Part I

Conventional technologies
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Retort technology
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2.1 Introduction

Heat sterilisation of food in containers is an old technology largely attributed to the work of Nicholas Appert in the 1800s. From Appert’s work a substantial industry has developed. For example, the estimated sales of canned products in Europe are 26,000 million/year.

The application of heat processes to containers requires not only the ability to heat and cool the container contents efficiently but also the ability to do so while minimising the stresses imposed upon the container. This controlled application of heat and pressure is the function of the modern sterilising retort.

When faced with plans to launch a new in-container sterilised or pasteurised food product, various pieces of information must be gathered before decisions on the design of an installation can be made. This chapter aims to give the background required to understand these decisions. The reader will be guided through some of the diverse and ingenious ways that retort systems have evolved to maximise process efficiency. These increases in efficiency have taken place simultaneously while additional challenges have been presented by the development of less rigid packing types.

2.2 The basic retort cycle

The layout of a typical vertical saturated steam retort is given in Fig. 2.1. Understanding the key features of this traditional retort system will give the required insight to the features of more modern systems.
The first action in the cycle of operation of a retort is to load the containers of product; in most systems this involves putting containers into crates. The sides and base of the crates, and any dividers used between layers of containers must be perforated sufficiently to allow heat to penetrate the load. The function of dividers between layers of containers can be to aid heat penetration but also to minimise container damage through abrasion and sometimes electrolytic effects from the crate. Once the required number of crates of product are loaded, the lid (or door) is closed and the steam turned on.

After early attempts to bring about product sterilisation at above 100°C using salt baths the heat preserving industry settled on the use of steam as the heating medium of choice. Steam is an excellent heat medium because of its ability to condense on container surfaces releasing large amounts of latent heat.

The main enemy of efficient heating in a closed vessel (e.g. a retort) using saturated steam is the presence of entrapped air, especially that trapped in the small spaces between containers in the load. Even a small quantity of air has a significant effect upon the temperature. For example, at any given location 10% of air by volume will reduce the temperature by about 3°C, which will have a dramatic effect on product sterilisation. This means that in order to bring about efficient and uniform heating, air must be purged, or as it is referred to in the industry, ‘vented’, from the retort at the start of the process.

In the canning industry venting is achieved at the start of the operating cycle by introducing high velocity steam into the retort. This steam is allowed to pass through the vessel and exit through a vent at the opposite side of the machine,
i.e. if the retort is in a vertical orientation the steam enters at the bottom and exits at the top. This flow of steam displaces air out through the vent and when the flow rate is sufficient draws air from within the load by a Venturi effect. The efficiency of this process is sometimes aided by allowing steam to bypass the main control valve giving more rapid steam flow and a shorter come-up time.

In practice, the efficiency of the venting process can be monitored by measurement of the temperatures in various locations throughout the retort, and the time required to remove all the air is determined experimentally. At the end of the venting time the vent valve is closed and the retort pressurised until the desired process temperature is reached. In the US target venting pressures, as well as times, are also commonly specified, though if the vent is sufficiently large in relation to the steam flow from the inlet, these should not be significant. Here it is interesting to contrast canning with other autoclaving industries which prefer to use automatic vent valves which operate throughout the entire cycle by opening on the detection of low temperature air. However, this does not give the high steam velocities that are considered to be necessary to draw air from the centre of crate loads of cans.

After venting steam utilisation is reduced, and depending on the heat, absorbing capacity of the load continues to diminish throughout the holding period of the process. This high demand at the start of the process means that in some installations with low boiler capacities only one retort may be started at a time.

During the hold phase there must be a means for the water generated as steam condenses to escape from the retort, because immersion of the lowest containers in the vessel could result in under-sterilisation. This is normally achieved either by a small condensate bleed that is permanently open or having the drain cracked slightly open. In either case the absence of water in the base of the retort can be detected by a free flow of steam.

On reaching the intended holding temperature the requirements are for a narrow spread of temperatures throughout the vessel and stable control at the intended temperature. For a properly vented steam retort a temperature range of less than 0.5°C is achievable, and this is a good target for all retort systems, though difficult to achieve in some types. The control of temperature fluctuations is generally by an automatic control system working from feedback from a temperature sensor in the instrument pocket of the retort. Formerly pneumatic controllers were used but electronic systems and/or programmable controllers have largely replaced these.

There are minimum standards of instrumentation expected of any retort system which aim to ensure that product receives the correct process, and operator safety. The expected instruments include:

1. A pressure gauge.
2. A chart recorder to generate a permanent record of the heat process applied.
3. A master temperature indicator (MTI). This is a calibrated thermometer
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independent of the chart recorder, which can be used to cross-check the chart record so that process safety does not rely on only one instrument. It is usually a mercury in glass or platinum resistance thermometer.

4. A process timer. In simple installations a wall clock, but increasingly commonly the timer is built into the programmable controller.

5. An automatic temperature controller, which may or may not operate from the same sensor as the chart recorder.

To ensure the even application of heat to all containers in the load it is important to ensure that during the holding period the services which are not in use (air and water for cooling) do not leak resulting in low temperature regions. Valve types are selected to give minimum risk of leakage and double valves, with a route to atmosphere, are sometimes used.

Once the desired hold period has been completed then the retort is cooled. The start of the cooling phase is most critical for ensuring the continued integrity of the processed containers. During the holding period the pressure inside the containers undergoing sterilisation increases as the contents heat and expand. With cans this internal pressure can be restrained adequately by the rigidity of the container and the external steam pressure, e.g. 1.0 kg/cm² (15 p.s.i) at 121.1°C. However, if at the start of cooling the supply of steam is turned off and the pressure allowed to drop quickly, then the internal pressure can be sufficient to cause permanent damage to the pack; in canning this is referred to as ‘peaking’. Although some canning operations producing tough cans do use this approach (air cooling) most operations introduce cold water for cooling. Introduction of water into a retort full of steam causes a very rapid collapse in the residual steam with a consequent loss of pressure. This is overcome by the replacement of the steam pressure with a supply of compressed air at the same, or a slightly higher, pressure, e.g. 0.1 kg/cm² above the steam pressure. Thus in a short period of time the internal pressure in the containers is switched from being balanced by the external steam pressure to being balanced by an external air pressure, which for both manual and automatic controllers is no mean feat.

On switching from heating to cooling the requirement is for rapid and uniform cooling. In practice though the uniformity of cooling rarely matches the uniformity of heating. As cooling progresses the internal temperature inside containers gradually falls and the internal pressure diminishes. When the internal pressure has been balanced by an external air pressure then there is a danger that the external pressure can crush the container; for cans this is called ‘paneling’. It is therefore necessary that a pressure control profile is developed that appropriately matches the internal temperature profile so that neither excessive container swelling nor crushing take place.

Once the target cooling temperature has been reached the water supply is switched off and any residual pressure released. The target temperature for product is normally in the region of 40°C which is a compromise to prevent the growth of heat-loving bacteria that survive the retort process and leave enough residual heat to aid container drying. The drain is then opened and the cooling
water released. The door or lid is opened and the crates unloaded. The retort is then ready for the next cycle.

2.3 Selection of container

The selection of a retort system cannot be made independently from the packing medium to be used; so the key features of each of the main packing types used for container sterilisation/pasteurisation are reviewed. Selection of the containers in which to heat process a food is to a large extent a marketing decision, based upon shelf appearance, ease of opening, micro-wavability and overall product quality. Technologically cans and jars have the advantage that they are well understood. Production lines for new container types, e.g. semi-rigid plastics or pouches, are likely to generate more teething troubles. The transport of plastic containers (trays and pouches) before use tends to be more economic than cans and jars (assuming the food manufacturer does not also make the latter). Trays can be nested, i.e. stacked one within another, for transport, whilst pouches can be transported flat. Both pouches and trays are light in weight for transport. Empty cans and jars are bulky to transport, and glass containers have a relatively poor ratio for container weight to product.

Cans have inherent strength to protect them from a degree of mishandling, both before and after filling. Plastics can be prone to puncture by handling equipment and even from sharp food components on filling, e.g. bones. Glass is fragile and presents a hazard if fragments contaminate the product; therefore plants must be operated under close supervision to minimise the potential for product breakage and product contamination. In processing and distribution, cans and jars can be stacked on top of one another with little damage, whilst pouches and trays tend to require outer packaging, e.g. board boxes, to protect them and allow stacking, though they will still only withstand relatively low stacking heights.

Filling operations for cans are faster than for glass and plastic containers. Pouches in particular are difficult to open and fill at speed, without contamination of the sealing area. Likewise sealing operations are faster for double seamed cans than heat sealed pouches or jars.

The shelf-life of product packed in cans/jars is theoretically longer than pouches/trays if the latter do not contain a complete oxygen barrier. Some plastics and glass are poor ultraviolet barriers so the detrimental effects of storage in light, during distribution and retail, must be considered. Cans and plastics can both contribute to product flavour development; glass is more inert.

2.4 Selection of a retort

As with all aspects of designing a production plant the selection of a retort system will be based ultimately on process economics. The main factors affecting the economics of a retort process will be:
process throughput
• energy efficiency
• product wastage
• retort life.

The rate of production required will play a part in the decision on whether batch or continuous retorts are selected, the latter offering higher rates of production. However, where an installation must cope with regular changes in container specification/process time requirements either because the plant has a wide product range or develops many new products, continuous retorts can lack flexibility. Hence in many factories both continuous and batch systems are installed.

The life of a retort system is largely dependent upon the material of construction and the treatment chemicals added to cooling water. Many older retorts are constructed of mild steel which is prone to corrosion especially if corrosive chlorine-based compounds are used for disinfection of the cooling water. In the absence of such chemicals the author has observed mild steel retorts in operation fifty years after their construction; however, using untreated water has product safety implications if the water is not from a source of good microbiological quality.\(^2\) With the newer generation of retorts with more complex computer control systems it makes little sense to attach such an investment to a vessel that will disintegrate in 5–10 years, so they tend to be constructed from stainless steel.

2.4.1 Temperature requirements

The process time/temperature requirements for a particular product can be predicted from a relatively small amount of experimental data. This data for products is usually expressed in terms of a heating factor \(f_h\), or thermal diffusivity for the product (formula and container size) in question. This information, which may exist from previous experimental trials or pilot trails upon a new product, is required as data input into finite difference models that allow prediction of product heating throughout a simulated retort heating profile. For example, these programs allow predictions based upon infinite combinations of container dimensions and differential surface heat transfer coefficients, e.g. for prediction of heating in a glass jar with a metal lid. From these predictions it is possible to determine approximate retort programs (times/temperatures) in order to achieve the desired level of microbial destruction. Once a time temperature profile has been resolved the entire installation can be planned based upon the plants throughput requirements.

Target microbial destruction levels are usually expressed as an \(F_0\), \(P\) value or time above a specified temperature. Selection of process targets should be done in consultation with a specialist microbiologist and a specialist in taking temperature measurements in products.\(^3\) \(^4\) Retort temperatures for sterilisation processes are generally between 110 and 130°C, a temperature range that gives
acceptable rates of microbial destruction while not presenting excessive risks of product burn. Sometimes temperatures are limited by specific characteristics of the packaging, for example welded seals on pouches soften significantly as the retort temperature increases and printing in lithographed cans will have an upper temperature limit. It is worth noting that containers/closures, which look similar, may be specified for use in pasteurisation or sterilisation processes only.

### 2.4.2 Pressure requirements

Selection of a retort pressure profile is as important to process safety as the retort temperature profile, because although the latter destroys the product’s microbial loading, minimising mechanical stressing of containers is essential to prevent recontamination. Pressure profiles can be determined from experimental trials by two means: measurements of internal/external pressures or by direct measurements of pack distortion.

As with measurements of product heating, consistent results from pressure measurements in containers (or deflections) will only be obtained if pack preparation is well controlled. The following factors can contribute to pressure conditions developed inside containers during retort processes:

- pack vacuum at sealing
- the product temperature at sealing
- the headspace size (the space above product in a container)
- the process temperature
- the product formulation
- the quantity of gas entrapped in the product.

Typical overpressures for different container types are:

- **Plastic trays**: 2.3–2.9 kg/cm² (32–40 lb/inch²) with a tolerance of 0.1–0.2 kg/cm²
- **Pouches**: 1.0 kg/cm² (15 lb/inch²) with a tolerance of 0.1–0.3 kg/cm²
- **Plastic cans**: 2.9 kg/cm² (40 lb/inch²) with a tolerance of 0.4–0.5 kg/cm²

### 2.5 The influence of heating medium on retort performance

#### 2.5.1 Batch retorts

The use of batch retorts allows far greater flexibility than continuous retorts, particularly if the batch system has a capability for overpressure throughout the heating/cooling process.

The use of overpressure batch retorts, using either full water immersion, raining water or a steam/air mixture for heating, allows independent control of temperature and pressure during the heating process. This contrasts with saturated steam retorts where the process pressure is directly related to the chosen holding temperature. In the overpressure retorts process pressure conditions can be established that minimise pack damage. Therefore, if jars,
semi-rigid trays or pouches are to be produced, overpressure retorts are generally used. Selection of specific retorts should also consider the sensitivity of the pack(s) in question to the rapid change in pressure or temperature that are inherent in some designs.

For batch retorts, new container designs may be accommodated in existing retort crates or, if necessary, alternative crate designs may be used. The loading of containers into the retort crates should be considered at an early stage of process design because retort performance can be adversely affected if the crate loading is too dense. If the loading pattern needs to be adjusted at a later stage, to achieve acceptable retort temperature distributions, original estimates of retort throughput will be reduced.

The support and orientation of containers within crates is also important as it affects retort temperature distribution and product heating. For example, a semi-rigid tray which heats at different rates through its lid and base, will give a different heat penetration performance if the pack is heated lid up or lid down, because of the insulation effect of the headspace on heat transfer through the lid. Product appearance, as seen by the consumer when the pack is opened, may also play a part in determining the required container orientation during retorting.

Some plastic containers require specialised support racks to ensure adequate temperature distribution and pack performance. It should be noted that during retorting, plastic containers can soften and change shape, their orientation and support during processing will affect the extent and nature of this deformation. The plastic containers (trays and pouches) do have one potential advantage for product quality because as they are generally of thinner profile than cans they heat more rapidly (so process safety requirements can be achieved with a minimum degree of overcooking).

Preliminary testing to ensure that any proposed combination of crate, container, pack arrangement, and layer divider can achieve acceptable temperature distribution performance is advisable. Purely practical considerations when planning the crate loading operation are the degree of automation achievable, the stability of containers, i.e. will they fall over when the crate is moved, and the potential for puncturing of containers during loading/unloading (a particular problem with pouches).

**Saturated steam retorts**

The basic operating principles of a saturated steam retort are covered in Section 2.2. A high number of saturated steam retorts are installed when production requires a large throughput of varying canned products. Installations may be in the order of 40 retorts, normally of the vertical type to save space. In such large installations the practice of venting significant quantities of steam to the atmosphere is problematic as the working environment becomes very hot and humid. On a practical level the presence of steam in the retort room can be controlled by the installation of a vent manifold to carry the steam outside the building. However, careful design is required to ensure that this does not inhibit the flow of venting steam.
Steam/air retorts
These types of retorts utilise the deliberate mixing of steam and air in the retort vessel to provide an overpressure environment suitable for processing pressure sensitive containers such as jars, pouches or semi-rigid trays. Typical examples of steam/air retorts are those supplied by Lagarde and Panini.

The principle of the steam/air retort is totally contrary to the traditional saturated steam retort where air removal is regarded as a necessary precursor to starting the hold period. In a steam/air retort a proportion of air is retained, or introduced, to balance the internal pressures within containers undergoing sterilisation. Clearly this principle will not give uniform sterilisation unless it is ensured that the mixture of steam and air is uniform, as the presence of large pockets of air will result in under-sterilisation. It should also be noted that as steam condenses, the air portion is left potentially forming an insulating layer around the packs to be heated. In commercial retorts this mixing and breakdown of the residual air layer is achieved by the use of a large fan which draws the steam-air mixture through the load and recirculates it to the opposite end of the machine (such retorts are almost universally horizontal) (Fig. 2.2). It has been suggested that the mixing could be achieved by continuous venting, but this is not used in commercial systems and is unlikely to be energy efficient.

The temperature uniformity of such steam/air systems relies heavily upon the correct operation and maintenance of the fan and circulation systems. Fan failure or damage would be regarded as critical process deviations.

There is debate as to whether the achievement of temperature uniformity in steam/air systems is best achieved by a full vent, followed by reintroduction of a portion of air, or simply modifying the ratio of steam to air progressively at the start of the process. It is also worth noting that for both a saturated steam retort and steam/air retorts rotary processing (see page 21 below) may not always be helpful in removing air from the centre of crates.

Like saturated steam retorts, steam/air retorts are potentially prone to steam collapse on the introduction of cooling water, which is particularly unhelpful in systems used for pressure sensitive packaging types. Retort manufacturers have addressed this issue by including a precool stage in the operating cycle. This precool stage involves the initiation of the cooling process using condensate collected from the base of the retort vessel and/or introduction of very small amounts of cold water. By this means the steam contents of the retort can be condensed in a relatively slow and controlled manner while the air content is increased.

Full water immersion
Probably the oldest mechanism for overpressure processing is to process containers under water with an overpressure applied to the free space above the water in the retort vessel (Fig. 2.3). The overpressure in the free space can be varied to give the required control over container deformation whilst the water can also be superheated above 100°C. Typical machines of the full water immersion principle are those produced by Stock and Lubeca.
Fig. 2.2 Schematic of a steam/air retort.
Fig. 2.3 Schematic of a full water immersion retort.
Given that the volume of water inside full water immersion retort systems is large, heating this amount of water could be a very slow process giving a long come-up time to the desired sterilisation temperature. A means of overcoming this problem, which also adds to the energy efficiency of the system, is to have a second vessel in which the water is preheated above the desired sterilisation temperature. When the process is started this water is then pumped or dropped under gravity into the retort vessel containing the product. Although there may be some temperature drop in the water as it is transferred this method significantly reduces the retort come-up time and increases throughput. This approach must be used with care where jars are being processed and a large temperature differential exists between the product and the incoming water, as thermal shock can result in breakage.

At the end of the holding period the water can be pumped back to the storage vessel for use on the next batch, thus saving on the energy required to heat water. Cooling is carried out with an external cooling water supply. A side effect of the double vessel water immersion retort process is that the water capacity of the storage vessel is usually matched to the requirement for a fully loaded retort. Therefore if part loads are processed there is insufficient water. To overcome this problem the retort manufacturers supply dummy crates whose function is simply to replace the missing crates of product.

In water there is a natural tendency for convection currents to develop which will make the top of the retort hotter than the bottom, and therefore there will be different levels of product sterilisation at each position. This problem is overcome by different means by different retort manufacturers. The more sophisticated systems use an external water circulation loop on the vessel, so that water is pumped from the colder regions of the vessel through a steam injector and back to the retort. Where possible this mixing process is combined with rotary agitation of the load, which further aids the mixing of the water.

It is not uncommon to find vertical full water immersion retorts that can also be used in saturated steam mode. In these systems the agitation of the water is sometimes provided by the use of a cross-shaped spreader which directly injects steam into the retort vessel. These are designed to give good mixing of the steam and water, e.g. by having two live and two dead quadrants to increase mixing. In addition, some systems have a small injection of air into the steam supply that bubbles through the water and mixes it.

The headspace above the water can either be filled with pressurised air or steam. The use of steam has the potential advantage that process deviations due to abnormally low water level are unlikely to result in gross understerilisation. It is generally recommended that the water level in such systems should be kept at least 10 cm above the topmost containers in the process.

Some packs will have a tendency to float during full water immersion processes; where this is not desired a suitable restraint must be put in place, e.g. tops on crates. There are circumstances where this buoyancy effect is beneficial, e.g. semi-rigid trays and pouches soften during processing at high temperatures; without support this can lead to permanent deformation under the effect of gravity. In water immersion this tendency for packs to sag is minimised.
Raining water/sprayed water retorts

Typical raining water retort designs are those of Barriquand and Prominox. Sprayed water retort systems are made by FMC, Radabe and Surdry.

It is difficult to say whether the raining water and sprayed water systems are directly comparable in the physical mechanisms by which they transfer heat to the load. The raining water principle is simple: water is sucked from the trough at the bottom of a horizontal vessel, passed through a heat exchanger, and pumped to the top of the vessel where it is dumped at high velocity onto a sieve plate in the top quadrant of the vessel (Fig. 2.4). The water is then distributed under gravity over the sieve plate and runs down through the holes onto the load below. Sprayed water systems operate in a similar manner except that the water rather than being put onto a sieve plate is put into one or more spreaders which run down the length of the vessel. These spreaders have spray nozzles along their length which spray water into the load from the top (and sometimes sides). A potential weakness of the sprayed water systems compared with raining water is the natural tendency for the water pressure to drop along the length of the spreader meaning that water coverage is less even. The relative roles of the perforations in the ‘stair rod’-forming sieve plate and mist-forming nozzles on the ability of the water to carry heat to the load is unclear.

The directional nature of the water input means that both types of systems are believed to be affected by what are referred to as ‘umbrella effects’ where the penetration of heat into some containers is slowed because the water flow impacts on a container above.7 The occurrence of such effects though appears to be highly dependent upon load content and layout. In practice the heat transfer rates in raining water systems seem to be comparable to those from saturated steam.

Although the use of a heat exchanger in the recirculation loop is common on this type of system other alternatives are possible such as

- a heat exchanger in the water trough
- direct steam injection into the water trough
- steam injection into the process vessel.

Clearly for any of the raining water or spray water systems correct maintenance of the water circulation system is critical for ensuring uniform sterilisation is achieved. This means that when water contamination is likely due to overspill at container filling, or pack failure during the process, regular cleaning is required. The recirculation system usually includes a filter that must be routinely inspected and emptied. The US Food and Drug Administration (FDA) like to see data proving that the water flow rates inside these retorts are uniform. Ironically one of the niche markets for raining water systems is the industry canning oily fish where these types of retort effectively double as can washers.

One of the benefits sometimes claimed for these systems is that the load is heated and cooled in the same water (the external side of the heat exchanger is
Fig. 2.4  Schematic of a raining water retort.
switched from steam to cold water). In theory this means that the water should be free from microorganisms and therefore is an excellent means of preventing post process recontamination. However, post process recontamination spoilage incidents have occurred which could be attributable to leakage in the heat exchanger, dead-legs (regions of low flow) in the recirculation loop building up contamination or contamination of the air supply.

_Crateless retorts_
These retorts are large vertical vessels with doors at either end. During filling the top door is opened and cans feed under gravity from a conveyor. The cans fall to the bottom of the retort and are cushioned on their way down by water. Once the retort is full the top door is closed and the water is flushed out by steam, and the process hold commences. When the hold is finished, the load is cooled with water, drained and the bottom door is opened. The cans then fall out into a cooling canal.

_Batch rotary retorts_
Increased retort throughput can be achieved for products that undergo forced convection by using rotary batch retorts. Such rotary agitation can be applied to any of the heating media described above, e.g. steam, steam/air, raining/sprayed water or full water immersion.

Rotary processes, which agitate the product inside the container, are often used in conjunction with higher process temperatures than would be used for the same product in a static process. The higher temperature is less detrimental to product because the movement prevents overheating, particularly at the container wall.

Two modes of agitation can be employed; these are referred to as ‘axial’, in which a can spins on its own long axis, or ‘end over end’ in which the can is tipped over. Commercial batch retorts generally use end over end agitation, as this is more suited to easy loading and simple design of the crate system.

A very important factor in the effectiveness of agitation in bringing about product heating is the size of the headspace (the free space in the top of the container after filling) which plays a big part in the mixing process.

In rotary retorts the product within the crates must be clamped in place preventing damage from the movement during rotation. If a range of container sizes/types is to be put through the same retort, then consideration will be required as to how the clamping mechanism will cope. Some containers are not suitable for rotary processing, as they do not perform well when clamped, e.g. the sealing compound in jar lids can be cut as a combination of the softening in the heat process and the pressure of clamping.

Some products are not suitable for rotary processes, for example where the product texture is adversely affected, e.g. cream or soft fruit. For those products that heat rapidly by natural convection, e.g. thin soups or vegetables in brine, the benefits of rotary processes are marginal.
2.5.2 Continuous retorts

*Hydrostatic retorts*

Hydrostatic retorts (Fig. 2.5) utilise a water lock to transfer conveyed containers into a pressurised process vessel. The incoming water ‘leg’ can contain a controlled temperature gradient for optimal preheating of the incoming containers. Likewise, temperature gradients in the cooling ‘leg’ can be optimised. The process chamber is normally filled with saturated steam but steam/air mixtures are sometimes used. Current manufacturers of hydrostatic retort systems include Stork and FMC.

The process applied is determined by the temperature in the process chamber (which is limited by the size of the hydrostatic legs) and the speed of the conveyor system. Hydrostatic retorts have historically been used for production of cans, glass bottles and plastic bottles, though this situation is changing (see Section 2.6). The loading mechanisms and orientation of the containers tend to differ, cans are loaded from a conveyor at right angles to the retort conveyor, while bottles are fed into pockets from the direction of travel of the retort conveyor. This configuration avoids pushing the relatively fragile glass/plastic containers against each other. Hydrostatic retorts are designed to work with a limited range of container sizes, depending upon the carrier bar diameter. Some systems have two sets of carrier bars of different diameters on either side of the conveyor chain. Those retorts using the bar mechanism can cope with variations in can heights without much difficulty, e.g. promotional packs, the pocket systems are less flexible.

![Fig. 2.5 Schematic of a hydrostatic retort.](image-url)
A small amount of product agitation is imparted during the change of direction on the conveyor of a hydrostatic retort, but this does not dramatically affect product heating. Some hydrostatic retorts are designed with a planetary motion of the carrier bars to enable high temperature short time processing, e.g. for dairy products.

Care must be taken in the design of hydrostatic retort installations (and any other continuous retort) to ensure that there is no possibility of the unprocessed containers jumping from the conveyors feeding the retort to those taking product away. With hydrostatic retorts there is also the specific issue that the water used in the preheat leg should not be in direct contact with the outfeed leg because cross-contamination from fill overspill can result.

**Hydrolock retorts**

These are retorts that operate on a similar principle to the hydrostatic retort except that the hydrostatic seal contains a mechanical element so that the ‘legs’ do not need to be so high. In fact the machines are like a hydrostatic retort operated in a horizontal orientation. Some of these machines have the unusual feature that during some of the conveyed distance inside the steam chamber the carrier bars become free to roll imparting extra agitation to the product.

**Reel and spiral retorts**

Despite its mechanical complexity the reel and spiral retort (Fig. 2.6) is, in fact, an old design dating from the 1930s. Current manufacturers of reel and spiral retorts are FMC, Stork, AMC and Molenaar.

The principle of operation is that cans (the system can only be used for cans) are fed from a conveyor system, twisted onto their side, so that they roll freely and then passed through a star valve directly into a pressurised retort vessel. Each can fits into a pocket between the points of the star, which as it turns moves the can from outside to inside the retort. Once inside the retort vessel, which is a horizontal cylinder, the cans are fed onto an internal spiral track in the inner wall of the cylinder and pushed along by blades attached to a reel rotating in the centre of the vessel. The spiral nature of the track means that the cans move from one end of the cylinder to the other, and when they are in the bottom third of the cylinder they rotate freely on the bottom wall.

At the end of the cylinder cans are passed out through another star valve and either exit the pressurised environment or are passed to another ‘shell’ (a similar retort vessel). Where such transfer values are used for moving cans between heating shells, the valves are fitted with a steam supply to ensure that cans in the valves are exposed to the intended process temperature and pressure conditions, especially during stoppages.

The configuration (number and types of shells) of reel and spiral retorts varies depending on the type of product to be processed. The process duration is determined by the length of the shells, the number of shells, and the rate of rotation of the reel (process time and reel speed cannot be controlled independently). For example, a reel and spiral retort processing a dairy product
Fig. 2.6 Cut-away diagram of an FMC Reel and Spiral retort.
might have a preheat shell operating a temperature well below sterilisation
temperature, one sterilisation shell and a cooling shell, while a machine for cans
of baked beans might have two sterilisation shells and two cooling shells (to
allow for the longer hold and cool periods required). The shells are generally
operated with steam or water for heating and water for cooling.

Reel and spiral retorts rely on the movement of containers rotating on their
sides, which limits their use to cans. There is little flexibility in can size that can
be processed, with machines being built for one can diameter and a limited range
of heights. Agitation is inherent in the reel and spiral design enabling high
temperature short time processes so they are not suitable for product sensitive to
mechanical action, e.g. strawberries.

For many years can rotation rates in reel and spiral retorts have been assumed
but more recent electronic can rotation counters have become available. These
devices can be put through the retorts to ensure that the theoretical rotation rates
are being achieved. Failures in can rotation have been attributed to track wear,
bowing of the reel and build up of deposits of lacquer removed from the rims of
cans as they rotate. There is evidence to suggest that changes in can specification
can alter rotation rates and therefore product heating.8

One of the greatest challenges in recent years for operators of reel and spiral
retorts was the introduction of the easy open can end. This was because during
the heating processes the internal pressures in the cans causes the ends to dome
slightly. With an easy open end this doming can cause the ring pull to stick out
to the extent that it can catch on the spiral tracks inside the shell, with the
consequence of turning the retort into a very large can opener. However, this
difficulty has now been largely overcome.

2.6 Future trends

2.6.1 High temperature short time (HTST) processing
Trends in the future will to some extent be extrapolations of patterns over the
last few years. Therefore we can expect to see a continued increase in high
temperature short time processes, generally aided by rotary processing to
minimise product degradation at the container surfaces. The science of in-
container mixing is not as well developed as the technology, and research is
under way to optimise process conditions to enhance the mixing processes
taking place. This might, for example, be achieved by study of the headspace
movement in products or simulants of equivalent rheological properties at the
intended process temperature which can determine when the headspace is most
effectively passing through the container to bring about mixing.9 If the mixing
process is well understood then we can expect benefits in terms of reduced
process times and/or improved product quality.

An interesting recently patented development by Crown Cork & Seal has
been the use of shaking type agitation to increase product heating rates.10 The
patent covers ranges of reciprocating acceleration movements, and these were
applied in an especially designed shaking retort system. Results seem to indicate that for several traditional canned products heat transfer rates can be greatly improved even in comparison with rotary agitation. The mechanism for this extra efficient agitation is presumably the fact that greater turbulence is introduced into the movement of fluids in the packs compared with rotary motions. One possible drawback of the approach is that the shaking motion may damage tender food components but trials using asparagus have indicated that this is not the case.

### 2.6.2 Flexibility in packaging formats

As the marketplace increasingly demands innovation, flexibility of retort systems, particularly in relation to packaging format, is becoming increasingly important. For example, it seems that there are forces developing which will drive canned food manufacturers, especially in the catering sector, away from cans toward packs that are more space efficient in disposal, recyclable and less likely to contaminate product on opening. It seems that the heat processable pouch is becoming the natural alternative to the catering can.

For batch retort systems a change to a new pack format may mean a simple, though not cheap, change of racking system. With batch systems there is an increasing move toward automatic retort loading and unloading which yields long-term benefits in reducing labour costs, as retort operators are commonly supported by a team of loaders. Second, automation of the loading system can be used to control the flow of product through the factory. If implemented correctly this automated control of the loading operation can be one of the mechanisms used to prevent unprocessed product bypassing the heat process, which is one of the major safety risks associated with any such operation. In some installations this control is enhanced by the use of double doors, one at either end of the process vessel, with a wall built to prevent product getting from one room in the factory to another without going through the retort (though this does not necessarily guarantee that a process is applied).

However, for the continuous retort systems, especially reel and spiral retorts, changes in packaging format have been more difficult. Stork have introduced their new Vario hydrostatic retort system which uses a cassette which allows a range of packaging formats to be processed through the same retort. These cassettes are the basic unit which is transported through the retort, within which, depending on the internal construction, any pack can be processed, e.g. pouches, glass jars, cans.

### 2.6.3 Environmental issues

It seems likely that the retorting industry, like many others, will in the near future have to take active steps to reduce energy usage and maximise water recovery. Most of the modern overpressure retort systems already incorporate energy and water efficiency features but there may be further developments.
2.6.4 Intelligent control
One of the most problematic aspects of controlling a retorting operation is dealing with product that has not received the intended thermal process. Such situations are described as process deviations and may result, for example, from failure in services, e.g. boiler breakdown. Historically deviations have been dealt with either during the process from tables prepared from experimental data or from experimental data generated after the problem has occurred. More recently, computational modelling methods have been used to predict off-line the effect of time temperature deviations based on known product heat transfer characteristics. Commercial programs of this type have existed for several years, e.g. CTemp from CCFRA and NumeriCAL developed by Technical. It is a logical step that in order to minimise the product lost from deviations and to minimise safety risks, this kind of mathematical model should be used on-line. Such predictive code has been included by FMC in their Log-Tech™ batch retort control systems. The application of such heat transfer models to continuous processes is more complex because the deviation will have a different impact upon containers at different points through their residence time. However, this is a likely development.

2.7 Sources of further information and advice
The most detailed advice on each type of retort system can be obtained from specific retort manufacturers. General guidance on good manufacturing practice is available from research organisations specialising in heat sterilised foods such as:
Campden & Chorleywood Food Research Association CCFRA (UK)
National Food Processors Association (NFPA) (USA)
CTCPA (France)
TNO (Netherlands)
KIN (Germany).
Information on packaging systems can be obtained from packaging suppliers or the Metal Packaging Association.

2.8 References


