In addition to the qualitative and quantitative tests referred to in Section 7.8.1 subjective assessment of flavour, odour and taint is carried out by statistically valid sensory testing panels.

7.9 Sealability and closure

7.9.1 Introduction to sealability and closure

The most important function of packaging is to ensure the protection and integrity of the product. This implies that the pack must be securely sealed. With plastic packaging, this can be achieved on the packing line by either heat sealing, application of a closure, such as a screw cap, or by the use of some form of adhesive system.

One of the most overlooked factors in the production line is the efficient performance of the packaging system. Sealing or closing systems are often presumed to perform with little consideration of the material/machine relationship.

The needs of the proposed material or container are seldom discussed with the machinery manufacturer. At the earliest stage, therefore, planning needs to take place between Production, Engineering, Purchasing, Product R&D, Marketing and Packaging Technologists with Machinery and Packaging Suppliers. It may be found that compromises will have to be made to find the optimum solution.

7.9.2 Heat sealing

Product protection and hence effective shelf life are a function of the quality of sealing of the package. Sealing strength is influenced by the thickness of the film web. With the same coating, a doubling of the base film thickness almost doubles the seal strength. Conflictingly, the thicker the material, the narrower the temperature sealing range under normal sealing conditions. The thicker film does not allow heat to flow so easily to melt the sealing coating or polymer, and when heated, the film retains the heat, allowing the sealant to remain fluid, with a detrimental effect on hot seal strength. Thick film also requires more pressure to bend the film and make intimate contact, particularly with crimp jaws, as found on f/f/s machines.

Jaw design has a great influence on seal integrity and strength. While the ideal seal jaw may be flat, in practice this is only true if there are no folds or tucks in the seals. Crimp jaws are used to compensate for variations in film thickness on vertical and horizontal f/f/s machines.

Seal integrity may now be evaluated as part of the in-line quality function by using standard instruments to test the pack under pressure or vacuum and identify how quickly air or oxygen will pass through the seals. A practical judgement has to be made on the time and pressure required to change the pack integrity.

7.9.2.1 Flat jaw sealing

Sealing conditions are a compromise between dwell time and the temperature and pressure of the jaws. The requirement is to apply sufficient energy to cause the sealant to fuse together and become one medium. Conduction of heat, combined with heat flow characteristics, needs to be carefully balanced to produce a perfectly formed seal, with no temperature distortion and an even seal strength throughout the sealed area. Energy input is a function of time and temperature. With heat-sensitive films such as PE and cast PP, a low temperature applied for a long period, with high pressure to remove air from between the film surfaces, is ideal. With films having a wide temperature-sealing range, the tolerance in dwell time, sealing temperature and pressure is much wider.

If possible, heat should be applied to both sides to achieve the quickest possible polymer melting. Sealing surfaces need to have good release properties to ensure that molten polymer does not stick to the heating surfaces and pull the newly made seal apart. An alternative is to use one heated surface in the form of a constant temperature metal bar, with a flat or curved profile, sealing against a rubber-faced anvil.

With PE, there is a need to avoid stressing the seal while the polymer is still fluid, and many machines are designed to have an air cooling blast or, alternatively, clamping of the seal whilst the film cools below the sealing temperature. With OPP films where the core of the film is not being melted, an effective seal is achieved by fusing sealant polymers of coextruded film or two surface coatings which flow together. The core will give rigidity to the seal, and to avoid destroying the new seal, it is only necessary to ensure that fluid coatings are not stressed. Pulling jaws apart at a perpendicular to the film overcomes the problem in practice. Film sliding over hot metal while under pressure is to be avoided as the coating may stick to the metal surface. If it is impossible to avoid the film sliding over metal under pressure, the solution is often to ensure that only point contact is made between the heated metal and the film. A rough surface minimises or avoids *hot-sticking* on the machine. The principle is to avoid total air exclusion between the contact surfaces which may be caused by the coatings flowing freely, creating a vacuum. Highly polished sealing surfaces are to be avoided. This seems contrary to the normal practice of polishing surfaces to make them more slippery but has been found to be the case on many machines.

Good film formulation with a balance of slip agents in the coating should minimise or avoid *hot stick* problems, whilst not affecting the sealing performance.

Accurate control of jaw temperature is important, particularly where the temperature sealing range is low and close to the melting point of an oriented film.

When a plastic film such as PVdC coated OPP is being used to overwrap a carton, it is only possible to use one heated surface, and the pressure necessary during sealing is provided by the rigidity of the carton. Precise jaw temperature control is essential to ensure that the envelope-shaped end folds of the film do not shrink during sealing and thereby become wrinkled and unsightly.

7.9.2.2 Crimp jaw conditions

Specific plastic film materials should, ideally, have a unique crimp jaw specification for each thickness, but a compromise is always needed as machines have to handle a wide range of films without modification or resetting mechanical parameters. As different thickness films keep crimp jaws apart by differing amounts, the loads on the crimp jaw slopes vary, and this is shown in the distortion or variability of the seal performance. Crimp jaws should be set to the ideal distance apart and spring pressures or loadings established when the crimp jaws are hot, at temperatures close to the preferred sealing temperature. Only then should knives be set to cut through the films.

Stenter-made PP films have greater extensibility in the MD, typically greater than 150% elongation before break and 70% in the transverse direction (TD). Form/fill/sealing (f/f/s) machines perform better and give better seal integrity with transverse jaw grooves to minimise stress in the TD and allow more extension in the MD.

It is seen that opaque cavitated Stenter-made films have a greater tendency to split across the film in crimp jaws which stress the film beyond their elastic limit. The film does not elongate as well in the TD as in the MD, and hence shallower angled jaws with an angle of 120° and sinusoidal profile have been developed to minimise the stress.

These designs conflict with blown (bubble) oriented films where extensibility is closer to 100% in each direction. Conditions of high pressure and the lower heat stability of bubble-made OPP will still give the same effect at the high end of sealing conditions.

PET and nylon PA films with their superior heat stability giving very wide sealing ranges do not normally develop split seals. Using PE or cast PP as the sealant of a laminate exploits the easy flow nature of cast and low-melting point polymers. The molten polymer can flow into crevices and fill any gaps or holes in the seal. While satisfactory for many pouches, the inability of the laminates to seal inside to outside layers limits the application to f/f/s with fin seals, as compared with overlapping seals, along the length and this uses slightly more material because of the extra width of film required.

The ionomer emulsions used as coatings with low melting points of around 80°C and a high level of hot tack have extended the sealing range of coated OPP to over 70°C, where the upper sealing limit is set by the shrinkage of the film, judged to be 150°C. Formally, acrylic-coated films had the widest range of 50°C with the starting point at 100°C, and this enabled linear packaging speeds of 50 m min^{-1} to be achieved.

With high packaging speeds, it is normal to have high temperatures to melt the sealant in a very short dwell time. When the machine speed varies, the high temperature of the sealing jaws damages the film. With the LTS (low-temperature sealing) coating, lower heat settings are possible, thus avoiding film damage at slower speeds. Such low sealing threshold temperatures mean that a very short dwell sealing time is possible at lower temperatures with crimp jaws, thus avoiding film shrinkage. In effect, the amount of energy required to make a seal is much lower than with other coatings, and film speeds of 100 m min^{-1} may be achieved. LTS coatings will not seal to other mediums and so only f/f/s applications can be utilised, which seal inside to inside, i.e. fin seals. Most seals are considered to be strong enough if the film tears when the seal is stressed. Seals provide built-in evidence of tampering, but the packs may still be opened easily, especially in the case of oriented films with their easy tear propagation properties. However, there is a school of thought that argues that if the seal peels open slightly and absorbs the stress without tearing, then the pack is still intact and continues to function. Tamper evidence in this case is less obvious.

In all cases of packaging small and low weight products using films/coatings which do not flow too readily during sealing, a minimum seal strength requirement of 300 g/25 mm is typical. Heavier product weights and free-flowing products such as nuts, rice, pulses and frozen vegetables may have to have seal strengths in excess of 1000 g/25 mm.

7.9.2.3 Impulse sealing

With impulse sealing, jaws are heated to fusion temperature by a short powerful electric impulse. The seal area remains clamped and is cooled under pressure. Impulse seals are generally narrower than hot bar seals but can be doubled up. When minor contamination is present, the impulse method may give a better seal. Voltage and duration are varied according to the material.

PE films may be sealed with impulse-heated wires or strips to make welded seals. If the seal is not to be cut through the web, the heating strip has to be covered to protect the molten polymer from sticking to the heated metal strip and destroying the seal. This is achieved by covering the strip with a release sheet such as PTFE-covered glass fibre woven cloth. The resultant seals achieve 100% film strength. It is possible to make the same type of seals with coextruded OPP using PE sealing equipment, but the seals are more sensitive to tearing close to the seal due to the normal easy tear propagation caused by high stress orientation.

7.9.2.4 Hot wheel sealing

In this form of heat sealing, the material to be sealed is drawn past a hot wheel. The seal area is kept under pressure until it cools and a seal has developed.

7.9.2.5 Hot air sealers

This uses hot air, heated by gas or electricity, to melt the plastic in the seal area. It is used for the sealing of plastic-coated paperboard.

7.9.2.6 Gas flame sealers

This form of sealing uses gas flames to melt the plastic in the heat seal area. It has a lower noise level and is more heat efficient than hot air sealing.

7.9.2.7 Induction sealing

A common form of induction sealing is that which is used to heat seal a diaphragm, incorporating a plastic or plastic-based heat-sealing layer, laminated or coated onto aluminium foil, already in place in the closure, to the rim of a plastic, or glass, jar or bottle. The closure is applied to the container and passed under a high-frequency induction sealing head which generates heat in the aluminium foil, which then melts the plastic and heat seals it to the perimeter of the container.

7.9.2.8 Ultrasonic sealing

This is similar to high-frequency induction heating, except that the heat is generated by molecular friction in the plastic material itself. This principle has been used to seal the corners of plastic-coated paperboard trays.

7.9.3 Cold seal

As already stated, sealing conditions are a balance of time, temperature and pressure. Where high-speed packing is required and the product is heat sensitive, such as a chocolate countline bar or chocolate-coated ice cream, the first choice sealant is cold seal latex. The adhesive is converter applied in a pattern on the reverse side where the seals are to be made, accurately registered with the print on the outside. This specification requires a release lacquer over the print on a single web film, or a release film laminated as the outer layer of a laminate.

7.9.4 Plastic closures for bottles, jars and tubs

In food packaging, the most common form of screw cap is injection moulded using PP. Where a flexible snap-on feature is required, as for instance, with an ice cream tub or as a reclosure after opening a long shelf life pack, PE is preferred. PE is used for plastic wine bottle corks.

The *hinge* property of PP has been made use of as a closure, which remains in contact with the container. A wide variety of designs are applied to containers for products which are dispensed from the container such as salt, pepper, spices and herbs.

Another thermoplastic used for closures is PS, which is harder and glossier than PP. The tightest tolerance, dimensionally, is provided by thermosetting plastic closures, though these are more commonly used for pharmaceutical and cosmetic closures. Most plastic closures can have a tamper-evident feature incorporated in the design.

7.9.5 Adhesive systems used with plastics

Most forms of adhesive can be used with plastics, e.g.

- a tie or grafting layer of plastic used to promote adhesion in extrusion coating and coextrusions
- dry bond adhesives used for laminations involving plastic substrates from which solvent is evaporated prior to bonding the surfaces together
- heat curing adhesives used for lamination, which are 100% solids, operate by cross linking to the solid state once the lamination has been completed
- hot melt adhesives, which include plastic components, for applying labels
- hot melt adhesives used to erect and close folding cartons on packing lines
- PVA water-based adhesives for side-seam-sealing folding cartons during conversion, including cartons made from one-side PE-coated paperboard, where the PE has been corona discharge treated
- pressure-sensitive and heat set label systems.

7.10 How to choose

The key to successful food packaging is to identify the packaging needs of the product. These relate to the nature of the product, the intended market, shelf life, distribution and storage, point of sale to the ultimate consumer and the use and eventual disposal of the packaging. The choice should take account of environmental and waste management issues. Ensuring food safety with respect to biological risks and needs relating to flavour, colour and texture is essential.

Packaging needs can be considered in terms of:

- protection of the product – quality, safety etc.
- appearance – sales promotion, pack design etc.
- production – extrusion, forming, printing, packing etc.

Having decided that a type of plastic pack selected from the range of possible choices, such as a film sachet, lidded tray, bottle etc., the next decision concerns the type of plastic or combination of plastics necessary to meet the functional needs. Performance is related to the structural design of the pack and whether it is made from film, sheet, moulding or expanded plastic. As we have seen, there are many plastics, each offering a range of properties, and within each packaging type there are differences.

All plastics provide barriers to the ingress of gaseous and volatile materials from the external environment into a hermetically sealed pack and from the food product both into and through the pack into the external environment. The extent to which these effects occur will depend on the food product and on the type of plastic(s), its thickness and on the temperature and RH ranges to be experienced during the life of the product.

Some plastics are heat sealable so that packs can be sealed; some are also heat resistant to meet defined needs, e.g. reheating by microwave, radiant heat and retort sterilization. Some are suitable for storage in deep freeze. Many specific needs can be met within the defined conditions of use.

In a chapter of this type, we can make readers aware of the choices and provide a basis for meaningful discussions between technologists whether they be suppliers or users of plastic packaging. The following Tables 7.1 to 7.3 give some guidance in terms of ranking for moisture vapour permeability,

Table 7.1 Ranking of various films with respect to specified properties

Polymer	Water vapour transmission rate (WVTR)	Gas permeability	Optics	Machine performance	Sealing
LDPE	3	4	4	4	1
Cast PP	3	4	2	4	2
OPP	2	2	2	2	2
OPP coated	1	1	1	2	1
PET	2	2	1	1	4
PVC (Plasticised)	3	2	2	4	2

1 = Excellent, 2 = Very Good, 3 = Good, 4 = Poor.

Table 7.2 General gas and moisture barrier properties

Film (25 μm thickness)	Water vapour transmission rate (WVTR)	Oxygen transmission rate
LDPE	10–20	6500–8500
HDPE	7–10	1600–2000
OPP	5–7	2000–2500
Cast PP	10–12	3500–4500
EVOH	1000	0.5
PVdC	0.5–1.0	2–4
PA	300–400	50–75
PS	70–150	4500–6000
PET	15–20	100–150
Aluminium	0	0

Units: WVTR in g m^{-2}/24 h at tropical conditions of 90% RH at 38°C and gas permeability in cm^3 m^{-2}/24 hrs.

gas permeability, optical properties, packing machine performance and heat sealability.

The commercial consideration of cost must also be considered. Run lengths and lead times are also important. It is not unknown for there to be run length cost differences, where at one point a particular solution is cost effective relative to an alternative solution and for the position to be reversed at a different run length.