Thermal Processes, Methods and Equipment

Lecture 03

Classification of thermal processing

Table 18.1 Classification of thermal processes

In-package processing	Bulk processing	
	Hot filling	Aseptic filling
Food	**Food**	**Food**
↓	↓	↓
Preheating	Heating (heat exchanger)	Heating (heat exchanger)
↓	↓	↓
Filling	Holding	Holding
↓	↓	↓
Exhausting	Hot filling	Cooling (heat exchanger)
↓	↓	↓
Sealing	Sealing	Aseptic filling
↓	↓	↓
In-package heating	In-package cooling	Aseptic sealing
↓		
In-package cooling		

Thermal Processing in Hermetically Closed Containers

- Commonly known as “canning”
- The food is heated and cooled while contained in hermetically closed packages
- Suitable for foods in all physical forms: solids, liquids or liquids with solid particles
- The packages can be cans, jars, bottles, trays, tubes, pouches

Filling into the cans

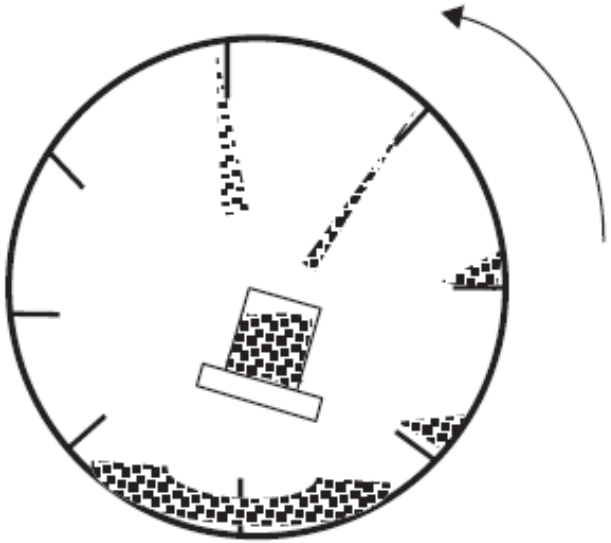
- Choice of a method - Product, the size of cans and the production rate
- Products can be filled into containers by volume (volumetric filling) or by weight (gravimetric filling)
- Volumetric filling is simpler and less expensive.
- Some free space (*head-space) is left above the*
- product in order to form some vacuum in the sealed can at the end of the process.
- In the case of products consisting of solid particles in a liquid medium (vegetables in brine, meat in sauce, fruit in syrup), the solid and the liquid are usually filled separately.
- Care must be taken to minimize the risk of leaving air pockets in the container.

Hand filling

- *Fragile products such as orange segments or* vegetables requiring orderly arrangement
- When production rate is too low to justify mechanical filling
- *hand-pack filling, the* product is filled manually into cylinders of known volume, then transferred mechanically into the cans

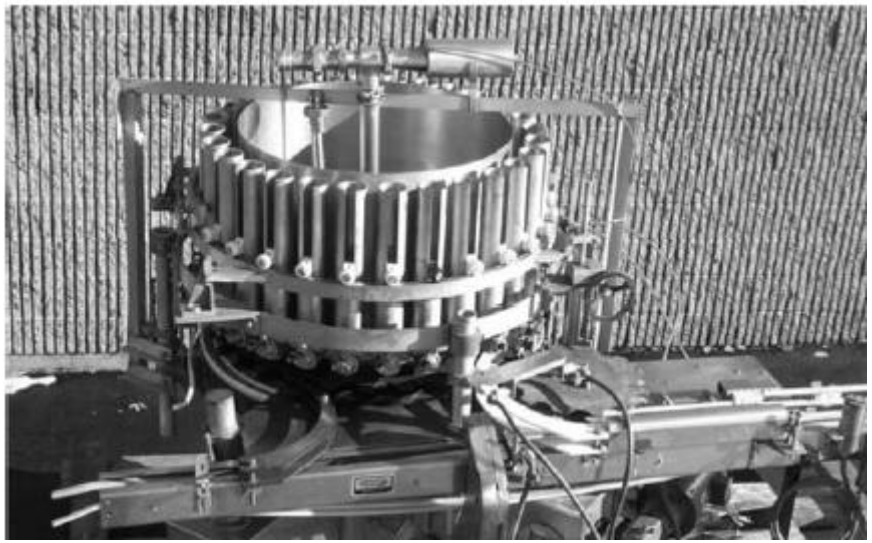
Tumbler fillers

- Consist of a rotating drum fitted with baffles and in it,
- A belt conveyor carrying the cans in the direction of the drum axis.
- The product is fed into the drum.
- As the drum rotates, portions of the product are lifted by the baffles then fall into the cans when the baffle reaches a certain angle.
- The can conveyor is slightly tilted to prevent over-filling and leave a void volume (head-space) in the can.



Piston fillers

- *Piston fillers are suitable for filling pumpable products.*
- *The 'filling* heads' are actually piston pumps, transferring a fixed volume of product from a buffer reservoir to individual cans.
- Piston fillers are usually equipped with a ' no-container-no-fill' control device, to prevent spillage when a container is, accidentally, not presented under the filling head.



Reason for expelling air from the head-space

- Air in the head-space expands and creates excessive internal pressure when the sealed can is heated. (Damage is prominent in flexible packages (pouches)
- Expulsion of most of the air (reduction of the partial pressure of oxygen) helps reduce the risk of oxidative damage (product/ metal can)
- Vacuum in the container is particularly important in the case of products for keeping the lids tightly attached to the jar body
- In flexible packages, good contact between the packaging material and the food is essential for efficient heat transfer during thermal processing. (Shrink wrap)

Methods for expelling air from the head-space

Hot filling

- It is desirable to fill the product at the highest possible temperature, so as to **minimize the quantity of dissolved oxygen** and to create a **head-space rich in water vapor** instead of air.
- Continuous preheating is possible in the case of pumpable products.
- Of course, hot filling also shortens processing time after closure.

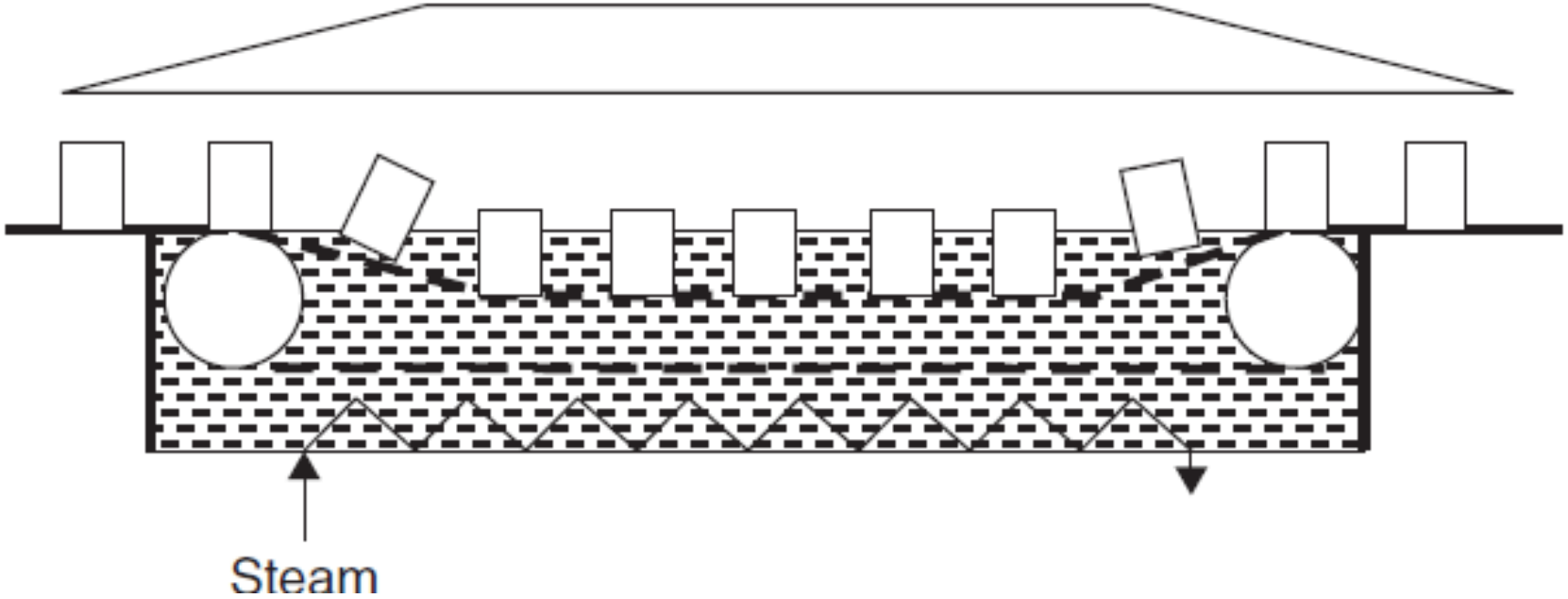
Methods for expelling air from the head-space

Thermal exhausting

- When filling at sufficiently high temperature is not a feasible option, the product is heated in the container, before closure.
- The filled open containers are conveyed through a bath of hot (near boiling) water, where the water level is kept about 1 cm below the container mouth.
- A slight bumping movement or vibration imparted to the conveying belt helps expel the air bubbles.

Methods for expelling air from the head-space

Thermal exhausting



Methods for expelling air from the head-space

Steam injection

- *Some closing machines are equipped with nozzles for injecting* food quality superheated steam into the head-space, just before the lid is applied.
- To be effective, steam injection must be combined with hot filling.

Methods for expelling air from the head-space

Mechanical vacuum

- The seaming machines are equipped with mechanical vacuum pumps.
- Vacuum closing is applied to products containing little or no liquid and to flexible packages.

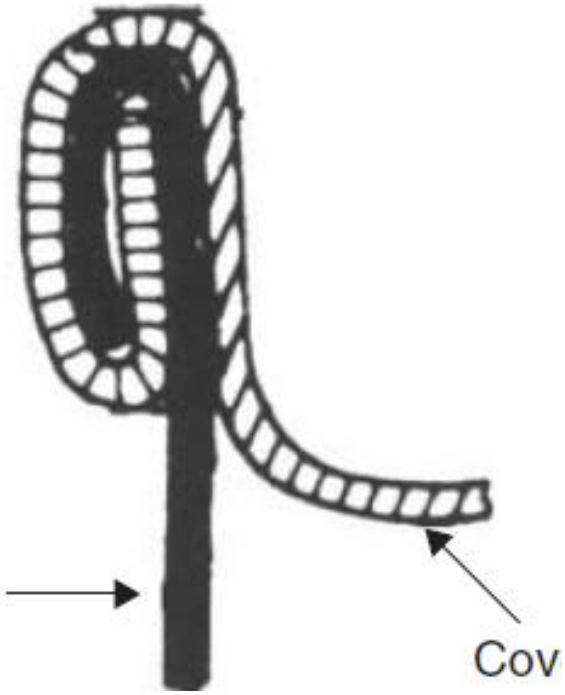
Sealing

- In **the beginning of the canning industry**, metal cans were closed by **soldering**. At that time, one skilled worker would seal about **10 cans per hour**
- **Lead-containing solder** was a matter of serious health concern
- The solderless ‘double seam’ used in industry today (invented in the beginning of the 20th century.
- Modern can seaming machines can close up to **3000 cans per minute** or more.

High speed can seamer

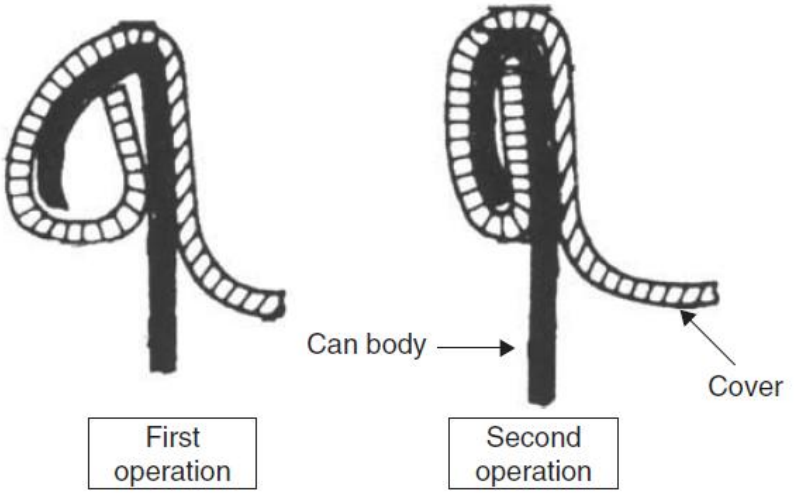
Double seam

- The double seam is formed by mechanically bending the edge of the can body and the lid and then pressing the two to create an interlocking seam.
- A thin ring of PVC or rubber, applied on the lid, acts as a gasket.



Double seam

- The double seam is formed in **two steps** or ‘operations ’
- (i) a *first operation of bending and (ii) a second operation* of tightening.
- The form and dimensions of the double seam must be in strict conformity with certain standards.
- In the food canning industry, routine inspection of the seams and adjustment of the machines are essential quality assurance operations



Heat processing

- *Sterilization in hermetic containers : low-acid foods (pH 4.5) are preserved* by sterilization
- Practical sterilization requires processing the food at temperatures well above 100°C.
- Sterilization is carried out in pressure vessels known as **autoclaves or retorts** to neutralize the saturation pressure of water vapour generated (120°C, 200 kPa – double of atm. Pressure)

Medium of heating

- In the case of **metal** cans, the heating medium is **saturated steam** at the appropriate pressure.
- In the case of **glass** containers and flexible packages, the heating medium is **hot water combined with compressed air** to provide the necessary external pressure.

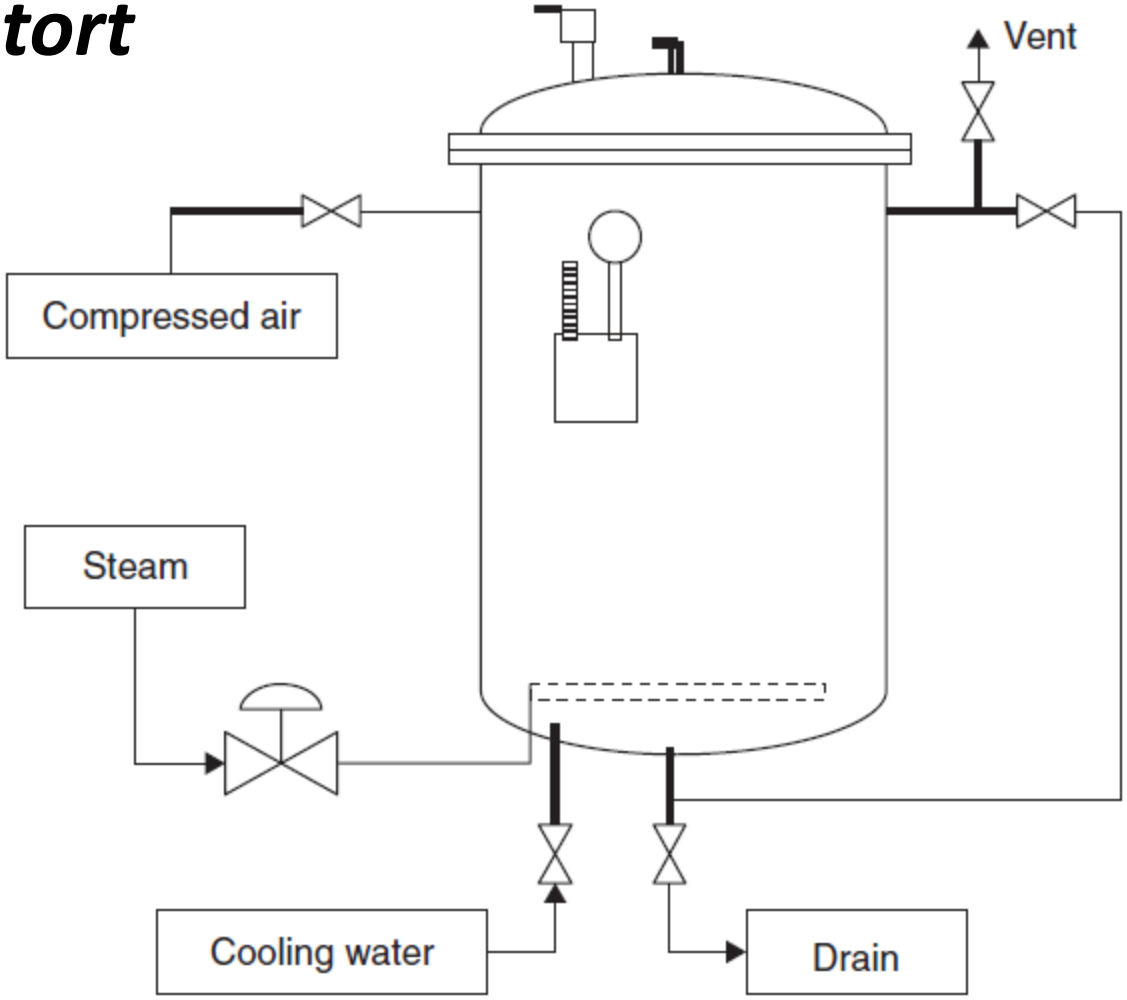
Types of retorts

Batch retorts :

- *batch retorts are pressure vessels fitted with inlets for steam,* cooling water and pressurized air and outlets for draining, pressure release and venting.
- They are equipped with a pressure gauge and thermometer and usually connected to automatic control systems.
- They can be vertical or horizontal

Batch retorts

Vertical retort



Batch retorts

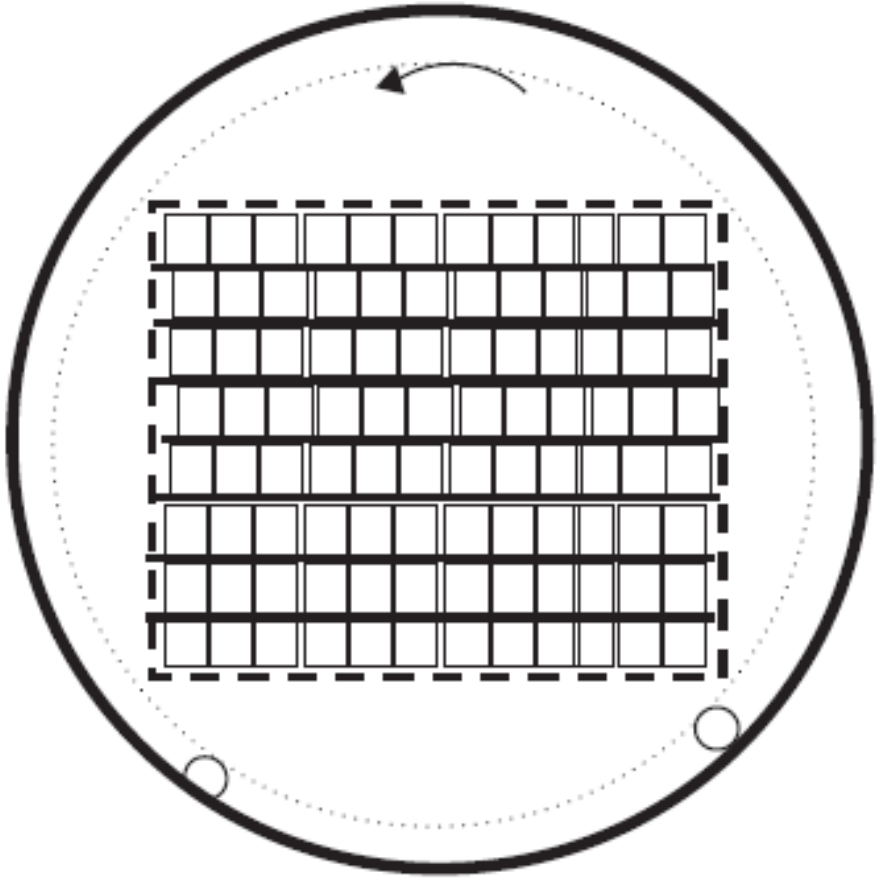
Horizontal retorts:

- Horizontal retorts are easier to load and unload and they can be equipped with rotating baskets for end-over-end agitation but they are less economical in floor-space.
- Very large (long) horizontal retorts are usually fitted with internal fans to assure uniform temperature distribution.
- The cans are loaded into the retort in baskets (crates).
- Their arrangement in the crates may be either orderly or random.

Batch retorts

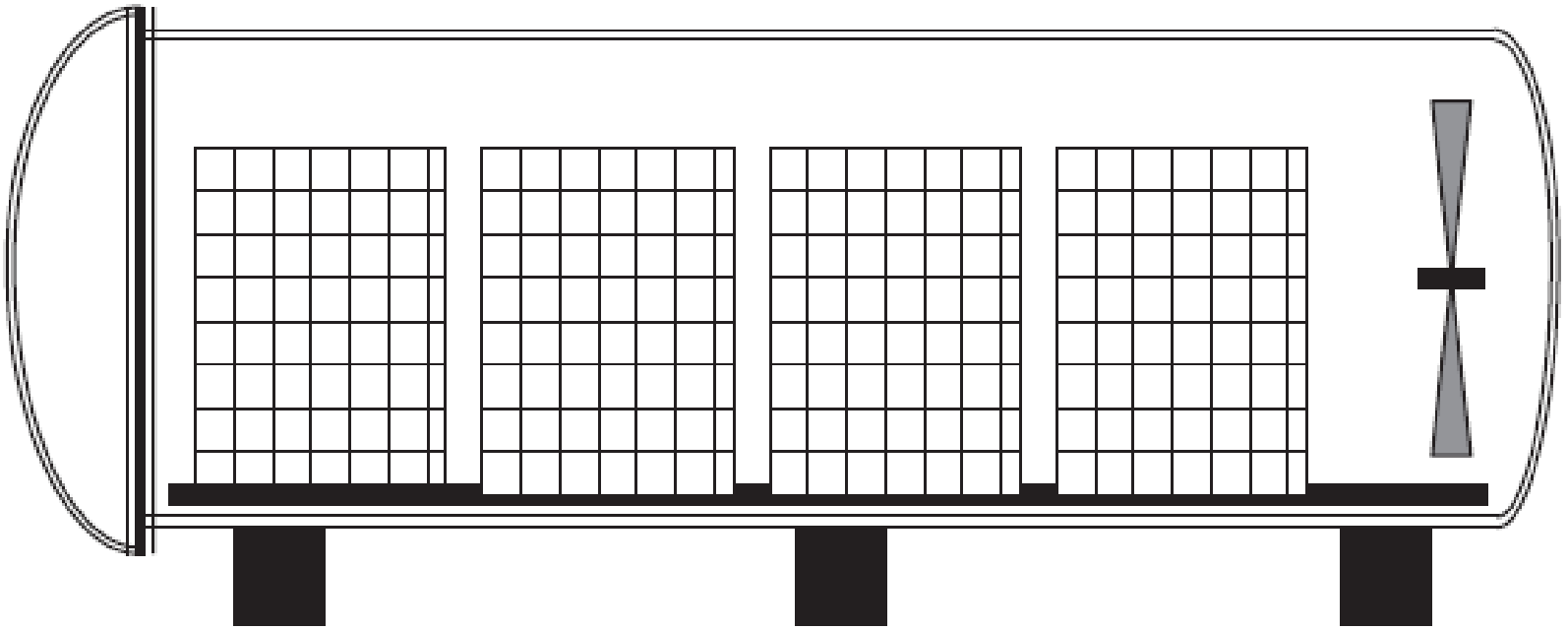
Horizontal retort

With rotating crates



Batch retorts

Horizontal retort (Arrangement of crates)



Crateless retorts

- These are large vertical vessels.
- They are first partially filled with hot water. The cans are fed from the top.

Crateless retorts

- The water in the vessel acts as a cushion to the incoming cans. When the retort is full, the vessel is closed and steam is admitted, pushing-out the water through a drain-pipe and starting the sterilization cycle. .

- After the heating and cooling cycles are complete, the cans are carried out by water, through an opening at the bottom of the vessel

Typical sequence of operations during one batch sterilization in metal cans

- The full crates are loaded into the autoclave
- The autoclave is closed
- Expulsion of the air (**purging**): steam is introduced
- Steam is introduced at high flow rate until the specified processing pressure and the corresponding temperature are reached (**retort come-up**).

Typical sequence of operations during one batch sterilization in metal cans

- Steam flow rate is controlled so as to maintain the specified retort pressure (temperature) during the specified process time
- At the end of the specified process time, steam is shut off. Compressed air is introduced to replace the steam, while maintaining the pressure to avoid deformation.
- Cooling can be done by spraying the water over the cans or by filling the retort with water.

Typical sequence of operations during one batch sterilization in metal cans

- Chlorination /Ozonation and UV treatment of water are possible alternatives.
- Overriding air is shut off when the temperature inside the cans is estimated to have dropped to below 100°C.
- It is preferable to stop the cooling while the cans are somewhat warm (40–50°C).
- The retort is drained, opened and unloaded.

Continuous sterilization

- Advantages
  - labor cost
  - energy expenditure
  - equipment down-time
  - significant in high-volume production
  - not requiring frequent changes in processing conditions or in container size

Types of continuous retorts

- **Continuous retorts with hydrostatic lock (*hydrostatic sterilizers):***

  The containers enter the pressure chamber and leave it through two columns of water of sufficient height to counter-balance the chamber pressure

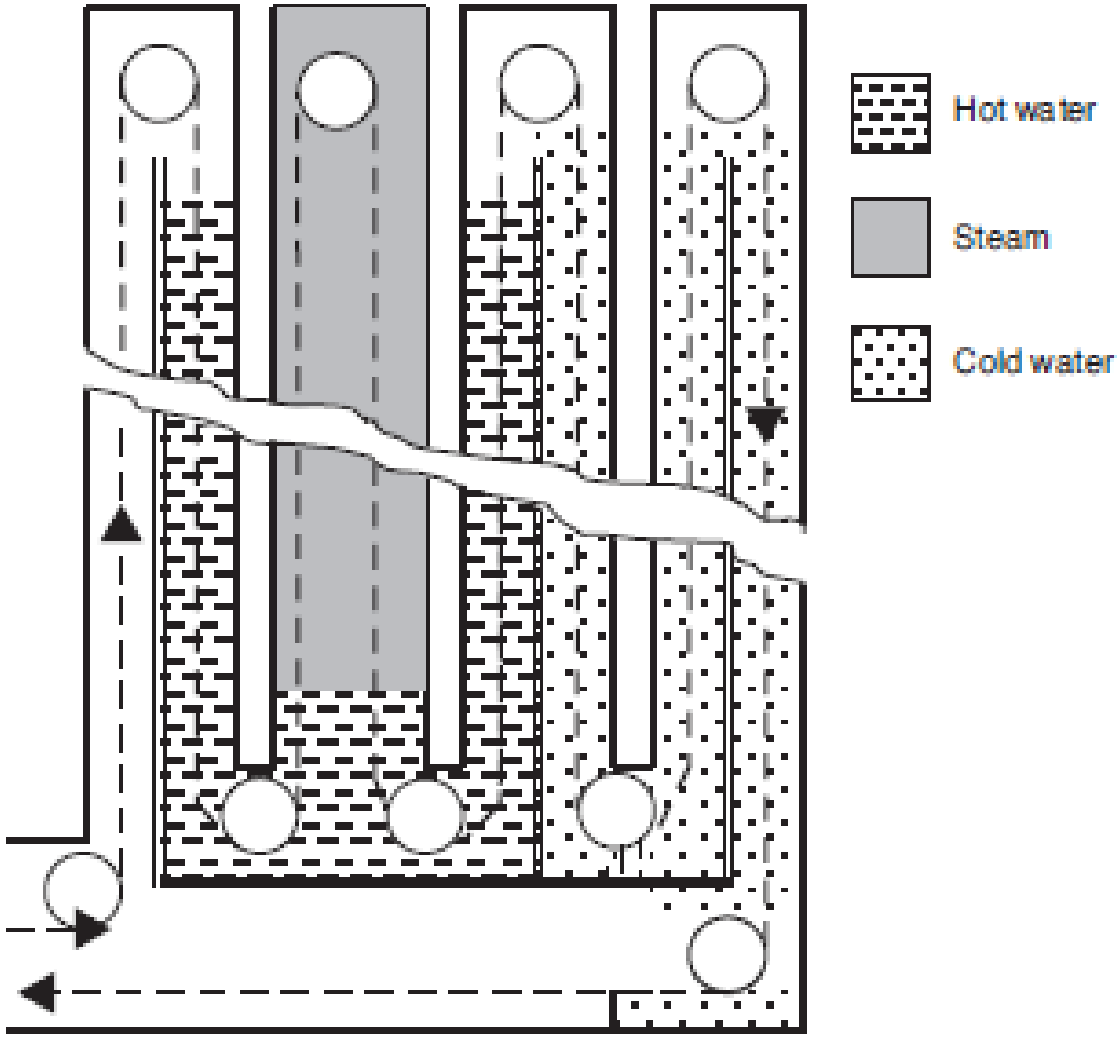


Figure 18.11 Hydrostatic sterilizer

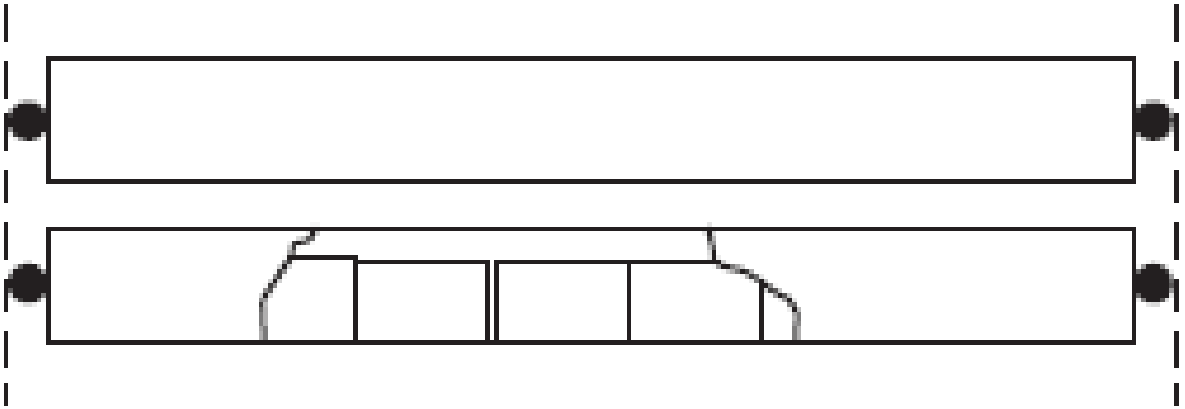


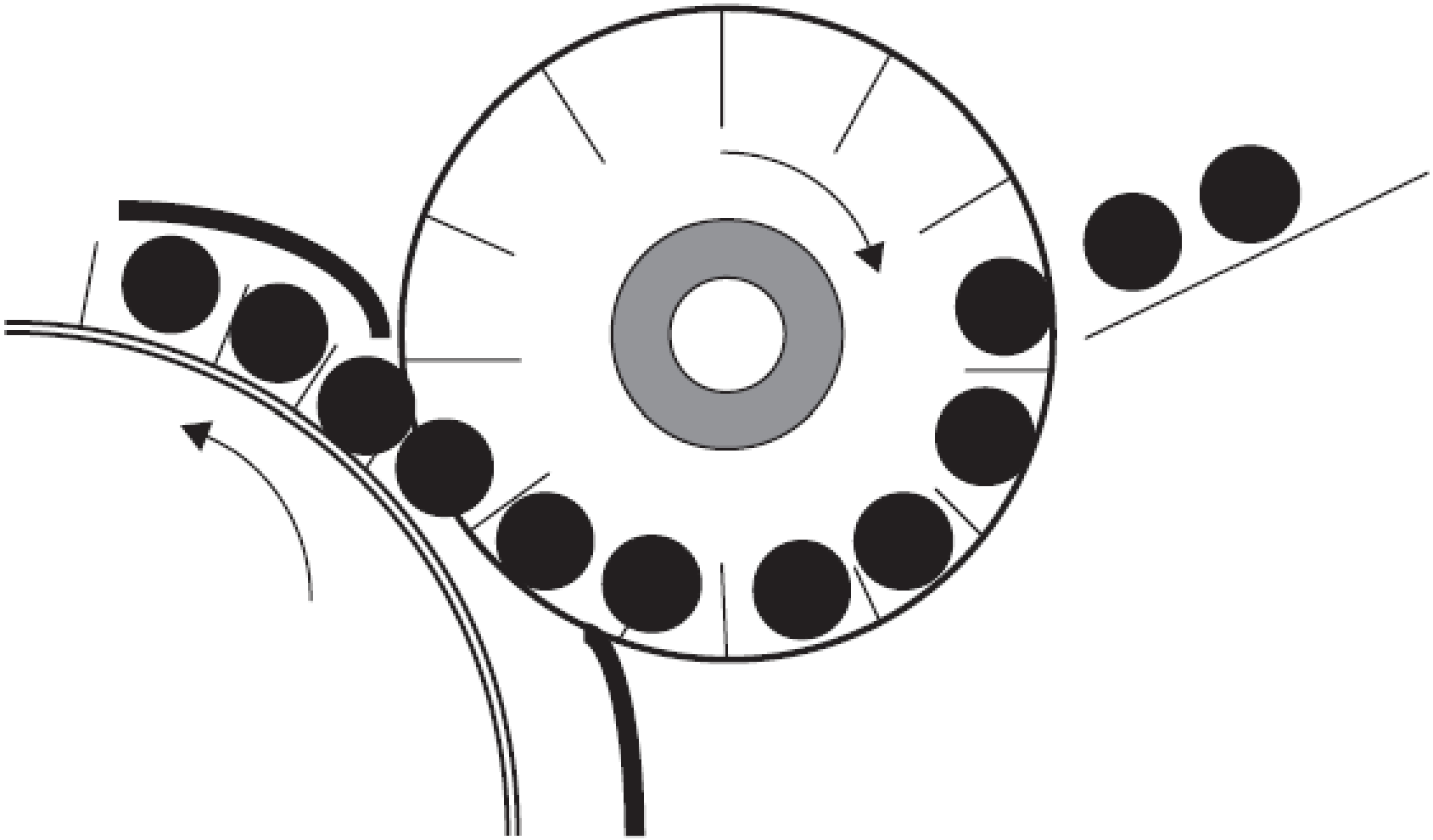
Figure 18.12 Arrangement of cans in the canisters of a hydrostatic sterilizer

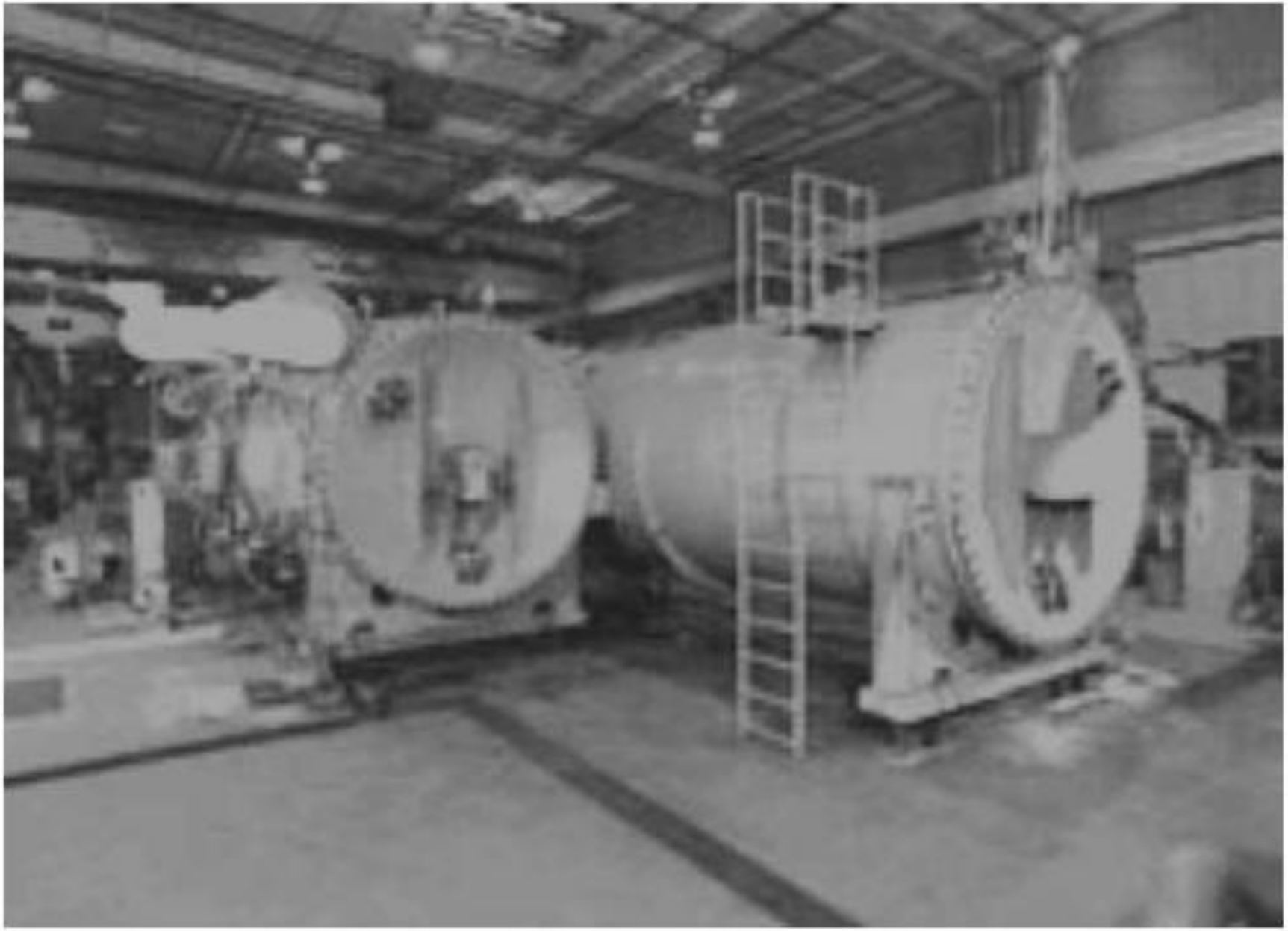
Types of continuous retorts

- **Continuous retorts with *mechanical locks***

  The cans enter the pressure chamber and leave it through '**rotary gates**'. The pressure chamber consists of a horizontal cylindrical shell where the cans are moved forward along a spiral path while slowly revolving.

  For cooling under pressure, the cans are transferred to a second similar shell, also through a rotating gate.





Flame sterilization

- *Flame sterilization is a method of continuous sterilization without a retort* (Heil, 1989). The heating medium is not steam or hot water but hot gas (1000°C or higher) from flames, at atmospheric pressure.
- After preheating in a tunnel with steam at atmospheric pressure, the rapidly spinning cans are heated using direct fl me, then maintained in a holding space before being cooled.
- Advantages
  - Processing time - shortened
  - High quality is maintained – due to short processing time.
  - No need for special devices for pressure

Flame sterilization

- At sterilization temperatures (e.g. 120°C) the **pressure inside the cans** is considerably higher than the external atmospheric pressure. Since there is no steam pressure to counteract the internal pressure, only small and particularly **rigid containers** can withstand such pressure difference

- Due to the direct contact with flames, the container surface reaches extremely high temperatures. In order to prevent scorching of the product inside, **very efficient heat transfer** must be provided between the can walls and the can contents. This is achieved by rapid spinning of the cans during their passage in front of the flames. Obviously the method is **not suitable for processing solid foods** where heating is solely by conduction.
- **Thermal processing of low-acid foods has been practically discontinued due to assurance of complete sterilization.**

Pasteurization in hermetically closed containers

- If the products with pH below 4.5 (e.g. most tomato products, pickles, fruit in syrup and artificially acidified products), appropriate preservation may be achieved at temperatures below 100°C, i.e. by pasteurization.
- After sealing, the containers are heated with near-boiling water. For continuous processing, the containers are carried by an appropriate conveyor through a bath of hot water. The residence time in the bath depends on the product and the size

Pasteurization in hermetically closed containers

- Ready to eat meals have a specified shelf life of 10 to 30 days under refrigeration, from production to consumption.
- Pasteurization at temperatures below 100°C is usually sufficient for their preservation.
- In most cases, these products are batch-pasteurized in vats containing hot water.
- Usually, the process of pasteurization serves also as the process of in-package cooking.

Thermal Processing in Bulk, before Packaging

- The case of **pumpable products** (liquids, semi-liquids, purees, suspensions of relatively small solid particles in liquids)

1. Only the heating is done in bulk, in a heat exchanger. After hot filling and sealing, the product is cooled in the hermetic container
2. Both the heating and cooling stages are carried out in bulk, in heat exchangers. A holding tube or holding vessel is provided between the heating and the cooling sections. The treated product is filled and sealed.

Bulk heating – hot filling – sealing – cooling in container

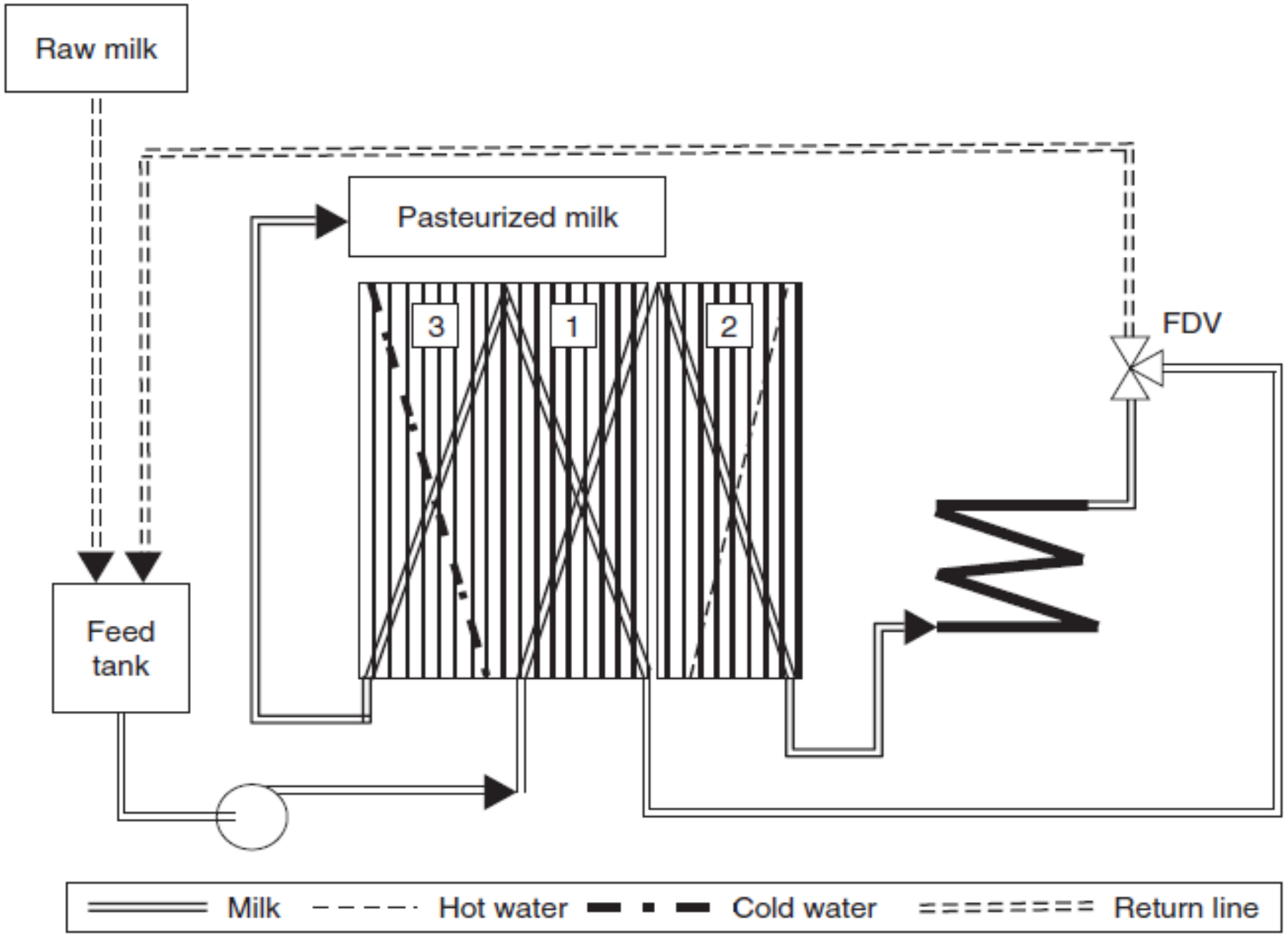
- Canning of high-acid pumpable products such as fruit juices and purees. The material is heated to pasteurization in continuous heat exchangers and then hot-filled and sealed.
- The filled containers are cooled by water, usually by spraying

Limitations

- Relatively long cooling time, resulting in over-cooking of the product
- Does not allow packaging in heat sensitive plastics

Bulk heating – holding – bulk cooling – cold filling – sealing

- The entire process is carried in a system consisting of heat exchangers and piping.
- The product leaves the system after continuous sterilization or pasteurization (depending on the time–temperature profile), holding and continuous cooling.
- If filling and sealing occur in open space, recontamination of the cold product may occur.
- This may not be objectionable if the product is to be marketed under refrigeration and its planned marketing time is sufficiently short.


Raw milk
Pasteurized milk
3
1
2
FDV
Feed tank
Milk
Hot water
Cold water
Return line

Aseptic processing

- Aseptic processing, also known as aseptic packaging or aseptic filling, is, without doubt, the most significant of the last developments in food technology
- '**Aseptic**' processes were developed before World War 2 and commercially applied in the 1950s.
- The early applications were liquid and semi-liquid foods, such as cocoa drinks, custards and banana puree. The packages were, invariably, metal cans and the process was therefore called 'aseptic canning'.

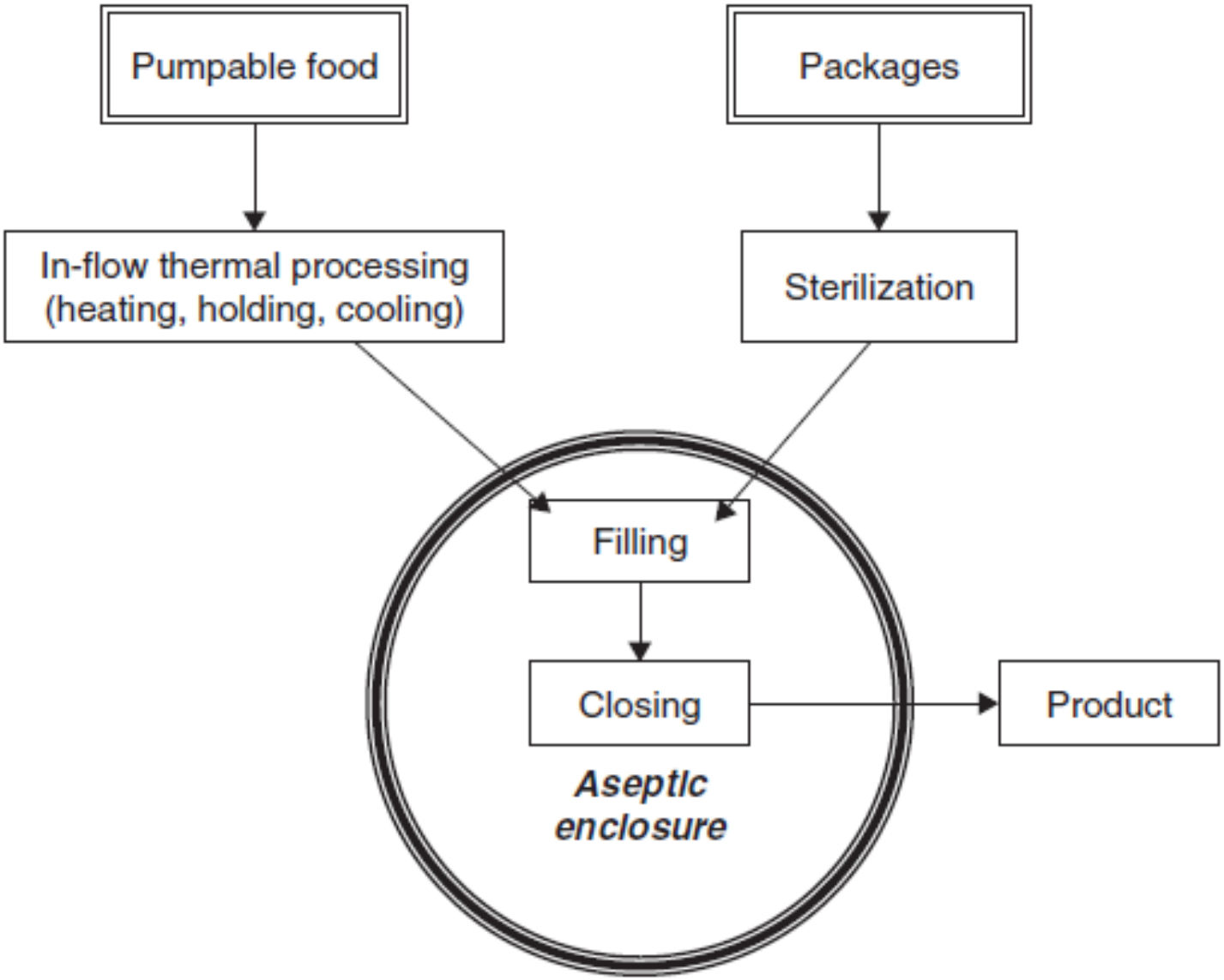
Aseptic processing

- The pumpable food was continuously heated to **sterilizing temperature** in heat exchangers and, after holding, continuously cooled.
- The **cans and lids were sterilized** with steam or a mixture of superheated steam and air.
- The sterilized food and the sterile cans met in an **aseptic enclosure** that contained the filling machine and the seamer, closely coupled.

Aseptic conditions

Aseptic conditions were maintained by a number of measures such as-

- Disinfectants
- A steady stream of superheated steam
- UV radiation
- The aseptic enclosure was kept at slight overpressure to prevent penetration of air from outside.


Pumpable food
Packages
In-flow thermal processing (heating, holding, cooling)
Sterilization
Filling
Closing
Product
Aseptic enclosure

Aseptic packages

- The innovations included in-place formation of the package from laminated paper, plastic sheet or film, sterilization using hydrogen peroxide, followed by hot air, filling and sealing in one machine etc.
- The packages suitable for aseptic processing now include carton boxes, pouches, trays, cups, large bags in boxes, metal barrels etc.