Specific Properties can be More Readily Exploited

This can be achieved by both physical and chemical means (see earlier). Physically, plastics can have their molecular structure orientated in a machine and/or cross direction by a process of stretching at a temperature below the material melting point. Orientation in films provides a shrink wrap material unless the film is held and heated to 'set' the in-built 'stretch'. Newer process such as injection stretch blow and extrusion stretch blow involve a stage where the parison is cooled and stretched (orientated) prior to the final blowing operation. Orientated materials show improvements in both physical and chemical properties, i.e., improved clarity, impact (drop) resistance and lower moisture and gas permeability. The highest success (USA and Europe) is found in PET (polyester) stretch blown bottles in the 1 - 2 litre size for carbonated drinks and coated PET bottles for beer. PVC and PP are also being stretched moulded. Bottle shapes for some designs, currently have some restrictions with the base which may either have to be 'petalled' or rounded. In the latter case a base cup has to be added to give stability. (As seen on larger 1 - 2 litre containers). With this interest in PETP for stretch mouldings interest is increasing in the use of this material (or PETG by KODAK) for conventionally, moulded bottles. Stretch blown PVC bottles are usually cheaper and more resistant to drop (impact) than a conventionally blown impact modified grade. The addition of an impact modifier to PVC (normally up to 15% of MBS)* is a further example of how the properties of a plastic can be changed. Straight PVC is likely to shatter if dropped when full with product at a 1 metre drop height. The addition of the modifier overcomes

*Note:- MBS is used in bottles whilst vinyl acetate is usually used in PVC films used for thermoforming. MBS = methyl methacrylate butadiene styrene.

this problem. Impact modified PVC (with vinyl acetate*) will also thermoform faster, at lower temperatures, and give better distribution than an unmodified material, and is used for blister or bubble packs.

However, the addition of modifiers will increase permeability to moisture. Stretch moulded PVC bottles can achieve good drop resistance without the additional costs associated with the use of a modifer. Although additives are the group of substances used to modify a plastic, it should be recorded that plastics, in terms of total constituents may also contain residues and processing aids. Since terminology in the industry tends to be rather loose it may be necessary to ask question on additives, residues and processing aids from the polymer supplier, compound/master batch supplier and convertor, if the detail on the total constituents is to be obtained.

The more commonly found constituents which may be in plastics include:

monomer residues
catalyst
accelerators
solvents
anti-oxidants
emulsifiers
mould release agents, lubricants
fillers
colourants - pigment and dyes
stabilisers (for PVC)
plasticisers - modifiers
extenders
slip additives
antislip additives
antistatic agents
whiteners and opacifiers
UV absorbers
flame retardants
antiblock agents
release agents

Reference to many of the above are found throughout the text.

Undue publicity and emphasis on plasticisers has frequently lead to misuse of this word, particularly as many less informed people see plasticisers as being migratory, possibly toxic and found in most plastics. It must be stressed that relatively few plastics contain plasticisers. (The main ones which are plasticized include PVC and the cellulose group (acetate, butyrate, propionate etc.)). However, the question, 'does the plastic contain plasticisers?' should frequently be re-addressed to the word 'additives' (processing aids and residues).

Most Plastics Can be 'Welded' by One Means or Another

More important with engineering applications but welding may occasionally be used in a packaging context. Methods of welding include hot gas, hot plate, high (or radio) frequency, adhesives, 'spin' and friction, and ultrasonic.

Coextrusion and Lamination

For film and sheet material the properties of two or more plastics can be combined by multiple extrusion or lamination. These materials, depending on their thickness, can be used for sachets, strips, blisters, tubes, solid phase pressure forming (SPPF), scrapless forming process (SFP), conventional thermoforming or directly coextruded and blown into a container. Coextrusion though excluding the use of paper and foil does enable the best properties of several plastics to be combined.

Positive Features - Summary

The above list, although not complete, clearly establishes both the flexibility and versatility of plastics and the processes associated with them. Many of these plus features can be combined to the general benefit of plastic packaging. Since packaging is inevitably a compromise of many factors, the earlier listed negative factors can either be overcome by selecting the plastic (e.g., a LDPE with a low melt flow index will normally eliminate a stress cracking risk), by preventative measures (e.g., using additional protective packaging to reduce risks associated with permeation of moisture, oxygen etc.), process controls or by simply accepting that the positive features outweigh any disadvantages. A number of examples of specific package or pack component usages are identified below to emphasise the effective utilisation of plastic.

New Closure Systems

1. Wadless Closures

A range of wadless closures are now widely used on metal, plastic and glass containers for solid and liquid products. The materials used include LDPE, HDPE and PP. The seal part of the closure can be achieved by a plug, an internal skirting, sealing rings or a curled-over feature (this is sometimes referred to as a 'crabs claw').

2. Pilfer Resistant Closures

Again, a similar range of plastics are used. Designs include lock-on bead with tear-off skirt, rachet bottles with interlocking tear-off skirt, or heat shaped under lock with screw-off perforated tear caps (e.g., Obrist closure) or caps with perforated extensions which lock on bottle with lugs etc. Heat shrinkable (PVC) seals provide another means achievinga pilfer resistant system, (Note increasing world wide interest since the Tylenol affair in the USA in September 1982).

3. Child Resistant Packs and Closures

Virtually all reclosable child resistant packs are based on plastic, with squeeze, press down, line-up features being widely utilised to achieve release. In the case of blisters and strips child resistant is achieved by hidden access features, in between unit perforations or by the stength of the material used. Opaque or deep tinted materials are essential to make the contents less attractive to children. Peelable and heat sealable packs such as blister, strips, sachets are inherently tamper evident.

4. **Overwrapping, Collation, Pallet Stabilisation**

Shrink, stretch, prestretch stretch wraps are being increasingly used to stabilise pallets, overwrap packs and items (either for purpose of collation or to reduce general spillage, or simply to make the product self-identifiable (recognition) or to encourage the more responsible handling of semi-fragile goods.

5. **Closures - General**

An increasing proportion of plastic closures are moving from thermosets (UF and PF)* to thermoplastics (PS, PP, HDPE). Whereas years ago a wid range of waddings and facings were used these are gradually reducing in number. Composition cork is largely being replaced by pulpboard, expanded polyethylene and flowed-in compounds. The most widely used facings include PVdC, polyester, vinyls (reducing) and polyethylene (reducing).

Sprinkler top closures (widely used for powders and at one time all in metal) have gradually been replaced by plastic.

Dispensing fitments for toiletries, pouring aids for medicines and difficult to control products, and general dropper systems for food colourants, sweetening liquids, etc., are further extending the use of plastics. Plastic toggle caps are an extension of dispensing aids in that the caps contain spouts or tubes for controlling the flow of a product from a squeezable plastic container.

Container Trends

To overcome the poor size impression of single walled plastic jars when compared with the thick walled glass jars then available, double shell plastic jars became the vogue in the late 50's, early 60's. A recent ruling in the UK which argued against the deceptive nature of double walled jars,

*(urea formaldehyde and phenol formaldehyde).

has made the single walled, smaller jar, virtually acceptable overnight. Single walled jars are now widely available in HDPE, PP, PS although the latter material may be suspect for creams where moisture losses can be problematical.

The plastic can - 1/4 litre bottles in polyester (PET) PP and PVC with a wide neck have recently been intoduced as a further competitor to the metal can and glass bottle beverage containers. Coextruded materials which can be thermoformed eg., PETP/PVdC/PE are also competing in this field.

Plastic Drums

Increasingly stringent safetly regulations for the carriage of dangerous goods and chemical substances generally, are encouraging the use of fairly thick walled plastic drums with high molecular weight, high density polyethylene being the preferred material. Drums of this nature have good impact resistance (including drop strength), good stacking strength, good chemical resistance and although some degree of chemical absorption may occur this is usually extremely small. However, if drums are reused it is always advisable to refill with the same material.

Films, Foils and Laminates

The use of plastic films and coatings is showing continuous growth with a predictable expansion in the future due to the more recent success of retortable trays and pouches. As a laminant ply plastic can play a variety of roles, covering heat sealing and cold sealing, protective plies giving climatic and biological protection and as a decorative ply to aid presentation. Collapsible tubes made from laminates are now showing a fairly rapid growth. An injection moulded neck is bonded to a tubular body lamination.

The more widely used heat sealing plies include LDPE, LLDPE, ethylene vinyl acetate (EVA), polymers modified with EVA, PVdC., Surlyn (Ionomer, DuPont) and a range of heat seal coatings. Surlyn in spite of it higher cost has seen considerable success in Europe and USA as it shows advantages on lower weight, lower caliper of ply, lower sealing temperatures, a wider in the seal (both powders and liquids), all of which lead to fewer rejects and higher output speeds.

For clarity, polyester, cellulose acetate (poor in dimensional stability), certain gauges and grades of polypropylene are widely used and for a protective over laquer (against rub and permeation) PVdc provides a useful coating base. Coextrusions can give higher barrier properties by the selection of the correct material provided relatively long runs are involved Coextrusion materials can be used to make bottles, thermoformings etc. Typical coextruded combinations include:-

PS/PE, PS/PP, PS/PE/PS (medium barrier materials), and

LLDPE/EVAL/LLDPE)
HIPS/PS/PVdC/PS)
HIPS/PS/PVdC/PE)
PS/Eval/PE) Which give relatively high barrier properties
PP/PVdC/PP)
PP/Eval/PP)
PETP/PVDC/PE)
(EVAL or EVOH = ethylene vinyl alcohol.)

Note 'tie' layers are frequently used between materials hence some of the above are actually made of more layers than those initially indicated. ie PP tie layer EVAL tie layer PP is used for Blow mouldings to make Ketchup Bottles in the USA.

Films

Polypropylene film is still finding increasing usage as a laminant ply, as an overwrap material replacing cellulose film, and as a form fill seal material for bags, sachets etc. The brittle nature of PP at lower temperature is overcome by copolymerisation, usually with ethylene. This addition improves its sealability. Coated PP using either a PVdC or PE coating also gives a good heatsealing and protective lamination. LLDPE linear low density polyethene, which is a combination of ethylene with either butene-1, octene-1, is a relatively new family of polymers which according to all accounts will largely replace LDPE as a film material in the near future. LLDPE also shows certain advantages over LDPE for other applications involving injection and extrusion moulding. Although the initial cost of LLDPE may be slightly higher than LDPE, the fact that it can be made in thinner gauges with good impact, tensile and tear resistance make it economically viable for stretch wraps, bin liners, bags etc. Large usage is already being seen in the USA, Canada, Japan and Europe. However competition is being met by combinations of LDPE with MDPE or HPDE, vinyl acetate/ PE copolymers and other combinations: Bubble film (film containing bubbles of air) is being increasingly used for product protection. Polyester, nylon and polypropylene strapping has widely replacing metal strapping. Plastic sacks, woven or unwoven are offering a significant competition to paper sacks.

Form Fill Seal - Reel Fed

Reel fed materials passing through a series of stages whereby the material is formed into a container which is subsequently filled and sealed are on the increase. As well as the better known thermoforming processes (vacuum, pressure forming with and without plug assistance), forming at lower temperatures (to give orientation) and cold forming are now finding specific applications. Both the food and pharmaceutical industries are using a cold forming process for such materials as nylon/foil/PE, polypropylene/foil/PVC and nylon/foil/PVC. These materials enable a fairly thick gauge (40 um) of foil to be stretched without perforation provided the form is well radiused and not too deep and angular. The formings give virtually 100% protection against moisture and gases and can be used for a retortable tray pack with the correct material combination.
From a pharmaceutical point of view cold formed blisters are not only competitive with foil strip packs but occupy less space, are easier to handle and provide a similar high level of moisture protection.
Conventional pharmaceutical blister and strip packs for solid dosage forms vary considerably in their usage throughout the world, i.e., less than 5% in the USA, approximately 20% in the UK and approximately 80% in Germany. Whilst the latter mainly use blister packs of the pushthrough type, the USA relies on peelable liddings. These conventional blisters use UPVC, and combinations of UPVC/PVdC, PVdC/PVC/PE, PVC/Aclar as the thermoforming ply, with paper and foil covered with heat seal layer for the peelable or push-through lidding. However, none give a high level of moisture protection, hence the need for a foil bearing materials (strips or cold formed blisters) if moisture sensitive products need to be packed in a unit dose form.

Expanded Plastics

The density of plastics can be further reduced by producing a cellular structure to give an expanded material. Expanded polystrene is most used, usually to mechanically protect such delicate items as cameras, TV's, videos, either as set formed pieces or as small pieces as a filling. Material can also be formed directly around an item when in its final pack. Expanded polystyrene sheets (sometimes laminated to polyethylene) are also used as protective covering. Plastishield (trade name) coated glass is an excellent example of a marriage between glass and plastic which enables a light weighted glass bottle to withstand impacts on the production line and in transportation. PVC coatings (plastisols), shrink and stretch labels also add to the protection of glass containers. Expanded materials can also be used to give insulation for products which require specific storage conditions (e.g., vaccines). Expanded polyethylene is now being widely used as a cap wadding, replacing naturally based composition cork.

OTHER COATINGS

Cold Sealing

A material based on a plastic coating which can be sealed by pressure offers faster throughput for a form fill seal process than one involving heat. Cold sealing materials have therefore been developed and are in use for confectionery sticks and bars. (ie. flow wraps).

Labels

Two label types are based on plastic coatings (a) self adhesive labels and, (b) heat seal labels. Both types are extending in use, frequently at the expense of plain paper labels which are applied by the addition of an adhesive (dextrin, starch, PVA etc). Coated labels present advantages in cleanliness, less machine down time, improved tack and setting time and their ready application to a range of substrates. Both heat sealing and self adhesive labels are available in cut singles and reel fed form. Since the latter indicates a degree of security, reel fed labels now with an additional identity code have become widely used for pharmaceuticals and products where security is essential. In the USA heat seal labels are predominant whereas in Europe self adhesive labels are preferentially used. Application speeds up to 600 labels per minute are now practical with both.

Enviromental Issues

The above examples emphasise the extensive usages of plastics in packaging. However, no paper would be complete without reference to certain environmental issues, which may occasionally take on an emotional aspect. Although many plastics are derived from petroleum, it should be noted that the main use of petroleum products are related to transportation and the production of energy whereas conversion to plastics still remains a relatively small percentage. Plastics do suffer criticism when compared with other materials in both energy required to convert them into a packaging application and difficulties associated with reuse and recycling. The attached Table 1, ex Metal Box Company, indicates typical energy comparisons.

Reuse of plastic packaging other than for the larger containers as mentioned previously is not usually recommended, except where circumstances have clearly established that reuse (plastic milk bottles in polycarbonate) is practical. Recycling again is difficult as once a plastic has been used for a product, some degree of contamination may have occurred. There is also a significant difference to the recycling of glass as cullet where the material is reheated to around 1200°C, thus driving off virtually all likely contaminants (other than certain metals) as carbon, hydrogen etc. Plastic scrap from the converting processes is suitable for recycling provided it is not contaminated by oil, dirt, dust during the conversion process. Whether a plastic is recycled as regrind from the conversion scrap largely depends on the final usage - it may not be permitted or restricted where food and pharmaceuticals type products are involved. Recycling is also difficult for a mixture of products involving various plastic packs since individual plastics cannot usually be segregated. Usages for recycled materials therefore tend to look for opportunities where an admixture of plastics can be found, i.e., pallets, corrugated sheets for roofing, cavity wall insulation, etc. 'Flotation' methods can provide limited segregation of plastics.

CONCLUSION

The introduction indicated a number of ways plastic and packaging could be considered. These have only been covered on a very broad basis in this paper. Each of the many aspects touched upon could be expanded into a topic which, when discussed in detail, could form a conference in its own right.

It is perhaps reasonable to conclude that every packaging function is a compromise of many factors - whether the compromise reached is the best can only be judged by the functional and aesthetic success which in turn relates to both the initial sell-in and the follow-up sales. The roles of plastics in packaging is already a success story and will continue to increasingly dominate the packaging scene. The environmental issues are being closely studied and will ultimately be solved by common sense and logic.

Two final points. First, the above paper places emphasis on the plastics which are already successful and economic. Although expansion tends to develop along such a path, usages for higher priced materials, like polyester (current prices in Europe $1400 - 1600 per tonne), can occur, with a result that the larger volume applications can further reduce the price of the basic material. Many plastics which have not been mentioned, have and will have, packaging applications, particularly where certain specialised properties are required. Their exclusion from this paper does not mean they have been forgotten, but that time and space has not permitted their inclusion. Secondly, any future developments in the extension to plastic packaging will largely depend on consumer trends and their purchasing power. Europe, the USA etc., have seen two virtually opposing trends, the need to have smaller portion packs to meet the demands of a growing elderly populations and the need for larger pack sizes to meet the demands of the less frequent shopper, i.e., shopping done once a month instead of once a week. An acute awareness of such trends is essential to predict any packaging development with constant reference to the definition of packaging given in the introduction. Other recent general trends which will benefit plastics include aseptic and controlled atmosphere packaging for a variety of foodstuffs.

Table 1: Energy Used in Container Production (Toe*/Tonne)

	Tinplate	Aluminium	Plastics	Board	Glass
Conversion to Containers	0.1	0.2	0.4	0.05	0.1
Heating and Lighting	0.04	0.08	0.16	0.07	0.04
Transport of Containers	0.02	0.02	0.06	0.02	0.02
Raw Material Production	1.0	6.0	2.3	1.45	0.3
TOTAL	1.2	6.3	2.9	1.6	0.5

*Toe = Tonne of oil equivalent

By kind permission of the Metal Box Co

Plastics in the Construction Industry by D A Dean

Up to 20% of plastics in Europe find application in construction type usages, i.e. piping, wall panels, doors, windows, sky lights, guttering, kitchen surfaces just to mention the more major applications. However, usage tends to be greater in cold and temperate climates as bright sunlight, high temperatures, coupled with wide temperature variations may prove to be somewhat restrictive. As with plastics used for packaging there are both obvious and less obvious advantages and disadvantages. The more negative factors include the following:

1. General lack of rigidity.
2. Poor load bearing properties.
3. Tendency to creep.
4. Reduction in strength (decrease in rigidity) as temperatures rise.
5. High thermal expansion - particularly when compared with metals.
6. Poor fire resistance.
7. Likely high costs - material, tooling versus output.
8. Not rodent resistant (rats have been known to gnaw through water pipes).
9. Poorer weathering unless specifically selected.

Positive factors:

1. No corrosion problems.
2. Light - less handling, delivery problems, easier transportation.
3. Wide range of forming processes.
4. Can be produced in a wide range of designs, frequently in fewer components than alternative materials.
5. Availability in a wide range of colours with some selected materials also offering good transparency. Less maintenance (no painting).
6. Offer a wide range of physical properties which are not only related to the type of polymer but which can be modified by additives (e.g. light resistance improved by carbon black*, strength improved by fibreglass etc.).
7. Good for heat insulation due to low thermal conductivity.
8. Broad freedom from attack by insects, bacteria, moulds and termites.

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* Note: Black absorbs heat significantly more than say white - hence black material is more likely to creep or soften.

9. Water resistance, low water absorbency (hence low likelihood of mould and bacterial growth).

10. If also follows from 8 and 9 that plastic surfaces are more hygienic - hence are widely used in areas for food preparation and eating.

The adoption of any plastic for a construction application requires the balancing of both the possible negative and positive features. Using plastics for new applications invariably involves some degree of a trial and error approach and a problem identified must be considered as the first step from which a problem can then be overcome.

Experience in Europe which is climatically temperate cannot always be immediately translated into performance in tropical areas where higher temperatures and longer hours of sunlight are involved. The raw materials used in Europe include the polyethylenes, polypropylenes, polystyrene and polyvinyl chloride (the economic four which find a wide range of applications) plus the following with lower usage, some of which have more specific applications, i.e. phenol formaldehydes, urea formaldehyde, polycarbonates, acrylics, acrylonitrile butadiene styrenes and polyesters.

Construction applications can broadly be divided into building structures, secondary building applications and services.

Building Structures

Conventional building materials such as rock, stone, wood, concrete, clay bricks, timber, tiles etc, particularly if available locally, still offer advantages over plastic, i.e. strength, rigidity, stability (partly due to density) and possibly fire resistance.

Plastics find structural uses for either small buildings, e.g. shelters, extensions, special features such as domes, spires etc or occasionally for larger specialised buildings using new and interesting but not necessarily economical designs. More widespread usage is found in lightweight wall panels (internally and externally) both for decorative effects and insulation.

Secondary Building Applications

In Europe one of the fastest plastic growth areas can be found in window surrounds, doors, door surrounds, room skirting etc, where freedom from maintenance (e.g. no painting) represents long term cost savings or increased leisure for householders who do such work themselves. Standardisation of sizes for windows, doors are useful in providing the best economics, particularly where older metal and wood items are being replaced.

Thermal insulation against either heat or cold can also be achieved by either lightweight cellular panels or a foamed in situ cavity insulation.

Plastic surfaces, using solid or plastic faced substrates also give both decorative and hygienic surface areas for bathrooms, showers, kitchens etc.

Services

The versatility of plastics is especially exploited in service usage where there are general improvements in economic viability. Plastics score for example where metals were previously employed, i.e. no corrosion, less maintenance, less frequent replacement and being less labour intensive in terms of initial installation. Plastics can frequently reduce component complexity, e.g. a T piece can be moulded as a single component.

The use of plastics for services include the following:

1. <u>Water Supply</u>

   Plastic water systems use PVC, polyethylene and polypropylene with joints based on mechanical, fusion and solvent welding techniques. Allied fittings such as taps, valves, basins, baths and showers also make extensive use of plastics.

   Plastics for hot water services, although not entirely problem-free, are becoming more established.

2. <u>Drainage</u>

   Improvements in hygiene are associated with both water supply, drainage and sanitation. Drainage covers rain water (guttering and pipes), domestic and industrial effluents and sanitary services, all of which are largely suitable for plastic, in terms of both connections and pipework. Inspection tanks, settlement tanks, header and feed tanks are also being increasingly used with glass reinforced plastics (GRP) being particularly to the fore.

3. <u>Ventilation</u>

   Air conditioning and general ventilation systems, including extractor fans also make a wide use of plastic and additionally contribute to comfort and health by maintaining a higher quality of air circulation.

Conclusion

Tropical areas impose significantly more stress on plastics than temperate areas such as Europe, due both to higher temperatures and longer hours of sunshine. Of the other technical limitations, plastic's poor fire resistance, a tendency to creep and a lack of rigidity are all likely to restrict their structural use, particularly for larger buildings. Cost also tends to limit their use even for small domestic properties.

Inspite of this an increasing number of advantages against a reducing number of disadvantages are gradually extending the use of plastics in all constructural applications. Establishing that plastics are successful in one area of application is frequently necessary before more wider areas of acceptance can be achieved. Advice from consultants, national and international organisations is always available to assist the increasing use of plastic for structural, secondary building applications and general building services.

Appendix I

Major Plastics in Building Materials

Polyethylene (LD to HD)

Cold water pipes, joints and water cisterns.
Sink and bath wastes.
Damp proof courses.
Cable insulations.

Polypropylene

Cold water and WC cisterns, overflow tanks.
Sink and bath wastes.
Effluent pipes (up to 1600 mm diameter).
Wall ties.

Unplasticised PVC (UPVC)

All types of piping and fitments (rain water, water, drain pipes, electrical conduit etc).
Wall skirting, roof lighting, dome lighting, wall lighting.
Window frames, shutters.
Doors and door frames.
Weatherboarding.

Plasticised PVC

Flexible coverings and connectors, i.e. electrical cables.
Floor, wall coverings and joining strips.
Stair hand rails, flexible roof membranes, window canopies, air-supported buildings.

Polystyrene

Water cisterns
Light fittings
Wall tiles

Expanded Polystyrene

Numerous thermal insulation applications for walls, floors, flat roofs, pipes, ceiling tiles. Also sound absorbing sheets.

Acrylonitrilebutadiene styrene (ABS)

Water supply pipes and fittings.
Internal sink and bath wastes.
Ventilator pipes and grills.
Inspection chambers and access systems.

Post-chlorinated PVC (CPVC)

Hot water and central heating pipes.
Internal sink wastes.

Polymethyl methacrylate (PMMA)

Most bathroom fitments including baths, sinks, basins.
Light fittings.
Wall and window glazing.
Wall lighting panels.

Polyurethane (PU)

Industrial and general hardwearing flooring and floor finishes.
Thermal insulation.
Flat roofs, ceilings and pipes.
Draught excluders and jointing gaskets.

Polycarbonate

Vandal-resistant glazing and light fitments.

Nylon

Hinges for doors and windows.
Door and curtain runners.
Tap fittings.
Protective coatings.

Phenol Formaldehyde

Decorative laminates and wall coverings.
Electrical fittings.
WC seats.
Foamed composition panels for insulation.

Melamine Formaldehyde

Decorative laminates.

Urea Formaldehyde

Wall cavity foam.
Electrical fittings.
Adhesives for plywood and chipboard.

Glass Reinforced Polyester (GRP)

Baths and basins.
Cold water cisterns, cesspits and collection tanks.
Roof lighting sheets, internal and external wall cladding panels.
Dome roofs and spires.
Architectural features.
Structures - sports, and swimming pool halls.
Door and door surrounds.
Pipe liners and pipe fairings.
Light standards (columns).

Other plastics with selected usages:

Acetal (POM) - Carbon black filled.

Polyvinylfluoride (PVF) - coating and glazing.

Polycarbonate - blended with ABS and PBTP (polybutylene terephthalate).

Ethylenetetrafluoroethylene (ETFE) - transparent roofing.

Polytetrafluoroethylene (PTFE) - coated woven glass cloth, roofing.

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