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Advances in Materials Technology: MONITOR

Issue Number 13

MATERIALS FOR FOOD PACKAGING, STORAGE AND TRANSPORTATION

Dear Reader,

This is number 13 of UNIDO's state-of-the-art series in the field of materials entitled Advances in Materials Technology: Monitor. This issue is devoted to one of the important problems confronting us every day: materials for food packaging, storage and transportation.

In each issue of this series, a selected material or group of materials is featured and an expert assessment made on the technological trends in those fields. In addition, other relevant information of interest to developing countries is provided. In this manner, over a cycle of several issues, materials relevant to developing countries could be covered and a state-of-the-art assessment made.

This Monitor was prepared with the generous help provided to us by PIRA Packaging Division whose information we used extensively. With the help of some of those specialists who participate in PIRA Packaging Division's meetings, we tried to look into the future of food packaging materials. Both the state-of-the-art and future trends in the field are also covered in the article written by Ronald R. Goddard, especially for UNIDO. We anticipate that the information published could lead to a number of questions related to particular materials and technologies used. Please send them directly to: PIRA Packaging Division, Randalls Road, Leatherhead, Surrey KT22 7RU, UK.

We invite our readers also to share with us their experiences related to any aspect of production and utilization of materials. Due to paucity of space and other reasons, we reserve the right to abridge the presentation or not publish them at all. We also would be happy to publish your forthcoming meetings (please see section "Past events and future meetings").

We would be grateful to receive your opinion on possible subjects for our forthcoming issues. In this way we expect to have a dialogue with our readership to establish the feedback which will allow us to effectively monitor the developments in the field and better serve our readers, especially in the developing countries.

For the interest of those of our readers who may not know, UNIDO also publishes two other Monitors: Microelectronics Monitor and Genetic Engineering and Biotechnology Monitor. For those who like to receive them please write to the Editor, Microelectronics Monitor and Editor, Genetic Engineering and Biotechnology Monitor.

Industrial Technology Development
Division

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1. MATERIALS FOR FOOD PACKAGING, STORAGE AND TRANSPORTATION

1. Introduction

Food packaging is concerned with the containment of surplus foods which are not required to be eaten immediately; and the protection of these from pests, dirt, moisture and other harmful climatic effects; from physical damage; and from contamination by microbes or bacteria. Some form of identification is also usually needed - to indicate the type of food contained in the pack, and its place and date of origin.

A pack or container may vary in size from a large bulk vessel of one ton or more down to a tiny unit pack of sugar or salt; and may be made from a wide range of materials. Each of them, however, has to provide the same mix of performance as already listed. In addition to those, consumer packs are increasingly required to "sell" themselves in modern retail stores; and to provide a degree of convenience to the end user. All of these functions must be achieved at the minimum cost, in a safe and lawful way and with the least possible harm to the environment.

2. Performance requirements

2.1 **Physical protection:** Packs may be split or torn during handling, or crushed under high loads in storage. They may be scuffed by vibration during a journey and suffer side shocks or punctured during mechanical transfers. All of these can be measured and packs can be made strong enough to withstand them, but only up to a certain economic limit.

2.2 **Climatic:** Heat, light, water and the oxygen in the air, can all have harmful effects on many foods; these effects are often made worse in combination. For instance, high temperature plus moisture; or light plus oxygen.

2.3 **Biological:** Attacks may come from minute spores or bacteria, tiny insects or small animals or birds. Protection from the first kind should start before the food is introduced into the pack, since if the pack is contaminated spoilage will certainly occur (unless retorted). It is more difficult to provide protection against insects and small animals by the package or packaging material alone, and this is in practice mainly achieved by good housekeeping conditions in the storage environment.

2.4 **Safety and quality:** Packaging materials intended to come into contact with foods have especially stringent requirements. They must not transfer any harmful constituents into the food, nor result in any unacceptable change in taste, texture or appearance. They should also provide protection against the loss of any component of the food (especially moisture or volatile ingredients) and against the ingress of oxygen or water vapour, where these would affect the food. Packaging materials should also ensure that no odour or taint is picked up from any external source.

As a rule, the higher the gas barrier performance, the better, but with certain moist and processed foods, complete anaerobic conditions must be avoided.

Manufacturing hygiene must be particularly good, and similar requirements apply to protective packaging and the conditions in which food packag. materials are stored and transported.

3. Developments in individual packaging materials and forms

3.1 **Metal:** The most commonly used metals are tinplate and aluminium: and the most important co.. factor in retail size metal containers is their materials content. This means that even small savings of material are worthwhile. In tinplated steel the greatest amount of development has centred on ways of reducing or totally replacing the tin component; in reducing the wall thickness; in reducing materials usage by modifying the fabrication processes; and in reducing the diameter of the steel ends. Three-piece cans made by seam welding the body cylinder are now using induction, or laser fusion and "cement" adhesion. These methods are all possible, and will give small materials savings as well as other benefits.

Tin-free steel is extensively used, modern inorganic coatings (chrome/chrome oxide) and organ: lacquers are used in association with this. These materials are also capable of being formed by the same deep-drawing techniques as tinplate and aluminium. Of the two best known techniques, the draw-wall-iron (DWI) allows greater materials savings than does the alternative draw-re-draw (DRD), since in the latter the wall and base thicknesses are virtually identical. Ultra-thin walls are acceptable for carbonated soft drinks d. to the stiffening effect of the internal pressure It is possible, with some limitation, to introduc. internal pressure into other food cans by the use o liquid nitrogen or CO_2. This technique, which is already beginning to find applications, is most appropriate for mobile liquids. Tinplate therefore has ample performance and it can be reduced in weight by the techniques mentioned but there is clearly an equation linking the materials savings to the higher processing costs and a break-even point must exist.

Extrusion coating and lamination offer prospects of utilizing the properties of steel and plastics in combination. This has already been commercialized in Japan, notably the small iron foil trays, adhesive laminated with polypropylene, from Toyo Seikan.

Aluminium is used for a wider range of applications than steel - examples are tubes, pressed foil trays and laminates. It is ductile enough to be rolled to thicknesses as low as 5-6 um although 7 um is normally the thinnest in general use. A major proportion of its cost must always be the energy required to refine it from the bauxite ore in which it is found. Since energy (especially the electrical form mainly used for this) is unlikely in the short term to become cheap, this will remain a limitation to the economic production of aluminium. However, if reprocessing of scrap aluminium recovered from the domestic waste stream, can be increased, then the picture becomes very different and it provides a big incentive for beverage containers (the major single use) to be made all of one material. All-aluminium containers are very common, but easy-open steel ends are now possible and all-steel or all-tinplate versions equally meet the requirement for improved recycling potential.

Some new approaches to the fabrication of aluminium containers have been developed: it is capable of being friction welded and extrusion- or adhesive-coated with polymers, both of which allow very lightweight containers to be made. Cold forming of polymer coated heavy foil is another technique which can be adopted for the manufacture of retort pouches and trays. The most extreme form of metal reduction is in vacuum metallization. This is a technique in which a minutely thin layer of metal (usually aluminium) is deposited as a vapour from a boiling crucible under high vacuum onto a reel of plastics film. The coating is about .02 um thick and is not fully opaque, but it does provide greatly improved barrier performance to gases and light.

Other forms in which metal is used include closures - which can also be in aluminium or tinplate. The former is usually applied by a technique in which the thread is produced by rolling it into the neck finish of the container; and the latter is more often a lug or preformed threaded closure. The traditional crown cork is now less used as single trip bottles are increasingly adopted, although a variation on this - the Scruseal - has been developed which has a plastics layer inside it. It is applied in the normal way by crimping but the plastic grips a fine thread on the glass neck finish and can thus be removed by unscrewing.

Metal strapping or wire is still used for the heaviest duty applications, but has been extensively replaced by plastics types in many areas.

3.2 **Paper:** This was the first material used for "mass produced" packaging and it has retained its pre-eminent position on a tonnage basis to this day. Paper making has evolved continually, mainly in energy savings and improved quality and hygiene, but there has been no fundamental change to the process, which remains basically the Fourdrinier technique with its high energy requirement for the de-watering and drying stages.

There have however been some major changes in application. All forms of bags and sacks are targets for substitution by plastics - usually high density or low density polyethylene, although the traditional SOS block bottom bag is making something of a comeback where its high quality graphics potential can be exploited. Small cartons have retained their traditional form and material, despite various attempts to develop plastics substitutes. In the larger sizes, very fine corrugated boards (E-flute and micro-flute) are being increasingly used (detergent packs are a good example). The problem of achieving high visual quality has been overcome by the extensive use of pre-printed liners or by laminating sheet with printed board or paper.

Moving up in material and pack sizes, corrugated boards continue to replace solid board for transit and shipping cases. Improved water resistance of the adhesives used, and enhanced stiffness by impregnating the fluting medium with resin (and in some instances, by combining two fluting layers with a stiffening adhesive/resin) have all improved the cost/performance ratio; and a steady pattern of down-gauging has continued.

Composite containers, based on the traditional spiral winding technique, retain their place for certain dry foods - a major benefit being the saving of space if produced in-house. There are, however, many competitive systems now available, including those using pre-cut blanks (Horauf, Can Shield and Cekacan). A new approach to this form of paper pack shown for the first time at Pack-Pro exhibition in Germany early in 1988, is the Sirpak made from narrow strips of paper in a continuous tubing technique around a shaped mandrel (somewhat akin to paper sack manufacture). This has board ends which are sealed and bead rolled - a characteristic also of the Cekacan.

The bag-in-box pack has found a niche for wine, milk and some catering products like tomato sauce, where it usually competes with metal cans or glass bottles or jars. Sizes range from 500 ml to 1,000 litre, although the smallest types (e.g. Cebox) have found limited applications to date; and the largest types - intermediate bulk containers - are related to changes in the transport and distribution of bulk foods such as frozen concentrated orange juice and tomato paste. The most popular size range for wine and other retail containers is 3-10 litres.

Without doubt the most significant developments in paper packaging are where this material is allied to a plastics component. Coated boards are used to produce liquid-tight trays - for microwave or conventional oven heating (depending upon whether they are extrusion coated with polypropylene, polyester, or TPX); and for liquid carton systems. It is in the latter where the most spectacular growth has been seen. Three companies dominate the area, Tetra Pak from Sweden, Combibloc from Germany and Elopak from Norway. All are multinational companies and the Tetra Pak in particular is today used in over 100 countries. Together they represent a total market between 60 and 100 billion containers per annum, in sizes from 150-3,000 ml.

Products packed in liquid cartons now include milk, fruit juice, wine, oil, sauces, tea, water, soups, tomato pulp, jam, jelly, cooked rice - even whisky, and many, many more. The foods may be packed under aseptic conditions to provide six or twelve months' shelf-life; or fresh and distributed under chilled conditions. Two main forms dominate, the "brick" and the "gable top", but there are variants ranging from the original tetrahedral pack (Tetra Pak standard) to the latest Tetra Top, a square cross-section carton with an injection-moulded top formed in situ, and incorporating a reclosable tab.

Among other manufacturers are Dai Nippon and Toppan from Japan - both of whom offer gable top cartons with plastics reclosable pouring spouts; International Paper in the USA; SIG in Switzerland (the latest to enter the field - in 1988); and Bosch in the Federal Republic of Germany with their aluminium-ended Hypa and Hypa-S packs.

Some recently published research results indicate that the Hypa-S might be able to withstand the internal pressure of carbonated drinks. If this is progressed then a further huge market development becomes possible (other countries are known to be similarly interested). Most of these liquid carton systems use reel-fed materials which invariably include polyethylene as the heat sealing medium, but can incorporate aluminium foil for high barrier, and other plastics as required.

3.3 **Glass:** This is the only technology involving a single process from raw material to finished pack. The basic constitutents of glass account for only about 15 per cent of the total cost of the pack, and for cost saving the emphasis must therefore be on process economies. This is one major area of development. It is known that the possibilities of using the theoretical strength of glass are enormous. The most promising development of this nature is one pioneered in Japan by Yamamura Glass Company. It involves the substitution of sodium ions in the surface layer of the glass by larger, potassium ions, the effect of which is to produce in situ a pre-stressed surface layer giving very much enhanced toughness. It has not been extensively adopted in other countries, largely because of the high capital costs involved.

Processing developments have included pre-mixing of constitutents, pre-heating by introducing ingredients via the hot flue, computer control of glass making machines, and electronic gob-weight control. CAD/CAM developments have led to improvements in wall thickness control and lower mould making costs, as well as reduced rejection rates of the finished product. All of these have helped to keep glass commercially competitive.

The second approach has been to protect the surface of glass from scuffing, abrasion and impact damage, which are the main causes of mechanical failure. "Hot" and "cold" end treatments using titanium and tin oxides and polyethylene emulsions, to provide a high strength surface and lubrication properties respectively, have been in use for many years, and improvements continue but these are a matter of degree rather than representing any fundamental breakthrough.

Shrink sleeves provide another form of surface protection, and both foamed polystyrene and clear PVC are used - in both instances they double as a label and can also provide tamper-evidence. Another protective route is to coat the bottle surface in a layer of plastics material. This may be achieved by spray, roller coating or dipping from an emulsion in the hot or cold state; it can also be used to provide attractive colours and, if applied over a label, will protect this. A recent innovation developed in Japan by Kirin Breweries is to coat the bottle with a surface lubricant and protective skin of zinc stearate. By use of an appropriate solvent washing technique, this coating can be removed each time a returnable bottle is used, and it is then re-coated on the filling line - so maintaining the bottle's surface strength throughout its life.

Improvements in dimensional tolerance to glass have made it possible to heat seal lacquer- or polythene-coated foil membrane lids to the rims of wide-mouth glass jars. This has led to some extension of the use of this material. Ceramic inks which are fused onto the surface to provide permanent "labels" can also be used to provide either opaque or translucent decorative coatings.

3.4 Plastics: As the most recently developed material to be used for packaging, and one based on high technology processes, it has shown the greatest versatility and development. About 10 basic polymers are used but the variations on these, and the range of possible combinations of two or more (as well as with non-plastics) makes the number of permutations almost infinitely large. It is therefore simpler to discuss plastics packaging developments under the headings of rigid, semi-rigid, flexible, and composites.

3.4.1 Developments in polymers: Completely new polymer materials rarely appear and the range already available is capable of meeting most requirements. Current developments include:

Linear LDPE - a branched molecular structure halfway between low density and high density in nature. It is made by a low pressure gas phase route, offering energy savings to the manufacturer. Physical performance is improved allowing down-gauging and consequent cost savings. Most new plant commissioned is capable of producing this.

Ultra low density polyethylene - in densities below 0.91 g/cm^3 also offers improved strength, better heat sealing properties (especially through contamination) and enhanced optical quality, while giving increased yield.

Many derivatives of the polyester family are being developed but only two have so far been commercialized. PETG - glycol modified polyester is extensively used for plastics bottles produced the extrusion blow moulding route. Amorphous PET in use for thermoforming, providing high gloss and mechanical strength. This is being offered as a replacement to PVC but at higher cost.

Other polyesters such as polybutylene terephthalate and copolyesteramides are also being evaluated.

Polycarbonate and polyetherimide are two engineering grade plastics being promoted for certain packaging uses. They have extremely high mechanical strength and heat resistance but their costs are equally high at present.

TPX - a methylpentene copolymer developed by ICI in the 1970s, and allowed to lapse - is now taken up by Japanese companies and offered in film form also for bottle blowing. It has high temperature, solvent, and grease resistance. It is also used for extrusion coating of board for oven use.

EVOH - a copolymer of ethylene and vinyl alcohol - has extremely good gas barrier performance but is moisture sensitive (pure polyvinyl alcohol is also made and used to produce water-soluble films, so the moisture sensitivity relates to the proportion of this element present). Grades are now available which are more stable and the material can be produced as coated films for lamination; but it is more often used in coextruded form in films or containers.

Most recently, and potentially very important, is the range of naturally derived copolyesters, typified by polyhydroxybutyrate (trade name Biopol when made by ICI). This is a truly biodegradable plastic material with properties very similar to polypropylene. It is made by a bacteriological conversion of carbohydrate feedstock (e.g. sugar). Different forms have been described including copolymers of hydroxybutyrate/ hydroxyvalerate; and of different molecular configurations e.g. 3-hydroxybutyrate/ 4-hydroxybutyrate. The proportion of all types can be varied to give widely different properties which range from elastic to rigid.

The most recent development announced by the Tokyo Institute of Technology holds promise of this material being produced at a cost little higher than traditional petrochemical based plastics. This is most significant since the early trial materials were extremely expensive.

3.4.2 Rigid containers: may be produced by injection moulding, extrusion blow moulding, rotational moulding, stretch-blow moulding, and thermoforming (from heavy sheet). The route chosen depends upon the shape required, the quality of internal or external finish and the selective control over wall thickness needed.

Injection moulding has traditionally been used to produce rigid packs. The high pressures involved allow extremely fine detail to be reproduced, material distribution to be selectively controlled, and extremely good dimensional precision - especially of the neck finish area. Recent developments in collapsible mould techniques have made it possible to produce more complex designs, including undercuts and threaded sections. At the same time, improvements in melt rheology of the plastics materials themselves have made it possible for extremely thin walled packs to be produced. Engineering techniques such as spark erosion and computer controlled milling also provide the necessary degree of precision for the manufacture of these very finely dimensioned moulds.

An important variation on injection moulding, developed over the past 10 to 15 years is injection-blow-stretch. This involves the production of small thick-walled preforms by injection moulding in which the neck finish and top aperture is produced full size. In a second production stage, these are "conditioned" by heating, mechanically stretched by pneumatically operated pistons and then blown into a full size mould to produce the final shape. This procedure of stretching the containers in two directions produces biaxial orientation of the molecules which improves physical strength, clarity and barrier properties. In narrow neck form these have been extensively adopted for carbonated soft drinks, where their light weight and pressure-resistance are advantages. The process can be used with a number of different polymers - PVC and polypropylene are used but PET (polyethyleneterephthalate or polyester) has been the major choice.

One important area of development specifically for pressurized products such as carbonated soft drinks, involves design of a flat base which can withstand the high internal pressures (4 bars). At first, all bottles had hemispherical ends to contain this pressure, and separate caps were applied by hotmelt adhesive to provide a stable base. The second generation "one-piece" containers employed an annular "champagne base" design to contain this pressure, but this is primarily suitable for small sized bottles up to about 0.5 litre. For sizes above this various permutations of multiple-dome and rib designs are used to contain this pressure. These have varied from relatively simple 5 or 6 dome arrangements (petalloid) to very complex engineering designs which lock up the stress into a series of ribs and facets. The disadvantages of these one-piece designs are that greater quantities of PET material are usually needed, more complex preforms and higher blowing pressures are needed for distributing the material into the detailed shapes, and they do not present a full-area, flat base to provide stability on the filling lines.

Even higher pressures can be withstood by the latest designs of PET bottles and aerosols made from this material are now in use for some limited products ranges. The high strength of these packs makes them also suitable for certain hazardous materials including agro-chemicals.

Another area of development has been directed into improving the gas barrier performance. To achieve this, external coatings (usually PVdC but other chemicals such as acrylic emulsions and EVOH (ethylene vinyl-alcohol copolymer) emulsion have also been described). An alternative approach is to make the preform using a co-injection moulding technique in which a high barrier material (EVOH, a form of nylon such as MXD6, or an acrylic multipolymer such as Barex) is introduced as a core layer between two outer layers of PET.

The third area of research has been in heat resistance. Currently, PET bottles and jars will deform if heated at temperatures over about 60-70°C. This means they cannot be used for in-container processing, or hot filling, and this restricts the range of potential applications. Enhanced thermal stability can be achieved by improving the basic polymer - much effort is targeted to this, especially in the area of modified polyesters - and some development materials are undergoing trials. Polycarbonate is an engineering plastic which is being considered: "TPX" (a methyl pentene copolymer) and "U" polymers (forms of polyacrylate) are also available.

A further route to providing heat resistance is polymer alloys, which are analogous to metal alloys - intimate mixtures of dissimilar materials which do not form new compounds as such but which offer a range of properties different from either of the constituents. Many of these use standard commodity polymers such as high impact polystyrene and polypropylene. Finally, a procedure for providing heat resistance which is applicable to certain limited ranges only - notably polyester - is to incorporate a crystallization initiator in the polymer which then, during a slightly extended heating period in the mould, will result in crystallization of the polymer into a much more heat stable form. This is most used with PET, the resulting material is usually commonly referred to as CPET and its primary use has been in thermoforming but some rigid PET containers in Japan are treated selectively in the neck area to induce this crystallization. Its characteristic white appearance denotes that this has been done.

Extrusion blow moulding is the second route for producing rigid plastics containers, and is the norm for narrow necked bottles and closed head plastics drums - essentially any item where internal access is not possible. The process can also be used to produce wide-mouth jars by trepanning the top from a bottle shape, or cutting two containers from one such form by centrally slitting. The main limitation is that only the outer face can be precisely controlled dimensionally since only this is in contact with the mould. The process also requires a nip-line across the base - where the extruded tubular parison has been closed off. A further limitation is that cooling can take place from one side only so mould cycles may be slower. Finally, material distribution within the wall - despite the development of variable thickness parisons by means of movable extruder dies - can never be as good as injection moulding.

Against these the process has some very important advantages. It is a single stage operation; and only one mould is required (which is less expensive than an injection moulding tool). A major benefit is that coextrusion techniques can be employed to provide multilayer bottles which make the best use of the properties of different plastics. Examples include, high gas barrier using sandwich layers of PVdC or EVOH, or an outer skin of polyamide or Barex; improved temperature resistance by incorporating one layer of polycarbonate; decorative high gloss and/or coloured external surfaces, e.g. by using an outer layer of polyamide. Other decorative effects include a "comb" coextrusion which allows different colour stripes to be produced in the bottle. In economic terms the incorporation of a middle layer of scrap material can be very important in optimizing production costs.

Due to physical and chemical differences in individual polymers, in only a few instances can two or more different materials be directly coextruded through the same die and adhere satisfactorily. The most important material development involved in this technology has therefore been in the technology of tie-layers - the "adhesive" needed to hold together these otherwise incompatible layers.

One specific technique developed by the Du Pont company in the USA is to extrude a blend of two imiscible materials in such a way that the smaller constituent forms a series of thin platelets within the matrix of the main material. Combinations evaluated have been mainly based on an amorphous polyamide (Selar PA) in a polyolefin (e.g. polypropylene). The platelet formation is encouraged by the mixing and extrusion processing arrangements; and these lie in a regular plane to produce a "tile-like" effect. The main benefit is a great improvement in the gas barrier performance for what is essentially a single (if mixed) material

Another process particularly suitable for improving the barrier properties of blow moulded containers is the gaseous modification of the inner surface. Best known of these is fluoridation - a technique particularly applicable to polyolefin materials and which uses the high chemical reactivity of fluorine containing gas to produce in situ, over the inside walls, a layer of fluoride-substituted polyolefin. This has much improved resistance to solvents, especially hydrocarbon types. The reactive gas (there are also others producing sulphonation, for example) can be incorporated into the blowing gas.

Rotational moulding is a method of producing relatively undemanding containers in large sizes by using heated moulds into which a controlled volume of granula polymer is introduced and rotated. The polymer then fuses and distributes itself around the heated wall of the container. This is frequently used for garden type tubs, rainwater butts etc. A major advantage is the lower mould cost, especially for very large items such as intermediate bulk containers.

3.4.3 **Semi-rigid plastics** containers (often called thin walled) are mainly produced by the thermoforming process from thin (0.5-1 mm) plastics sheeting. This is extruded by the conventional routes and offers all the advantages mentioned above, under extrusion blow moulding. Major benefits of thermoforming are that less material may be used; in-house production is possible (and provides benefits in reduced storage of packaging materials); mould costs are lower; and in particular in-line thermoform-fill-seal systems are available.

A major limitation is that material distribution uniformity can be difficult especially if a deep-drawn and square profile container is formed. Since in most instances the material is drawn in one suction action, the areas of the body furthest from the initial plane are most excessively thinned. Ways of overcoming this include plug assist in which the sheet material is stretched into a certain preformed configuration prior to the final blowing; and the development of other "hybrid" techniques such as solid phase pressure forming a melt phase thermoforming where either moulded preforms with selected distribution of material are used, or the container is formed directly from the extruder on a die into a mould. A special variation of multilayer thermoformable sheet is that used in the NAS (neutral aseptic system) which involves stripping away a poorly-bonded surface layer to expose a sterile surface into which processed food can be filled after themoforming under sterile conditions.

Another variation on thermoforming of thin walled containers is the incorporation of in-mould paper or plastics labels which can improve both the barrier and stiffness of the container.

3.4.4 **Flexible packaging:** Although not all materials used in flexible packaging are plastics-based, there is a close association between the two. Flexible packaging materials are often defined as thin single or multi-layer structures, which may be supplied in reel form for use on form-fill-seal machinery, or in prefabricated form as bags, pouches or covers. In this review a wider interpretation is adopted, adhering more to the literal definition of "flexible" but restricting discussion to materials up to about 300 μm thick.

The materials used in flexible packaging include paper, aluminium foil, regenerated cellulose film, in addition to the major polymers of polyethylene, polypropylene, polyamide, polyester polystyrene and PVC. All are capable of being handled separately, and may be combined in various forms to produce materials for use on either vertical or horizontal form-fill-seal machines - these are the materials traditionally associated with flexible packaging.

The materials may be combined either by adhesion lamination (in which the adhesive layer performs only that function) or extrusion lamination - usually with a polyethylene or EVA resin, when the adhesive can provide some further functional properties in its own right. An alternative to separate lamination of discrete films is coextrusion. The principle involved has been described earlier - multiple extruders feeding different materials into a common die. Major benefits are that very thin layers of high cost constituents can be produced in situ. The process is a single stage one. The compound material may be stretched to enhance clarity or strength, and two-sided effects (e.g. different colours) are possible.

Disadvantages are that tie layers are often required, sandwich printing is not possible, non-thermoplastics materials cannot be incorporated, and process scrap cannot usually be recycled in house.

Each of these processes has its market suitability; neither meets all requirements of flexible packaging and therefore both are used. A "compromise" approach is to use coextrusion and adhesive lamination or to use coextruded layers as adhesives themselves.

The properties of flexible materials may also be modified after forming. Film manufacturers can produce modified forms of standard polymer films with increased tensile strength, clarity and barrier properties as a result of orientation (stretching) and heat setting techniques. Oriented polypropylene, high density polyethylene, polyester and nylon films are the best known examples, but other materials are also available in similarly modified form.

Treatment by gamma, electron beam or ultraviolet irradiation to promote cross linking and to improve bonding between components, is another post film treatment, and the introduction of ozone into the interface between laminates or coextruded materials combined outside the die, are other examples of process modification.

A range of films often described as pearlized OPP makes use of an effect which is neither a function of the initial polymer properties nor the result of post film treatment. By incorporating a small addition of an expanding agent and sometimes traces of white pigment in the polymer the plastic film is formed with a microcellular foamed structure in its core, and the effect of light diffraction on these results in varying degrees of opacity and a pearlescent effect. Due to the cellular texture this material has a high degree of stiffness and an extremely low density - making it suitable as a substitute for paper in a number of applications. These range from small food pouches made on form-fill-seal machines, to labels and carrier bags.

Woven plastics, made from thin stretched tapes of HDPE or polypropylene, after about 20 years on offer for sacks, are now finding their greatest application in the manufacture of flexible intermediate bulk containers where their high strength and flexible fabrication potential is particularly appropriate.

Early problems of u/v degradation have been overcome. They can also be laminated or extrusion coated to provide strong, siftproof materials.

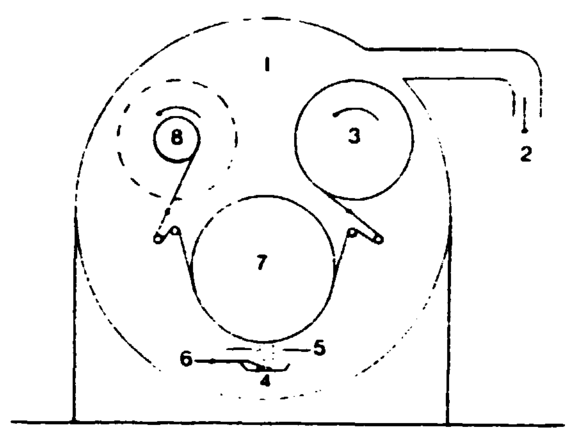
3.4.5 **Surface coatings and high barrier:** A variety of surface coatings can be applied to flexible films either to enhance their existing properties or to provide completely new ones.

Vacuum metallization, a technique using well established principles, is described earlier at 3.1. Initially the process was used mainly for its decorative appeal, but these materials are now accepted as providing significantly increased barrier properties to water vapours and gases as well as the more obvious light barrier and thermal reflection potential.

Most plastics are suitable as substrates, cellulose films were dominant in the early period (1970s). More recently the benefits of barrier improvement and low metallizing costs have been recognized with ultra thin layers of polyester, oriented nylon and polypropylene film.

The enhancement of gas barrier performance depends upon the value for the original material. It is achieved to only a limited extent for an initially good barrier such as regenerated cellulose (in respect to oxygen) but is very significant for medium range barrier materials such as PET and PA. Through these the oxygen transmission rate can be reduced by a factor of about 100 (from 60-100/m^2/day to 0.5 or less). The process requires a very high vacuum - pressures of 10^{-4} or $^{-5}$Torr being typical - and so batch processing is still the preferred method. Setting-up times on the machine are a major cost component which is why the very thin films (12 um and even less) and increasingly large machines (now up to 2.3 m in width) are used to improve production economics. A schematic diagram of a vacuum metallizing chamber is shown below.

R R GODDARD



Simplified layout of vaccum metalliser.
1. Sealed vacuum chamber; 2. high vaccum pump (10^{-4} torr); 3. unwind roll-base film; 4. electrically heated boat crucible containing the feed metal; 5. heat shield; 6. metal wire feed; 7. chilled drum; 8. take-up roll, metallised film.

Other materials based on polymer layers deposited from emulsions, solutions, or by hotmelt extrusion, include nitrocellulose, PVdC (polyvinylidene chloride) acrylic compounds, pressure sensitive adhesive layers, and hotmelt sealing films. Many of these perform two functions simultaneously - improving barriers and making heat sealing possible.

Cold seal coatings have greatly increased in use over recent years - they are formulations of natural latex which stick only to themselves and may be coated all over (either solid or patterned) or in specific areas where seals are required. This is achieved by register printing of the latex during the printing stage. Benefits are mainly in machine speed and simplicity - no heaters, temperature control or minimum contact time are needed. Earlier problems with short shelf-life, taint and susceptibility to dust, have been largely overcome.

Notes on barrier performance:

The most effective flexible barrier to gas, water vapour and light is a continuous layer of aluminium foil. When incorporated into a plastics/foil laminate even the tiny pinholes which are present in the thinnest gauges, do not result in any effective gas transmission.

The barrier performance of metallized and other coated films is a function of the weight of coating material, its intrinsic impermeability and the "compactness" with which it has been laid down. For metallized materials, three ways of measuring this can be used. Chemical analysis of the amount of aluminium per unit area; electrical resistance in ohms per square; and optical density. Of these the last is the simplest, and research work has shown reasonable (but not absolute) correlation between this and barrier performance. As a general guide, optical density (OD) values in the numerical range of 3 to 4 or above represent extremely good barrier materials.

Variations on the metallization process have included the use of electron beams as a high energy source to vapourize the metal (previously electric induction heating had been the norm); and the use of this same energy to produce coatings of clear inorganic materials on plastics films. Most important of these in recent years has been silicon oxide which can be visualized as a microscopically thin layer of flexible glass. Silicon nitride is also used, and this has a whiter appearance than the yellow tint which is characteristic of a silicon oxide.

More fundamentally different is the alternative way of producing metallized films - indirect or transfer metallization. These processes make use of a metallized film produced in the traditional way, but the base film is treated to resist adhesion and the surface of the metal layer is coated with a heat activated lacquer. To produce metallic layers on other substrates, this "carrier web" is brought into contact via a heated roller and the metallic layer is stripped off and transferred. Major benefits of this (considerably more expensive) route are that extremely high gloss effects can be achieved on poor surfaces such as paper, and the problem of moisture loss for paper which occurs during direct metallization as a result of the high vacuum conditions, are overcome.

A topical use of special types of metallized film is as a "susceptor" for use in packs intended for reheating in microwave ovens. The small amount of metal, adhesively attached to cartonboard or a bag, concentrates the microwave energy and gets very hot (up to 200°C) promoting crispness and an improved baked effect to foods contained in the packs.

There are also some extremely high barrier materials produced as a result of composite treatment techniques (barrier lacquers such as PVdC on top of metallization, and the use of two metallized layers adhesively laminated metal to metal).

3.4.6 **Applications of flexible packaging materials:** Form-fill-seal machines, as already mentioned, are a major area of application. Others in which technical developments have been recorded, include:

Cling and stretch film - these are used in two major ways; the first is as high clarity overwraps for trays, lidding or collation of packs. Two types of material are in common use; plasticized PVC, and PE or PE/EVA. As a result of adverse publicity on the possibility of plasticizers used in the former type migrating into certain fatty foods, newer, low plasticizer, types have been launched recently. Other materials, based on various polyolefin blends, are also available. Cling performance, transparency and stretch resilience of these non-PVC materials have been greatly improved over recent years but they still do not usually match the PVC in all respects.

For stretch wrapping similar properties are required but are often less critical, and grades of polyolefin, especially LLDPE and EVA are widely used. Some are coextruded layers of two materials to enhance blocking and/or to minimize sticking to wrapped items.

In shrink wrapping, where heat is used, similar coextruded materials are available which prevent the film from adhering to plastics coated pallet loads (e.g. polyethylene sacks).

Heavy duty plastic sacks may also be produced in coextruded material, with improved barrier performance, although this is not common. High mechanical strength is a requirement, though, for some arduous distribution systems or for containing very hazardous materials; and two variations of cross lamination technique (multiple layers of materials stretched in one direction each, and cross laminated) have been developed. "Valeron" is a twin layer adhesively combined structure; "Reed XF" consists of four layers combined by a cold blocking process.

3.4.7 **Labels:** Label stock can also be considered a form of flexible packaging - especially when this is based on a plastics material. In brief, current developments include greater use of self-adhesive types, and their increasing sophistication. Multiple layers, over-laminated, embossed textured effects, all now widen the scope of the traditional label. Two major innovations in the self-adhesive area are based on eliminating the traditional released coated backing web. "Monoweb" from J. Waddington in the UK is similar to printed tape and the special shapes of the labels are cut from this in line on the application machine at the users' premises. "Solo" is a form of stack fed self-adhesive labels using modified traditional applicators and magazines. Both have involved developments in the release coating materials themselves and in their application. Related to this is an electron beam cured process which makes it possible to coat silicone release material onto very thin and inexpensive plastics webs (the reduced heating effect gives less stretch and distortion, making cheaper substrates technically possible).

The use of plastics labels has also widened including "invisible" ones of printed clear PET and of a pearlized OPP. One benefit from the latter material is its ability to stretch when used in a full wraparound style label on a large PET bottle for carbonated soft drinks. These bottles under pressure have a slight tendency to creep and bulge, and this can snap a sealed paper label.

In-mould labelling techniques can be used. These rely on the heat of the molten plastics to adhere a heat sensitive layer on the label at the time the container is produced. They provide two different types of benefit. One (already mentioned at 3.4.3) is when they are used in thermoforming to provide a wall-stiffening function. The second is in conjunction with injection moulding, extrusion blow or injection-blow-stretch moulding of plastics containers. No loose edges or wrinkles with paper labels occur, and this was originally seen as the main benefit. But more recently the concept has been extended to plastics labels. If these are of the same polymer (or a compatible variant) then in-plant scrap containers may be recycled directly. This also facilitates ultimate recovery and recycle in the post consumer waste stream (see section 5 below).

The most significant single change in labelling has been the wider introduction of the shrink-sleeve technique developed in Japan in the 1970s. Printed transparent film is adhesive- or heat-sealed into sleeves (print surface on the inside) and flattened for handling. These are slipped loosely over the necks of containers and heat applied which causes them to shrink and grip tightly, conforming to the pack shape (within certain limits). Most of the sleeves are made from UPVC, but recent advances have made polypropylene suitable as a material, and this can be expected to grow.

Shrink labelling offers other benefits in addition to simply providing the label. They include:

A security function, since the label can readily be positioned to cover the closure (with perforations or tear strips as required to facilitate opening).

Coloured base films give the impression of coloured glass containers when used with standard white flint glass.

When all-over applied to bottles for carbonated soft drinks, the label can reduce the spread of flying fragments in the event of a filled bottle being dropped and broken.

Multiple items may be combined together to provide promotional multi-pack offers, sets of associated products, or for attaching samples or gifts.

3.5 **Timber based materials:** Wood, one of the most traditional materials for heavy duty packaging, retains its role for large machinery and certain other very demanding applications. Most of the developments of recent years have been into ways of using forest products with greater efficiency. In packaging this means exploiting better the inherent strength properties and at the same time making the most efficient use of the material. Plywood and large particle board panels achieve the former; and hardboard is a good example of the latter.

All sheet materials based on wood have very high rigidity and puncture resistance, and offer very versatile fabrication options. Some of the softer grades also provide cushioning properties which may be exploited. All are more expensive than the heavy duty grades of corrugated and solid boards now available, and so their use must be justified by either extremely demanding conditions or on their potential after-use (which they offer to a greater extent than any other packaging material).

3.6 Ancillary materials or packaging components

3.6.1 **Closures:** Many of the traditional metal closures are now being replaced by plastics. This is especially true in the carbonated soft drinks area, now that some of the earlier problems of thread creep and "missiling" have been resolved. Interest currently centres on tamper resistance or tamper-evidence as a requirement for closures - the latter is a much more realistic expectation than the former. Where determined criminal tampering is intended, the necessary levels of expertise and resources can be employed to overcome most available systems. Child resistant closures are another important sub-section and almost all of these are made in plastics due the intricacy of moulding which is possible with these materials. To achieve tamper evidence, techniques such as oxygen removal and the insertion of oxygen sensitive coloured indicators is one method being promoted. Destructible multilayer with very strong adhesives are another, complex designs such as holograms are also used on closures and/or labels associated with them, others make use of pressure differential to provide diffraction effects from grating patterns printed on surfaces which are stressed due to positive or negative pressure.

3.6.2 **Adhesives:** These can be the most vital ingredient in all forms of packaging, from high speed food lines to heavy duty corrugated cases; an importance which is frequently underrated. While the traditional animal and starch based types are still in general use (and the latter has undergone major developments), it is in the synthetics area where there has been the greatest amount of technical development. Water based emulsion types, especially those based on polyvinylacetate (PVA) offer greatly improved performance, although details of formulation and adhesion mechanisms are rarely publicized.

Hotmelt and cold seal (already mentioned) have in common their instant adhesion performance. Both have been developed to meet the needs of the very high speed machinery now in use - line speeds of up to 1,000 per minute are possible. These are also far less dependent upon the properties of the substrates than are the acqueous based types - also enhancing their "tolerance" level on sealing lines.

In the self-adhesives tape and labels area, the most recent developments are in water based systems - especially those based on acrylic emulsions. Their most important benefits are to the converter who is able to meet the increasingly stringent emission regulations and who can install plant for greatly reduced capital outlay. This can result in lower production costs which may be passed on to the end user.

3.6.3 **Tapes and strapping:** The major developments in sealing tapes concern the range of self-adhesive materials now available (mentioned above). The effect of this is likely to be to increase the use of self-adhesive tapes at the expense of the traditional water-activated paper types. In strapping tapes - made from steel, polyester, polypropylene, polyamide and rayon - the situation is similar. They have been replaced for many applications by shrink and (especially) stretch films for palletized collations. They remain, however, important for specific situations such as newspapers, bundles of tubular items. For very heavy duty situations only steel can provide the "ultimate" in high strength.

4. Specifications, standards and legislation

4.1 **Specifications:** Allow properties of a pack or a material which affect its performance to be described in terms which can be measured. The two main types are material properties and performance based. The first is the more often used - largely because such properties are easily checked - but it is the latter which is much more important. Some material properties reflect only its basic nature, others do relate closely to its performance.

In writing performance or any other specific quantitative requirements into purchasing specifications, both supplier and buyer should use standard and easily understood terminology. Standardized units, by reference to agreed standard laboratory test methods, are also essential, and a tolerance level for every value should also be set. This should take into account commercial manufacturing limitations and the discrimination which is possible with the defined test methods. Test conditions must also be quoted, especially for paper-based materials. Excessively tight tolerances can only add to the costs since a high level of inspection and rejection rate may result.

Sampling and testing procedures carried out on receipt at the user's premises are often called "quality control" - this is wrong, because at this stage no influence can be brought on the manufacturing process - the only scope is to record any shortcomings observed. True quality control, carried out at the manufacturer's premises on the production line, may be duplicated by materials testing or quality assurance procedures carried out at the user's premises, but these latter do take into account any deterioration or changes which have occurred since the time of manufacture and despatch.

The supplier should be asked to agree that information on the manufacturing test results is made available, together with specimens of samples and/or test pieces to his customer. This minimizes the costs to the user. A procedure should be agreed whereby, in the event of any dispute, there is both the mechanism and the necessary samples which can be subsequently checked by either the purchaser or an independent assessor.

Non-standard materials, shapes or styles are always more expensive than those made in large quantities for wide ranges or standard applications. It is possible, for instance, for a lightweight paper to cost more than one of heavier weight, if the latter is a "standard" material. Purchasers should always check initially on what standard materials are available before setting their own specifications.

Proliferation of pack sizes and styles often grows up in large companies over a long period of time. Benefits of reducing these can include larger ordering quantities and reductions in stock holding and storage requirements.

Large scale purchasing usually results in lower prices, particularly at the lower end of the scale. Against this there can often be operational disadvantages, including tied up capital, risk of damage and deterioration during storage, inflexibility when design changes are contemplated and larger storage requirements. The aim should be to balance all of these.

Quality assurance schemes are becoming increasingly widely used, and the International Standards Organisation has set out a unified procedure for checking that good standards are applied in this respect. ISO 9000 is awarded to manufacturers meeting certain laid down standards of manufacturing quality, inspection and control procedures. The possession by packaging supply companies of this or a national equivalent (in the UK it is BS 5750) provides a level of confidence to their customers.

Once specifications have been agreed it is equally important to monitor the performance of the material or packs supplied. This is best done on the production line itself and in the market (since these represent the ultimate quality tests).

By checking on physical, machine running, and protection performance under actual conditions, specifications may be refined and costs reduced. Establishing the difference between "critical" parameters and others is the most important single aspect of this exercise.

4.2 **Standards:** are documents issued by national and governmental organizations and other bodies to describe procedures, performance and test methods. They are very important in the context of specifications and quality inspection or assurance. The two main functions are to establish minimum performance or safety criteria (e.g. pressure resistance of aerosol cans) and to define the test methods which should be used to measure such properties.

4.3 **Legislation:** The extent and nature of legal constraints applicable to packaging varies widely from country to country. In most situations laws which do impinge upon packaging come within one of the following areas:

- Health and hygiene of food packaging
- Packaging for the transport of dangerous goods by road, rail, sea and air
- Health and safety at the work place for manufacturers of packaging materials or their subsequent use
- Protection of the consumers e.g. tamper evidence and child resistance
- Weights and measures, legal requirements
- Product information and other labelling laws
- Environmental aspects
- Patent and design protection.

The first of those listed has the widest application, but few countries have anything as comprehensive as the FDA approval scheme operated in the USA and the similar BGA system in the Federal Republic of Germany. Within the EEC there is some legislation on specific items (e.g. vinylchloride monomer in PVC) and other more generally applicable (e.g. Materials and articles in contact with food Directive). Where no laws exist, organizations and companies often attempt to comply with the US FDA procedure, regarding this as a "best defence" in the event of any problems arisin

In view of the variable situation in respect of each of these aspects of packaging, the best advice is to point out that attention must be given to them in the design, specification, purchasing and use of all packaging materials.

5. Environmental concern

In recent years a number of individual aspects of packaging have attracted attention under the umbrella title of "Environmental Impact". They include matters of health and safety, honesty of trade practices, consumer convenience, and social behaviour in addition to those identifiably related to the environment and man's ecological relationship with it. The scope is too numerous to detail here, but under the classifications given above the following may be mentioned:

Health and safety

- Dioxins in bleached paper board, and in emissions from waste-burning incinerators
- Migration of plasticizers, pigments or other additives from plastics into foods
- Lead from soldered seam cans

- Danger of pressurized glass bottles used for carbonated soft drinks exploding if dropped

Trade practices

- Deceptively large packs
- Imitations of well known products (brand piracy)
- Adulteration of contents
- Limitation of choice (e.g. by imposition of multiple packs as the only unit of sale)

Social behaviour

- Litter - in which used packaging features prominently but is not in itself the cause
- Product tampering

Consumer convenience

- Open ability of packs and their availability in a convenient size range

Environmental

- Use of CFCs (cholorfluorocarbons) in aerosols and for the manufacture of plastics foam
- Use of natural resources and recycling/recovery
- Disposal of household waste (including packaging)
- "Excessive" packaging.

These cover most, but certainly not all, areas of concern, and in strict terms only the last should properly be regarded as an environmental matter.

The subject is highly emotive and there are few "facts" on which all observers agree. "Environmental concern" has been used as a pretext for trade barriers on the one hand, and exploited shamelessly to sell products on the other. This is not, of course, to imply that all people expressing concern over packaging and the environment come into either of these categories; the majority of independent organizations are motivated by true concern for the environment - something in which they do not have a monopoly though.

Most of the health risks described are extremely small and almost always exaggerated on the basis of highly sensitive analytical methods which now permit detection of materials such as dioxins in quantities as low as parts per trillion. They are also almost never put into the context of the alternative of less or inferior or, indeed, no packaging, when food safety standards would fall with very serious consequences for health and safety of consumers. In any discussion of this subject, impartial and objective advice should always be sought.

Simplistic "solutions" should be scrutinized carefully before being adopted. Examples of this include:

Banning or taxing one-way beverage containers. This can result in a reduction of choice and increased costs to the consumer as well as (possibly) greater environmental pollution from the container manufacturing and cleaning processes.

Degradable plastics are proposed as one way of dealing with litter. This is treating a symptom not the cause, and could in fact lead to higher levels of littering as well as significant economic penalties for the package manufacturers, and inhibiting the prospects for recycling.

Where scientists do agree on a real (or high probability of a) problem, as has been the case with CFCs, action can be taken quite quickly. Even so, the commercial pressures of individual countries often pose problems in getting universal action accepted - and even more on its implementation.

On the interrelated questions of resource conservation and waste disposal, if an economic case can be made for recovering used packaging materials then this is technically possible for all materials which are currently used. Economics depend upon the cost of collection, the technical difficulty in sorting and cleaning, and the market which can be developed for the recycled products - in which they must compete freely with alternatives.

6. Social problems for developing countries

In a number of ways, packaging problems in developing countries are both more vital than in industrial nations and at the same time compounded by local conditions. Distributing safe and nutritious foods requires good quality packaging. This is one area in which development in industrialized countries can help - liquid-tight cartons are an example of a self-contained technology able to be operated anywhere in the world. The materials required, though, must have highly consistent performance and are usually produced in countries having the required standard of paper making and coating/laminating technology.

Protecting perishable products shipped for sale overseas calls for the appropriate performance standards, and for a good standard of "perceived quality" to promote sales. Farmers and packers are frequently unable to obtain the kind of packaging quality needed from local sources and often governmental restrictions prevent its import. Where packaging standards are laid down, inspection and enforcement is often patchy and always difficult.

The same problem of "perceived quality" acts against the exports of many manufactured products. In addition to the actual damage rate incurred during transit, the appearance of packaging itself frequently conveys an impression of low quality merchandise.

This is an area where government funded export boards have a major role to play - in conjunction with market development organizations and local packaging groups. Advice is available from specially qualified bodies such as the ITC in Geneva, and local packaging research institutes.

Indigenous resources of material suitable for packaging should be used where they do not detract from the quality. If these materials are suitable for simple traditional packaging forms - e.g. grass baskets or wooden crates - they should be used mainly to promote an "association with tradition" and their manufacture treated as an integral part of the export drive. It is also very feasible to combine ancient and modern, for example plastic bubble film protecting fruit inside traditional baskets.

In other instances where natural materials are converted into other forms (such as paper) this should be used as a basis for developing a modern packaging supply industry, and the product range increased to include such materials as laminated board and high performance corrugated material from which precision die cut cases can be made.

7. Economics

Packaging is always part of a larger commercial activity, and for many product manufacturers it is seen merely as an on-cost. A famous figure (Ruben Rausing - responsible for the development of the Tetra Pak system) often said "A pack should always save more than it costs". The problem is that the direct cost is easily seen but the indirect savings which it may make possible (reduced insurance, damage rates, improved margins, better reputation, lower shipping costs etc. etc.) often occur at a position removed from the point at which the packaging is purchased.

For the manufacturers of packaging also, better performance from their products improves the economic viability of their customers and so the cycle is maintained. Packaging is not only about money, but this is the only completely standard unit in which cost performance can be analysed and compared.

8. Future trends in packaging

Making prophecies is at best uncertain and at worst dangerous, but the following is a "best guess" in the light of present trends, taking into account some of the emerging influences.

Metal packaging: A major move to reduce the amount of "mixed" metal packs is likely, based on aluminium, tinplate, and tin-free steel. In the longer term one or other of these will emerge as the dominant metal; the outcome dictated by cost and recycling developments. Lighter-weight cans for processed foods, using liquid gas internal pressurizing methods will grow. Aerosol use will decline as alternative methods of dispensing products are adopted. There are many of these already available, ranging from finger pump dispensers to chemical gas generating and mechanical (spring or elastic sleeve) pressure dispensing systems. These are necessarily expensive and can be expected to find applications only for certain speciality uses.

Glass: No major breakthrough is expected and the material will consolidate its position in the high quality sectors for wines, spirits and toiletries. The parallel application as a very basic reusable container for liquid foods and drinks depends also very much upon the level of encouragement or preferential taxation it receives on "environmental" grounds. Protective sleeves are likely to become the norm for all carbonated liquids.

Paper based: Its versatility, renewable source, and scope for being recycled will ensure a strong future for paper in all its forms, especially where it is used in combination with plastics components. Liquid-tight retail packs will grow, and their use for processed and other foods will expand significantly.

The corrugated case sector will remain at the present level in total while continuing to lose quantity to shrink or stretch wrapping and to the greater use of bulk units. Gains will come from continued replacement of wooden cases and crates a· from higher volumes of smaller cases and trays for presentation packs e.g. for fresh produce, meat and fish. Paper sacks will decline, also due to greater use of bulk transport and substitution by plastics varieties.

Traditional cartons are to some extent "at risk" as they may be seen as non-essential for many food pack applications. Their growth will be a function of general prosperity - tempered by the environmental issue.

Plastics: The fastest changing sector and the only one which offers direct competition for virtually every other material. The greatest growth is likely to come from the flexible part especially for foods, as improvements in barrier, mechanical strength and heat seal quality continue to appear. These are seen as "effective use of resources" and, with the exception of the occasional demand for degradability, are not felt to be at major risk on environmental grounds.

Rigid plastics bottles and containers face a mixed future. Optimum cost performance is achieved by combinations of materials but this inhibits direct recycling; lightweight flexible sachets offer economic savings; and bag-in-box offers a semi-bulk alternative.

Wide-mouth clear plastics jars, especially in PET, are likely to replace some metal, glass and composite forms for food. They are technically suitable for a minor part of the food range but polymer and processing developments can be expected to broaden this quite quickly to include hot-fil'ed, pasteurized and oxygen sensitive foods. Polypropylene is likely to show the most sustained growth in the whole range of applications; PVC will undoubtedly suffer from the question marks over its chlorine content - with some substitution by PET although at higher cost. PET offers a very high potential indeed for food packaging - a major factor influencing this is likely to be the development of recycling programmes.

The "environmental" factor is the greatest unknown for plastics, which are singled out for disproportionate concern - largely, it would seem, on the grounds of their bright appearance and durability. It may be possible to overcome this "hostility" by helping to promote recycling operations within the industry where these are technically and economically feasible. Alternatively the use of waste plastics packaging can be exploited as a secondary fuel source in power generation. This is effectively recovering most of the energy content of the original petrochemical feedstock. With current incinerator designs there remain technical and environmental questions to the greater use of this material. Both are capable of solution but at a price which can make the operation not economically viable at present.

2. FOOD PACKAGING FOR THE 1990s

2.1 The Future of Metals in Food Packaging by F. Savrij Droste, Thomassen and Drijver - Verblifa NV

Metal in food packaging - Forecast

To have the correct data of today is already a miracle, to forecast figures for 1995 seems impossible.

Developments in the areas of materials and processing are going in an ever increasing speed. And what to say about the attitude of the consumer towards subjects as convenience, appeal and environmental issues in the coming decade. We all know what happened in the 1970s by the increasing oil and energy prices. Will there be a second oil crisis, will the global political situation alter drastically? We just do not know.

However we do use figures for the future sales of metal cans for food packing.

Heat processed foods

	1985	1990	1995
Tons of product (x 1000)	1386	1336	1269
Open top cans (x million)	4060	3929	3733

Heat processed food products include: fruit, vegetables, meat, ready meals, fish, milk products, beans, pasta and soup.

The long term structural decline in the UK canned food market is expected to continue in the coming decade.

In several segments of the heat processed food industry there will be an impact of alternative processing technologies.

Canned soup may be hit by aseptic packaging in cartons as is the case for milk products.

The meat segment, the vegetables segment, and the segments of fish and ready meals will be hit by the freezing process and by the technique of packing fresh products under modified atmosphere combined with chilling.

Quite a different picture can be shown as forecast for petfood sales.

The production of petfood and especially dog food is expected to grow considerably.

Petfood

	1985	1990	1995
Tons of product (x 1000)	1091	1418	1773
Open top cans (x million)	1893	2140	2305

Even the can sales is predicted to grow. We see incursions from other packs e.g. coextruded multilayer plastic barrier containers, especially in the high price segment of the market. Like the Sheba product which is now available in the UK market.

Another inroad can be expected by aseptic filling.

Although aseptic filling in cans is a proven process, a preference is expected for aseptically filled plastic containers.

Although the three-piece can is still around for pet food, it is expected that pet food will be a complete 2-piece show in the UK in the coming years.

Carbonated soft drinks and beer

	1985	1990	1995
Litres (x million)	4175	4815	5650
DWI cans (x million)	4120	5300	6100

The outlook for beverage cans looks prosperous.

The beverage can has a modern image, is convenient through the easy opening and is competitive in price. Because of the pressure in the can, very thin walled containers can be used. The pressure makes the thin wall can more rigid during transit.

The same principle is used for non-carbonated high-acid drinks e.g. fruit juice. By inserting liquid nitrogen in the headspace of a filled can, the pressure is increased and also the oxygen in the headspace will be removed adding to the quality of the product.

Metal can characteristics

In the lifetime of a container after leaving the can maker we can distinguish five major steps with each specific demand as regards the container:

Food processor
Distribution
Trade
Consumer
Environment

For each segment a number of characteristics can be listed, related to the product (container and content) or the process.

If we consider the relevant marketing and technical requirements and take a closer look at tinplate as a packaging material it becomes clear that tinplate fulfils most of these requirements.

Tinplate cans have remarkable assets like:

- Is gastight, no oxygen, water vapour or CO_2 can penetrate through the material
- Is impermeable for light
- No flavours can permeate through the container
- Mechanical strength (radial, axial) is high, also at higher temperatures
- Topload strength is high
- High impact strength allows rough handling
- High puncture resistance
- Temperature resistance and thermal stability are excellent
- Can is rodent and insect proven
- Simple transport possible by magnetic conveyors
- A perfect closing system by double seaming, fast and reliable
- Easy opening systems available
- Pilfer-proof closing system
- Excellent product promotion possible by high quality printing
- Versatility in size, from small portion packs to large containers

- Can oe handled and filled at high speed
- Low weight material
- Unbreakable also at low temperatures
- Environmentally acceptable
- Material can be recycled

Development of material

Following the work of Nicholas Appert in 1810 the remarkable characteristics of metal cans were recognized and the triumph march of the can started. After all those years the concept is proven, but the development work still goes on. The tinplate manufacturers have been creating materials with new characteristics.

The change from ingot or batch to continuous casting of steel improved the quality of the steel. Compared to ingot casting the general quality and the consistency in properties of continuously cast material is of a completely different level. Also the forming character of the material changes, allowing the use of beads for strengthening low gauge material.

Another important development has been the introduction of the continuous annealing process. With this thermal treatment steel can be produced with a very clean surface. Besides, better control of the different annealing parameters is possible like the temperature and the cooling speed.

Another important development is the processing of low gauge material. Although the material we use nowadays for three-piece cans is much thinner than in the past, the strength of the can has almost remained equal.

Both material specification (high temper steel) and can design made this possible. However the limit seems to be reached for a material thickness of 0.12 mm. In the coming years a thickness down to about 0.08 mm can probably be realized by the steel companies.

A container made out of that material will probably look different from the actual 3-piece cylindrical can. A trend towards a semi-rigid steel container might be underway.

At the end of the plate production line the coating and finishing processes are also subject to constant change.

The tincoating of tinplate came down to one third of the quantity of thirty years ago. Can specifications with only 1 gram of tin per square metre on one side of the can body are already realized.

Chromium coated plate (ECCS) is a further step avoiding totally the use of tin. The electrolytically coated material has a coating of only 50-70 milligrams per m^2 of chromium and of 7-35 milligrams per m^2 of chromiumoxide. It provides good corrosion protection for the steel and imparts excellent adhesion of subsequently applied organic coatings by the canmaker. Welding of ECCS plate is only possible after removal of the chromium coating by the edge cleaning process. Application of the material therefore is limited to production of ends and deepdrawn cans.

In the United States the use of ECCS for a co coating line has been announced in 1987.

Campbell Soup Company is making a significant commitment to using coilcoated steel for two piece draw-redraw soup containers.

Campbell is the first large-scale user of coilcoated steel in the food industry. Large scale means in the USA that with a 100 per cent conversion two billion of these soupcans, each year, will be produced by Campbell out of 85,600 tons of steel.

Mr. R. A. Iezzi of Campbell stated that conversion to full coil coating is only limited by how hard Campbell and his partners are willing to work together as partners - partners for the future.

The enormous investments involved in keeping up with this state-of-the-art of technology do require partnerships of steel companies, equipment manufacturers, enamel companies, converting companies and food industries.

Container development

Until about 1970 the soldered three-piece can was the standard can.

Since then other manufacturing processes and container types entered the market.

As there are:

- The deep drawn two-piece can
- The drawn and wall ironed two-piece can (DWI)
- The welded three-piece can

Two-piece cans

The two-piece can is still in its development phase.

The enormous success of the two-piece can in the beer and soft drink area showed that the design of a can effects its image. Consumer interviews in Holland learned that younger people regard the soft-drink can as sturdy, smart and young.

We also see the two-piece can advancing in the food area (Campbell) and the petfood area.

Latest developments in Europe are the triple necking to reduce the cost of the lid end and to improve the stacking of cans and the introduction of non-detach steel easy-opening lids.

The process of wallironing results in a can with a thin wall. To give you an idea, actually cans are produced with a thickness of the bottom of 0.29 mm whereas the wall has a minimum thickness of 0.085 mm. Such a can was for a short time only used for carbonated drinks as the pressure in the can causes the required firmness. As I explained earlier by adding liquid nitrogen to the can just before seaming the same principle is applied to high-acid products like fruit juice.

However it is not advised to apply this process to low-acid food products. Microbial spoilage of foods in metal containers is often characterized by swells.

Acid foods (pH 4.6 or lower) do not support the growth of Clostridium Botulinum. In underprocessing situations of low-acid foods the occurrence of swelled containers, caused by the gas produced by Clostridium Botulinum serves as a warning of potential danger to the consumer.

The application of this technology to low-acid food products would preclude the possibility of finding a swelled container that could contain Botulinum toxin.

Three-piece cans

The development in the area of three piece cans is directed towards:

- Decreasing the costprice
  less material (e.g. thin steelplate)
  cheaper material (e.g. tin-free steel)
  higher production speed
  automated production lines.

- More convenience
  easy opening systems
  single necking (stackability)

- Increasing the image
  new can shapes
  improved printing techniques
  graphic designs

Image

The image of canned heat processed food products is that of a group of colourless, static articles. The consumers in Holland think that it is risky to buy cans of unknown brands and generally they believe that the quality increases with the price of the product. The general preference is given to fresh produce or deepfrozen products. Preserved goods are regarded as lower quality.

To change the consumers perception of the product inside the container, it will be necessary to increase the design activity on the package.

The package will have to stand out from the rest. This can be achieved by the designer by using different overall colours. Or by trying to appeal with the design to the consumers lifestyle.

The Heinz company has been successful with the product called Haunted House whose fun appeal is targeted specifically at children. The unusual dark blue colour made it easily noticed by the consumer.

A feel of quality can also be given by using the base quality of tinplate. Well-known is the Lyles Golden Syrup can where the tinplate is allowed to shine through with a golden glow.

Another example in this category is a design from the Packaging Innovation Group of a Trebor mint pocket tin. It has a matt finish to simulate the denim cloth feel but allows the gloss of the tinplate to shine through for the studs.

Tinplate allows designers to produce intriguing effects through the surface finishes that are achievable with lacquers and varnishes.

But there are more techniques that the tinplate user can incorporate to build uniqueness into their design.

The use of shrink sleeves as the decorative medium can provide a better quality image than paper labelling.

Besides it is waterproof and can easily be shrunk over the end seam covering up this seam giving the can a two-piece like image.

Recycling

It is fully accepted that environmental interests have to be taken into account when dealing with packaging. We see that in the Netherlands an infrastructure has been set up for the recycling of ferrous and steel waste material. The factory scrap of the converting industry - the can makers - is recycled for almost 100 per cent. It is however not so simple to organize the recycling of cans that fall free after use as household waste.

Since about 1970 our company is actively involved in programmes concerning recycling. As most of the containers finally end in the garbage stream we concluded that the best way for recycling is to separate mechanically the cans from the waste stream.

We have to rely on technical equipment rather than upon the willingness of people to co-operate. Fortunately the magnetic properties of steel facilitate aggregation whenever domestic waste is treated in bulk.

In our country refuse is collected by the municipality and the garbage is delivered to:

1. Landfill sites

2. Composting plants

3. Incineration plants

In collaboration with our main material supplier in the Netherlands (Hoogovens) we stimulate separation of metal before composting and incineration.

After separation the cans are cleaned to remove the organic dirt. The can material is then treated in a detinning plant. The tin can be extracted and re-used as well. Cans that are burnt in an incineration plant can be extracted from the ash. The material however is contaminated with minute quantities of fused tin and can only be accepted in a limited way by the steelmakers. Ideally extraction should be carried out before incineration.

We have now reached a recycling percentage of about 45 per cent of the cans in the household waste stream. A further increase of this percentage depends above all on the willingness to invest at several governmental levels. It is estimated that this percentage will grow to about 70 per cent in 1995. Indeed a very good and encouraging result. That contributes to the strong position of metal in future food packing.

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2.2 The Future of Glass in Food Packaging by Michael Campbell, Rockware Group PLC

The only thing that is constant - is change.

This is the main theme for this presentation about the future of glass packaging in the foods markets. In looking to the future we need to be aware of the Meta and Mega Market trends - and their likely consequences for our industries.

Meta trends are important trends of change in the values and qualities of societies and organizations. Meta trends change the needs of people and therefore the marketplace.

Mega trends are significant trends of change which are measurable - by quantities, numbers of examples and so on. These are the changes of the marketplace.

The combination of Meta and Mega trends creates tomorrow's marketplace.

It is all very well to be aware of and to discuss changes and trends but the key essential is - as stated by Albert Einstein - "That for decisive people, the future is what we make out of it".

But making something out of the future often requires change and we are all too good at having reasons and excuses for not changing. Some of the more common excuses are:

"Never done it before"

"Always do it this way"

"That is far too new"

"No - too cheap"

"No - too expensive"

"Well, let's study it - then we will decide"

"Let's organize a committee"

Then there is always someone who will say - "Don't tell me what business is!"

Well, so much for our excuses against changing things - but what are the changes which are happening around us?

Firstly, a brief look at some of the major areas of meta trends (i.e. trends of change in values and qualities). One of these is that the view of the basic model of the world, of reality, is always evolving and changing - currently from a mechanistic philosophy to a view which embraces dynamism and vitalism.

In the personal field there are changes to our fears:

- Pollution, contamination;
- Disease - cancer, heart attacks, AIDS;
- Unemployment, poverty.

There are also changes to our aspirations:

- Back to nature, purity;
- New medicines and cures;
- Affluence and hedonism.

There are changes to our beliefs as well:

- Quality versus quantity;
- To participate;
- To be individual.

But with all these changes there are often contradictions as well. For example, in the economic sphere the forces for global perspectives and controls are opposed by demands for local considerations and freedoms.

In the ecology the demands for convenience in our lifestyle are often at odds with the requirements for preserving the qualities of the environment.

Within organizations there is the conflict between the needs of control and hierarchy and the aspects of flexible performance.

Within industry - especially ours - there is the contradiction of the benefits of standardization and the opportunities from innovation.

But at the end of the day - change is, and will always happen, whether we like it or not.

The second topic about change is the subject of Mega trends (i.e. the measurable, noticeable changes).

There are mega trends in all aspects of life. All we can do this morning is to briefly look at some of the main topics and points arising therefrom.

In the sociological area the trends mean that there is no longer one typical consumer; also that consumers' decisions are forced by not only their own needs but external forces as well.

In the Economic sphere there are three main paradoxes:

- Global v Local;
- Concentration v Flexibility;
- Technology v Unemployment.

The result is that the system becomes more and more de-stabilized which is both the reason and the effect of transformation.

In the ecological arena the trends are borne out of both necessity - for environmental protection - and desires for the maintenance and improvement of the environment.

There are many and varied trends in consumption. These range from quality to conspicuous consumption - from social values to convenience. The key effect is - that consumption is forced by both time and money condition and also by new values - especially attitudes and hopes and fears.

In industry there are numerous trends. In the area of product trends there is especially a polarization between basic/low cost items and innovative/added value products. There is also a general 'trading-up' and increasing market segmentation.

The next topic is Mega trends as regards their influences for packaging in glass. All areas of Mega trends do affect our business but for today's discussion I wish to concentrate on life-style Mega trends and briefly illustrate some of them before discussing their implications for packaging in glass.

One of the main trends is concern about improving health not just preventing illness. This has proved not just to be a jogging fad but a trend affecting our eating, drinking and general living habits.

The attitude to diet is not just health food and cranks but now influences all aspects of our eating.

With the pressures on time from both work and increased leisure activities there is more and more demand for convenience - microwave cooking is one example.

The trends for modernity are typified by the growth and use of computers.

The demands for quality penetrate all aspects of our lives and living standards. We want the best.

There is a growing consensus that individual actions affect - beneficially or adversely - other people and that there are good as well as bad consequences.

There is a significant increase in leisure time and leisure activities - whether voluntary or whether forced by unemployment.

For the majority of people living standards are rising. There is more money to spend and this tends to go on luxury and enjoyment.

At the same time the average size of family and house is declining - but more money is spent on both.

What we need to do is examine the resultant trends from these life-style trends as regards food consumption and retailing.

The main resultant trends in food markets:

1. HEALTH AND QUALITY - the main points are the demands for pure, clean, non-chemical, additive free products - these are seen as 'fresh', 'natural'.

2. DIET - the changes in diet have also led to demands for more 'natural' food products i.e. more fibre, less fat, less sugar, less salt and so on.

3. CONVENIENCE AND SMALLER HOUSEHOLDS - these trends can in some ways contradict the Health & Diet trends. All this does is remind us that there is no one typical consumer. These are the trends which are the driving force behind portion packs, ready-to-eat, fast food and retail shopping changes.

4. ORIGINALITY/MODERNITY, LEISURE AND AFFLUENCE - the combined effects of these trends are forcing many changes - new (often exotic) foods - more adventurous and less traditional meals. This results in product proliferation and increased competition.

5. SOCIAL RESPONSIBILITIES/VALUES - desire to protect the environment and disapproval of unnecessary waste.

So what does all this mean to us in the packaging industry? Firstly, we need to question and understand the role of packaging.

Packaging has a dual role to play:

1. A marketing role in complementing and contributing to the overall brand marketing activities aimed at the consumers awareness, perception and acceptance of a product.

2. A technical role in preserving, protecting and serving the contents.

As regards the former - good packaging contributes to or even largely creates a brand's identity and consumer perception.

The cosmetics and also drinks industries are expert at utilizing the versatility and creativity of glass packaging. There are also notable examples in the food market and this trend appears to be growing all the time.

The future is likely to bring ever increasing demands for brand appeal and differentiation.

Glass is uniquely suited to meet these demands - it still is, and will continue, to rank best overall for consumer preference. It is very versatile in its scope for presentation excellence. The ability to create brand image, identity and differentiation is enormous with glass packaging. This coupled with the quality perception and association ensure that the future marketing demands can be best met by packaging in glass.

There are also the environmental aspects of packaging. No other material comes even close to matching the current and likely future demands of the ecology in the way which glass already does.

Glass uses naturally abundant raw materials - not forest or petroleum based.

Glass is used for returnable containers. For instance if the milk bottle were to be replaced with one trip packaging - of whichever type - the country would be faced with the problem of the disposal of an additional 12,000 million pieces of rubbish every year.

Glass is recycled and without loss of material or quality and is perfectly re-usable for its original purpose. Glass does not need to be disposed of or incinerated adding to the waste management problems for society and the pollution of the environment.

As regards the technical role of packaging - glass is a technically excellent packaging material for preserving, protecting and serving its contents.

In the future, especially the next five years, there are going to be many questions asked of the packaging industry and many answers demanded. One of the main topics will be that of particle migration and chemical contamination of food and drinks from packaging materials. The background to this is new legislation to be enacted which has arisen out of the concern regarding potential health hazards from packaging materials in contact with food and drink. This subject continues to gain in importance and is being brought sharply into focus by:

- The proliferation of new packaging materials with complex chemical structures and ingredients;

- The trends for healthy, additive free, pure products;

- The demands for quality products.

Glass is the completely natural packaging material. It does not need artificial additives nor multi-layers to preserve the natural qualities of food and drink.

Nor will it require expensive and comprehensive testing to satisfy current and forthcoming legislation.

Glass packaging is a pure, natural, inert and taint-free material which satisfies the most demanding of existing and proposed standards on non-contamination of foodstuffs. One very important point is that items of glass packaging i.e. bottles, jars etc., satisfy and withstand the most rigorous of testing régimes and still exist and perform as bottles, jars etc.

Moreover, glass adds to the consumers' perception of quality, purity, taste and general good feeling about food and drinks products.

- Glass containers are considered most suitable for pure and healthy foods by twice as many consumers as for any other packaging material. (Source: Audience Selection - Adults - 1987)

- Consumers consider that the two most important attributes of a container to be that it keeps the product well and does not affect the taste.

Sixty-eight per cent of consumers think that glass containers are best for keeping products well.

Seventy-nine per cent of consumers think that glass is the best material for not affecting the taste of food and drinks.

Eighty-two per cent of consumers consider glass the best packaging material for suggesting quality. (Source: Marplan - Adults - 1987)

Perhaps this topic is best illustrated by a very successful consumer campaign in Italy. The copy reads 'It does not taste of plastic, it does not taste of metal, it does not taste of cardboard, it does not even taste of glass - it is glass.

We have said that packaging has a dual role to perform - which can be summarized as:

- Product Protection;

- Image Projection.

The demands already made upon packaging materials to satisfy these criteria are great. Though the future is likely to hold even greater requirements which will have to be faced up to and hopefully satisfied.

There is considerable activity and change within packaging materials technology with all materials striving to further improve their characteristics in the light of the two roles which packaging must perform.

The reason for this is that the perfect packaging material does not exist - yet.

We strongly believe - with justification - the glass comes closest to matching and supplying the variety of characteristics demanded.

You know, and have often been told, the many excellent characteristics of glass packaging so I will only recap them briefly:

- Consumer preference and appeal;

- Quality connotations;

- Quality, perception/low actual cost;

- Impermeable to gases, aroma and moisture;

- Impenetrable to malicious or accidental tampering;

- Clarity, resealibility;

- Taint-free;

- Excellent design flexibility - shape, colour and decoration;

- High speed filling;

- Fully processible inc. microwave;

- Strong under top load and stacking;

- Environmentally responsible - refillable and recyclable.

Also you know the one major area where we are striving for further improvement.

The most significant development for the future of glass packaging and quite possibly all packaging is the formation of the International Partners in Glass Research.

The members of IPGR are all leaders in the worldwide glass packaging industry: Rockware is the sole UK member.

IPGR was formed in response to the challenges and demands of the future marketplace. The objective is to produce container glass which is significantly stronger and lighter compared to existing packaging in glass.

The basis of the project is that glass is already very strong i.e. in its pristine state as strong as steel. Glass looses strength as it is cooled and formed hence this project is about retaining more of the inherent strength in glass. The relationship between the operating strength of a glass jar on a supermarket shelf and the intrinsic strength of glass in the furnace is in the region of a factor of three hundred times.

So you can see that there is a vast amount of scope for strength improvement in glass packaging using the existing glass material - we are not trying to invent a new material but make better use of the one we already have. To date some $5 million have been committed to the project.

Initially, universities and research associations submitted more than 100 proposals to the IPGR Technical Committee with projects which would lead to improving the strength of glass. Forty were considered to be feasible and subsequently put into action in phase one.

Phase one

Under phase one all research work was laboratory based and covered four specific areas:

- Process physics;

- Composites and coatings;

- Surface modifications;

- Tribology.

PROCESS PHYSICS: is a broad study of the production of surface defects, the effects of surface viscosity, defect healing, defect detection and process modelling.

Research is underway into the forming process - from gob formation to packaging - as a function of temperature, viscosity, glass contact with a variety of materials, and other process parameters.

A detailed model of the forming process has been developed, based on this data, allowing optimization of forming conditions, temperatures, pressures, mould designs and glass distribution in the final container.

COMPOSITES AND COATINGS: covers development of protective coatings on the glass surface to be applied as early as possible in the forming process to preserve the higher strength which has been achieved.

Sol-gels, which appear to offer good potential as protective surface coatings, are amongst the materials being evaluated.

SURFACE MODIFICATIONS: surface chemistry changes through vapour phase reactions can improve resistance to surface abrasion and damage.

Improved strength can also be achieved by ion exchange, though the process is diffusion controlled and, at normal temperatures, time consuming and expensive.

Therefore, current research is concentrating on high temperature ion exchange where the process is very much faster. Significant strength increases have been obtained in the laboratory using this technique.

TRIBOLOGY: research covers the tribological characteristics of the contact of hot glass against various metal surfaces with and without lubrication.

Elimination of mould lubrication and swabbing would have a beneficial effect on strength as well as production efficiency.

Phase two

Whilst some 14 laboratory-based research projects are still being carried out in phase one, phase two is well underway with the application of the most promising research which has been completed into the manufacturing process.

In 1987 IPGR carried out an intensive pilot plant study to evaluate the applications technology which may be functional to achieve a stronger and lighter glass container. Almost 100 experiments were carried out. The knowledge gained has shortened associated research work considerably.

Numerous in-plant feasibility studies are planned for the coming year to determine the best ways that the knowledge obtained from the basic research can be applied to glass container manufacture.

Phase three

Phase three will see the implementation of findings in a full scale glass container production plant operating as a commercial venture.

From the extensive work carried out so far we believe that IPGR's goal will come from a combination of research projects rather than one specific approach and that the resulting strength increase will be cumulative with each action.

The strength of a glass container is a function of bottle design, surface damage and wall thickness distribution. The next topic is about bottle design - in fact 3-dimensional computer-aided design.

In this area of technology Rockware has consistently led the Glass, and the rest of the Packaging Industry. Rockware's 3-D CAD system already provides the benefits of:

- Full colour container design;

- Translucency;

- Symetrical and non-symetrical design;

- Immediate full technical specification;

- Instant colour photography;

- Major time saving on design exercises.

In the future we intend to be able to offer actual label graphics in addition to the existing label panels.

So far this presentation has concentrated on the more macro topics which is right and proper when addressing such a large topic as the future

Though it is also appropriate to consider a few of the more specific areas as regards the future opportunities for packaging in glass.

For this section - as with the whole presentation - I am confining myself to the foods markets and excluding soft drinks, wines and spirits, etc.

The first area is microwave. The opportunity for microwave is immense - both in on-premise consumption outlets and for domestic usage.

Household penetration is now approximately one in five.

With the trends to convenience there is an excellent opportunity for glass packaging in this market. This is because glass provides the total packaging concept, i.e.:

- Original food pack - fully processable:

- Retail pack - high consumer appeal:

- Microwave cooking pack - 97 per cent transparent to microwave energy.

- Eat out of the pack - consumer acceptibility.

We see some of the market opportunities as these:

- Baby foods;

- Soups;

- Ethnic snacks;

- Sauces.

Rockware has considerable knowledge on this subject and together with Campden Food Research Association have fully tested this concept.

With growing microwave ownership and usage there is a real future for a total packaging concept material. Especially one which does not suffer accelerated particle migration problems whilst being processed or microwaved.

The second topic is Heat Seal Foil and again there are various benefits:

- Reduced overall packaging unit cost;

- High degree of tamper evidence;

- "Fresh" image and appeal;

- Design flexibility for glass containers.

Another topic is the design flexibility of glass in general - whether it be rounds, ovals or even square jars - and specifically table top presentation. This falls into the following categories:

- Eat out of, i.e. soups, snacks;

- Drinks out of, i.e. drinking yogurts;

- Serve out of, i.e. preserves, sauces etc.

There is going to be an increasing demand for design excellence, and bowl-shaped glass containers for the whole range of table-top products will be an important area for the future.

There will continue to be developments in secondary decoration as well. The two main areas will be pre-sleeving and also printing.

Another important future development is going to be the growing number of super and hyper markets which will be installing bottle banks in their car parks. There is considerable pressure building up not just from the EEC but from local and national UK Government as well - on this very point.

As commented before the packaging industry will cause, and see, many changes in the future.

The driving forces behind this will be the goal of totally matching the dual requirements of packaging:

- Product protection;

- Image projection.

Glass is the closest to the gold standard which packaging materials are constantly striving to reach.

Though the packaging industry must guard against foisting ever more costly, ever more chemically complex packaging compromise materials onto the market. This sort of latter day alchemy will, as always, produce at best Iron Pyrites (Fools Gold).

Glass packaging is changing to meet the needs of tomorrow and will continue to do so.

2.3 The Future of Plastics in Packaging by Dr. J. Chapman, Metal Box PLC

It was 20 years ago that Mr. Robinson advised Ben in the film "The Graduate" that the future lay in plastics. He gave good advice because plastics is considered to be the rising star of packaging and will play a major role in food packaging in the 1990s. Currently plastics packaging accounts for 20-25 per cent of the total packaging market in both Europe and the USA. Predictions from the USA suggest that by the end of the next decade plastics will have between 40 and 50 per cent of this market.

What will this mean to the food industry? There are a number of factors which have been used to explain the growth of plastics as a material for food packaging and its popularity with manufacturers, retailers and most importantly consumers over the last 30 years. These are:

- Lighter weight but with good rigidity, physical integrity and impact resistance;

- Shape flexibility;

- Quality image;

- Non-corrosive;

- Low cost.

Major businesses have been created for instance in plastics film packaging and in thin wall plastics containers for dairy products. The UK demand for thermoformed and injection-moulded containers is expected to be about 5,000 million per annum at the beginning of the next decade and over 80 per cent will be for conventional dairy foods such as yoghurts and desserts, yellow fats and cream products. Some of the factors mentioned earlier will continue to have an influence on the growth of plastics packaging for food products. However there are indicators that other factors such as advances in technology, material developments and the desire for convenience will help to enhance the position of plastics as a food packaging material.

During the '80s there have been large scale investments in high technology plastics developments coming out of Japan, USA and Europe which are now just becoming commercial.

To match these high tech developments, resin suppliers are also making increased investments in two areas.

(1) Increased volume production of existing commodity polymers;

(2) Development of new special materials with improved properties such as gas and moisture barrier, higher temperature resistance and clarity.

Both of these areas can be profitable to resin suppliers in different ways. Many packaging resins are low cost commodity resins and significant increases in output volume can improve returns. Extensions into speciality markets can lead to increased profits because these resins are often value added products.

Convenience has become the "buzz" word of the 80s in food packaging and will continue to be so. A number of reasons has been put to explain this phenomenon. An American opinion is that there are demographic ones such as:

- Aging population;
- Smaller households;
- Working women;
- Two income families.

The microwave oven has become the symbol of this need for convenience. If we look at current and projected sales of microwave ovens worldwide, we will see that containers will have to be "microwave friendly" and have a quality image to serve this potentially enormous convenience market.

Percentage of households with microwave ovens

	1986/87	1990 predicted
USA	55-60%	75-80%
UK	25-30%	50%
Japan	60%	75-80%

Currently the plastics container is perceived by the consumer as such a package. Most of this business is in the frozen and, to a lesser extent, chilled food markets. However, shelf stable products will be an important part of this microwavable convenience market in the future.

The main objective of this paper is to review some of these high tech developments in plastics packaging which will have a major impact on packaging of food in the 1990s.

Three topics to highlight this revolution that is currently taking place:

(1) High barrier multilayer laminate containers;

(2) Polyester containers;

(3) High barrier multilayer bottles and jars.

(1) High barrier multilayer laminate containers

A review of the typical requirements for this type of packaging for food shows that the essencial ones are:

- Safety;
- Prevention of oxygen ingress;
- Prevention of moisture ingress/egress;
- Temperature stability in range 100-130°C if used in retortable applications;
- Compliance with relevant food contact legislation;
- Rigidity and structural integrity;
- Cost effectiveness.

No single polymer is able to meet these requirements cost effectively and so it is therefore normally necessary to employ materials in a laminate structure. Each material contributes towards the total property spectrum in an economic way. Typically such a structure would combine a commodity polymer - polystyrene, polyethylene or polypropylene - as the skin layers adhesively bonded to a barrier material. The resulting laminate could have 5, 6 or even 7 layers in its structure and some manufacturers have the technology to incorporate recycle layers.

Most of the container systems are thermoformed from high barrier multilayer co-extruded sheet. The only exception being the Omni-Can from American National Can which is made by a co-injection moulding process.

The concept of the "plastics" can has been around for about ten years. Originally it was considered to be a direct metal replacement but it is now accepted that heat processable barrier plastics containers will also find their own markets. These include quality products for convenience ready meals and snack food, pates, quality desserts and premium petfood.

A large number of companies are involved in this particular development and a few systems are commercially available. The following list is by no means complete but it indicates the growing interest from the major food and packaging companies of the world in this type of packaging:

(a) Benedict: compartmented trays for ready meals from 4P in Federal Republic of Germany;

(b) Hormel: snack meals in Omni-Can from American National Can in USA;

(c) Sheba: quality petfood in small pots from Metal Box's Lamipac System in UK;

(d) Dial's Lunch Bucket: snack meals in tubs from DRG Plastics in USA

Many other systems are on test markets including:

(i) Campbell's "Cookbook Classics": soups in bowls;

(ii) Hormel's "Top Shelf": meals in trays;

(iii) Del Monte's "Vegetable Classics": quality vegetables in trays.

In the past two years these barrier container systems have begun to be sold in increasingly large numbers in the Federal Republic of Germany, UK and the USA. In excess of 100 million containers per annum are currently being sold in Europe and 500 million containers per annum in the USA. Sales projections for the USA are that by 1991 barrier plastics containers will account for 4-5 billion sales and in 1995 out of a total market of pre-formed containers of 170 billion, 27 billion will be barrier plastics containers. Meanwhile in Europe by 1991 sales figures for barrier plastics containers could be in excess of 1 billion per annum.

To achieve long shelf lives of 6 to 24 months the commonly used barrier polymers are PVdC and EVOH. It is unlikely that a new thermoplastic barrier material will be developed in the next few years which approaches PVdC or EVOH in terms of barrier/unit thickness and cost effectiveness. One area of materials development which may have an impact is advances in resin technology to produce a single material. This may be a new high barrier grade of polyester, polyamide, polycarbonate or some of the other engineering resins being developed which could give an adequate shelf-life of 3-6 months for some products. The bonus would be to achieve clarity and increased heat resistance over polypropylene laminates which are currently used for retort applications. It is expected that these materials will be more expensive than barrier laminates but will find their own niche markets.

Finally, the barrier plastics container systems can be used in many food packaging applications which could open up new market opportunities.

These include:

(1) Aseptic filling, especially with developments in particulates;

(2) Pasteurisable and hot-fill products;

(3) Processed foods retorted at temperatures up to 121°C for convenience and quality products;

(4) Modified Atmospheric Packaging and Controlled Atmospheric Packaging applications to extend the refrigerated shelf-life to preserve product moisture, colour, flavour and texture.

(2) Polyester containers

Polyester is a material which is predicted to be a major packaging resins for food products in the 1990s following its success in the beverage market over the last 10 years.

There now exists a frozen and chilled market which is mainly using crystallized polyethylene terephthalate (CPET) trays for ready meals. Current projections for consumption of PET resins for trays in W. Europe is for a twenty-fold increase in the next 10 years. This market in the USA which is currently around 250 million trays per annum is expected to reach 2 billion in 1992. The main advantage put forward for using CPET is its dual ovenability and grades of PET have been developed for use over the temperature range -40°C to 230°C. Even this range is not large enough for some resin manufacturers who are working on polyester developments to increase the maximum temperature up to 260°C.

With these developments to improve temperature resistance of PET and other polyesters alongside barrier improvements it will be possible to produce containers with good hot fill and in-pack processing potential as well as being suitable for dry products. Shelf stable foods such as mincemeat, quality fruits in jelly and nuts are examples of the up-market products beginning to appear in PET containers. Without doubt polyester will feature strongly as a major packaging material in the 1990s offering the consumer the choice that plastics is able to deliver.

(3) High barrier multilayer bottles and jars

Similar in materials construction to the barrier thermoformed containers discussed earlier are barrier bottles and jars. These are manufactured by blow moulding either from co-injection techniques or from co-extruded multilayer structures. Polyethylene and polypropylene, when heat resistance for hot filling up to 95°C is necessary, are commonly used polymers with EVOH providing the barrier. Similar technical requirements are also needed as those described earlier for barrier thermoformed containers.

American Can's Gamma bottle and Metal Box's Lamicon bottle were among the first into the "squeezable" plastics market. Over the last few years we have seen these bottles being used as a glass replacement. High quality ketchups, sauces and mustards were some of the first products to be sold in these bottles. Now salad creams, dressings and mayonnaise products are moving into them. A major reason for the growth of this packaging system is that the consumer sees it as convenient to use, easy to handle, hygenic, not wasteful, easy to keep clean and safe. The first hurdle of a technology development being successfully transferred into commercial production has been completed and the high performance squeezable barrier plastics bottle and jar are firmly on the shelf as a food package for the 1990s.

This paper has dealt with some major developments in plastics packaging which are beginning to be accepted in the market place today and by the 1990s will be well established high output systems. I have not attempted to cover the use of laminates of plastics with paper or metal, but there will no doubt be advances in these technologies to provide a wide array of cartons, trays, films, bags and pots for every type of food.

In conclusion these high performance systems will allow the food processor the opportunity to introduce new high quality products which bring added value in packages which are part of the fastest growing packaging markets and have considerable consumer appeal. The future of any packaging system has to be compatible with the advances being made in food processing technology and retailing. Plastics packaging will respond to these challenges because of its flexibility and versatility.

* * * * *

2.4 The Future of Paper/Board in Food Packaging by P. Harrison, Waddington's Cartons Ltd.

The Paper and Board Mills Contribution

Firstly we should examine the areas which are likely to change in the manufacture of paper and board.

Furnish and Forming. There is unlikely to be much major change in the furnish used other than the possible addition of synthetic fibres. The ecologists will push for more recycled fibre to be used, but for food packaging this is unlikely to expand other than possibly in the dry foods area where migration is not a major problem. Taint however, can still occur even with dry foods so care will have to be exercised. Recycling is much more prevalent on the continent than in the UK with ratios quoted of 68 per cent Duplex 32 per cent Chipboard in this country against Germany's 65 per cent Chipboard 35 per cent Duplex.

There is unlikely to be a success story in this century with regard to dry forming however desirable this may be from an energy saving point of view.

There has been a major change to thermo mechanical pulps in the Duplex area and C.T.M.P which is the chemically treated version are now widely used.

The manning levels have been drastically reduced by the introduction of automation of on line checking and control.

Speeding up of rate of drainage at the former stage and better drying has given rise to economies which can be passed onto the converters usually in the form of smaller price increases.

Here again there is not a lot of milk left in the coconut.

Coating. The coating technology is well advanced to give a very smooth surface with good hold out of oil based, U.V. cured and aqueous inks and varnishes. Blade coating, multiple coating and burnishing all help to give better surfaces resulting in better print definition and higher gloss levels. This also permits much improved gravure print performance.

Quality. The improvements made in forming and coating give rise to a more consistent quality with tighter tolerances being possible. Automation of the controls in the mills also lead to smaller variations in the properties of the finished products. Some checks such as coating weight, substance, thickness and moisture content can be monitored continuously and automatically throughout production.

This enables trends to be identified before they become a problem.

One property which is important to the food packer is board stiffness for this determines the lowest weight of board which can be used for a particular carton.

It is hoped that the UK carton industry will change from specifying board thickness to weight for the converters buy at £X per tonne and sells by area i.e.: number of cartons. This means that the cost is solely related to weight per unit area. Thickness is important to indicate stiffness of a particular grade of board once the weight is specified.

Barriers. The existing barrier materials are likely to continue at their present level in the water repellant, grease resistant, milk or lactic acid resistance and release properties. Sizing of the surface and throughout the furnish is likely to remain especially for the frozen food applications.

Extrusion coating with polyethylenes in high and low density forms, polypropylene, ethylene vinyl acetate copolymers, other copolymers and polyethylene terephehalates to give product resistance, barrier properties, heat sealability and heat resistance are probably remaining as the ideal means of providing product protection.

An alternative method of providing this type of protection would be lamination with single or multilayer films.

The latter films can be tailor made to give gas barrier or controlled transmission to provide ideal conditions within the package.

These methods of production of protective laminates apply equally to paper or board packaging and are used extensively in 'Bag in Box' Systems.

The Converters Contribution

Decorative Effects. The most striking effects produced on paper or board are via lamination of metal foil, metallized films or decorated films. The two former laminates also provide good barrier properties. Lamination is carried out via adhesives or extrusion coating techniques which again can provide additional barrier properties.

Other decorative effects which are not yet generally financially viable are hot blocking foils carrying printed patterns or holograms. Direct metallizing could prove to be a practical proposition within the next few years.

Gloss waxing is a process which has never been promoted as it has in the USA. Some of this is due to the deterioration of the surface finish on shrink wrapping and the ease of surface marking. This is unlikely to change dramatically in the foreseeable future.

Printing Processes. Further attempts to decorate make use of the printing processes which have made rapid progress over the last few years in speed and drying rates.

The advent of 'Just in Time' means that much of this emphasis on high throughput could be reversed for more frequent short runs are being demanded to cut down inventory. This is making the time when the press is non productive a much more important factor in costs. The pre press make ready is thus having a very marked influence on the ability to convert economically.

The inks are giving much better dot reproduction and the drying techniques of I.R., U.V., E.B. and accelerated drying of water based inks means faster speeds with good print quality results.

Varnishes using identical drying techniques and similar chemical formulae mean the high gloss can be achieved at speed which is tending to make the slower roller coating methods obsolete.

Varnishes are available with high gloss, mat finish, heat sealability, heat resistance, product resistance, water repellency and controlled slip. These can be printed to give areas without varnish to make gluing easier to accomplish.

Gluing. The changes in this process are the ability to spot glue at speed with aqueous and hot melt adhesives. There will no doubt be improvements in the next few years in this area of production.

Paper

On the purely paper front it is likely that direct or transfer metallizing will become a viable proposition to replace full laminates.

Improved stability to enable more accurate sizes and flatter labels to be produced should be achievable.

Paper/Plastics Composites

The area of plastic/paper composites may be covered elsewhere but will still be an important usage of paper/board in the 1990s.

Board is a useful means of supporting flimsy plastic containers or alternatively will allow weight reduction of plastic component. Similarly paper labels provide strengthening of side walls of bottles and pots. These systems will continue to be used for food packaging.

Plastic trays, plates, bowls etc., require protection in their handling, transport and storage. This is achieved by the use of cartons and overwraps produced from paper based materials. The greater use of high speed packing lines will require the continued use of these packages. The higher incidence of multiple packs will continue thus collation using board based combination systems will be necessary.

The need for dual ovenable packages has produced the C.P.E.T. tray but the P.E.T. extrusion coated board tray system continues to have a position in the market. Nevertheless the market acceptance of paper based package use in conventional ovens is rather poor thus a slow growth of this type of container is expected. The use of the same system with H.D.P.E. or P.P. extrusion coated trays in microwave only applications is likely to grow.

Controlled atmosphere packaging tends to be limited to the plastics packaging area, but bag in box applications have a major position in the market place and with good barrier liners could have a greater impact within the next few years. Lidded laminated board trays could also make some impact in this market with improved sealing techniques.

Paper based aseptic packs are occupying a major place in the dairy industry and will continue to do so on their lower cost basis. Similarly paper based extrusion coated pots and tubs could take a larger share of the market now committed to plastics.

Packaging Systems

There has been a rapid increase in packaging machinery speeds which is now levelling off but this demand for automation and high throughput at high efficiency puts much pressure on the packaging materials.

The requirement will become greater for the converter to provide a Packaging Engineering service which gives a total machinery/carton erecting/filling/ closing system.

The Food Manufacturers Contribution

Food Processing. Irradiation of foodstuffs will become more acceptable to the public when the word 'irradiation' loses its fearful meaning. The products thus processed can be packaged satisfactorily in paper based packages. The food can be preprocessed or treated in the package.

Aseptic packaging has already been mentioned where both contents and packaging material can be treated to give fully aseptic packs.

Controlled and modified atmosphere packaging has also been covered earlier when paper based systems can be a satisfactory solution to the storage needs.

Vacuum packaging is likely to remain in the flexible packaging area but cartons as an outer protection is a most suitable answer to the problem of pack stability.

Frozen foods will continue to be a large proportion of the sales of convenience foods where cartons are an ideal means of display, storage and transport.

Demographics

The trend towards an older population means that in the 1990s the elderly will become a larger proportion of the food packaging market.

More women are going out to work and are therefore not 'slaving over a hot stove'. This results in a higher disposable income which allows her to pay more for food which is preprepared.

Shorter working hours allows for greater leisure interest for all the family. The result is that each member of the family is likely to eat at different times. This in turn means fewer formal family meals when all sit down to eat together.

There is an increase in the number of single and two person families. All of these factors lead to a greater reliance on convenience foods requiring little or no preparation and which can be heated or cooked quickly. This means a need for smaller volume packs of food requiring heating only.

Overseas travel is more prevalent and will continue to be popular, thus creating an interest in more adventurous foods.

Health awareness is more noticeable thus vegetarian, additive free, balanced diet foods are becoming more popular such that separate compartments in the Store Freezers are being devoted to these products.

The ownership of freezers is very extensive at present and that of microwave ovens is increasing rapidly so that frozen foods are available in a very extensive range and the incidence of microwave only foods will expand rapidly.

The Cooking Processes

Conventional Ovens. The conventional cooking operation requires a resistance to temperatures in excess of 200°C for periods of 30 minutes or more. The only commercially viable materials at present are crystaline polyester plastics and board extrusion coated with polyester. It may be that during the next decade alternative heat resistant polymers may become more cost effective and could then replace polyester. Alternatively the polyesters themselves may be able to be produced in a more heat resist ~t form.

Customer acceptance of in-package cooking is: foil trays are very popular, plastics a poor second with paper based having a great deal of suspicion as to their suitability. Almost the opposite view is present with regard to microwave cooking where people are quite fearful of the use of foil trays.

The ability to eat from the package in which the food is cooked is seen to be an advantage especially if it is then disposable.

Microwave Oven

Microwave heating and cooking is an expanding area of food preparation.

The texture of microwaved foods is different from that cooked in a conventional oven therefore the trend is to try to produce a similar effect by both routes. Formulation of the foods can result in a close approximation in appearance, taste and texture by conventional and microwave cooking but there is a need to produce a crisp and browned surface on many products other than by a secondary heating process such as grill or in a combination oven. The use of 'Receptors' can achieve this effect in many instances by heating locally to much higher temperatures than those achieved by microwaving alone. Again specially formulated products are often necessary to produce this effect.

There is a great likelihood of the food processor cooking the foodstuffs in the package in which it is to be sold especially with the introduction of more microwave cooking facilities. The packages will then only need to be collated, lidded and/or closed and are then ready for despatch.

Safety

There will be legislation introduction within the next few years aimed at controlling the migration from paper based packaging into foodstuffs. This will cover the basic furnish, coatings, treatments, extrusions, laminates, waxes etc. We may therefore be required to introduce intermediate overwrapping of the foodstuffs to prevent direct contact with some of the surfaces involved. Until the legislation or extraction work is completed the impact on packaging will not be known for certain.

Certification

With the introduction of BS 5750 and the I.S.O. 9,000 series, packaging suppliers will be required to certify the quality of their products. This means giving assurance that the specification is being met. Systems will therefore be introduced by converters wh h will give this information in a suitable format for presentation to the customer.

Summary

1. Paper/Board Packaging will remain a relatively cheap form of protection of foods.

2. Packaging enables the foodstuffs to be transported safely from the place of manufacture to the final customer so its future is assured.

3. Graphics requirements will continue to push packaging towards paper-based systems which are able to reproduce the required effects faithfully.

4. Product resistance can be afforded to the packaging by surface treatments applied in line with the paper/board production or via a separate operation and will continue to be so.

5. Barrier properties are imparted by extrusion coating, lamination or surface treatments. These should be improved by development of new polymers and resins and lower costs ought to result from increased production.

6. Liquid packaging will continue to predominate in paper-based systems particularly in the dairy and fruit juice industries.

7. The market for convenience foods will increase resulting in higher demands for reheatable and cook-in-the-pack products.

8. The market for multipaks will increase, demanding more collation systems many of which will be paper based.

9. Packaging systems with associated cartons will continue to grow in line with the demand for automation and higher line speeds.

10. The quality assurance and safety assurance on packaging will become of greater importance over the next few years.

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2.5 Future Legislation for Food Packaging Materials by D.W. Shorten, BP Chemicals (Suisse) SA.

1. Introduction

The basic principle for any legislation today, or in the future, must be the same; the packaging must not contaminate the foodstuff in any way which could cause it to be a danger to the health of the consumer. The interpretation of this basic ideal has varied from country to country, and without doubt the requirements to be met are becoming more stringent every year.

The future legislation discussed in this paper is mainly concerned with that which is likely to come from the EEC and Council of Europe; this legislation has been discussed for many years but I think we can all anticipate with confidence that it will be with us by the 1990s.

Although the title of this paper does not state any specific type of packaging, all that follows is concerned with plastics materials on which EEC and COE have concentrated their efforts so far. It is highly likely that other packaging materials will in the 1990s have requirements, e.g., limits of migration and heavy metals content, etc., similar to those now being finalized for plastics.

2. Plastics packaging materials for foodstuffs - today

Before discussing what is likely to be the situation in the 1990s, it is necessary to briefly review the situation today.

When discussing food contact requirements anywhere in the world, the F&DA regulations of the USA are probably the most well-known. Some fifteen years ago the only criteria which mattered to a plastics raw material supplier, convertor or food packager was that the packaging in contact with the food met the requirements of the F&DA regulations. How times have changed, especially in Europe.

In Europe now we have a maze of national requirements in the form of legislation, codes of practice and recommendations. Unfortunately, the compilers of these requirements did not always use the same toxicologists for advice: but probably more important is the fact that different systems of control were developed in each country. It is not within the remit of this paper to discuss these differing requirements in European countries, but it must be said that the present situation is most difficult for an international company, and for any company whose products have to cross European country frontiers. An example of this difficulty is that if a company wishes to use a new monomer or additive in the manufacture of a plastics food packaging material, up to nine submissions to European countries would have to be made. With the speed of response from countries varying from one month to three years, even though they were all supplied with the same toxicological and technical data, it can be clearly seen that to promote a new product for sale in Europe is generally a costly and time-consuming exercise.

3. Probable legislation for food packaging materials in the 1990s

3.1 Because of the confused situation in Europe, the EEC and COE embarked on harmonization exercises, rather more years ago than most of us like to remember. The EEC are required to harmonize national requirements under Article 100 of the Treaty of Rome, and in 1973 the EEC Council adopted a resolution asking the Commission to initiate such a programme of work. As an EEC directive is mandatory on member states, legislation has to be enacted in each country within a stated time period, 2-3 years.

The COE covers more countries in Europe, but its proposals are non-mandatory. Initially it appeared that the COE and EEC worked completely independently, but there are good signs now that they are co-operating with each other. The COE have produced two editions of their document on food contact plastics, but it did not have the same effect on the plastics and food industries in every European country, mainly because of its non-mandatory status.

3.2 The EEC proposal

The EEC Commission DG III, under the Chairmanship of Dr. L. Rossi, was set up with the objective of harmonizing existing national requirements in respect of materials and articles intended for usage in contact with foodstuffs.

After the Framework Directive of 1973, the next important council directive (82/711/EEC) appeared, this detailing the plastics materials referred to in the Framework Directive (76/893/EEC). In 1985, the Classification of Foodstuffs Directive appeared (85/572/EEC).

This directive clearly defines the four food simulants:

- Distilled water;
- Three per cent (W/V) acetic acid in an aqueous solution;
- Fifteen per cent (V/V) ethanol in an aqueous solution;
- Rectified olive oil or sunflower oil or mixture of synthetic triglycerides

and which should be used for each foodstuff, together with "reduction factors" that can be applied.

Clearly, this is migration into the food simulant and thus the migration into the foodstuffs theoretically can be calculated.

"Reduction factors" were allocated as migration of a constituent from a plastics material into a foodstuff simulant is usually higher than into the actual foodstuff itself.

This specific directive opened the door again for the arguments on total (overall) migration, which some consider to have no toxicological or technical significance in respect of safety of foodstuffs, but is a useful politician's/regulator's safety net. The migration limit figure of 60 ppm (or 10 mg/dm^2) is still provoking argument.

However, the most important work by EEC Commission DG III has been the compilation of positive lists:

(a) For monomers and other starting materials;

(b) For additives;

(c) For polymerization/processing aids

and the present situation on these is:

(a) Draft Positive List of Monomers and Other Starting Materials

This consists of a list of all monomers and other starting materials that member states considered could be used in the manufacture of a plastics material intended for use in contact with foodstuffs. Each substance is identified by a C.A.S. (Chemical Abstracts Service) Registry No., and is allocated an EEC classification. Some substances are classified provisionally. The provisional classification means that the substance is approved for a certain number of years (probably five) and then a new decision will be taken. This provisional classification has caused some misunderstanding amongst users of plastics materials (i.e., the food packers) who started to request that only monomers fully approved be used. If this was enforced, it would eliminate many conventional and well established plastics packaging materials from the market place. The question must be asked, why are they denoted provisional?

The answer to this question stems from the deliberations of the Scientific Committee for Food

(SCF), which is a body of toxicologists appointed as advisors to the EEC.

The Draft Positive List of Monomers was submitted to the SCF and all supporting available toxicological data (not much with quite a number of monomers) was sent by national authorities and industry. After several meetings the SCF produced their verdicts, allocating each substance to a list O-IX, the real significance of which is that a material having a classification SCF VI, VII, VIII or IX is only provisionally approved.

The work on this Monomers List was completed at the EEC, and the first publication of this list in the Official Journal was in 1988, and it contains a large number of provisionally approved monomers.

The provisional approval in most cases is stated to be due to a lack of toxicological data and it is requested that more testing be carried out. A possible relaxation of this requirement for toxicological testing is that it has been indicated that the criteria for setting these priorities should include data on exposure, e.g. usage and extent of migration, availability of analytical methods, the toxicological and biochemical profile and consideration of chemical structure in relation to toxicity. Over the last two years, a multi-client study at PIRA has shown well the small amounts of residual monomers in a number of well-known food contact plastics manufactured from monomers provisionally approved at present, and further that specific migration of these residual monomers into the four specified food simulants is very low or non-detectable. It is optimistically forecast that this PIRA study, which is continuing, will enable many monomers to get full approval status.

(b) Draft Positive List for Additives

Additives are being dealt with in exactly the same manner as the monomers and, although SCF have considered most of them and given their verdicts, it is not anticipated that the final publication will occur until the end of 1988 or early 1989. Again, there will be a large number of additives provisionally approved, but it is hoped that the PIRA project on migration into the four EEC food simulants will improve the situation as with the monomers.

(c) Draft Positive List of Processing Aids

The EEC have not started on this yet, but the COE have given consideration to a first draft prepared by the UK. It is too early yet to speculate exactly the form this positive list will take, or indeed precisely what detailed information it will contain. Without doubt, the drawing up of a positive list of processing aids - which includes catalysts, PH regulators, chain stoppers, chain transfer agents, cross-linking agents, initiators, etc. - will be very difficult.

The good news on this item is that the EEC will probably take any COE proposal as the basis for a future directive.

OVERALL MIGRATION INTO EEC SPECIFIED FOOD SIMULANTS

As this subject has provoked more discussions and arguments than any other within EEC DG III and member states, and much misunderstanding, perhaps a few words are appropriate here.

It has been proposed that plastic materials and articles shall not transfer their constituents to foodstuffs in quantities exceeding 10 milligrams of substance(s) per square decimeter of surface area of material or article (mg/dm^2). However, the limit is 60 milligrams of substance(s) released per kilogram of foodstuff (mg/kg) in the following cases:

(a) Containers, or articles which are comparable to containers, or which can be filled, with a capacity of not less than 500 ml and not more than 10 litres;

(b) Articles which can be filled and for which it is impracticable to estimate the surface area which is in contact with foodstuff.

To get from the 10 mg/dm^2 of surface area to the 60 ppm in the foodstuff, the "conventional" factor of six is used. However, the 500 ml figure in (a) above is not unanimously accepted yet, and an agreement may only come if this is reduced to 250 ml.

There are two important issues:

(1) Why do the test if it is not of toxicological or technical significance?

(2) Test methods.

The answer to (1) is that overall migration gives an indication of safety of the final product in contact with the foodstuff, provided monomers and additives used in the manufacture of the final product are approved. Further, in most cases, it eliminates the necessity to carry out specific migration testing for every constituent - monomers, additives (and possibly processing aids).

Hopefully, PIRA will resolve issue (2), with the round robin inter-laboratory study that they are carrying out on behalf of MAFF.

4. Council of Europe (COE)

4.1 Coloured plastics for food contact

A proposal from COE, produced by the UK in collaboration with ACEM (international group of plastics and pigments manufacturers) is at an advanced state and it is understood that the EEC will consider this proposal for a future specific directive.

The proposal is based on the principles of purity of colourants and lack of migration from the coloured plastics into food simulants. It specifically differentiates between the requirements for the colourant and those for the coloured plastics, and provides full test methods.

5. What will the legislation actually consist of in the 1990s

Each member state of the EEC must enact legislation within the stated period of time in accord with the directives. The responsibility for and systems of control is left to each member state.

As all the specific directives are unlikely to be published at the same time, enactment of legislation will probably take place in stages.

However, we can postulate that in the 1990s legislation on plastics will consist of:

(1) Positive lists of monomers, from which the plastics material may be manufactured (of interest mainly to the polymer manufacturer);

(2) Positive lists of additives (of interest to polymer manufactuers, convertors and additives suppliers);

(3) Positive list of processing aids (of interest mainly to polymer manufacturers);

(4) Overall migration limit into food simulants. This limit will apply to the finished product in the state in which it will actually contact the food.

Undoubtedly, this will be of interest to all in the chain, polymer manufacturer - convertor - food packager - food retailer.

Exactly how the responsibility for complying with the overall migration limit and how this will be controlled is still being discussed and doubtless will provoke some questions/comments at the end of this paper.

Additionally, some countries may put test methods within their legislation.

Exactly how legislation on coloured plastics, and other subjects under discussion, e.g., plastics for micro-wave oven usage, will be dealt with is not known.

6. Conclusions

Plastics are already the most regulated packaging material for foodstuffs, and in the 1990s there will be further legislation, but hopefully it will be harmonized throughout Europe.

Other packaging materials will eventually be dealt with under EEC Framework Directive 76/893/EEC which essentially laid down the criteria for GMP and set the programme for future action to ensure the inertness of food contact materials.

Plastics have just been dealt with first and, with a following wind and tide in our favour, we could see all legislation on plastics enacted during the 1990s.

The timing of forthcoming EEC Directives and the subsequent enactment of legislation on other food packaging materials is of course unknown, but it will come and maybe sooner than many people think. Once agreement on plastics directives has been reached, progress on other materials could be very rapid.

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3. FUTURE INTEGRATED PROCESSING AND PACKAGE SYSTEMS

by Dr. Jeremy Selman, Deputy Head of Experimental Packaging & Processing, Campden Food Preservation Research Association

Introduction

The opportunity for the development of new products and processes is influenced by a complex interrelation of several constantly changing facets of our civilization. These include demographic changes, changes in consumer perceptions and the availability of new knowledge.

Demographic changes include factors such as the increasing employment of both spouses outside the home, the shrinking size of household units, and the proportional aging of the population as a whole. Consequently there has been phenomenal growth for prepared convenience foods such as frozen whole meals designed for microwave cooking, and growth of the food service industry such as the fast food and take-away trade. In the USA the number of one- and two-person households is increasing dramatically and is resulting in foods being packed in smaller portions, with a trend towards single serving convenience foods. The increasing proportion of older people is fostering the development and marketing of products with low sodium content and other aspects directed at the nutritional needs of the elderly.

There is a massive change in diet based on consumer perceptions regarding health and fitness, particularly when coupled with new knowledge and information. The consumer has clearly stated interest in fewer calories, less sugar, less fat, less salt, less alcohol; and more fibre, more whole grains; and more fresh fruits and vegetables. This has resulted in increased fish and poultry consumption at the expense of red meats, lower consumption of saturated fats such as butter, and increased interest in low calorie foods and drinks.

The development of new knowledge greatly influences perceptual changes. When the American Cancer Institute stated that cereals, fruits and certain vegetables have a cancer preventative role, the demand for such foods increased dramatically, particularly when the foods and products also offer sensory and variety appeal. Developments in new technologies also contribute to this, for example according to recent reports, vegetable oils may be chemically modified to become non-absorbable potentially allowing full flavour and texture, no calorie fats to be included in products.

Whatever the product types demanded by the consumer, the food preservation operations and the associated packaging permit the establishment of the high quality attributes of the foodstuffs.

Processing and packaging requirements

The appropriate combination of raw materials, preparation and processing techniques as well as packaging, storage and handling systems, is essential in ensuring the production and availability of safe high-quality products. Packaging is a key factor in influencing the integrity of the pack once the food has been prepared and processed. The requirements for such packaging may include:

(a) Prevention of microbiological and chemical contamination;

(b) Retention of product quality including nutritional values;

(c) Must be economic and safe to manufacture and distribute;

(d) The packaging itself should not contaminate the product;

(e) Must not present a hazard during the opening of the package or consumption of the product;

(f) Must fulfil marketing requirements, including display of product and brand name and other information required by law.

In addition to the global changes in requirements for foods, changes in the choice and forms of packaging have been influenced by:

(a) Cost of raw materials: reduction in raw materials; use of alternative material; recycling properties;

(b) Energy savings on production of package;

(c) Improved integrity of package; barrier properties of material; integrity of seals and seams;

(d) Developments in processing technology; desire to improve product quality;

(e) Improved efficiency of production and distribution; effect on filling and sealing speeds; weight and shape of container;

(f) Improvement in market image; attractiveness of package; visibility of product; consumer convenience;

(g) Environmental and health pressures: contamination of food by constituents of packaging material; recycling potential; biodegradability.

Developments in processing and packaging

A. In-container heat processed foods

(a) Metal cans

Tinplate and aluminium continue to be widely used for food and beverage packaging because of their mechanical strength, low toxicity, superior barrier properties, and their ability to withstand extremes of temperature. There is a trend towards the production of lighter cheaper cans, with reduced tin coating weights, increased use of aluminium, and the development of the duplex chromium/chrome oxide treated low-carbon steel known as tin free steel. Can metal thickness has been reduced, necessitating beading or profiling of bodies to withstand high internal vacua.

The thin-walled steel beverages cans and DWI (Drawn and Wall Ironed) aluminium cans have been applied to the packaging of carbonated beverages, where the pressurized product structurally supports the container after filling and cooling. Trials at the Campden Food R.A. have indicated that various fruits and vegetables could also be packaged in these types of containers under a nitrogen pressure, giving savings on container costs. Commercial use of this is likely when internal pressurization can be achieved more consistently, and when a suitable can end is developed to allow visual indication of a blown can resulting from microbial or chemical spoilage.

Integrity has been improved through developments in lacquer technology, and the welded side seam, and novel shapes and uses have been developed to meet with increasing competition from other packaging materials, for example easy open ends, the rectangular can from Carnaud with round ends to allow use of conventional double-seamers, and the redevelopment of the self-heating can.

(b) Semi-rigid plastics and laminates

In the last two to three years there has been considerable interest and significant developments in the use of retortable semi-rigid containers.

An earlier development was the Swedish Letpak which is a laminated can composed of polypropylene (PP) with a barrier layer of aluminium foil (Al). The Letpak can consists of a seamless body tube extruded from polypropylene which is overwrapped with a multilayer polypropylene-aluminium foil pre-printed web material. The pre-moulded laminated base and lid (easy-open) are welded to the body by a high frequency alternating current.

The more recently developed retortable semi-rigid plastic containers are composed of structural layers of polypropylene or polyolefin in combination with barrier layers of polyvinilidene chloride (PVdC) or ethylene vinyl alcohol (EVAL).

The Omni can produced by American can is a co-injection blow moulded container with five layers (polyolefin/tie (with dessicant)/EVOH/tie (with dessicant/polyolefin). Inclusion of the dessicant layers is necessary because EVOH absorbs water during retorting and the dessicant leaches the water out of the EVOH as the container cools, restoring its effectiveness as an oxygen barrier.

The injection moulding of the flange on the 'preform' provides the precision needed for a high integrity double seamed metal easy-open end. It is claimed that these plastic cans be filled and seamed on the same equipment used for metal cans at a rate of 400 to 500 per minute. The plastic cans offer the advantages of good stackability, are lightweight, dent free and allow a product shelf-life of up to two years.

Metal Box and Cobelplast have developed semi-rigid thermoformed containers consisting of two layers of polypropylene with a high barrier PVdC in the case of Metal Box's Lamipac containers and EVAL in those from Cobelplast. Such containers can be formed into the shape of pots or trays with a heat sealable film or lid and are retortable at temperatures up to about 121°C.

Reed Plastic Containers also have the ability to produce thermoformed containers from similar co-extruded sheets using their Hitek process which can produce deep drawn cans as well as pots and trays.

Heat sealing efficiency (so essential to the subsequent maintenance of sterility) is reduced if the sealing area is contaminated with product so it is an advantage that the container is not brim-filled before sealing, this however leads to the presence of significant headspace. Under the TOR sealing systems (patented by Metal Box) the heat sealing of the lid material (normally a plastic coated foil) takes place in a vacuum chamber so that all the air is removed from the headspace. Once sealed the lid is deformed until it is touching the meniscus of the product fill. That is the container is now air free and headspace free thus making a solid pack which is much less susceptible to heat distortion.

The thin profile of the tray system allows for rapid heating and cooling thereby saving energy and improving product quality. Foods packed in the thermoformed containers and preserved in this way can have a shelf-life at ambient storage conditions of up to two years depending on the product.

(c) Flexible containers

(i) Retort pouch - The retort pouch is made from a three-ply laminate where aluminium foil is sandwiched between an external polyester film and an internal high density polyethylene polypropylene or polypropylene-polypropylene co-polymer layer. Pouches after filling and heat sealing can be sterilized in steam/air using air overpressures to support the flexible pouch during the heating cycle.

It is now over 20 years ago since commercial exploitation of retort pouches began and although substantial development has been undertaken by several packaging manufacturers and food processors (ability to withstand retort conditions; high barrier requirements for long shelf-life: satisfactory sealing) the retort pouch has been commercially successful only in Japan apart from some specialist applications such as for military rations, and high quality, low volume products (delicate sauces, special diet items).

Further exploitation of the retort pouch failed because of slow filling speeds and the high capital investment required for filling and processing plant. In addition expensive secondary packaging is necessary to give the packaging acceptable shelf-appeal and protection.

(ii) Achilles process - This process is specifically designed for liquids such as milk. The process integrates the processing and packaging so that the packaging material does not only serve as a barrier between the milk and its environment during storage but as a barrier between the milk and the heating and cooling media. In the Achilles system plastic film is folded and fed into a trough which receives the milk. The film is sealed to form a tube and then flattened and fed through the heat sterilization zone. The tube is also surrounded by water and the system forms a moving heat exchanger through which heat first sterilizes the milk and is then removed by the water. The liquid runs 10 times faster than the tube which is why the full name of the process is 'Achilles and the Tortoise'. After leaving the heat treatment zone the milk enters a device in which the tube is first blown up by the arriving milk and then sealed transversely and cut into separate packages.

The claimed advantages of the Achilles system have been summarized as follows:

(a) Improved taste;

(b) No fouling of the heating surface as it is continuously replaced;

(c) No chemicals for pack sterilization;

(d) No presterilization required;

(e) No waiting or cleaning before or after processing;

(f) Versatile system for pack size.

(iii) Multitherm process - This process is intended for solid food materials where it is much more difficult to achieve a HTST treatment than for milk and other fluids due to the fact that conduction heating cannot heat solid food fast enough.

Multitherm is based on form-fill-seal packaging technology. The packaging material is supplied from a reel, formed, filled and vacuum sealed. The process utilizes conventional and microwave heating to ensure even temperature distribution. The pre-heating with conventional methods is done to a temperature of 80°C which the food can withstand for some minutes without degrading followed by rapid surface cooling to 40°C so that the surface temperature is similar to that of the centre. This is followed by microwave heating in water (127°C, 0.5 to one minute) followed by cooling and drying the sterile packages. As the sterilization runs at around 139°C a large overpressure is needed in the microwave section. This is achieved by use of hydrostatic column in series. Such columns alternating with air columns are arranged in the pre-heating section to build up the overpressure step by step and in the cooling sections to bring the pressure down again in the same way. The multitherm process provides an opportunity to reduce the sterilization time compared to other pouch or canning processes. Such a process should provide shelf-stable packs at ambient temperatures having a less 'cooked flavour' to conventional sterilized foods and the quality of some foods tested have been claimed to be comparable to deep frozen food.

However, the first products to be produced commercially using a multitherm system are reported to be pasteurized products which will be distributed and retailed under chill conditions.

B. Aseptic technology

This is a method of food preservation which involves separate sterilization of the food and the packaging material prior to the food being filled aseptically into the package under commercially sterile conditions (figure 1, table 1). Attention was first focused on this technology with the commercialization of the James Dole aseptic canning plant. However the relatively high costs of the metal cans inhibited wide acceptance of the technology. Nevertheless, aseptically canned products are still the base for commercially successful operations (e.g. white sauce, custard, ice-cream mix). However more recently the development of monofilm and co-extruded plastics together with laminated packaging materials has led to a capability in producing a range of aseptically packaged foods and drinks in flexible bags and pouches and semi-rigid pots and cartons at economic costs (see table 2, figure 2).

The impact which aseptic packaging has had on the market for fruit juices and certain dairy products is now well known while within the last year the commercial launch of non-dairy low-acid foods has occurred with the introduction of soups in Combiblocs and Tetrabriks. There is now considerable interest in extending the range of low-acid foods including the manufacture of particulate products. The Campden Food Preservation Research Association has recently published a set of Good Manufacturing Practice Guidelines for the Processing and Aseptic Packaging of Low Acid Foods Part 1. Principles of Design, Installation and

Commissioning. This first part is essentially a management document while the second part which is currently in preparation will deal with the methods for assessing performance of the heat processing, aseptic filling and packaging operations.

Aseptic packaging linked with UHT processing was originally seen as a means of improving the quality of heat processed foods and enabling some heat labile foods (custard, rice-pudding) to be preserved and stored at ambient temperatures. Whilst this may still be true much more emphasis is now given to the economics of the operation and the need to modernize the image of heat processed foods.

The potential advantages of UHT processing and aseptic packaging over in-container sterilization can be summarized as follows:

(i) Reduced heat denaturation during HTST process;

(ii) Reduced energy cost during sterilization;

(iii) Allows flexibility in packaging, cheaper containers;

(iv) Quality no longer is dependent on package size;

(v) Versatility of package, small pots to bag-in-box to tankers.

The dream of many food processors is to be able to purchase high quality low cost commodities from all over the world or to store them from different harvest periods and then blend them aseptically with perhaps the addition of high quality HTST processed sauce into a range of retail or catering size containers.

While further developments in the technology are required the above is looking feasible with the use of bag-in-box aseptic packaging and aseptic repacking into cartons, pots and pouches (see table 1).

C. Frozen and chilled foods

Frozen foods we understand as those which are cooled to sub-zero temperatures and held at around -29°C in primary and secondary stores and which are recommended for retailing at -18°C. Chilled foods on the other hand are perhaps less well defined but I would advocate that the definition used in the IFST Guidelines for Chilled Foods is adopted. That is chilled foods are those which are recommended for distribution between -1°C and +8°C.

Advances in the packaging of chilled and frozen foods have largely emanated from developments in plastic technology, particularly co-extrusion and thermoforming developments. These processes have resulted in a much wider product range with modified barrier properties to suit particular requirements. For example the Cryovac super L3 bag offers good clarity but a high moisture barrier, thus eliminating dehydration and weight loss of frozen meat.

Within frozen and chilled foods the main growth area has been in value added or convenience foods especially the ready-meal sector. This applies both in the retail and catering sectors of the food industry with the adoption of cook-freeze and cook-chill operations.

The increased demand for convenience foods has also corresponded with the substantial increase in the use of domestic microwave ovens with approximately 25 per cent of households in the UK owning microwaves in 1986 rising to 50 per cent in 1990.

The packaging materials commonly used for chilled and frozen foods appear to fall into three categories:

(a) Foil containers - These have many advantages and perhaps represent the traditional means of packaging both chilled and frozen-ready meals. They are available in an almost endless variety of shapes and sizes with embossed ribs giving additional rigidity if required. Foil containers can be considered fully impermeable to moisture and gases and they are able to withstand high oven temperatures. The heat transfer characteristics of foil containers are very good so that cooling and subsequent reheating is readily achieved.

The one criticism of foil containers, however, is that they are not microwaveable and certainly at retail product level there is a significant trend towards microwave-compatible containers.

(b) Plastics - These are generally co-extruded and then formed into rigid or semi-rigid containers or into some type of plastic bag.

One of the major recent developments for the food industry is polyethylene terephthalate (PET) ovenable trays. PET trays are made by a conventional two-stage process of extrusion into a sheet and then forming the sheet into the required shape. The feature of the PET that makes it particularly attractive is its dual ovenability. The sheet is crystallized at the thermoforming stage and it will subsequently withstand temperatures from -40°C to 220°C and can therefore be used for reheating frozen and chilled products in conventional or microwave ovens.

Two types of lidding systems are possible. A fully heat sealable peelable plastics material co-extruded with low density polyethylene film and laminated to polyester film. This film can be peeled off the trays straight from the oven or freezer without leaving any residue around the rim of the container. Alternatively a film can be used which welds to the tray giving a watertight boil-proof seal. This allows reheating of product in boiling water as well as in microwave or conventional ovens.

A further material being developed with similar intended use is polycarbonate. The General Electric Company in the USA is currently producing trays made from four-ply laminate material including EVOH as a barrier and Lexan polycarbonate to confer ovenability up to about 240°C.

If microwave only applications are considered polypropylene-based materials are also finding some popularity.

Apart from forming trays, plastics materials may be used for making variations of the plastic bag and these may be large enough for bulk storage of meal components or smaller for individual portions. The CapKold system utilizes a four-ply laminate material for pasteurized food of a pumpable nature. About 4 kg of food is filled into the bag which is closed with polyclips and then rapidly chilled to give a claimed shelf-life of up to 21 days. Nylon polymer bags are also used for individual servings of prepared meals. Food is vacuum sealed into the bag prior to cooking in steam ovens and chilling. Such products have a shelf-life of up to 10 days.

(c) Fibre and board laminate containers - These may be relatively simple using a plain fibre base on the inside of which is bonded, generally, to a plastic material such as polyester or polypropylene, perhaps with an additional barrier such as PVdC. Simple microwave cook and serve cartons are now available that contain special high temperature non-metallic materials to act as a browning board and ensure uniform heating of the frozen product.

Somewhat more sophisticated are the dual ovenable containers of the Ovenware II range produced by Chinet in the USA. These again are individually moulded for a special blend of films and then laminated with polyester heat resistant film.

The use of chill temperatures (-1°C to +8°C) in combination with other preservation parameters has expanded considerably in recent years. This expansion of the chill food market has particularly resulted from applications of packaging technology and new product development in terms of number and type of ingredients. Many of the products sectors have no counterparts in other preservation areas (e.g. salad and delicatessen products) while certain sectors have expanded at the expense of other methods of preservation. For example the use of controlled atmosphere packaging of fish and chill distribution at the expense of frozen fish.

Within the chilled food sector there is considerable interest in the use of modified atmosphere packaging to prolong the shelf-life of a range of products. Two broad categories can be differentiated in relation to their packaging requirements, firstly non-respiring produce such as meat, fish, poultry, pasta and bakery products and secondly respiring produce, i.e. fruit and vegetables.

The first category which has already been commercialized for the products mentioned requires a high barrier packaging material to maintain the gas mixture flushed into the package (see table 3). It is important that the gas concentration within the packs remains stable throughout the storage period if shelf-life is to be extended. Therefore the package material must have very low permeability to the gases used, specifically oxygen and carbon dioxide.

Several plastics manufacturers have developed special base and top web materials for modified atmosphere packs. For example a package widely used to package meat consists of a base tray made from PVC polyethylene laminate which is lidded with PVdC coated polyester polythene laminate. The formed base provides strength and allows gas access all around the product. The meat within this package, gas flushed with 80 per cent O_2 and 20 per cent CO_2 mixture, stored at 2°C will have a 10-day shelf-life compared to five to seven days for prepacked meat normally.

Modified atmosphere packaging of fruit and vegetables reqires a completely different approach from the other forms of packs. This is because after harvest the fruits and vegetables are still living and continue to respire taking up oxygen and producing carbon dioxide.

In a sealed package of fruits or vegetables a modified atmosphere is produced naturally as a result of oxygen uptake and carbon dioxide production. Initially the concentration of CO_2 rises and the level of O_2 falls. However as CO_2 concentration rises, CO_2 will start to diffuse through the packaging film at an increasing rate. Similarly as oxygen it utilized, the difference between the levels of oxygen inside and outside the package results in O_2 diffusion into the pack. Eventually an equilibrium concentration of both gases is established when the rate of gas transmission through the package is equal to the rate of respiration.

The exact equilibrium values attained will depend on several factors, the respiration rate of produce (see table 4), fill weight, surface area for gas exchange, and film permeability to O_2 and CO_2 (see table 5). Due to differences in respiration rates and film permeability, the oxygen and carbon dioxide permeabilities required to achieve any one specific modified atmosphere must be defined for each commodity at one specific storage temperature.

The Campden Food RA currently has a programme of work on developing modified atmosphere packs for a range of prepared vegetables. To date considerable success has been attained with some products and this has stimulated significant commercial interest.

D. Irradiation

The potential uses for the preservation of foodstuffs using ionizing radiation are well documented, but remain largely untried and tested on a commercial basis (see table 6). However a variety of packaging materials currently available have been shown to be suitable in principle, although further work is required on the potential migration of chemicals that may arise from the radiation itself (figure 3). The process is suited to in-container treatment, and offers precision preservation for certain high value commodities, with reduced chemical preservatives as in the case of the preservation of spices (see tables 7 and 8). There is one sterilization parameter-time, no post-processing treatments are required, and there is the ability to quantitatively monitor dose received using appropriate indicators. It will be several years before such products will be permitted in the UK whilst good manufacturing practices and testing procedures are agreed at an international level.

E. Combination treatments

Apart from the above extreme high temperature treatment to give shelf-stable products there is a resurgence of interest in combining chemical, physical and biological agents to preserve food at ambient temperatures or at chill temperatures, the latter area already showing substantial market growth and which is forecast to be the largest growth area in the next two to three years.

The 'Hurdle Concept' of food preservation consists of a series of sub-lethal preservative factors which together give a microbiologically stable product. Individually each factor is not adequate to preserve the product and similarly does not have an adverse effect on product quality. Such preservative factors include mild heat (pasteurization), chill, water activity, pH, redox potential, chemical preservative, competitive microbial flora, modified atmospheres and irradiation.

Certain combinations of the above factors have traditionally been employed on a variety of foods. For example canned hams which utilize a preservative (nitrite), low water activity (salt content) and a mild pasteurization together with storage at chill temperature. Similarly carbonated beverages contain two preservatives, benzoate and carbon dioxide, have a low pH and may be given a mild pasteurization.

It is likely that novel combinations of the above factors will be used in the future to provide new products or give extended shelf-life to existing products using a variety of packaging materials and forms.

Conclusions

The developing trends in food preservation referred to are those we are likely to see progress during the next decade. Associated with these will be developments in high speed handling particularly of plastics and laminates, and the increasing need to monitor pack integrity automatically on-line. Underlying these aspects will be the positive seeking of food processors to innovate value-added products which give the consumer increased convenience.

Table 1

Sterilization systems of materials used in aseptic packaging

Packaging system	Chemical/physical sterilization treatment
Dole (metal cans)	Superheated steam
Tetra Pak (reelstock carton, plastic/ paper/metal laminate)	Cold or hot hydrogen peroxide bath/radiant heat or hot air
Combibloc (pre-formed carton, plastic/ paper/metal laminate)	Hydrogen peroxide spray/ hot air
Hesser Hypa S (pre-formed can plastic/ paper/metal laminate)	Hydrogen peroxide spray/ hot air
Gasti Dogaseptic (reelstock or pre-formed plastic pots)	Hydrogen peroxide spray/ hot air
Metal Box Fresh Fill (pre-formed plastic pots)	Hydrogen peroxide spray/ hot air
Conoffast (reelstock plastic pots)	Delamination of packaging material, thermoform
Bosch Servac 78 AS (reelstock plastic pots)	Hot hydrogen peroxide bath, thermoform
Metal Box Marston Trinicon (bulk plastic bag)	γ irradiation
Bowater Liquid Packaging (bulk plastic/metal laminate bag	γ irradiation or hot fill for acid products

Figure 1

Aseptic Flow Diagram

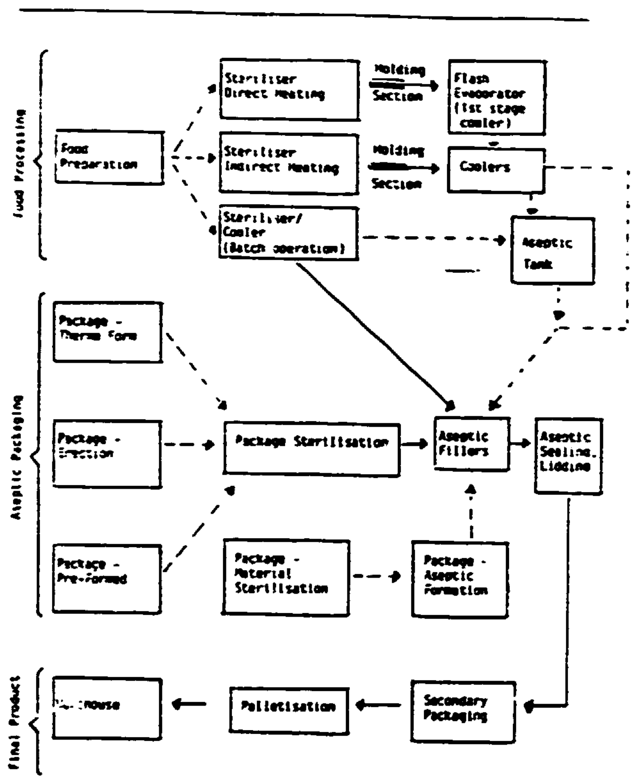
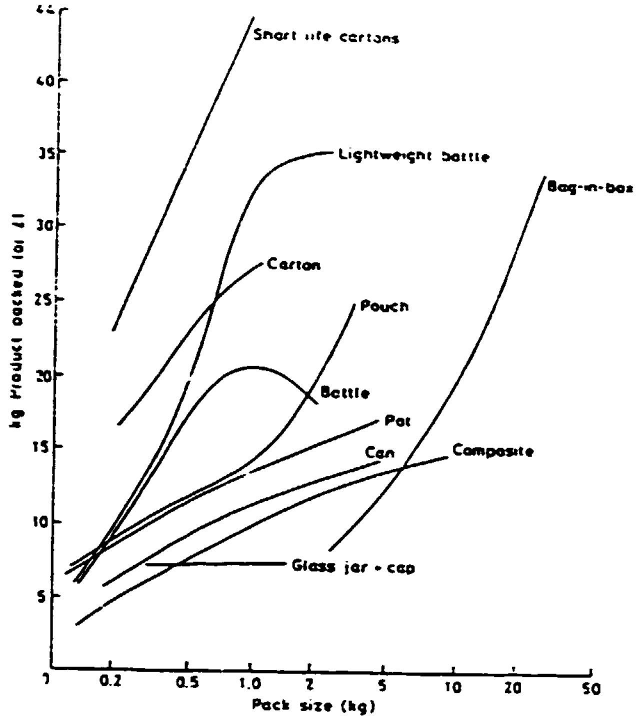


Table 2

Properties sought in laminate components for aseptic packaging

Property	Example of suitable material
Tear resistance	PVC, PE, PVdC/PVC, PP
Stiffness	Paper, PS
Puncture resistance	Ionomer, PET
Printability	Paper, aluminium foil, PS, PE, PET
Folding	Aluminium foil, paper
Heat sealing	LDPE, PVC
Light barrier	Aluminium foil, paper, metallized film
Water vapour barrier	Aluminium foil, PE, PVdC
Oxygen barrier	Aluminium foil, PET, PVdC, PVAl, EVAL

Figure 2



Cost comparisons of some packaging materials
(Ex. Metal Box with other data from Bowater and Rockware)

Table 3

Typical gas mixtures

	O_2	CO_2	N_2
Red meat	60-85	40-15	-
Poultry	-	25	75
Cooked meats	-	25-30	75-70
Fish (white)	30	40	30
Fish (oily)	-	40	60
Pizza/quiche (France)	-	50	50
Bakery (non dairy)	-	20-70	30-80
Cheese (hard)	-	0-70	30-100
Breads (FRG in particular)	-	100	-

Table 4

Respiration rates of fresh produce

Carbon dioxide production (mg kg^{-1} hr^{-1})

Commodity	Temperature 5°C	20°C
Asparagus	44	127
Tomato	9	30
Parsnips	11	49
Calabrese	58	240
Lettuce: Kordaat	11	37
Kloek	24	80
Brussels sprouts	30	90
Leeks (Musselburgh)	28	110

From Robinson et al. (1975)

Table 5

MANUFACTURERS' SPECIFICATIONS OF AVAILABLE PLASTIC FILMS

FILM	THICKNESS (μ)	PERMEABILITY (cm^3/m^2/24h/atm) O_2	CO_2	H_2O TRANSMISSION (g/m^2/24hr)
PVC Film (VHY)	15	20300	121600 (23°C)	150 (25°C, 75% RH)
PVC Film FRM-61	17	15200	101300 (23°C	140 (25°C, 75% RH)
PVC Film VF-70	17	10100	65800 (23°C)	90 (25°C, 75% RH)
Butadiene Styrene Copolymer	25	9300	37100 (23°C)	190
Low Density Polyethylene	25	8900 (25°C)	47100 (25°C)	6 (25°C, 90% RH)
Low Density Polyethylene	38	5900 (25°C)	31000 (25°C)	4 (25°C, 90% RH)
Polystyrene (Polyflex)	30	3000-4000	13000 (20°C 0%RH)	50-55 (25°C, 75% RH)
Cellulose Acetate	40	1500-3000	15000 (20°C 0% RH)	200-400 (25°C, 75% RH)
Polyester	12	120 (25°C, 45% RH)	500 (25°C, 45% RH)	40 (38°C, 90% RH)
Polypropylene (Oriented)	15	2600 (21°C, 44% RH)	7500 (21°C, 44% RH)	9 (38°C, 90% RH)

Table 6. Irradiation Applications

Typical Dose Range (kGy)	Desired Effect	Products
10 - 13	Decontamination	Spices, Dried Ingredients, Animal and Poultry Feeds
3 - 10	Elimination of Non-sporing pathogens (Radicidation)	Poultry, Shrimp, Frogs legs, Cocoa
0.5 - 5	Shelf-life extension by reduction in microbial load (Reduction)	Meat, Poultry, fish, Strawberries
1 - 3	Delayed cap opening	Mushrooms
0.25 - 0.75	Disinfestation (of insects)	Grain, Flour, Fruit and Vegetable Quarantine
0.25 - 0.5	Destruction of parasites	Meat (Trichinella)
0.25 - 1	Delayed Ripening	Avocado, Mango, Banana
0.05 - 0.15	Sprout inhibitors	Potatoes, Onion, Garlic

Figure 3

Relative sensitivity to radiation of principal materials used in packaging

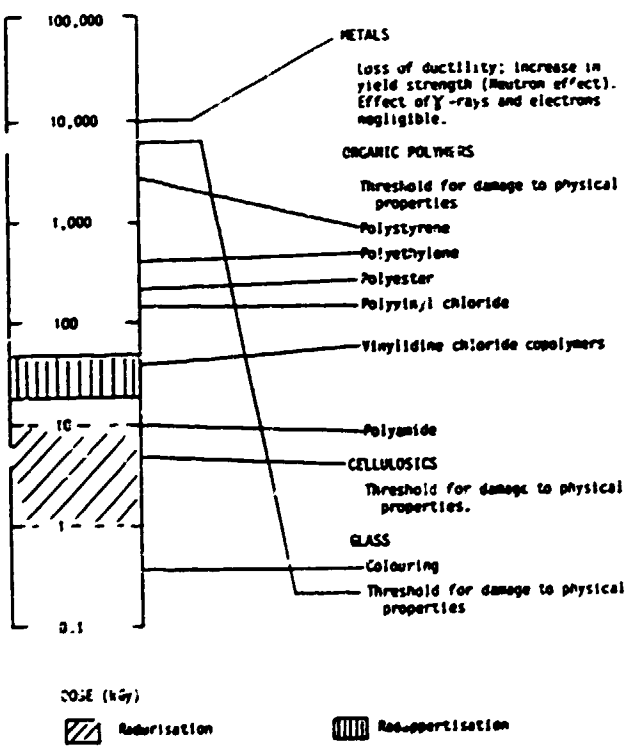


Table 7. Comparison of Sterilization Methods for Spices

Consideration	Steam	Ethylene Oxide	γ-radiation
1. Product Design	—— No sealed cavity ——		No restrictions
2. Packaging	— Permeable material or second sealing —		No restrictions
	—— Expansion during vacuum ——		
	—— Vacuum stress on seals ——		
3. Sterilization Parameters	Vacuum Pressure Temperature Humidity Time	ETO Concn. Vacuum Pressure Temperature Humidity Time	Time
4. Process Reliability	Good	Good	Excellent

Table 8. Comparison of Sterilization Methods for Spices - 2

Consideration	Steam	Ethylene	γ-radiation
5. Post Process Microbial Test	Desirable	Required	Can be eliminated
6. Quarantine Period	—— 7 - 14 days ——		Can be eliminated
7. Post Process Treatment	Dry Product	Aerate Product	None
8. Quantitative Process Monitoring Possible	No	No	Yes
9. Economics	—— Good on Low and High Volumes ——		Good on High

4. CURRENT AWARENESS

Equipment - machinery

Package keeps apples fresh

A heavy-duty plastic tray sealed with a computer-tailored plastic film keeps apples fresh up to eight months in rooms at 32°F to 38°F. Each package simulates a miniature controlled-atmosphere storage system, says inventor Syed S.H. Rizvi, an associate professor at the College of Agriculture & Life Sciences, Cornell University, Ithaca, N.Y., USA. The film and tray allow oxygen and carbon dioxide to pass through, resulting in an atmosphere containing about 3 per cent to 5 per cent of each. (Source: Industry Week, 5 September 1988)

* * * * *

Following five articles appeared in Commercial News USA, June 1988:

Accurate, simultaneous filling and bagging

Producers of granular and powdered material, dry milk, tablets, pellets and capsules can use the "Airvan Model 2000" to fill, weigh and package goods automatically. Featuring two filling positions with a single-operator control, it is fast because one side fills while the other side is being changed. Made of stainless steel that conforms to the US Department of Agriculture's food-grade, 3-A requirements, it is easy to operate, clean, and maintain. Agents are sought for this machine, which is priced from $20,000 to $40,000. (Herman Teitsma, Airvan Co., Dept. CN, 3118 N. Clybourn Ave., Chicago, Illinois, 60618 USA)

* * * *

Packing system cuts labour costs

By gently elevating a product through the open bottom of a corrugated carton, the "Automatic Case Packer" can be used to collate virtually any product in the desired pack pattern. It first elevates the goods up into a previously erected, knock-down corrugated carton, then folds minor and major flaps, and finally seals flaps with either pressure-sensitive tape or hot-melt or cold glue. Basically a custom-designed machine, this packer has features and configurations to fit each customer's needs. Featuring heavy-duty stainless steel construction and solid-state controls, this system is priced from $110,000. (Sabel Engineering Corp., Dept. CN, USA)

* * * * *

Electronically controlled filling machine

The "PRO/FILL 3000 Liquid Filling Machine" handles a wide range of products, from clear liquid to viscous, chunky fillings, for food processing, pharmaceutical, cosmetic, and chemical applications. This electronically controlled unit is equipped with a positive displacement, lobe-type rotary pump. This system's features include digital electronic controls for quick set-up, clean-up, and changeover; positive shut-off nozzles for no-drip filling; and rugged stainless steel construction for durability. Volumes ranging from millilitres to litres can be filled at accuracies to 0.1 per cent. (Oden Corp., Dept. CN, 255-C Great Arrow Ave., Buffalo, New York 14207, USA).

* * * * *

High-speed bagger

Bakeries, food processors, and paper products manufacturers can use the "Variety Bagger" to package such items as pastries, produce, candy, toys and sundries. At a speed of more than 90 units/minute, it bags single items, groups, trays, or clusters quickly and carefully without damage to the product. The unit uses sales-stimulating, clear reusable polyethylene bags that are easy to open and close and come with handles. Features include a quick-change bag tray that makes it possible to change from one product to another in just seconds. (Formost Packaging Machines, Inc., Dept. CN, 19211-144 Ave. NE., P.O. Box 359, Woodinville, Washington 98072, USA)

* * * * *

Automatic packaging machine for food processing

The "601 Four-Fin Seal Packaging Machine" produces high-quality pouches that are suitable for liquids, semi-liquids, powders, portion packages of condiments, and granulated products. This automatic form, fill, and seal machine operates at speeds ranging from 50 to 700 packages per minute, depending on the requirements. Its features include accurate heat control, easy-to-adjust vertical sealers, and positive cut-off and bag release. (Prodo-Pak Corp., Dept. CN, 77 Commerce St., P.O. Drawer D, Garfield, New Jersey 07026, USA)

* * * * *

Glass

Super-barriers from glass make new packages safer

A transparent, inorganic "super-barrier" that is claimed to surpass existing barrier resins by "an order of magnitude" is now a commercial fact. Using vacuum-deposited glass as an ultra-thin flexible barrier layer on PET film, Japan's leading food producer, Ajinomoto Co. Inc., Tokyo, has succeeded in marketing a shelf-stable, retortable pouch that, according to the company, combines the advantages of aluminium foil and high-barrier resins while adding significant new protection values of its own.

Unlike aluminium-coated printed structures which tend to delaminate under high temperature and humidity, says film manufacturer Toppan Printing Co., the glass-coated barrier film can be retorted without major loss in moisture or oxygen barrier. At about 50 nm, the microscopically thin barrier layer loses the brittleness of glass and becomes flexible enough for normal film converting operations. (Extracted from Modern Plastics International, September 1988)

* * * * *

Paper-carton

Hot-melt carton sealer

The "HMC-900E Hot Melt Automatic Carton Closer" seals standard three-flap, top-loaded chip-board cartons. Featuring a patented flag infeed system, this machine can seal cartons containing such items as ice cream novelties, taco shells, and doughnuts at a rate of up to 80 per minute. Just 1.2 x 3 m in size, it is fully adjustable to handle carton sizes ranging from 13 x 9 x 2 cm to 30 x 20 x 9 cm. (A.E. Randles Co., Inc., Dept. CN, 4617 S. 3rd Ave., Tucson, Arizona 85714, USA) (Source: Commercial News USA, June 1988)

* * * * *

Machine for waterproof corrugated cardboard

There is an increasing demand for waterproof corrugated cardboard as a material for food, fish and vegetable containers. Corrugated cardboard is generally processed either by a paraffin or resin impregnation method, but the waterproof corrugated cardboard processed by these methods involves problems in relation to durability, processing costs, and hygiene. Using a water-soluble resin, Hamaguchi Distribution Packing, Japan has developed a special resin which, after drying, exhibits excellent water-resistance, and using this special resin it has developed a machine for manufacturing a new type of waterproof corrugated cardboard. By the machine, both sides of the cardboard are coated when relatively low-water resistance is required, while the cardboard itself is impregnated for high-water resistance. The machine can of course be used for both applications. (Source: Appropriate Technology Documentation Bulletin, November-December 1987)

* * * * *

Plastics

Flexible food can made of plastic

Four Japanese companies have jointly developed a new type of multilayered food container, the "FK", which is made of plastic.

The can is primarily made of polypropylene film and is (1) odourless, (2) impervious to oxygen and resists food deterioration, and (3) easy to retort (pressurized heating) sterilize. It can also be used as a wrapping material for microwave oven prepared foods, and after being used it can be disposed of and incinerated without causing any atmospheric pollution.

With the FK can, the outside of a polyethylene film is wound with seven to eight layers of polypropylene film, and the top and bottom covers given a high-frequency seam. The can is roughly 0.7 mm thick, and it is sealed on the top and bottom with aluminium foil to inhibit oxygen infiltration. An inorganic material is added to the polypropylene film to increase the can's strength.

One of the most outstanding characteristics is that the can resists temperatures of up to 150°C. Therefore, compared with the plastic cans developed up to now, it can be sterilized with a retort without any resin effusion. In fact, it has passed the high-retort specifications prescribed by the Food and Drug Administration (US), and removing the aluminium foil permits the can to be used as a container for foods prepared by microwave oven.

The can's combustion calorific value is kept roughly 7,000 cal/kg, so it can be incinerated together with regular garbage without generating any toxic gas. In addition, it is comparable to metal cans in strength, flavour, and food preservation. (Extracted from JETRO, March 1987)

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Plastic can of high heat resistivity

Another Japanese company has commercialized a plastic can which features a high degree of shaping flexibility and a long period of content preservation that can be sterilized at high temperatures. It is expected to lend itself ideally for replacing metal cans whose popularity has decreased steadily in recent years owing to disposal problems.

Cans for preserving foods must meet rigid conditions such as sterilization at high temperatures, long-term preservation of contents and non-effusion of toxic materials from its inner walls due to the action of acids and alkalis. Based on these requirements, the company introduced a five to seven layer high-barrier coating material. The coating is produced by co-extruding and processing ethylene vinyl alcohol (EVOH) copolymer as the gas barrier layer of the plastic can proper and a polypropylene (PP) material excelling in heat resistivity as the internal/external layer. An aluminium pull-top is used as the lid, that features excellent high-barrier and heat-sealing characteristics. The lid can also be pealed off with ease.

The new plastic can lends itself to high-temperature sterilization for one hour at 135°C and its oxygen permeability rate per day is 0.02 cc, making it an excellent food preservation can. Existing plastic containers, meanwhile, can at best be heated for only 30 minutes, at 120°C, and their oxygen permeability rates are as high as five to 10 cc, more than 100 times greater than the new can.

Compared with metal cans, the plastic can be produced in a transparent mode, coloured with ease, is free of any metallic flavour and can be heated in a microwave oven without getting too hot. When used for preserving jellies, it is guaranteed to preserve freshness for two to three years. When preserving fruits and vegetables it preserves their freshness for about one year. (Extracted from JETRO, March 1988)

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A new food-preserving process

After more than 30 days in a chilling room, rump steak would normally be rotten and inedible. A Melbourne company, Garwood Limited, has invented a food packaging system which allows the steak to remain rich, red and fresh after weeks of chiller storage. The new food-preserving process, called Flavaloc, represents a technological advance over the plastic-wrapped foam trays that have protected meat and other fresh foods for more than a decade.

The Flavaloc pack does for meat, fish and other fresh foods what controlled-atmosphere storage did for apples. The new plastic pack has a polymer membrane pillow which serves as a reservoir for a gas mixture that diffuses, at a controlled rate, into a chamber containing the perishable food, preserving its freshness and appearance while suppressing bacterial and fungal growth.

According to the company, the controlled-atmosphere package had evolved because food retailers and meat packers in the United States and Europe were looking for an alternative method to freezing food to preserve it. Previous controlled-atmosphere packages had been unattractive to the market because of their higher cost, bulkiness and lack of customer appeal. (Source: Journal of Scientific & Industrial Research, Vol. 47, May 1988)

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Barrier bags keep rice tasty

Rice now being packed in bags made from Barex acrylonitrile copolymer resin will retain its taste for at least a year, according to suppliers of a new packaging system in Japan.

Rice is normally packed in polyethlyene bags, but it gradually loses its flavour, owing to polyethylene's relatively high permeability to oxygen. In the new system, one or two kg of rice is packed in bags made from Zexlon film. This is produced by Mitsui Toatsu from Barex barrier resin, which the comnpany also manufactures (under licence from Standard Oil). Once filled, the bags are flushed with carbon dioxide or nitrogen; CO_2 is recommended by the supplier of the packaging system, Kyokujitsu, because the gas prevents mold growth.

The bags are produced in 280-micron film. This has an oxygen permeability of 1.8 $cm^3/m^2/24$ h at 35°C, zero relative humidity, 1 atmosphere. Under the same conditions, a film of low density polyethylene of the same thickness has a permeability of 7,000 $cm^3/m^2/24$ h.

Prior to this application, Zexlon has been used primarily for packaging more expensive products, such as fish, eggs, cooked meats, and biscuits. (Source: Modern Plastics International, September 1988)

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Copolymer polypropylene for food packaging

Pro-fax SD-422-2 is a 20 per cent talc-filled medium-impact grade for multilayer containers. The product complies with FDA sanctions for use in articles used for packaging as well as for containers holding food during cooking. The resin can be subjected to the high-temperature, high-pressure environment of retort applications. (Himont USA, 1313 N. Market St., Wilmington, DE 19894, USA) (Source: Modern Plastics International, October 1986)

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New type of plastic container

Two Japanese companies have jointly come out with a new type of plastic container (NP Can) that will preserve foods for as long as metal cans and which can be opened with ease.

It is flat type composite container using polypropylene and aluminium foil, and its developers expect it to gain popular acceptance equal to aluminium and steel cans.

The container uses polypropylene of high rigidity, heat resistance and frigidity resistance, and is lined with a polypropylene film that conforms fully with the foodstuff retort specifications demanded by the Federal Drug Administration (US). Aluminium foil is used in the barrier layer (shielding layer).

The new container's characteristics may be summarized as follows:

1. The can is lightweight.

2. It lends itself to multicoloured printing and therefore appears most fashionable.

3. The use of aluminium foil in the barrier layer permits retort sterilization (heat sterilization treatment) to enable the plastic can to be preserved as long as 1.5 to 2 years, like metal cans.

4. For the innermost layer, a non-elongated retort polypropylene film is used, which improves the can's flavour characteristic and makes it usable for a wider range of processed foods than conventional stainless steel cans.

5. The can is opened easily and safely without the use of a can opener.

6. It retains its original shape for convenient handling during physical distribution, in addition to being dust-free and incombustible. (Source: JETRO January 1988)

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Plastic trays

Tedeplast, a subsidiary of Thomassen & Drijver-Verblifa N.V., has developed a new type of packaging for the French company, Ets Jean Larnaudie. Well known for its paté de foie gras and related products, the company launched seven ready-meals onto the market in May. And, they are packed in a new type of plastic tray.

These plastic trays have been specially developed by Tedeplast. They are extruded from a plastic foil made up of several layers of which one is a very dense barrier layer. Once the trays have been filled with the gourmet meal, they are sealed with an aluminium foil closure. After being sterilized for a short time the filled package is put into an attractive cardboard carton.

The great advantage of these Larnaudie meals in Tedeplast packaging is that they keep for at least a year without needing to be chilled in any way. (Tedeplast, subsidiary of Thomassen & Drijver-Verblifa N.V., Deventer, The Netherlands) (Source: Food Engineering Int'l., August 1988)

Metal

A new type of packaging promises to double the shelf life of foods such as vacuum-packed coffee and candies. The material, developed by Camvac Ltd. of Norwich, England, uses layers of metallized film so that defects in one layer will not let moisture or oxygen penetrate a sealed package. The film is also flexible, and thus less likely to rip than aluminium foil when applied to pouches or boxes. Camvac currently uses the material to package food products, but is considering industrial uses such as packaging delicate engineering components and photographic film. (Source: High Technology Business, July 1988)

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Innovative, flexible packaging film for food

"Metallized film" for packaging and related products is said to offer excellent MVTR and O2TR barrier and a light barrier that prevents oxidative rancidity. Its bright foil appearance, high slip, high resistance, and flexibility combine to make it a material that results in attractive laminations. This static-free film, used for such items as candy, snack foods, and coffee, is priced from $3 to $11/kg. (Scharr Industries, Inc., Dept. CN, 40 E. Newberry Rd., Bloomfield, Connecticut 06002, USA) (Source: Commercial News USA, May 1988)

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5. MARKETING

Market data on drinks packaging

Two recent meetings in the UK and the Federal Republic of Germany produced useful (though not exactly comparable) data on drinks packaging and the degree of penetration by plastics. In the UK, executives from Cadbury-Schweppes told the BPF Business Trends conference that plastics can replace glass for small containers, high carbonation beverages and pack-pasteurizable products, given the right material development. In the Federal Republic of Germany, the discussion was more on the future of one-way packaging:

Estimates for the Federal Republic of Germany were given by Bengt Ellesson, chief executive of PLM Europlast and PLM-Raku GmbH, who said that introduction of one-way containers (of whatever material) had actually helped to increase the number of trips made by glass. From 1970 to 1981, while one-way beer containers had grown from about 3 per cent to 10.5 per cent of the FRG market, the number of trips made by glass had increased from 23 to about 53.

Package type as percentage of carbonated soft drinks markets

	1979	1981	1982	1983	1989
UK market					
Bulk	5.5	8.0	8.0	9.0	
Cans	22.0	20.0	24.0	21.0	
Glass non-returnable	18.5	16.0	9.0	9.0	
Glass returnable	51.0	46.0	41.0	36.0	
PET	3.0	10.0	18.0	25.0	
USA market					
Cans	37.6	33.8	33.8	34.0	34.0
Glass non-returnable	15.5	15.6	15.6	15.2	8.0
Glass returnable	34.0	33.5	31.5	31.0	19.0
PET	12.9	17.1	19.1	19.8	39.0

Component reduction	Standard part reduction
48%	
50%	
60%	
63%	62%
44%	72%
	82%

Beverage packaging in the Federal Republic of Germany (BN litres)

	Beer	Mineral water	Alcohol-free	Total	Percent
Total	6.6	2.8	4.3	13.6	100.0
Multi-trip	5.8	2.5	3.4	11.8	86.8
One-trip	0.7	0.2	0.9	1.8	13.4
Glass	0.4	0.1	0.3	0.9	6.4
Cans	0.3	n.a.	0.6	0.9	6.4
Plastics	-	0.1	n.a.	0.1	0.6

(Source: Popular Plastics, February 1988)

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New rigid and flexible packaging films market in Europe

Consumption of flexible packaging films in three materials - oriented polypropylene (OPP), polyethylene terephthalate (PET), and nylon - in Western Europe will top 32,000 tons in 1992. That is one conclusion of the report which also highlights the progress made, thanks to new plastics materials and processing technologies, in creating new applications from conveniently packed fresh foods such as salads to plastics-pack replacements for canned foods.

The study analyses and forecasts the market by country for the three types of flexible packaging films. The total OPP market for seven countries (UK, Federal Republic of Germany, France, Italy, the Netherlands, Belgium and Denmark) was 136,000 tons in 1987, forecast to rise to 141,500 tons in 1988, and to 162,000 tons in 1992. In value (1987 US$), the OPP market is expected to climb from the 1986 level of $480 million to $589 million in 1992.

The nylon film market totalled 25,000 tons in 1987, with 26,100 tons forecast for 1988 and 32,000 tons by 1992. In value, the 1986 market of $145 million will grow to $193 million by 1992. The PET film market, at 17,440 tons in 1987, and set for 19,000 tons in 1988, will rise to 26,000 tons by 1992 - and in value grow from $110 million in 1986 to $179 million in 1992.

In OPP, the UK has the largest market share with 31 per cent, the Federal Republic of Germany and Italy have about 22 per cent each, France 14.4 per cent. The Federal Republic of Germany accounts for more than one third of total nylon film consumption, mainly for packaging meat products. France and Italy each have about 18 per cent and the UK 14.6 per cent. In PET film, the Federal Republic of Germany and the UK each have a 24 per cent share, Italy 18.8 per cent, and France 16.9 per cent.

The Federal Republic of Germany is reported as being the powerhouse of the flexible packaging industry, with Federal Republic of Germany companies today "securing a position of technical and market leadership in Europe". The study finds that "given its size, Denmark's flexible packaging industry is second to none". France is a net importer of flexible packaging, as are the Netherlands and, to a large extent, the UK - though several major manufacturers cited in the study, e.g. BCL and ICI, are British.

Coextruded films and sheet, whether for flexible packaging or for thermoforming into rigid containers, are still in an early growth period, with packer, retail, and consumer acceptance only now beginning to show real strength. PET trays are successfully challenging aluminium foil and board for frozen, ovenable meals.

Coextruded products are also moving into aseptic packaging of daily products and fruit juices, using form-fill-seal techniques. They are also replacing laminates in vacuum packaging and particularly in modified atmosphere packaging for fresh meat and fish. Flexible packaging for medical disposables was a $63.6 million market in Europe in 1987, and is growing at a 6 per cent per year rate. For pharmaceuticals, the 1987 European market was $47 million and is growing at a 4.5 per cent annual rate.

The study highlights some problem areas, such as overly slow filling systems for the new containers. The complete 327-page report costs $2,900. Frost & Sullivan Ltd., Sullivan House, 4 Grosvenor Gardens, London SW1W ODH, England. (Source: Modern Plastics Int'l., September 1988.)

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Du Pont tags rigid packaging for growth

Rigid barrier packaging, where plastics replace metal and glass, remains one of the fastest growing segments of the packaging industry. Growth rate for plastics in this segment is more than 15 per cent annually, according to E.I. Du Pont de Nemours & Co., which had total sales of over $1 billion to the packaging industry last year. The company points out that these new containers can be composed of a single plastic resin or multiple layer structures incorporating different plastics, where the various plastic layers provide structural or barrier properties.

Du Pont, which has introduced two new families of its "Selar" oxygen barrier resins for use in impact-resistant, tamper-proof containers, estimates high-barrier containers and packaging for convenience meals will grow from 200 million units produced in 1985 to 12 billion units in 1994. The company uses its trade-name for a range of barrier resin products, including "Selar" OH ethylene-vinyl alcohol resins, aimed at oxygen-sensitive foods and beverages in multi-layer containers; "Selar" PA, an amorphous nylon resin that combines oxygen barrier properties with glass-like clarity; "Selar" PT, toughened polyester resins, which are expected to open up new markets for plastic containers where hydrocarbon barrier or flavour protection is required; and "Selar" RB, a modified nylon concentrate that is used with a proprietary Du Pont laminar technology to provide economical hydrocarbon barrier. (Source: Chemical Marketing Reporter, 25 July 1988)

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Paper and plastic packaging to grow through 1992

Plastic packaging materials continue to expand their share of the overall packaging market, despite technological improvements in paper and board packaging, according to Freedonia Group Inc., Cleveland, Ohio, USA. Domestic plastic packaging shipments will reach 7.8 billion pounds by 1992, and US paper and board shipments will grow to 33.5 million tons. Operating capacities will remain high, but shortages are unlikely. Prices for both paper and plastic containers will continue to rise.

Dominance in rigid packaging will maintain the paper industry's strong market position. Favourable costs, improved production and better graphics will push this segment beyond 29 million tons by 1992. Technological advances will enable corrugated fibre boxes to compete directly with drums and pails. Increased computerization in manufacturing, improved coatings and adhesives, and a greater use of corrugated and plastic combinations will also fuel growth.

Paper, however, will continue to lose market share in flexible packaging. Plastic bags, sacks and wrapping all show promising growth, though disposability problems, the development of recycling and biodegradable plastics and possible legal action may all affect the growth of plastics. Greatest opportunities are in rigid plastic packaging, such as drums, crates and boxes. Motor oil and sanitary food containers also show promise, Freedonia says.

Major companies in the industry are highly diversified and have verticle and horizontal integration. Many paper and board producers now manufacture plastic containers to maintain market share. Larger companies continue to seek horizontal diversification, fueling acquisitions and mergers. The industry is becoming increasingly consolidated, placing small firms at a disadvantage relative to large ones. (Source: Chemical Marketing Reporter, 12 December 1988)

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Plastics Service Centres

The Plastic Service Centres, Parkersburg, W.Va., USA, a nation-wide distribution network for thermoplastic products, is now representing GE Plastics' "Lexan" polycarbonate resin. The resin is used in the manufacture of products in the appliance, automotive, packaging, electrical and electronic markets, the company says. (Source: Chemical Marketing Reporter, 12 September 1988)

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Borden acts to strengthen international packaging position

Borden, Inc. announced the acquisition of two plastic packaging manufacturers, Macaple SA of France and Pelapack Plastics Pty. Ltd. of Australia, and a $22-million expansion of its Texas packaging film plant.

The actions are intended to strengthen Borden's position as a producer of plastic packaging materials, a key segment of the company's chemical specialties strategic growth area.

Macaple, based in Pithiviers, is the largest French producer of injection moulded and thermoformed plastic packaging and catering products (such as trays, dishes, cups and cutlery) for the airline and catering industries.

Pelapack, located in Braeside, Victoria, Australia, is a manufacturer and printer of polyethylene film and bags, used for poultry and other frozen foods, fresh foods such as bread and produce, other packaged consumer goods and boutique shopping bags.

Pelapack also manufactures and markets trash bags for hotels and hospitals.

At Borden's Gainesville, Tex. plant for Loadmaster pallet-wrap film, construction will begin this year on an 80,000 square foot expansion scheduled to be completed in 1990. Borden currently has a position in pallet-wrap film that clings on two sides. The expansion provides capacity for one-sided-cling film, the fastest-growing segment of the market. (Extracted from Chemical Marketing Reporter, 17 October 1988)

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Du Pont launches transparent Selar additive

Du Pont has introduced a new transparent polymer in its Selar range of barrier resins (added to other materials to form a 'platelet' barrier during blow-moulding). The range was originally polyamides (Selar RB), later extended with EVOH (Selar OH) and toughened polyesters (Selar PT). The new grade is an amorphous nylon (Selar PA), with properties of a nylon six plus better resistance to oils, flavours, gases and water - and it is transparent. Price is reported to be in the region $1.50-$1.75 per pound. Awaiting FDA approval, household and cosmetics packs are under study, but the aim is to try for the baby food jar market. (Source: Popular Plastics, February 1988)

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General Electric details multi-layer packaging development

General Electric has started a $16 million coextrusion development programme at Mount Vernon, Indiana, USA, with a special unit, named GEPAX, to co-ordinate development work on packaging, involving its engineering plastics, notably Lexan polycarbonate and Ultem polyetherimides. Containers retortable at 270°F, containers for fresh vegetables and packs to resist both conventional oven and microwave oven cooking are under study. With Graham Engineering Co., GEPAX has developed high-speed coextrusion blow moulding able to process up to 1,000 pounds per hour. Sheet coextrusion/ thermoforming plant is also installed. (Source: Popular Plastics, February 1988)

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New packaging film that can keep food fresh

Shinagawa Fuel and Mitsubishi (both Japan) have developed a new packaging film that can keep food fresh. A special inorganic material made of alumina and silica was combined with a resin. The material has a large number of angstrom-sized holes that absorb bacteria. The two firms have applied for patents in Japan and abroad. After getting approval from the US FDA they will begin foreign sales. (Source: Jpn Econ J, 20 February 1988, p. 9)

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Unique bearing material for food processing

Extensive research, development and testing have produced "RULON 641", a new self-lubricated bearing material. Made solely from Food and Drug Administration-cleared materials, it is said to be suitable for food, drug, and dairy processing applications. It is non-abrasive and compatible with a variety of matting surfaces, including mild steel and types 303 and 316 stainless steel. Featuring a low coefficient of friction, this material was designed to replace brass, bronze, and carbon bearings. (Dixon Industries Corp., Dept. CN, 386 Metacom Ave., Bristol, Rhode Island 02809, USA) (Source: Commercial News USA, May 1988)

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A new packaging system for frozen food

A new packaging system for frozen food is designed as a possible replacement for aluminium or polyester trays, which have to be additionally packed in cartons. Features: The packaging system and the sales pack are produced in one operation without additional outer packaging required. For use from the freezer or refrigerator to microwave oven, the hermetic seal meets current requirements. (Sciencebiz, Joam Muyskenweg 22, 1096 CJ, Amsterdam, The Netherlands) (Source: Int'l New Product Newsletter, October 1987)

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Packaging system saves 20 per cent in bag costs

At Pack Expo '88, 14-18 November 1988, the Diamant S form/fill/seal system for packaging free-flowing granular materials, including plastic resins, dry chemicals and fertilizers, demonstrated its efficiency-boosting and cost-cutting features.

Form/fill/seal bags produced by the Diamant system cost 20 per cent less than pre-made side-gussetted polyethylene (PE) or paper bags of equivalent size. (Pre-made bags cost from 30 to 40 cents.) That is because the Diamant system forms the bags from continuous, gussetted PE film tubing, which requires less material. During forming, the system creates a short 0.03-inch seal overhang, also saving material. The automatic Diamant S system produces 44 to 110 lb PE bags at speeds of up to 1,200 per hour; that is 43 per cent faster than machines filling and sealing pre-made bags.

According to a Windmoeller & Hoelscher spokesman, the Diamant system produces bags with stronger seams than are possible using conventional bag machinery. The stronger seams are achieved by means of in-line diagonal corner seals in the gussetted area of the bag. This seal also relieves the stress on the horizontal seals, which helps minimize breakage due to seal stress. Corner sealing also creates a square-shaped bag that can be stacked higher in pallets than side gussetted bags without corner seals.

With the Diamant system bag lengths can be adjusted to accommodate products of different bulk densities. This feature ensure optimally filled bags, which stack and palletize well. Size changeovers are a simple pushbutton adjustment. (Source: Plastics World, October 1988)

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Hercules ventures into fresh food packaging

In a new application for polypropylene film, Hercules plans to commercialize a food packaging system that extends shelf-life of fresh fruits and vegetables one-and-a-half to three times current expectations for conventionally wrapped produce.

At the heart of the system is a permeable polypropylene film that doubles as a label. Called FreshHold, the label is applied over vent holes in a rigid gas-impermeable container, thus allowing a controlled exchange of oxygen and carbon dioxide to maintain an optimum atmosphere inside the package.

The President of Hercules Engineered Polymers says the system has a bright future in the 55 billion lb US produce market. It can extend the useful life of especially perishable produce and ultimately save some 5 billion lb in spoiled produce annually, while also significantly increasing sales of products thus protected. The FreshHold system itself may generate some $200 million to $300 million in sales within the next two to three years, says Knox. He adds that the new business venture is expected to turn a profit in 1990. Hercules has invested about five years and $5 million on R&D to bring its new packaging system to market.

Hercules supplies the impermeable container, heat-sealing equipment, and permeable film lable - all the components necessary to bring broccoli, cauliflower, strawberries, raspberries, and other produce to market. Hercules manufactures only the permeable film label, and can make 1,500 labels from a pound of customized polypropylene film. The other components are supplied by outside vendors and assembled by Hercules. Growers and distributors will do the actual packaging. Costs are competitive with conventional packaging methods.

The process does not require the use of preservatives to maintain the appearance, taste, and colour of produce. The system has been test-marketed in Richmond (Va.), Baltimore, Chicago, Los Angeles, Minneapolis, and Dallas.

Meanwhile, W.R. Grace's Cryovac Division recently introduced a plastic film packaging system that also promises to extend the shelf-life of fresh fruits and vegetables. (Source: C&EN, 24 October 1988)

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French Pechiney to build five plants in USSR

The French firm, together with the Soviet State, is on the verge of creating two packaging firms with joint capital.

For nine months Pechiney (Fr. 37.3-billion turnover in 1986 in the aluminium, packaging, and advanced materials sectors) has been negotiating with the Soviet Government for the creation of two packaging firms with joint capital (joint venture). This project is close to being signed and could be the first joint French-Soviet venture involving a major company.

The first plant would manufacture food packing materials in aluminium, whereas the second industrial site would produce pliant aluminium tubes for the agro-food and cosmetic sectors. Neither case would involve the acquisition of a turnkey plant, but rather a marriage between the Pechiney group and the Soviet State inspired by market forces. (Extracted from L'Usine Nouvelle, 3 December 1987)

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Results of a research indicating the percentage of various kinds of packaging materials used for some food products: 1986

	Packaging material %						
Product	Glass	Plastics	Metal	Paper board	In bulk	Not consumed	Home made
Milk	19	-	-	3	73	5	-
Yogurt	1	24	4	-	28	1	42
Olive oil	2	-	49	-	2	47	-
Sun-flower oil	3	28	53	-	4	12	-
Tomato paste	-	-	63	-	3	2	32
Ready mated Stewed fruit	1	-	3	-	-	86	10
Canned	1	-	32	-	-	52	15
Vegetables fruit juice	33	-	-	1	-	66	-
Jam marmalade	13	3	5	-	-	12	67
Cacao nut paste	27	3	-	-	-	70	-
Honey	39	3	8	-	12	38	-
Sesame oil grape juice	5	13	12	-	10	60	-
Vinegar	28	19	-	-	-	53	-
Pickle	1	7	-	-	6	14	72
Green olive	8	3	-	-	31	58	-

CONSUMPTION OF PACKAGING MATERIALS IN EUROPE (KG/CAPITA)

	Tin	Alu	Glass	Paper	Corrug	Card	Plas
Fed. Rep. of Germany	10	1.7	47	10	34	8	20
France	11	1.0	50	10	30	7	15
G. Britain	14	0.8	36	8	26	9	14
Italy	9	1.2	32	5	23	7	10
Holland	23	0.5	46	15	27	12	16
Sweden	12	0.8	12	15	24	12	24
Denmark	20	2.0	24	25	-	16	18
Spain	8	0.6	27	5	27	6	9
Portugal	-	-	26	-	15	6	7
Greece	-	-	7	5	16	6	6

EUROPEAN DRINKS MARKET 1985-1995 (M UNITS)

	1985	%	1995	%	%change
Cans	11,431	11	17,090	12	+ 4.0
Cartons	19,499	18	29,757	21	+ 4.5
Glass	76,891	58	69,451	49	- 1.0
Plastics	10,271	12.5	24,520	17.5	+ 9.0
Bag-in-box	169	0.5	772	0.5	+16.0
Total	118,261	100.0	141,620	100.0	+1.75

(Extracted from "Global Trends: A Review, Popular Plastics, March 1988)

6. PUBLICATIONS

Plastic films for packaging: technology, applications and Process Economics

By Calvin J. Benning, Ph.D., 1983, 912 pages, 6 x 9, hardcover.

Detailed guide to today's plastics packaging films - the polymers, processes, applications and performance. Extensive technical data is included.

Contents: 1. Economics, Markets and Supply Trends of Plastic Packaging Films; 2. Oriented Packaging Films; 3. Orientation Techniques; 4. Technology of Commercial Shrink Films; Stretch Films and Laminates; 5. Properties of Heat-Shrinkable Films; 6. Film and Laminates and Their Markets; 7. Shrink vs. Stretch (A Problem of Economics and Energy); 8. Non-Packaging Applications; 9. Coextrusion; 10. Comparison of Commercially Available Shrink Films; 11. Economic Evaluation of Shrink Film Processes and Products; 12. Future Outlook.

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Consumer goods. Colour brochure details company's wide selection of consumer, industrial and bulk packaging products as well as their technical support and other customer services. Sonoco Products Co., Hartsville, S.C., USA.

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Better packaging. The latest techniques to help meat department managers reduce costly rewraps are detailed in a slide presentation. The 20-minute presentation is designed to help end users increase their profitability by cutting down on expensive rewraps. Goodyear, Akron, Ohio, USA.

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Consultants. The first comprehensive directory of US packaging consultants will include the names, addresses, telephone numbers, and specific areas of packaging expertise for nearly 100 packaging consultants. The Society of Packaging Professionals, Reston, Va., USA.

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Vinyl packaging. Colour brochure describes the advantages of vinyl bottles and features profiles of well-known products packaged in vinyl with comments from the packaging professionals who specified the containers. The Vinyl Institute Packaging Council, Wayne, N.J., USA.

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Encyclopaedia of polymer science and engineering

Volumes 9 & 10, Ed. J.I. Kroschwitz, New York and Chichester: John Wiley & Sons, 1987. Volume 9, Ppxxiv + 840, ISBN 0 471 80941 1. Volume 10, Ppxxxv + 835, ISBN 0 471 80942 X.

Volume nine commences with a useful article on 'Liquid crystalline polymers', and the final article in volume 10 is devoted to 'Pentadiene polymers'. Major articles in the two volumes of general chemical interest include those on 'Litographic resists', 'Mechanical properties', Medical applications', 'Microencapsulation', 'Mass spectroscopy', 'Neutron scattering', 'Nuclear magnetic resonance', 'Oilfield applications', 'Polymer morphology', 'Nonwoven fabrics', 'Olefin fibres', and several sections discussing 'Packaging materials', 'Paper' and 'Paper additives'.

In addition, volume nine includes an article on 'Literature of polymers', which provides a useful summary of the many available journals and books on polymer science and plastics technology.

Also, volume 10 includes a critical account of the data bases on patents on these subjects, and gives suggestions as to how these could be improved.

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Business Communications Co. Inc. (BCC), 25 Van Zant Street, Norwalk, CT 06855, USA, published, inter alia, the following:

Food packaging closures. This BCC report analyses the market for the two types of closures - sealing films based on aluminium foil/plastic and paper laminates and caps which are made from metal and plastic. This study carefully considers films used for both plastic and glass jars and bottles, and the steady replacement of metal closures by plastic caps. Projections and estimates are provided by units of closure, category of container and raw materials consumed through 1996. Published November 1987, 182 pages.

Adhesives for packaging. New concepts, such as reactive bonding will become commercial and will revolutionize packaging adhesive usage over the next decade. This BCC report deals with hot melt, solid and fluid adhesive systems used for the manufacturing of containers and for sealing of secondary packaging. The systems, technology, applications and markets are assessed with estimates of present and likely future usage. Published August 1987, 221 pages.

Hot-fill & retort packaging. BCC report examines the rapid proliferation of new packaging materials, types of containers, processing techniques, and equipment. Changes and new developments are described, analysed and quantified with projections for 1991 and 1996. Advantages and disadvantages of each method of processing, future market developments for foods processed, and the activities of the major companies and suppliers are covered. Considerable attention is given to the materials in packaging thermally processed foods. Published January 1987, 187 pages.

Food and packaging interactions

Edited by Joseph H. Hotchkiss. Washington, DC: Am. Chemical, 1988. 350 p. 664 092 TP374 88-1273 ISBN 0-8412-1465-4

Contents, abridged: Flavour-polymer interactions: coffee aroma alteration. Overview of sterilization methods for aseptic packaging materials. Chemical changes in food packaging resulting from ionizing irradiation. Recent advances in metal can interior coatings. Moisture transfer and shelf-life of packaged foods. Indices.

Note: Covers 21 papers from a symposium sponsored by the Division of Agriculture and Food Chemistry at the 193rd meeting of the American Chemical Society in Denver, 5-10 April 1987, on the study of food and packaging interactions. Focuses on state-of-the-art as well as areas in need of research, new technologies and predicted change.

Polymers as materials for packaging

Edited by J. Stepek et al. NY: Wiley, 1987. 489 p. 668.4 TS195.2 86-27424 ISBN 0-470-20720-5

Con. ts: Basic principles of chemistry and technology of production of plastics. Structure and properties of polymers and composition of mixtures of plastics. Production of basic types of plastics, their properties and application to packaging technology. Processing of plastics with special reference to mechanized packaging procedures. Index.

Note: A comprehensive basic handbook covering problems with the applications of plastics to packaging. The first three chapters describe packaging technology in general, the basic chemical and physical properties involved in the production of plastics, and the structure and properties of plastics and additives. The production, properties, and processing of plastics as applied to packaging technology are covered later. A final chapter evaluates hygienic aspects of plastics technology. For collections in polymer technology, packaging, and applied chemistry.

Materials journals guide

Publisher's address, standard abbreviation, or area of specialization for any journal dealing with metallurgy or materials science, is now available in the updated Source Journals in Metals and Materials from Materials Information.

The Publication gives title, standard abbreviation, name and address of publisher and frequency of publication for over 1800 technical journals in steels, non-ferrous metals, polymers, ceramics or compos materials. A separate table lists journals by the fields they emphasise. (Materials Information, The Institute of Metals, 1 Carlton House, Terrace, London SW17 5DB, UK)

Thermoplastics elastomers - a comprehensive review

Edited by N.R. Legge, G. Holden, H.E. Schroeder. Published in 1987 by Carl Hanser Verlag, Kolbergerstrasse 22, D-8000 Munich 80, Federal Republic of Germany. 574 pp.

Book provides a detailed review of research and development of all classes of thermoplastic elastomer (TPE), concentrating on the latest developments. It begins with polyurethanes, and moves through styrenic block copolymers, polyolefin-based TPEs, elastomer-thermoplastic blends (including dynamically vulcanized types), ester- and amide copolymers, to ionomer systems. There follows a section covering current work of eight academic researchers, chapters on applications for TPEs, interpenerating networks in TPEs, and a discussion of future trends.

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Applied polymer analysis and characterization

Edited by John Mitchell Jr. Published in 1987 by Carl Hanser Verlag, Kolbergerstr. 22, D-8000 Munich 80, Federal Republic of Germany, 573 pp.

Book is view of recent developments in techniques and instrumentation in the analysis and characterization of polymers. Chemical and physical techniques described include DSC, TG, FTIR, F-NMR microscopy, electrochemical, elemental and functional group analysis. Also covered are breakthroughs in computerization that now permit greater automation and reliability coupled with lowered limits of detection and improved accuracy.

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Proceedings from 33rd SAMPE

Symposium and Exhibition, titled Materials - Pathway to the Future, is available from the Society for the Advancement of Material and Process Engineering. The 1807-pp. volume, edited by Gilberto Carrillo, Earl D. Newell, William D. Brown, and Patrick Phelan, contains 164 papers presented at the convention held 7-10 March 1988. SAMPE, P.O. Box 2459, Covina, CA 91722, USA.

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Joining fibre-reinforced plastics

Edited by F.L. Matthews. Published in 1987 by Elsevier Applied Science Publishers Ltd., Crown House, Linton Road, Barking, Essex IG11 8JU, England. 319 pp.

Book brings together key data on the most important aspects of joints in fibre-reinforced plastics composites for load-bearing structures. Chapters cover theoretical and practical analysis of both mechanically and adhesively bonded joints, as well as aspects of design. Various types of lap joints are considered, although for bonded joints, most consideration is given to single and double laps. For mechanical joints, attention is focused almost exclusively on double lap constructions.

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UK materials information sources 1989 is a comprehensive directory of sources of information and advice on all types of engineering materials available to users in the UK. More than 650 sources are listed alphabetically, including consultancies, trade associations, publications, commercial firms, on-line databases and so on. The directory has been compiled by Keith Reynard, a consultant with extensive experience of handling data and information for engineers - he is presently chairman of the Engineering Group of the Association for Information Management.

The 80-page directory is published by the Design Council, 28 Haymarket, London SW1Y 4SU.

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Fracture of non-metallic materials

Edited by Klaus P. Herrmann and Lars Hannes Larson. Boston: Reidel Pub., 1987. 396p (Distributed in the USA and Canada by Kluwer Academic) 620.1'126 TA409 86-29710 ISBN 90-277-2392-3.

Contents abridged: Recent developments in fracture materials. Engineering performance prediction for ceramics. Transformation toughening of ceramics. Fracture mechanics of polymers and adhesives. Structure of concrete and crack formation. Numerical analysis and simulation of crack formation in composite materials such as concrete. Index.

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Computer simulation in materials science

Edited by R.J. Arsenault. Metals Park: ASM, 1988. 372p. 620.1 TA403 87-70939
ISBN 0-87170-296-7.

Contents, abridged: Interatomic potential development in materials science. Thermodynamics of metallic solids and fluids from molecular dynamics. Fracture from an atomistic point of view. Computer simulation of dislocations on an atomistic level. Friction modelling in forging. Synthesis of atomistics and continuum modelling to describe microstructure. Index.

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Reference materials

The National Bureau of Standards (NBS), Gaithersburg, MD, offers the IBS Standard Reference Materials Catalog 1988-89, which lists nearly 1000 standard reference materials. The standard materials include cements, ores, metals, glass, plastics, food, environmental, and clinical items. The annual catalog also has an expanded list of nutrition and health standards.

Copies of the catalog are available from the Office of Standard Reference Materials, B311 Chemistry Bldg., NBS, Gaithersburg, MD 20899, USA.

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Science of engineering materials

By Srivastava, C.M. & C. Srinivasan. NY: Wiley, 1987. 462p. 620 1 TA403
ISBN0-470-20859-7.

Contents, abridged: Bonding in solids. Chemical equilibria, reaction rates and diffusion. Imperfection in solids. Thermal properties. Electronic conduction in solids. Superconductivity. Wave phenomena, acoustic, and optical properties of solids. Polymers. Amorphous materials. Modern techniques for material studies. Index.

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Residual Stress in Design, Process and Materials Selection

William B. Young, ed. Metals Park, OH: ASM International, 1987. ix, 209 pp. Hardcover.

This book is the proceedings of the Conference on Residual Stress in Design, Process and Materials Selection, held in Cincinnati, OH, 27-29 April 1987, under the sponsorship of the Residual Stress Committee of the Highway/Off-Highway Vehicles Division of ASM International. The proceedings are composed of 22 papers organized into three major groups: measurement methods, thermal processes, and mechanical processes.

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Worldwide guide to equivalent irons and steels

Consulting editor: Harold M. Cobb. 2nd edition. Metals Park: ASM, 1987. Various pagination 669 TA464 87-072577 ISBN 0-87170-305-X.

Contents: Cast iron. Cast steels. Wrought carbon steels. Wrought stainless, heat resistant and corrosion-resistant steels. Tool material. Metric-to-English conversions. Index.

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Materials data for cyclic loading Part A: unalloyed steels Part B: low-alloyed steels Part C: high-alloyed steels Part D: Aluminium and titanium alloys Part E: cast and welded metals

NY: Elsevier, 1987. 370p, 568p, 550p, 165p, 201p, respectively. 620.1'6 TA460 87-22149
ISBN 0-444-42875-5 (set).

Materials data for cyclic loading are important as tools for materials characterization and engineering design. They can serve as the basis for comparative judgement of a material's mechanical behaviour; provide knowledge of stress-strain behavior during cyclic loading; and provide input for fatigue life estimation. The 5 volumes provide a useful reference for materials science collections.

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Corrosion atlas: a collection of illustrated case histories Vol. 1: Carbon steels Vol. 2: Stainless steels and non-ferro materials

Compiled by Evert D.D. During. NY: Elsevier, 1988. Various pagination. 620.1'623 TA462 88-3912
ISBN 0-444-42804-6.

Vol. 1: Classification of the case histories. Phenomena index. Glossary of terms used in this work. Background information on this Interphako technique. Information about the microprints. Information about the magnifications of some macroprints. Steel qualifications used. Blank form. Carbon steels.

Vol. 2: Stainless steels and non-ferro materials. List of national corrosion associations. Bibliography for corrosion study. Information on supplements.

Note: Two loose-leaf volumes comprising case histories relating to corrosion, cavitation, erosion, fatigue superheating and plastic attack, classified by material. Case histories are further divided by system and phenomenon. Intended for use by practicing corrosion engineers, emphasis is on practical solutions rather than theory. Features 240 colour photographs. A comprehensive list of references will be useful for those needing further information on corrosion and corrosion control. Annual updates, supplements and replacements are expected. For working collections in corrosion engineering.

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Worldwide guide to equivalent non-ferrous metals and alloys

Consulting editor: Harold M. Cobb. 2nd edition. Metals Park: ASM, 1987. Various pagination. 669.1 TA479.3 87-072576
ISBN 0-87170-306-8.

Contents: Wrought aluminium. Cast aluminium. Wrought copper. Cast copper. Wrought and cast lead. Wrought and cast magnesium. Wrought and cast nickel. Wrought and cast tin. Wrought and cast titanium. Wrought and cast zinc. Metric-to-English conversions. Index.

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Field metallography, failure analysis, and metallography: proceedings of the 19th Annual Technical Meeting of the International Metallographic Soceity

Edited by Michael Blum et al. Metals Park: ASM, 1987. 584p (Microstructural Science; Vol. 15) 669'95'05 TN689.2 87-71608 ISBN 0-87170-299-1.

Contents: Field metallography and fractography. Metallography in failure analysis. Corrosion and hydrogen embrittlement. Microstructural characterization. Metallographic preparation. Metallography of stainless steels.

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High-temperature property data: ferrous alloys

Edited by M.F. Rothman. Metals Park: ASM International, 1987. Various pagination. 669.1 TA485 ISBN 0-87170-243-6.

Contents: Irons. ASTM steels. Elevated-temperature service steels. Ultrahigh strength steels. Tool steels. Maraging steels. ACI casting alloys. Wrought iron-nickel alloys and iron-nickel superalloys.

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Plastics mold engineering handbook

4th edition. Edited by J. Harry Dubois and Wayne I. Pribble. NY: Van Nos Reinhold, 1987. 736p. 668.4'12 TP1150 86-24666 ISBN 0-442-21897-4.

Contents, abridged: Basic mold types and features. Materials for mold making. Compression molds. Cold mold design. Blow mold construction and design. Thermodynamic analysis of molds. Index.

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Future trends in polymer science and technology: polymers: commodities or specialties

Edited by Ezio Martuscelli, Carlo Marchetta and Luigi Nicolais. Westport: Technomic, 1987. 247p. 660 86-51370 ISBN 0-87762-512-3.

Contents, abridged: Achievements of the "Finalized Project on Fine Chemistry" in the sector of polymer chemistry: university-industry research relationships. Synthetic fibres and enzymic reactors. Electron beaming of polymers for advanced technologies. Future trends in engineering resins. Evolution of polypropolene production process. Solution characterization of polysaccharides from small angle x-ray scattering. Polysaccharides: target-oriented research in Italy. Trends in the search for strong and stiff fibres from flexible molecules.

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Materials analysis by ultrasonics: metals, ceramics, composites

Alex Vary, ed. Park Ridge, NJ: Noyes Publications, 1987. xv, 348 pp. Hardcover.

Materials Analysis by Ultrasonics is a proceeding for a conference that was held at NASA Lewis Research Center, November 1984. The main interest of this book is in results and advances in analytical ultrasonics applicable to materials research and testing. The book covers applications of ultrasonics to the complete spectrum of engineering materials: metals, composites, and ceramics.

The various papers in this book cover the application of several ultrasonic phenomena to the determination of material properties, characteristics of defects, effect of heat treatment, and the measurement of residual stresses. Several papers describe new tools for material characterization, including scanning laser acoustic microscopy and digital signal analysis, as well as mathematical tools such as a transfer function concept. The book also contains discussion of the use of ultrasonics for NDE of materials microstructure and texture.

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Ceramics databook

By the Technical Association of Industrial Products. Translated from the Japanese by Douglas Fir. NY: Gordon & Breach, 1987. 739p. 666 TA430 87-23679 ISBN 2-88124-247-2.

Contents: Special contributions. Basic science. Resources - raw materials. Measurement and evaluation. Molding and sintering processing Fireproof insulation. Fine ceramics. Compound materials - concrete. Author index.

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Engineered materials handbook Vol. 1: composites

Prepared under the direction of the ASM International Handbook Committee. Metals Park: ASM, 1987. 983p. 620.1'1 TA403 87-19265 ISBN 0-87170-279-7.

Purporting to be the largest, most complete, most up-to-date volume of in-depth engineering information ever made available, the focus is primarily on "advanced composites" - thermoset polymer matrix materials, reinforced with continuous fibres, used mainly for structural applications. Articles cover essential topics regarding the use of composites. Discussions include properties and forms of basic fibre and matrix materials; analysis and design of composite materials; testing of composites; manufacturing and fabrication process; and applications. Intended for use by engineers, be they novices or experts in composites. Future volumes will cover engineering plastics, ceramics, and other materials.

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Testing technology of metal matrix composites

DiGiovanni/Adsit (ed): 1988, Philadelphia, PA, ASTM, 472pp., ISBN 0 8031 0967 3.

This book contains 28 peer reviewed papers covering materials systems from the continuous silicon carbon-titanium system to the particulate reinforced aluminium system. Material forms vary from precast block to braided pieces.

Audience: composites researchers and designers; aerospace engineers; materials scientists.

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Advanced composites

The $3,400 million world market for advanced polymer composites, with a growth potential of some 11 per cent annually through 1997, has witnessed over 30 completed acquisitions in the last four years. The largest segment, aerospace, was worth over $2,100 million in 1987, followed by the recreation ($500 million) and industrial segments ($460 million). A study is available from Kline & Co, 330 Passaic Avenue, Fairfield, NJ 07006, USA.

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Adhesively bonded joints: Testing, analysis, and design

W.S. Johnson (ed.): 1988, Philadelphia, PA, ASTM, 320pp., ISBN 0 8031 0993 8.

Twenty-one peer reviewed papers present the latest advances in the understanding of mechanical behaviour of adhesives. Their focus is on aircraft and naval applications, which are primarily concerned with bonding composite and/or metallic components.

Audience: aerospace and automotive designers and engineers; composite researchers; adhesive manufacturers.

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Aluminium technology '86

Proceedings of an international conference held to mark the centenery of the Hall-Heroult molten salt electrolysis method of producing aluminium.

Papers cover the current fundamental metallurgical science of alloy production and properties, together with the more practical aspects and the principles involved for the diverse applications of aluminium alloys, including aerospace, architecture, electronic discs, packaging and transport.

Book 391 280 x 210mm. 850 pp.
ISBN 0 904357 85 6. Casebound Published 1986.

The Institute of Metals, Subscriber Services Department, 1 Carlton House Terrace, London SW1Y 5DB.

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7. PAST EVENTS AND FUTURE MEETINGS

Meetings on Materials for Food Packaging

PIRA Packaging Division has/will organize the following seminars and conferences: (PIRA, Packaging Division, Randalls Road, Leatherhead, Surrey KT22 7RU, UK)

1988

14 September	General Introduction to Packaging Goods for Transport
29 September	A Review of Adhesive Technology Developments
11 October	Is Plastics Packaging Rubbish?
3 November	Pack Development/Design Evaluation
8 November	Plastics for Food Packaging

1989

26 January	Packaging for Export
8 February	Packaging Solvent Based Products in Plastics
11 May	High Performance Polymers in Packaging
14-15 June	The Impact of Plastics Technology on Packaging

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8 May 1987 Bombay, India	Plastics for Food and Beverage Packaging (Indian Plastics Institute, Bombay, India jointly with the Organisation of Plastics Processors of India) About 200 participants from plastic raw material manufacturers, processors, equipment suppliers, industrial consultants and food and beverage industry attended.

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1988

-15 September Beijing	CIP '88. The International Packaging Technology Exhibition (Duesseldorf Trade Shows Inc., The Empire State Building, Suite 4621, New York, N.Y. 10118)
14-16 September Chicago, USA	Future Pak '88. Sixth International Ryder Conference on Packaging Innovations. Presentations by industry experts on advanced technology in packaging materials, design, and processing. (Ryder Associates, Inc., 5 Sharon Drive, Whippany, N.J. 07981, USA)

1988

10-11 October London	SPE Ninth International Conference on High-Performance Plastics Packaging. (Rigi Ltd., Lambrechtshoekenlaan 12, B-2060 Antwerpen-Merksem, Belgium)
11-15 October Goteborg,	Scanpack '88. International Packaging Exhibition (The Swedish Trade Fair Foundation, Box 5222, S-402 24 Goteborg, Sweden)
28 October - 2 November Buenos Aires Argentina	Envase '88. Packaging Exhibition (Argentine Packaging Institute, Ramon L. Falcon 2120, 1406 Buenos Aires, Argentina)
16-17 November Brussels, Belgium	EUROPA-PAK '88. (Elsevier Seminars, Mayfield House, 256 Banbury Road, Oxford OX2 7DH, UK)
5-10 December Paris, France	Emballage '88. Packaging Exhibition (Emballage, Sepic, 17, rue d'Uzes, 5002 Paris, France)

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1989

11-13 January Scottsdale, Arizona	Fundamentals of Protective Packaging (Presented by Society of Packaging Professionals, SPHE)

6-9 March
Orlando, FL
Foodplas VI Conference (Plastics Institute of America)

17-21 April
Birmingham
PAKEX '89 - International Packaging Exhibition (Industrial and Trade Fairs Ltd., Radcliffe House, Blenheim Court, Solihull, West Midlands B91 2BG, UK)

23-26 June
Hong Kong
PACK-PRINT ASIA '89
Third International Packing and Printing Exhibition (Business and Industrial Trade Fairs Ltd., 4/F, China Underwriter Centre, 88 Gloucester Road, Wanchai, Hong Kong)

18 October
London
Is Plastics Packaging Rubbish? The Search for Solutions. (RAPRA Technology and PIRA Packaging Division) (RAPRA Tech. Ltd., Shawbury, Shropshire SY4 4NR, UK)

1 November
San Diego
Symposium on Food Packaging Technology (ASTM, American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA)

7-11 November
Milan, Italy
PACKINTEC '89, International Packaging Show (Delia Ass. Rte. 22, West, Whitehouse, NJ 08888, USA)

21-26 November
Havana, Cuba
Havanapak '89 - International Packaging Exhibition (National Packaging Centre of Cuba, Ave. del Bosque No. 121, entre Ave. del Zoologico y Calle 36 Nuevo Vedado, Ciudad de la Habana, Cuba)

4-6 December
Miami, Florida
Future-Pak '89. 7th International Ryder Conference on Packaging Innovations (Ryder Ass., Inc., Five Sharon Drive, Whippany, NJ 07981, USA)

Meetings on Materials

1988

7-10 November
Blackpool, UK
Advanced Composites (British Plastics Federation, 5 Belgrave Square, London SW1X 8PD)

30 November
Teddington, UK
Superconductors (Institute of Phsyics, 47 Belgrave Square, London SW1X 8QX)

30 November - 1 December
London
Plastic cars (Plastics and Rubber Institute, 11 Hobart Place, London SW1W OHL)

7 December
London, UK
Characterization of High Temperature Materials - Mechanical Testing (Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB)

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1989

11-13 January
San Francisco, CA
Second Annual International Superconductor Applications Convention, "SC GLOBAL 89" (Superconductor Applications Assn., 24781 Camino Villa Ave., El Toro, CA 92630, USA)

18-20 January
Cocoa Beach, FL
13th Annual Conference on Composites Materials and Structures (United States Advanced Ceramics Association)

13-17 February
Chicago, Ill.
Energy from Biomass and Wastes (Institute of Gas Technology, 3424 South State St., Chicago, Ill. 60616, USA)

18-21 February
Hong Kong
Interplas Asia, Plastics Exhibition (Cahners Exposition Group, 1507 Shun Tak Centre, 200 Connaught Rd., Central, Hong Kong)

20-22 February
Philadelphia, PA
Advanced Ceramics '89 (Society of Manufacturing Engineers, Box 930, Dearborn, MI 48121, USA)

27 February - 1 March
London
Non-destructive testing of composite materials (Imperial College, Composites Centre, Prince Consort Rd., London SW7 2BY)

28 February - 3 March
Seoul, Korea
Korplasmex '89 - International Plastics Exhibition (Cahners Exhibition Group, 1507 Shun Tak Centre, 200 Connaught Road, Central, Hong Kong)

1-2 March
Stuttgart, Fed. Rep. of Germany
11th Stuttgart Plastics Colloquium (Institut f. Kunststoffpruefung und Kunststoffkunde, Universitaet Stuttgart, PF 80 11 40, D-7000 Stuttgart 80, Fed. Rep. of Germany)

6-9 March
Denver, Co.
Industry-University Advanced Materials Conference (Advanced Materials Inst., Colorado School of Mines, Golden, Colorado 80401)

8 March
Institute of Metals, London
Characterization of High Temperature Materials Series

14 March
Institute of Metals, London
Corrosion pitting and its practical implications

20-22 March
Oxford, UK
4th International Conference on Mechanical Properties of Materials of High Rates of Strain (University of Oxford, Department of Engineering Science, Parks Road, Oxford OX1 3PS)

20-23 March
Bordeaux, France
Eurocomposites and new materials (Eurocomposites et Materiaux Nouveaux, 24, ave. des Gresillons, 92601 Asnieres Cedex, France)

4-7 April
Swansea, UK
Annual Convention (Institute of Ceramics, MDD, B552, Harwell Lab. UKAEA, Oxon. OX11 ORA, UK)

8-14 April
Denver, Co., USA
Wear of Materials (University of Michigan, Mechanical Engineering Department, G.G. Brown Bldg., Ann Arbor, MI 48109, USA)

9-13 April
Denver, Co.
International Conference on Wear of Materials '89 (Oak Ridge National Laboratory, Metals and Ceramics Division, Box X, Oak Ridge, TN 37831, USA)

17-19 April University of Surrey, UK	Metals and Materials '89 (Materials Science Committee and Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB, UK)
17-21 April San Antonio, Texas	X Inter-American Conference on Materials Technology (Southwest Research Inst., San Antonio, Texas, Instituto de Investigaciones Electricos and a number of industry and government organizations. (Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78284, USA) Conference Topics - Physical Mechanical, Extractive, and Manufacturing Metallurgy; - Ceramic, Composite, and Refractory Materials; - Cements and Concrete Technology; - Wood Science and Technology; - Nondestructive Evaluation; - Materials Education; - Energy Systems - Plant-Life Extension; - Corrosion Engineering; - Transportation Systems and Highway Construction; - Technology Transfer.
19-21 April Paris, France	European Congress on Composites (Centre de Promotion des Composites, 65, rue de Prony, 75017 Paris, France)
25-28 April Beijing, People's Republic of China	7th International Conference on Composite Materials (China Society of Aeronautics and Astronautics, 67 South Street, Jiao Dakou, Beijing, People's Republic of China)
26-27 April Split, Yugoslavia	Production, processing, applications and testing of PVC (Society of Plastic and Rubber Eng., Kaptol 22, P.O. Box 119, 41000 Zagreb, Yugoslavia)
26-28 April Bad Nauheim	Third International Conference on Joining Ceramics, Glass and Metal. (Deutsche Gesellschaft für Metallkunde EV, Adenauerallee 21, D-6370 Oberursel, Fed. Rep. of Germany)
8-11 May Toronto, Canada	Plast-Ex '89 (The Society of the Plastics Industry of Canada, 1262 Don Mills Rd., Suite 104, Don Mills, Ontario M3B 2W7, Canada)
12-18 May Sao Paulo, Brazil	Brasilplast '89 (Alcantara Machado Feiras e Promocoes, Rua Brasilio Machada 60, CEP 01230 Sao Paulo, SP, Brazil)
22-24 May London	Introduction of fibre reinforced composites (Imperial College, Composites Centre, Prince Consort Road, London SW7 2BY)
24-26 May Lakewook, Co.	SERI Photovoltaic Advanced Research and Development Project, Ninth Review Meeting (Solar Energy Res. Inst., 1617 Cole Blvd., Golden, Colorado 80401-3393, USA)
19-21 June Los Angeles, CA	Third International Electronics Materials and Processes Conference (Society for the Advancement of Material and Process Eng., 843 West Glentana, Covina, California 91722)
19-23 June Maastricht	First Biannual Meeting (European Ceramic Society, MECC, Box 1630, 6201 BP, Maastricht, The Netherlands)
19-23 June Denver, Co.	American Solar Energy Society, Annual Meeting and 14th National Passive Solar Conference (ASES, 2400 Central B-1, Boulder, Colorado 80301, USA)
23-26 June Hong Kong	Plastics Asia '89 (Business and (Industrial Trade Fairs Ltd., 4/F, China Underwriters Centre, 88 Gloucester Road, Wanchai, Hong Kong)
25-29 June Jerusalem, Israel	International Conference on Composite Materials for High Temperatures (Israeli National Council for Research and Development; Ministry of Science and Development, Box 18195, 91181 Jerusalem, Israel)
28-30 June New York, NY	WORLD TECH '89. Forum for the exchange of science and technology around the world. (American European Trade and Exhibition Centre Corp., 225 W. 34th Street, Suite 906, New York, NY 10122)
27 June - 1 July, Kuala Lumpur	Plastics and Rubber '89 (Overseas Exhibition Serv. Ltd., 11 Manchester Square, London W1M 5AB)
3-5 July, Oxford, UK	BMP 7th International Conference, Powders, Metal Matrix Composites Magnetics (BMP Metals Technology Centre, Wantage Business Park, Wantage, Oxfordshire OX12 9BJ)
5-7 July Cambridge, UK	Materials for Non-Linear and Electro-Optics (The Institute of Physics, 47 Belgrave Square, London SW1X 8QX)
17-21 July Paris	Third International Symposium on Acoustic Emission from Composite Materials (Euro Physical Acoustics S.A., 74, Rue des Grands Champs, 75020 Paris)
23-24 July Charlotte, NC USA	International Symposium on Computer-aided Materials Characterization (Worcester Polytechnic Institute, Worcester, MA 01609)
23-28 July Stanford, California	International Conference on Materials and Mechanisms of Superconductivity: High Temperature Superconductors (Meeting Planning Ass., 883 Santa Cruz Ave., Suite 30, Menlo Park, CA 94025)
24-26 July Paisley, Scotland	Fifth International Conference on Composite Structures (Paisley College of Techn., High Street, Paisley, PA1 2BE, Scotland)

31 July - 4 August, Tsu, Japan	2nd International Symposium on Plasticity and Its Application (Aero, Mech. and Nuclear Eng., University of Oklahoma, 865 Asp Ave., Room 212, Norman, OK 73019, USA)
1-4 August Beijing, China	7th International Conference on Composite Materials (China Society of Aeronautics and Astronautics, #67 South St., Jiao Daokou, Beijing, People's Republic of China)
16-18 August Montreal, Canada	2nd International Conference on Development and Design with Advanced Materials (Institute of Fracture and Solid Mechanics, Lehigh University, Bethlehem, PA 18015)
4-8 September Kobe, Japan	World Congress on the International Solar Energy Society (ISES Solar World Congress 1989 Kobe, c/o International Communications Inc., Kasho Building, 2nd floor, 2-14-9 Nihombashi, Chuo-ku, Tokyo 103, Japan)
5-7 September Sheffield, UK	Interfacial Phenomena in Composite Materials (Butterworth Scientific Ltd., P.O. Box 63, Westbury House, Bury Street, Guildford GU2 5BH)
12-14 September Philadelphia, PA	Plastics Show & Conference East (Society of Plastics Industry and Society of Plastics Engineers, 14 Fa.rfield Dr., Brookfield CT 06804-0403)
12-14 September Hong Kong	THERMTECH ASIA '89 International Exhibition and Conference in the Asia-Pacific Region for Thermal Technology in Materials Processing (Thermtech Asia '89, Queensway House, 2 Queensway, Redhill, Surrey RH1 1QS, UK)
13-14 September Brussels, Belgium	AEROPLAS '89. Applications for Polymers and Polymer composites within structures, systems and interiors (Corporate Development Consultants Ltd., 13 High Street, Thornbury, Bristol BS12 2AE, UK)
18-21 September Padua, Italy	First International Scrap and Secondary Metals Conference (Metal Bulletin, Marketing Department, 16 Lower Marsh, London SE1 7RJ)
19-20 September London	Symposium: Mass Production Composites (Imperial College, Composites Centre, Prince Consort Road, London, SW7 2BY)
26-28 September Atlantic City, NJ, USA	21st International Technical Conference, SAMPE (SAMPE = Society for the Advancement of Material and Process Engineering, P.O. Box 2459, Covina, CA 91722, USA)
27-29 September Belgrade, Yugoslavia	Conference, Fibre-reinforced Composites (Society of Plastics and Rubber Engineers, Kaptol 22, 41001 Zagreb, P.P. 119, Yugoslavia)
28 September - 2 October, Bangkok	THAIPLAS 89. Second International Plastics Show (SHK International Services, 22/F National Mutual Centre, 151 Gloucester Road, Hong Kong)
3-6 October Blacksburg, VA	4th Technical Conference, American Society of Composites (Virginia Techn., Department of Engineering Science and Mechanics, Blacksburg, VA 24061-0219, USA)
9-11 October Bowness on Windermere, UK	1989 Powder Metallurgy Group Meeting: An opportunity to influence the future? (Institute of Metal, London)
12-17 October Melbourne Australia	AUSPALS '89 - International Plastics Exhibition (Exhibition House Pty. Ltd., 193 Rouse St., Port Melbourne, 3207 Victoria, Australia)
31 October - 1 November Duesseldorf, FRG	1989 International Plastics and Rubber Planning Conference (Schotland Business Research Inc., Princeton Corporate Centre, Three Independence Way, Princeton, NJ 08540)
31 October - 1 November Paderborn, FRG	EUROMECH 255: Thermal Effects in Fracture of Multiphase Materials (Lab. fuer Techn. Mechanik, Paderborn University, Pohlweg 47-49, D-4970 Paderborn, FRG)
2-9 November Duesseldorf, Fed. Rep. of Germany	K '89 - International Plastics and Rubber Trade Fair (NOWEA, PF 32, 0203, Stockumer Kirchstr., 61, D-4000, Duesseldorf 30, Fed. Rep. of Germany)
6-9 November Orlando, FL	3rd Symposium on Composite Materials: Fatigue and Fracture (US Army Aeroconstructures Directorate ARTA-AVSCOM, MS 188E, NASA Langley Research Centre, Hampton, VA 23665)
8-9 November London, UK	Metal matrix composites applications
9-10 November Madrid, Spain	Polypropylene-the way ahead (The Plastics and Rubber Institute, 11 Hobart Place, London SW1W 0HL)
22-24 November Aachen, Fed. Rep. of Germany	EUROMAT '89 - First European Conference on Materials Science and Technology (Fed. of European Materials Soc., Deutsche Gesellschaft für Metallkunde EV, Adenauerallee 21, D-6370 Oberursel, Fed. Rep. of Germany)
6-9 December Jakarta, Indonesia	4th International Plastics and Rubber Machinery, Processing and Materials Exhibition (Overseas Exhibitions Services Ltd., 11 Manchester Square, London W1M 5AB)

UNIDO MEETING

3 May 1989 Vienna, Austria	UNIDO-ASM INTERNATIONAL/EUROPE MEETING. Discussions with a number of ASM Members from the USA and Europe were held on possible areas on UNIDO-ASM INTERNATIONAL/EUROPE co-operation to meet the problems of the developing countries. (ASM INTERNATIONAL, Metals Park, Ohio, USA. ASM EUROPE: ECCO, 19, rue de l'Orme, B-1040 Brussels)

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Issue No. 12	Cutting tools

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Advances in Materials Technology: Monitor
Reader Survey

The Advances in Materials Technology: Monitor has now been published since 1983. Although its mailing list is continuously updated as new requests for inclusion are received and changes of address are made as soon as notifications of such changes are received, I would be grateful if readers could reconfirm their interest in receiving this newsletter. Kindly, therefore, answer the questions below and mail this form to: The Editor, Advances in Materials Technology: Monitor, UNIDO Technology Programme at the above address.

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Readers' comments

We should appreciate it if readers could take the time to tell us in this space what they think of the 13th issue of Advances in Materials Technology: Monitor. Comments on the usefulness of the information and the way it has been organized will help us in preparing future issues of the Monitor. We thank you for your co-operation and look forward to hearing from you.