and during subsequent storage and handling. Certain organic compounds may have an adverse effect on bond strength to the extent that weakened bonds can result in layers peeling apart.

10.A3.2.6  Heat sealing properties
Effective heat seals are essential for maintaining the desired gas composition within the pack. The ability to form effective heat seals through contamination such as meat juices, powders, fats and oils is an advantage in many applications. Heat seal quality is dependent on many factors including seal material, seal width and machine settings such as temperature, pressure and dwell time.

10.A4  Modified atmosphere packaging machines
The function of MAP machines is to retain the product on a thermoformed or pre-formed base tray, or within a flexible pouch or bag, modify the atmosphere, apply a top web if required, seal the pack and cut and remove waste trim to produce the final pack. Pack format, presentation and machine performance and versatility and pack costs are essential factors for the packer filler to consider before selecting a machine for a particular product application. The following section provides an overview of the types and operation of MAP machines.

10.A4.1  Chamber machines
For low production throughput, chamber machines are sufficient. These are generally used with pre-formed pouches, though tray machines are available. The filled pack is loaded into the machine, the chamber closes, a vacuum is pulled on the pack and back flushed with the modified atmosphere. Heated sealing bars seal the pack, the chamber opens, packs are removed and the cycle continues. These machines are generally labour intensive and cheap, with a simple operation but are relatively slow. Some chamber machines can handle large packages and are suitable for bulk packs.

10.A4.2  Snorkel machines
Snorkel machines operate without a chamber and use pre-formed bags or pouches. The bags are filled and positioned in the machine. The snorkel is introduced into the bag, draws a vacuum and introduces the modified atmosphere. The snorkels withdraw and the bag is heat sealed. Bag in-box bulk products and retail packs in large MAP master packs can be produced on these machines.
10.A4.3 Form-fill-seal tray machines

Form-fill-seal (FFS) machines form pouches from a continuous sheet of roll stock (flow wrap), or form flexible or semirigid tray systems comprising a thermoformed tray with a heat sealed lid. FFS machines may be orientated in a vertical plane or a horizontal plane. Flow wrapping machines are available in both vertical and horizontal formats. The type of format is dependent on the nature of the food product being packed. FFS machines using pre-formed trays or producing thermoformed trays are almost exclusively horizontal machines. This section focuses on horizontal form-fill-seal MAP machines which are used extensively in the food industry.

Thermoformed form-fill-seal tray machines use rollstock film for base web and lidding material. Base film is carried through the machine by clamps which attach onto the edge of the web and carry it through the forming, filling, evacuation, gas modification, sealing, cutting and discharge stages.

Base trays are produced by applying heat to the base roll stock, which when softened is immediately moulded into the desired shape and size. Forming of the heated, softened sheet can be achieved by applying a vacuum, air pressure, mechanical drawing or a combination of these processes. The softened heated film is normally drawn into the forming mould under the assistance of vacuum applied through evacuation holes located along the base edges and corners of the mould. This process produces a more defined and uniform tray shape. Where deep trays are required, a more uniform distribution of plastic can be achieved by prestretching the film using mechanical devices (plugs) which prevent excessive thinning of the container walls at the base edges and corners.

The tooling for the moulds represents a significant initial capital cost of thermoformed form-fill-seal tray machines. Moulds are generally fabricated from either steel or aluminium, the latter being cheaper but less durable than the former. Inserts, called filler plates, can be placed on the base of the die to decrease the forming depth and therefore produce shallow trays. Roll stock for base tray and lidding is supplied in reels of film wound on to a core of standard diameter (usually 3 or 6"") which matches the film unwind system on the thermoforming machine. Reel diameters are usually supplied from 300 mm to 1000 mm, in increments of 50 mm.

Thermoformed trays are produced by one of the three following methods.

10.A4.3.1 Negative forming

Negative forming is suitable for flexible films but has limitations with rigid materials, unless the cavity shape is shallow with well-rounded corners. It comprises a two-stage cycle:

1. compressed air blows film up against a heating plate which softens the film
2. the softened film is blown down by compressed air through the heating plate into a mould (Fig. 10.3).
Plug-assisted negative forming is used when deep or complex tray shapes are required. The plug prestretches the film to produce improved distribution of the softened plastic. This is essential to ensure tray corners have a sufficient thickness of material in order to prevent pinholes from forming or material becoming damaged during handling. This method can be used for flexible and rigid materials. It comprises a three-stage process:

1. film is softened between heated plates. Preheating can occur in one or several stages
2. plug descends and stretches the film
3. final shaping stage occurs by compressed air which pushes the film into the mould (Fig. 10.4).

Plug-assisted positive forming is used for shaping rigid trays, where a more controlled distribution of film material is necessary to maintain the material thickness at the base and corners of the tray. It comprises three stages:

1. the film is heated between temperature-regulated plates
2. a vacuum produced at the base of the mould prestretches the film
3. the positive plug descends, and the film is blown up to it by compressed air. The plug forms the shape of the tray (Fig. 10.5).

Following the forming stage, the base tray advances to the filling station, where it is manually or automatically loaded with the food product. The pack then advances to the gassing station where the modified atmosphere is introduced and the top web heat sealed to the base tray. The sealed trays are labelled, coded and separated as necessary.
Stage 1: the plastic base film is softened by the heating plate

Stage 2: the plug descends and pre-stretches film

Stage 3: the film is blown into the mould by compressed air to form the base tray

Figure 10.4 Thermoformed base tray produced by the plug assisted negative forming method (courtesy of Multivac).

Stage 1: the plastic base film is softened by heating plate

Stage 2: the heated film is pre-stretched by vacuum and forming plug descends

Stage 3: the pre-stretched film is forced up to the plug by compressed air to form the shape of the plug

Figure 10.5 Thermoformed tray produced by plug assisted positive forming (courtesy of Multivac).
10.A4.4 Pre-formed trays

The alternative to thermoforming the base tray is to use pre-formed trays. These are loaded manually or automatically by a tray denester into the machine infeed and pass through the filling, gas flushing and sealing stages as would a thermoformed base tray. Examples of pre-formed trays are shown in Figure 10.6.

10.A4.4.1 Pre-formed trays versus thermoformed trays

Pre-formed trays have several advantages compared to thermoformed trays:

- Pre-formed trays offer more flexibility in tray design. A greater range of intricately shaped pre-formed trays are available than is currently possible to produce on thermoform machines.
- Pre-formed trays can offer enhanced appearance and presentation at point of sale.
- A greater range of tray materials can be used for pre-formed tray manufacture than would be possible with thermoform machines.
- Trays of the same shape but different colour or depth can be handled with no changeover.

Figure 10.6 Examples of plastic pre-formed trays for MAP foods.
• Greater flexibility in tray loading is possible with pre-formed trays. This operation can take place before packing and in an area separate from the packing operation.
• Generally, pre-formed trays require less downtime for changeover between different tray sizes compared to thermoform-fill-seal machines. A tooling set comprising the sealing die, frame carriages and cutting die has to be changed when a tray of different outer dimensions is used.

Thermoformed trays have the main advantage of lower packaging material costs. It is estimated that tray pack savings of between 30 and 50% are achievable mainly because costs of the thermoforming process are carried by the filler packer rather than the tray supplier. Transportation and storage costs will be higher for pre-formed trays compared to the roll stock equivalent for thermoformed trays.

10.A4.5  Modification of the pack atmosphere
MAP machines use mainly one of the two techniques to modify the pack atmosphere.

10.A4.5.1  Gas flushing
This method employs a continuous gas stream that flushes air out from the package prior to sealing. This method is less effective at flushing air out of the pack, and this results in residual oxygen levels of 2–5%. Gas flushing is therefore not suited for oxygen-sensitive food products. Generally, gas flushing machines have a simple and rapid operation and therefore a high packing rate.

10.A4.5.2  Compensated vacuum gas flushing
This method uses a two-stage process:

1. The evacuation stage – a vacuum is pulled on the pack to remove air. Generally, it is not possible to achieve a full vacuum, since reduced pressures will result in water to boil, at which point the vacuum cannot be improved. The vacuum achieved is generally between 5 and 10 Torr (1 Torr = 1 mmHg). As a general rule, the cooler and drier the food, the lower the achievable vacuum.
2. Gas flushing stage – the pack is flushed with the modified gas mix. The evacuation of air from the pack results in lower residual oxygen levels than that achieved by gas flushing, and therefore this method is better suited for packing oxygen-sensitive products.
The two-stage process employed by the compensated vacuum method results in a lower packaging rate than that possible with gas flushing.

10.A4.6 Sealing

An effective heat seal is critical to maintaining the quality and safety of the packaged product. Film factors (thickness and surface treatments) and plastic composition (resin type, molecular weight distribution and presence of additives) will determine the machine settings for the sealing operation. The correct combination of time, temperature and pressure of the seal bars is necessary to produce a good seal. Insufficient dwell time or temperature can result in ineffective seals that separate at the bond interface. Excessive dwell time or temperature can result in weakness adjacent to the seal area.

10.A4.7 Cutting

Packs are discharged as a continuous arrangement of filled and sealed packs from a thermoform-fill-seal machine, and therefore, the final operation is to separate into individual packs. This can be carried out by two methods – die cutting and longitudinal and transverse cutting.

Die cutting is achieved in one operation. A shaped blade is forced through the film which is clamped in place by a frame assembly. Transverse cutting separates packs into rows and is carried out by guillotines or punches which are driven through the film that is supported by anvils. This may be carried out in conjunction with longitudinal cutting where circular knives cut through the tray flanges parallel to the length of the film.

Regardless of the cutting method, it is important to ensure that an even flange remains around the lip of the tray in order to maximise the seal strength. Offset cutting could leave one side of the tray with a thin flange that may open during handling and distribution. Waste trim is either wound onto spindles at the machine discharge or removed by suction into collection bins.

Figures 10.7–10.11 show some of the above operations in a Multivac R230 thermoforming machine.

10.A4.8 Additional operations

Machines are generally integrated into production lines and combined with operations such as automatic filling, top web labelling, base web labelling, registration of printed top web, over printing and pack collation and case loading.
Figure 10.7 Multivac R230 thermoform fill seal machine.