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Precision and Progress: A Comprehensive Study of Dairy Packaging Machinery

Sharanabasava[1*], Nagaratna[2], Devaraju[3] and Akshay Kumar[4]
[1]Ph.D. Scholar, Department of Dairy Engineering,
ICAR-National Dairy Research Institute, Karnal (Haryana), India.
[2] REVA University, Bengaluru (Karnataka), India.
[3]Assistant Professor, Department of Dairy Engineering,
Dairy Science College, Kalaburagi (Karnataka), India.
[4]Assistant Professor, Department of Dairy Microbiology,
Dairy Science College, Kalaburagi (Karnataka), India.

(Corresponding author: Sharanabasava)*

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ABSTRACT: The main goal of dairy packaging, much like any other food packaging, is to shield the food from potential damage (such as physical harm, contamination by microbes, etc.) while upholding the top-notch quality of the product. Ideally, packaging should minimize both weight loss and nutrient depletion, while also extending the shelf life of the product. Packing machines play crucial roles in containing, safeguarding, communicating, and providing utility for the packaged items. This section will examine various types of packaging machines, exploring their capabilities, operational principles, and other defining features.

Keywords: Packaging, shelf life, machine, dairy, principles.

INTRODUCTION

In an age characterized by technological advancements and an ever-evolving industrial landscape, the dairy industry stands as a testament to precision and progress in packaging machinery. The intricacies involved in preserving and delivering dairy products while ensuring freshness, quality, and safety demand a nuanced understanding of packaging equipment (Schneider *et al.*, 2010). This comprehensive study embarks on a journey through the intricate world of dairy packaging machinery, unveiling the symbiotic relationship between precision engineering and progressive innovation. From the initial stages of product handling to the final packaging and distribution phases, this exploration navigates the multifaceted components and mechanisms employed in dairy packaging systems.

The significance of precision engineering within dairy packaging machinery is evident in its role in enhancing product shelf life, maintaining product integrity, and meeting stringent industry standards. Moreover, this study sheds light on the amalgamation of automation, robotics, and smart technologies, heralding a new era of efficiency and sustainability in dairy packaging processes (Rejeesh and Anto 2023).

Packaging is a critical operation within the dairy industry. Practically each food product will be packaged before it reaches the end customer. Packages are used at each stage in the food production and delivery of food goods: from farms to processing plants, from processing plants to warehouses to retail outlets, and from retail outlets to consumers.

A package can contain one dairy product, multiple food products, or food packages. Several product types are available, including pouches, wraps, boxes, bags, cups, cans, trays, tubes, and bottles. The four primary functions of a package are performed by packages: containment, protection, communication, and utility. Without packaging, the new food processing and distribution system couldn't work.

The key factors influencing a packaging line's performance and usage can be listed under three headings:

— The appropriateness of the machine for this function
— The required production speed;
— The probability and duration of delays
— The time is taken to clear them

We can break down the packaging machinery functions into a variety of subsystems. In these conditions, when the overlap of subsystems occurs, examining the possibilities is more straight forward.

Subsystems consist of:

— The product handling system- loading, filling, weighing, etc.
— The packaging handling system-unreeling, erecting, closing, etc.
— The essential machine context
— The transmission of power
— The control system
— The timing system
— The lubrication system.

PACKAGING MACHINES FOR LIQUID DAIRY PRODUCTS

Anne and Henry (2012) characterized liquid filling in several ways:

— By viscosity, e.g., low-viscosity (milk, special milk, whey), viscous semi-liquids (cream, fruit lassi, condensed milk, ghee) and highly viscous ‘semi-solids’ (high fat cream, high TS condensed milk, shrikhand)

— Otherer characteristics such as surface tension may result in behavior such as frothing or foaming when agitated.

There are three main ways of filling liquids:
(1) By level
(2) By volume
(3) By weight.

Within these three types, the filling can be done either from the top or the bottom of the container. Top filling involves inserting the filling tube into the neck of the container and either allowing the liquid to drop to the bottom or directing the liquid to run down the container sides. The latter will minimize turbulence and air entrapment. Bottom-up filling involves inserting the filling tube down to the bottom of the container and gradually withdrawing it as the container fills. This can be done by moving the tube itself (Fig. 1a) or raising and lowering containers on the packaging line (Fig. 1 b). The bottom-up filling effectively minimizes air entrapment, limits frothing or vaporization of more volatile liquids, and is particularly suited to filling flexible containers such as sachets.

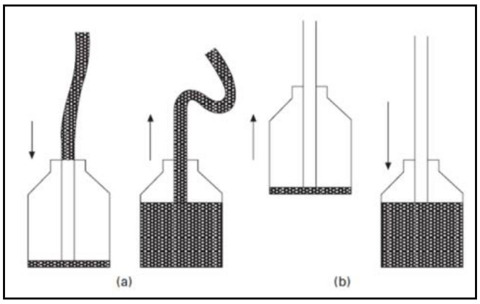


Fig. 1. Liquid products: bottom-up filling to minimize foaming (source - Anne and Henry, 2012).

Level fillers. Level fillers use the container's volume to measure the amount of liquid-filled. Since containers of the same design will have differing volumes due to slight variations in dimensions and wall thicknesses (Fig. 2), this form of filling is less accurate than volume or weight filling. Therefore, it is used for lower-cost liquid products such as soft drinks, beer, and sauces where accurate volume is less important than a visually constant fill level. In many cases (e.g., milk, as already mentioned), customers will expect a container to be filled to a certain level and for that level to be consistent between containers, even if that means there are slightly differing volumes in each container (Ahmed, 2004).

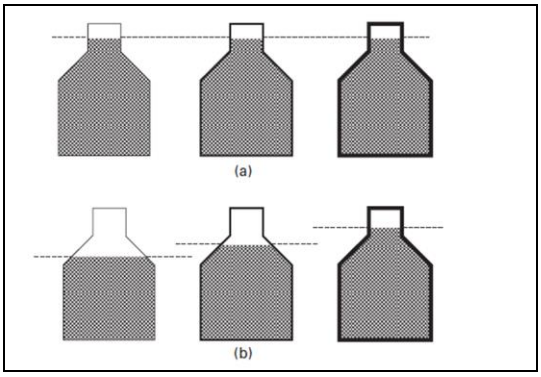


Fig. 2. Liquid products (a) filling by level; (b) filling by volume (source - Anne and Henry, 2012)

There are three main types of level filler:
— Gravity fillers
— Vacuum fillers
— Pressure fillers (also known as over-pressure or counter-pressure fillers).

Gravity fillers. In basic gravity fillers, the liquid flows from a supply tank into the container below (Fig. 3 a). The height of the supply tank above the container determines the flow rate. A typical design involves a filling tube with a valve connected to a spring-loaded outer tube that fits over the container neck. As the container is raised, it activates the spring to open the valve to fill the container (Fig. 3 b). In some systems, a sensor identifies when the liquid has reached the top of the container and closes the valve. A control computer autonomously times an individual valve to deliver the target amount to the container.

Any excess can be channeled into an overflow tank. Gravity filling is a relatively cheap process but is slower than vacuum filling. It is particularly suited to liquids prone to foaming since there is less agitation during filling. The bottom-up filling can be used for very foamy products. For a wide range of container types. They are less suitable for viscous, slow-flowing products or products containing large particulates (Frank and Heather 1992).

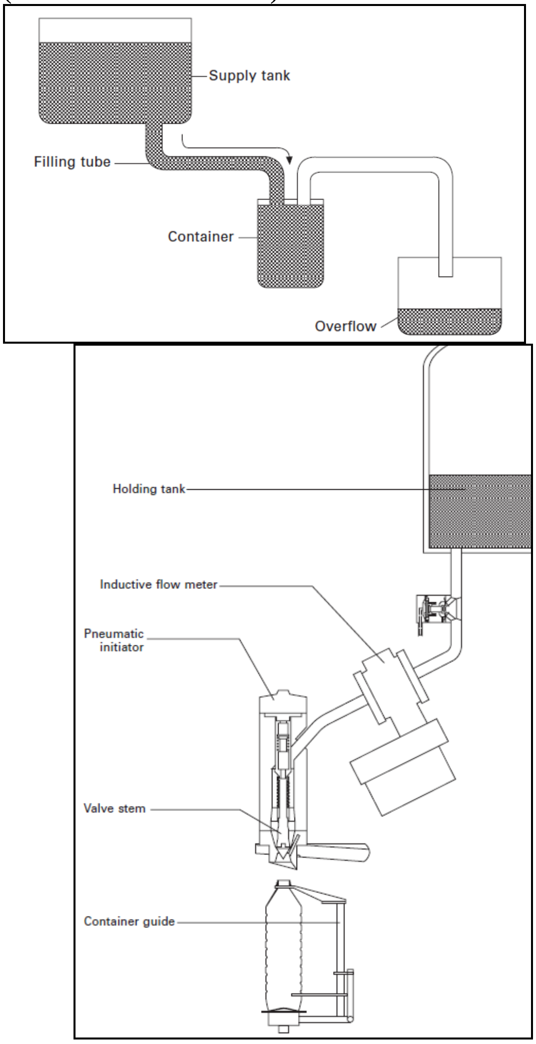


Fig 3. Liquid products (a) basic gravity filling and (b) gravity filling using a flow meter and valve (source - Anne and Henry, 2012).

Vacuum fillers. Vacuum fillers typically work by lowering a filling tube and a vacuum line (connected to a vacuum pump) into the neck of the container and then sealing the neck (Fig. 4). Air is then drawn from the container to create a vacuum using the vacuum pump. The liquid is then drawn from a supply tank through the filling tube into the container.

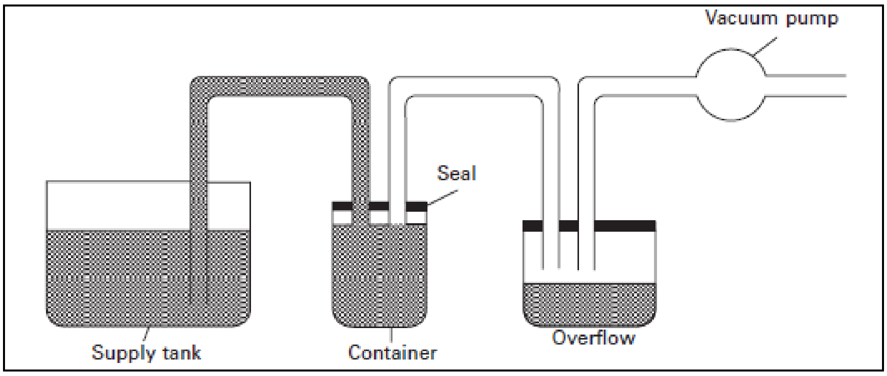


Fig. 4. Liquid products: vacuum filling (source - Anne and Henry, 2012).

When the liquid reaches the vacuum line, suction draws it into an overflow tank, ensuring the desired level is not exceeded. The surplus liquid can then be returned to the supply tank. An alternative approach involves keeping the supply tank initially at a low vacuum to draw the liquid in. The pressure then equalizes, allowing the liquid to flow into the container by gravity. As with other systems, vacuum fillers also use sensing devices to identify when the desired level has been reached, halting further flow until the system is ready for the next container. Vacuum fillers are fast, flexible, and relatively low cost. However, they are limited to rigid containers (e.g., glass bottles) that are not distorted by creating vacuum conditions in the container and liquids less susceptible to aeration.

Pressure fillers. Pressure filling uses a pump to move the liquid from a supply tank to the container (Fig. 5). The supply tank is kept at high pressure in over-pressure or counter-pressure machines, forcing the liquid through the container. The fill level is determined by the vent tube inserted into the container. When the liquid reaches the vent tube, the supply is interrupted by the difference in pressure. Alternatively, the pressure difference can also be used to draw off any surplus liquid into an overflow tank. Pressure filling is relatively fast and is suited to viscous products which need minimum agitation.

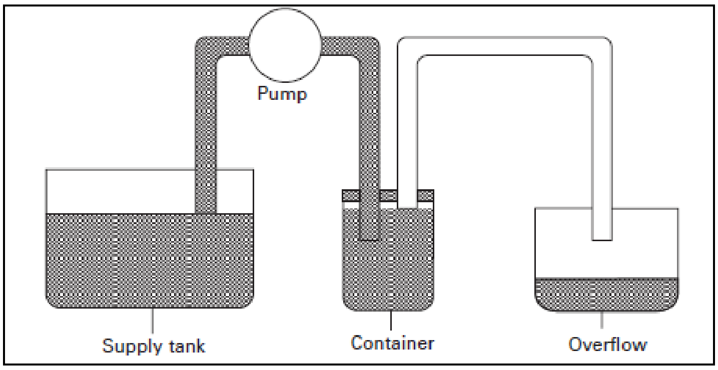


Fig. 5. Liquid products: pressure filling (source - Anne and Henry, 2012).

Volume fillers. A measured volume of liquid is placed into the container in volume filling. This means more accurate measuring than a level filling but may result in variations in a liquid level in containers, depending on variations in container size. This will be obvious to the consumer if the container is transparent, although this can be obscured by the careful application of a neck label. Volume filling is used for high-value products and particularly for products sold by weight or where accurate weight or volume is essential (e.g., pharmaceutical products)

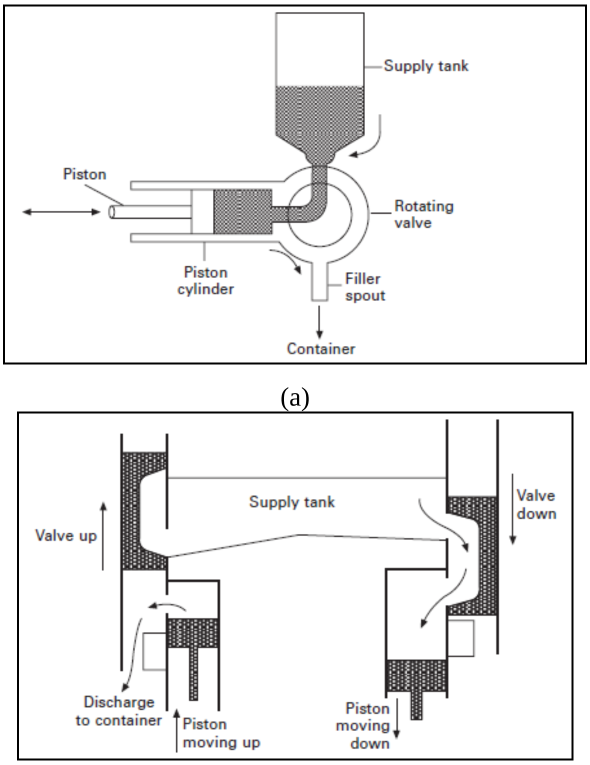
The three main types of volume filler are:

— Piston
— Cup
— Flow: time-pressure or flow meter

Piston fillers

The primary type of piston filler is the piston force-pump, which is connected to an adjustable crank, driven by a control system similar to the parking mechanism of a car windscreen wiper (Fig. 6 a). When the pump is activated, the crank makes one complete turn, delivering the contents of the piston to the container and then re-filling

The piston is in readiness for the next container. The amount of product supplied is controlled by the size of the piston cylinder and the stroke, which is adjusted by the setting of the crank. Piston fillers typically have a control device that prevents the piston from turning if no container is ready to be filled.



(a)

(b)

Fig. 6. Liquid/paste products filling by volume using a piston filler (a) and piston filler using automated rotary pumps (b) (source - Anne and Henry, 2012).

Piston fillers are typically fully automated with groups of positive action rotary pumps working in sequence (Fig. 6 b), with electronically controlled drives that regulate the number of turns the pump makes to provide the product to each container and allow adjustments to be made without stopping the machine. A control machine monitors the number of pump rotations to precisely calculate how much liquid was poured in. When the target filling is reached, the machine stops the pump. Piston fillers can be used for low viscosity liquids, but there can be problems with leakage between the piston and the cylinder. Piston fillers are usually the most cost-effective, rapid, and accurate filling viscous products. As an example, pastes can be filled into tubes using piston fillers. The product first has to be drawn into the measuring cylinder. The machine nozzle fits into the tube so that the paste is pushed off the nozzle as it is filled, thereby minimizing the amount of air trapped inside the tube.

Cupfillers

In cup fillers (Fig. 7), the liquid product (curd milk, shrikhand, ice-cream mix) flows from a supply tank into a measuring cup. Once this is full, the measured quantity of liquid is emptied into the waiting container. Time-pressure controlled fillers divide the liquid into portions using a valve and feed it to individual containers. It is important to keep a steady liquid supply to ensure accurate measurement.

This means maintaining constant pressure and temperature and consistent viscosity in the liquid. Flow meter filling machines use meters that control the opening and closing of measuring valves. Meters measure the liquid in several ways, including its conductivity or mass. These machines typically use positive displacement pumps or constant output impellers (Frank and Heather 1992).

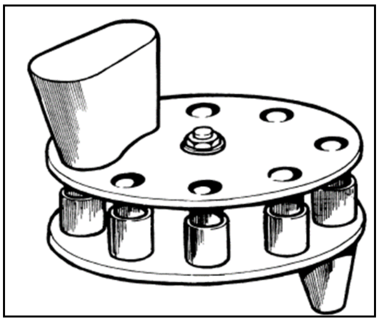
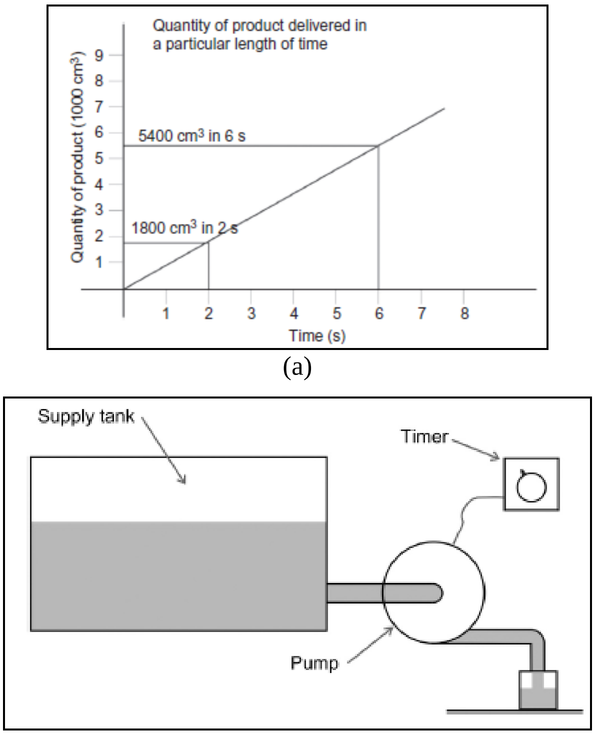


Fig. 7. Volumetric cup filler (source-Frank and Heather, 1992).

Fillers based on time-flow. When liquid fluid flows at a constant rate into a specific size tube, the overall quantity of the product produced depends on the amount of time in which the product flows. (ex, if one cup flows in 1s through the tube, two cups flow in 2s through the tube, three cups in 3 s, etc.). The precision of the metering process maydepend on flow evenness and timing mechanism accuracy (Fig. 8a). The set of devices embraces a supply tank, a pump, a timer, and numerous pipes (Fig. 8 b). The timer setting is increased to fill bigger containers. Volume/unit of time is augmented or lowered to change filling speed (Harold, 2013).

The fillers conferred above are projected mainly for liquids use such as milk. There are variations in equipment that allow the machinery to be used with thicker dairy products.



(a)

(b)

Fig. 8. (a) Timed flow filler product delivery and (b) Timed flow equipment arrangement (source – Harold, 2013).

Weighing fillers. Weighing fillers (Fig. 9) for liquids typically use scales that weigh the desired quantity and open and close a valve to fill the container. Net weight liquid fillers are commonly suitable for liquids filled in bulk or smaller quantities of products with a high value and traded by weight. Filling by weight is suitable for liquids of varying consistencies. The advantage of this type of filler is high accuracy; the disadvantages are the high cost per filling head and the relatively slow filling rate. Weight filling is used to meter uneven density products and products requiring extra precise metering compared to volumetric fillers (Harold, 2013).

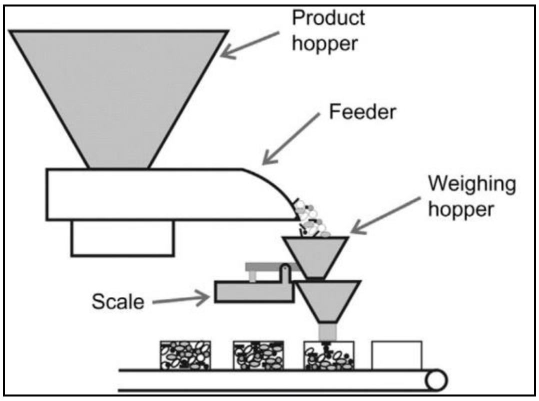


Fig. 9. Net weight filler (source – Harold, 2013).

ROTARY OR IN-LINE FILLERS

The dairy industry follows two simple filler configurations: in-line and rotative. Every is listed and discussed below (Harold, 2013).

In-Line Fillers. In-line fillers are commonly used to fill liquid and paste dairy items, such as milk fruit juices, high TS cream, mayonnaise, condensed milk, and other items into glass bottles, metal cans, and other containers. A filler in-line consists minimum of one head of filling (Fig. 10). Many may have six heads or even more. The in-line filler and a short conveyor belt section are typically placed between an out-feed conveyor and an in-feed conveyor inside a packaging line. The conveyors are usually much broader than the container diameter.

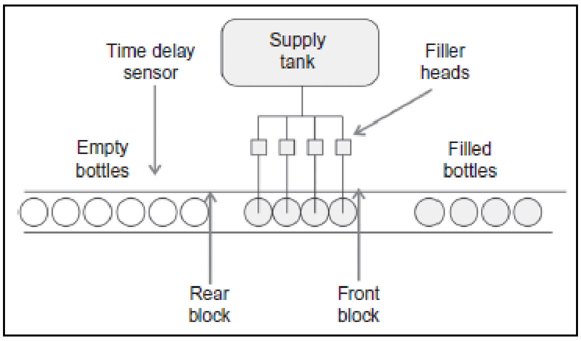


Fig. 10. Inline filler(source – Harold, 2013).

The description of operation refers to the four-head unit (Fig. 10) Yeah. The process of filling begins when the in-feed conveyor moves empty containers into the filler in a single tray. The rear block holds the containers in position until they fill all four containers correctly. The filler heads are lifted and moved back, allowing the anew-filled four containers to continue flowing down the line towards the conveyor outfeed. The rear block is pushed back and out of the way after a time lag (operated by a time delay sensor), allowing empty containers to initiate moving into the filling position.

Later the four containers filled have passed past the front block; this block is repositioned to avoid the upcoming collection of containers from merely moving the unfilled machine through. After moving the rear block by four tubes, the rear block is repositioned, the filler heads shift in place, and the process continues.

Rotary Fillers. These fillers detach blank containers from the in-feed conveyor and place them on the filler's rotating turret. When the containers move around the filler's perimeter, they are filled and then loaded onto the conveyor for outfeed (Fig. 11). Scope of rotating units in size from as few as four heads to as wide as 140 or even more heads. Wideunits are used on milk beverage high-speed lines to fill metal containers. Those lines can run as quickly as 2500 cans /min or 1600 glass bottles/min.

Slower lines can be used for milk, ghee, etc. The in-feed star wheel rotational speed and the revolving turret should be coordinated so that the empty container is positioned in the appropriate location setbelow a filler head. Likewise, on the out-feed side, the star wheel must comply with the filled containers when they are removed from the turret and positioned back on the conveyor (Harold, 2013).

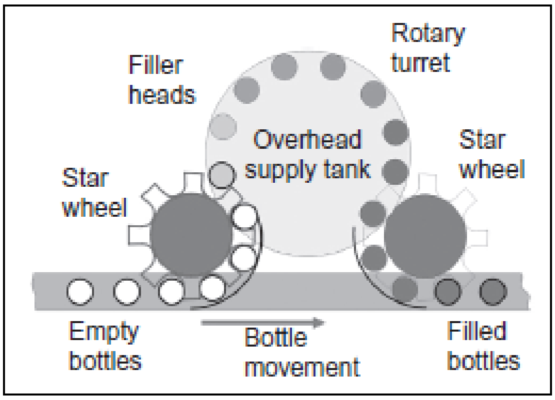


Fig. 11. Rotary filler(source – Harold, 2013).

Capping of bottles and jars. Soroka (1999) reported that it continues downstream, after the package has been filled, to the upcoming unit, usually the caper. Cappers may be used as fillers in either an in-line or rotary system. At the same time, caps are introduced to a chute from a cap-orienting machine which positions all caps in the identical direction (Fig. 12). Using an in-line cap, the containers move under the end of the cap chute, set to the upper portion of the container's leading-edge, reach the bottom edge of the cap, drag it out of the chute, and place it up the top of the container. Then the package, using the cap, passes through a set of spinning disks, which tighten the lid to the desired application torque.

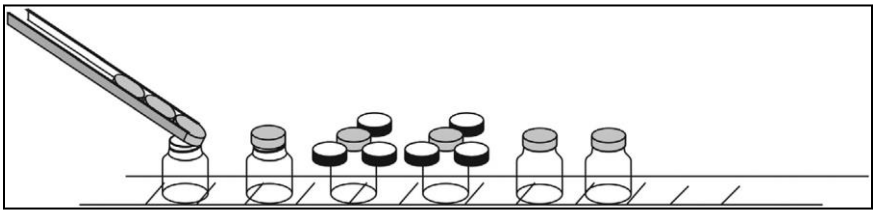


Fig. 12. Cap tightener(source – Harold, 2013).

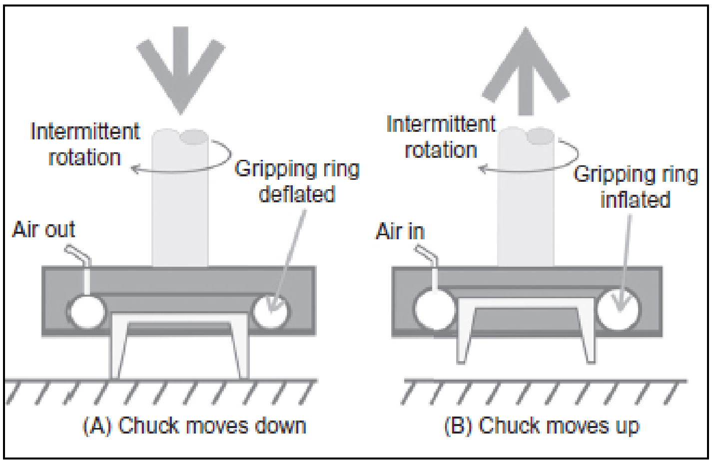


Fig. 13. Operation of the pneumatic chuck. (source – Harold, 2013).

Then it uses a system for spindle capping. A spindle (Fig. 13) is mounted on a vertical shaft, which revolves it travels around the machine's periphery. At the bottom end of the spindle is a "chuck" with a torque limiting clutch above. Depending on the appropriate fill speed, a rotary caper usually has 3 to 12 or even more spindles.

Clutches and Chucks. Screw caps may be used by rotating capping devices with pneumatic chuck spindles, hydraulic chucks, or roller mechanisms. The pneumatic type appears in Fig. 13. The donut-shaped gripping ring is comfortable or flattened once the chuck is let down to pick up a hat. The ring is built of smooth, flexible material which does not scratch or marks the cap surface. This grips the cap when the ring is inflated, allowing it to be picked up. Different size rings can be installed in the chuck to provide gripping properties suitable for a particular combination of bottles and caps. There are also differences in the way force is applied. Mechanical chucks work comparably, except that a spring attachment holds the jaws closed. The connection opens when the torque of the preset function is exceeded while the limit is applied (He and Du 2011).

Press-On Cappers. The maneuver of a press-on caper type chuck is analogous to the process of capper type screw, excluding the twisting action used to screw the cap down is not necessary. Instead, the cap is held in the chuck and pressed straight down on top of the container while it is positioned. The force of application can be regulated in many ways. The pressure of applying the spring-operated capper head can be controlled by regulating the collar and setting the spring tension. Likewise, in a pneumatic device, the movement of the caper head may be governed by the pressure of air. Press-on capers type chuck is intended to fit caps and bottles of nearly any size and shape (Soroka, 1999)

Roller Type Cappers. The cap is dropped on roller-type press-on cappers or located on top of the bottle, which is moved under rollers that tightly press the tap onto the containers. A single roller can press a shallow cap on. Deeper casings can need two or even three rollers to move them on thoroughly. Roller capers are typically used to add flat-top caps. The first degree of rollers and the cap are seated. Residual rollers Push the cap onto the bottle further (Fig. 14). Irregular shapes also root problems when moving underneath the rollers (Soroka, 1999).

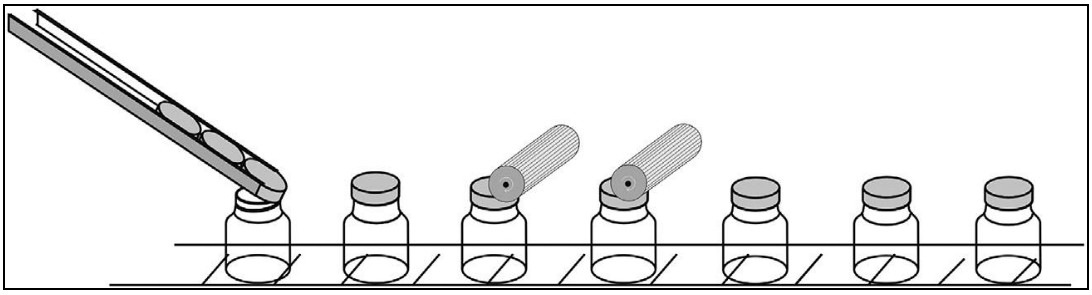


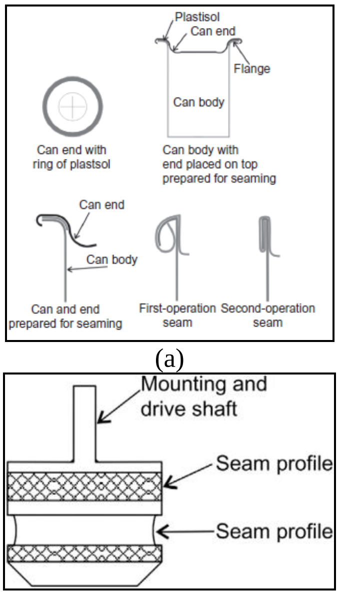
Fig. 14. Roller-type press-on capper (source – Harold, 2013).

CANNING MACHINERY

Harold (2013) discussed that there are two forms of tins available which are three-piece and two-piece. The cans are removed from the pallets by depalletizing machines at the milk factory. The cans fly to the can washer down a conveyor, then onto the filler. Cans are filled, even in very batch operation, by a rotary filler (section 3.2). The end of the can is put on top of the can cylinder after the cans have been packed. The projection is made on the can end, and the flange on the can are then tightly folded around the edge, leading to a strong seal known as a double seam (Fig. 15 a).

Folding and sealing, which connects can end and seals the containers, is done by a seamer can or can closure. The unit is called a double seamer when used in a can manufacturing facility. They are used on metal-type cans, either three-piece or two-piece, and the cans are made from other materials such as plastic. In both forms of the can, the operation is practically similar. The double seam device includes a "first operation" curling the outside of the can end around the can flange and a "second operation," shaping cum ironing out a strong hermetic airtight seal between the can and can end.

The airtight seals are protected from microorganisms entering and can preserve the sterility of the food or beverage sealed in the container. Two types of seamers are general: head-spin and can-spin. The can is held on a head-spin seamer; on the other hand, the seaming head, which has first and second operation seaming rolls, revolves around the can and progressively forms the end of the can and can flange into a tight seam. The can is rotated around its center axis on a seamer which can spin. In a series, the seaming rolls, placed on levers, are pushed to engage the can and shape the seam (Fig. 15 b). A variant of the can-spin method uses a seaming chain, which was machined to the seam's desired final form. The top of the rotary can is forced to form the seam against the rail (Soroka, 1999).



(a)

(b)

Fig. 15. (a) can seaming and (b) Roller for can seamer (source – Harold, 2013)

FORMFILLSEAL EQUIPMENT (FFS)

These devices use a reel of flexible material (paper, film, or paper/film/foil laminates) and either form it into a tube and then seal and fill it at regular intervals or fold it lengthwise and seal it to the fold at the right angles to create a series of filled and closed pockets (sachets) (Frank and Heather, 1992)

FFS machine performs three different operations:

— Forming the package.

— Filling the package.

— Closing and sealing the package.

FFS machine is available in three forms:

— Vertical form fill seal machine (VFFS).

— Horizontal form fill seal machine(HFFS).

— Thermo-form fill seal machine (TFFS).

Vertical form fill seal machines (VFFS). Vertical FFSs are commonly used for packaging a wide variety of dairy items, such as milk, ghee, sweet lassi, etc. The basic operating principles of VFFS machines are shown in Fig. 16. The film is unwound from a reel and drawn over a forming collar to create a bag shape. It is then wrapped around the vertical filling tube and sealed along what will become the length of the bag. The drawdown belt pulls the film and is sealed at the bottom. The product is loaded through the tube into the bag. Horizontal jaws come up to seal the top of the bag and cut it away so that the filled bag can fall down the outfeed chute of the machine. The finished pack can be a simple pillow shape, as shown. Alternatively, it can be formed in an appropriately shaped forming box to give a rigid rectangular cross-section with excellent ‘stand up’ properties (e.g., for liquids). The sides can be gusseted to improve shelf and pallet stacking.

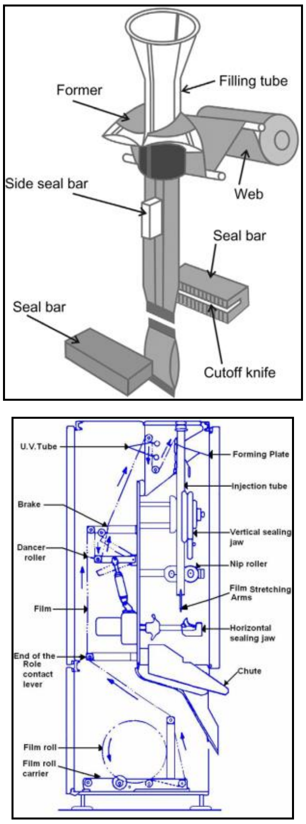


Fig. 16. Operation of a VFFS machine (source-www.agrimoon.com).

Opening and reclosing features such as plastic zippers can also be incorporated. Rotating the sealing bars can be used to create tetrahedron shapes (Ahmed, 2004).

Vertical FFS machines styles of the pack (Frank and Heather 1992)

Pillow packs (Fig. 17). It features fin or overlap seals at both ends at the pack base followed by transverse seals. Commonly used for milk, milk candy bars or milk chocolate enrobed biscuits, and collections of smaller preformed solid items, e.g., a given weight of pre-wrapped sweets or a given volume of unwrapped dairy sweets.

Sachet packs (Fig. 18). It consists ofa four-sided fin seal (rarely only three) around the edge of the pack. Commonly used for powdered and granular or similar products (e.g., instant dairy desserts).

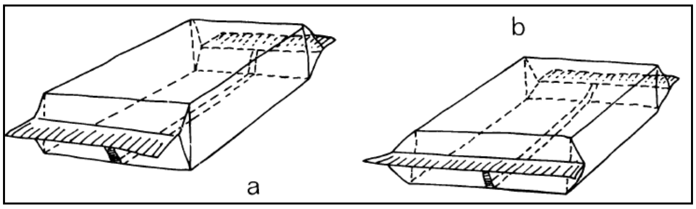


Fig. 17. (a) Pillow packs with gusset and (b) without gusset (source-Frank and Heather 1992)

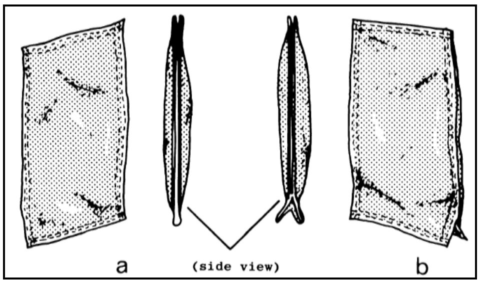


Fig. 18. Sachet packs: (a) ungusseted; (b) gusseted (source-Frank and Heather 1992).

Strip packs (Fig. 19). These have sealed two-layer material to envelope the product between the individual pockets. They are commonly used in pharmaceutical industries.

*Sealing techniques***:** various variables can decide the packaging material used, including the quality of the product, its marketing conditions, and the distribution system used for the product. The chosen material would have a critical effect on the sealing device used on the packaging machine. This is probably one of two styles (Mahalik and Nambiar 2010).

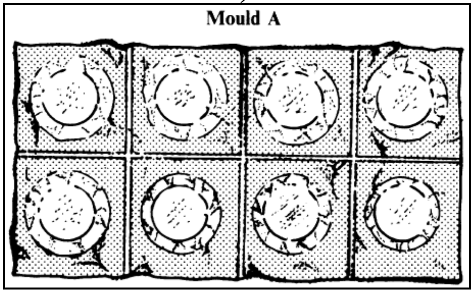


Fig. 19. Typical strip pack (source-Frank and Heather 1992).

Resistance sealing (Fig. 20) can be used for the film containing heat-sealed carrier or body material. The heat usually will not impact the carrier material and does not react with heat and pressure (e.g., aluminum foil, cellulose film, or paper) on its own. Those products shall be covered with a heat-sealable film or laminated. Incessantly heated sealing jaws are often grooved or corrugated, so the corrugations on the jaws should be in mesh to get a strong seal. These sealing systems use a knife (one-bag base seal, one-bag top seal) to break the seal in two.

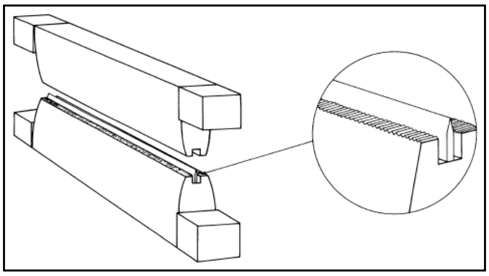


Fig. 20. Typical resistance sealing jaws (source-Frank and Heather 1992).

*Impulse sealing*can be applied to unsupported materials, where the material on either surface is sealed to itself. Fig. 21 displays the components of an impulse sealing device. A precisely spaced, low voltage electrical current impulse heats the nichrome resistance strip (often to red heat).

The radiant heatwave melts clamped polymer films in the sealing jaws. A cooling time is followed by the short duration of the impulse (to give reasonable seal force).

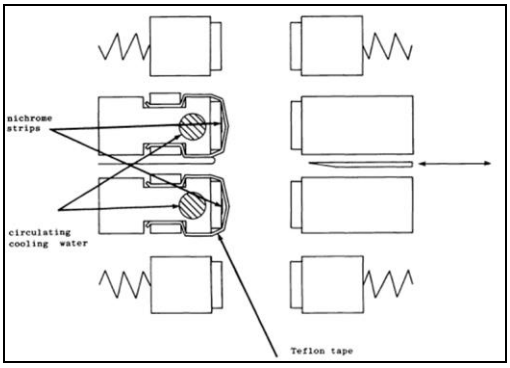


Fig. 21. Typical impulse sealing jaws system (source-Frank and Heather 1992).

Aseptic packaging of UHT milk. The UHT milk packing machine is different than the usual FFS machine in that the packaging material is multi-layered, and the filling is done in an aseptic condition. The filling room is kept at a positive pressure, and the air inlet is through HEPA filters. Starting from a reel of packaging material, the Tetra Brick Aseptic (TBA) filling machine produces filled packages. The packaging material is first sterilized and then formed into a tube. The tube is filled with product and then shaped and cut into individual containers (Ahmed, 1985)

There is a range of Aseptic packages, all deriving their origin from the same forming technique. The commonly available Aseptic packaging machine in India is from the Tetrapak company.

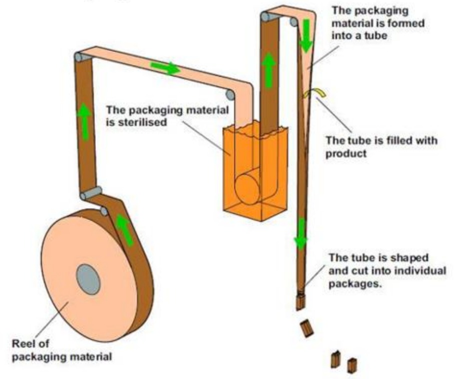


Fig. 22. Typical aseptic filling (source -www.agrimoon.com)

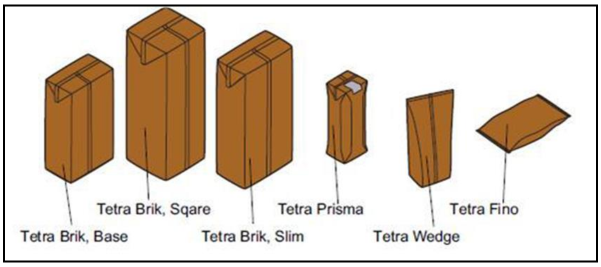


Fig. 23. Forms of Tetrapak packages (source -www.agrimoon.com).

Process of filling

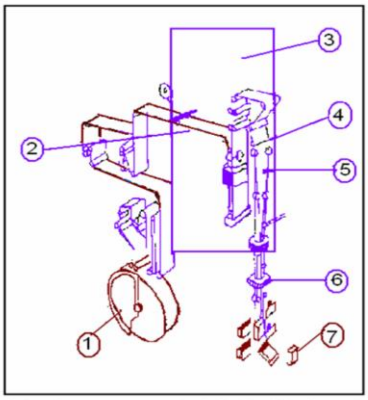
There are four sections of filling used in Fino packaging:

— Feeding of the packaging material into the filler

— Application of hydrogen peroxide (H_2O_2) – concentration and means to evaporate the same to have no residual traces

— Forming the packaging material tube

— Evaporation of hydrogen peroxide and filling under an aseptic environment



1.Continuous paper feed 2. Sterilization of flat packaging material web3.Few machine parts in the aseptic area 4. Tube formed in a sterile environment 5. Simple filling of the products 6. Package formed and sealed under the product level 7. Tetra fibre pillow

Fig. 24. Parts of the aseptic filling machine (source - www.agrimoon.com).

Tetra Brik filling machines are built from so-called modules or main groups with similar functions in the various machines. The machines may also have different additional equipment and accessories.

1. Automatic splicing unit (ASU): The automatic splicing unit splices reels of packaging material. This means that production can continue uninterrupted when one reel of packaging material comes to an end. The packaging material has to remain still in the splicing head during splicing. The magazine provides the necessary material supply so that the machine does not have to stop.

2. PullTab unit: The PullTab unit is additional equipment, providing the packaging material with a PullTab opening before entering the peroxide bath. The PullTab opening is created by punching a hole in the packaging material. The hole is sealed with plastic on the inside and aluminum on the outside.

3. Strip applicator: It applies a plastic strip, the LS-strip, along one edge of the packaging material. The strip is used on the inside of the container and is envisioned to prevent the product from being soaked into the raw paper edge of the longitudinal seal. It can also support the seal. Only half of the LS-strip is sealed to this edge of the packaging material. The other half will be sealed to the other edge later when the packaging material is transformed into the shape of a tube.

4. Peroxide bath: The packaging material will be sterilized in the peroxide bath. In machines with deep baths, as shown in the example, the packaging material will be immersed in warm peroxide, and both sides will be sterilized. In machines with shallow baths, the inside of the packaging material will merely be covered with cold peroxide, and the sterilization will be finished in the tube heater.

5. Aseptic chamber: The packaging material will be dried with heated air. The example shows that deep baths, an aseptic environment around the sterilized packaging material, are maintained with an overpressure of heat-sterilized air. This takes place in the aseptic chamber. In machines with shallow baths with no aseptic chamber, heat sterilized air will be blown into the tight tube. This way, a sterile area is maintained where the tube is filled with product. The packaging material will be formed into a tube and sealed longitudinally. Finally, the tube will be filled with product.

6. Jaw system: The tube is sealed transversally and cut into separate packages in the jaw system. The sealing is made by induction heating, using the aluminum in the packaging material to melt the plastic. It is essential that the package design, with the creases, appear by the jaws. This is controlled and corrected by the jaw system.

7. Final folder: The separate package gets its final shape in the final folder. The fins are folded, and the flaps are folded and sealed. Hot air is used to close the flaps. The plastic outer coating on the packaging material is heated, and the flaps are pressed against the package's sides and bottom. When the plastic gets cool, the flap is sealed.

8. Operator panel: The operator panel allows the operator to communicate with the machine. It is used to start and stop or make the machine take any other action.

9. Electrical cabinet: In the electrical cabinet, a significant part of the electrical components are included, such as • Temperature regulators • Control system • Contactors • Induction Heating unit, etc.

10. Service unit: The service unit includes parts and supply systems needed for the machine function, for example, • Water and air system • Lubrication and hydraulic oil system • Pneumatic and peroxide systems

11. Drive system: The drive system includes the motor, gear, and cam. These parts run the jaw system and the final folder on specific machines.

Horizontal Form Fill Seal Equipment (HFFS). HFFS machines or 'flow wrappers' are used when the product is fragile and cannot withstand the drop-down filling chute of a vertical device, e.g., bars of chocolate, cake bars, and biscuits. The film is fed into a forming box where it is formed into the desired shape, continuously sealed along the sides, and partially cut so that it starts to form an individual container (Fig. 25). The product is fed into the container from a conveyor belt using push bars or 'flights' to separate and direct each product into a single container. Each container is sealed at both ends and then split into individual packs. Most flexible films or laminates used on VFFS or HFFS machines are heat-sealed (Mahalik and Nambiar 2010).

The heat sealer heats the surfaces and applies pressure to fuse them. The seal strength is estimated by the pressure, temperature, and time of sealing and the type and thickness of the two films or the heat-sealable coating. The seal is weak until it cools and avoided stress during cooling.

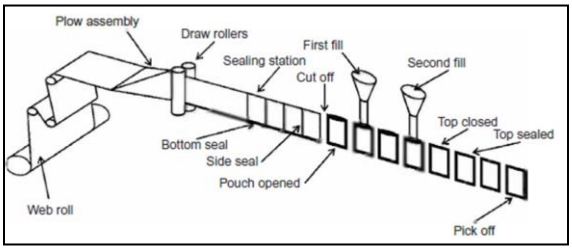


Fig. 25. Operation of a horizontal form fill seal machine (source – Harold, 2013).

Thermo-Form Fill Seal Equipment (TFFS). (Frank and Heather, 1992) reported that the TFFS machine makes packages using two films. One web film is thermoformed into a tray in the most common setup, and the other heat is sealed onto the tray to form the cover. The material at the bottom unrolls from the supply roll and moves into the TFFS system initially fitted with heaters for softening the packaging material. When it advances, it moves next into the shaping unit, where anamalgamation of vacuum and pressure forces the plastic into the tray shape to be used as the foundation of the container. This plastic travels then into the loading portion, where the product is placed in the cavities of the tray. The loading process is performed by hand, robots, or metering systems similar to the previously mentioned dry products and liquid goods (Fig. 26).

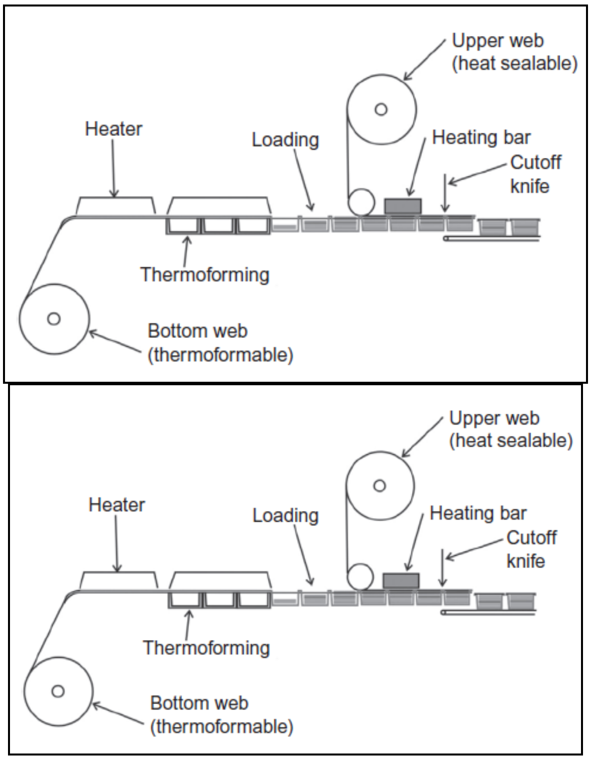


Fig. 26. Operation of TFFS machines. (source – Harold, 2013).

The second plastic web is introduced from the top after the trays are filled, and heat is sealed onto the tray's edges. The final procedure is to isolate the individual trays and send them down the line for any further packaging measures.

FILLING SOLID DAIRY PRODUCTS

Solid dairy products (e.g., milk powder, infant foods, whey powder, etc.) are filled into containers by:
— volume
— weight
— count (for unit items such as tablets) (pharmaceutical industry)

Filling by volume. *Cup filler*: The simplest form of volume filling machine consists of a device for holding open cups, filled in turn as they are passed under a hopper. A typical design involves a circular plate that revolves to presenting each cup under the product hopper (Fig. 27). Scrapers or brushes (called 'doctor' brushes) wipe over the top of the cup to level off the amount of product in the cup. The cups then move to a discharge point where they tip their contents into the final container. An alternative system uses trap doors under each cup to release the product directly into the container. Some systems use adjustable telescopic cups which can be opened to accommodate (Anne and Henry 2012) a larger volume of product in each cup. These systems are suitable for free-flowing solids of consistent density. Maintaining a constant level in the product hopper feeding the cups is essential since this maintains an even flow into each cup.

Some volume filling systems make use of a vacuum in addition to gravity. As the product flows from the hopper into the cup, a vacuum pump draws out air to compact the product. A fine mesh prevents the product from escaping. The cup then delivers the compacted product to the container. This technique is suitable for light powders that might otherwise trap air, lead to inaccurate filling, and reduce shelf life through oxidation.

Auger filling

An alternative to the use of cups is auger filling. A typical auger filler consists of a hopper with a funnel or tube at the bottom. An auger or screw runs through the middle of the hopper together with an agitation blade (Fig. 28). Each turn of the screw (or flight) is calibrated to a precise volume towards the bottom of the auger. As the auger rotates, the agitation blade rotates opposite to remove air, homogenize, and then feed the powder into the flights. As the powder enters the lower flights of the auger, it is divided into separate doses defined by the volume of the flight, which can then be delivered to separate containers. Tapered augers can be used to compact finer powders. Auger filling is particularly suitable for non-free-flowing solid. It is not appropriate for solids with variations in bulk size or particle size and distribution, or where precise doses are required, where weigh filling may be more suitable (Anne and Henry 2012).

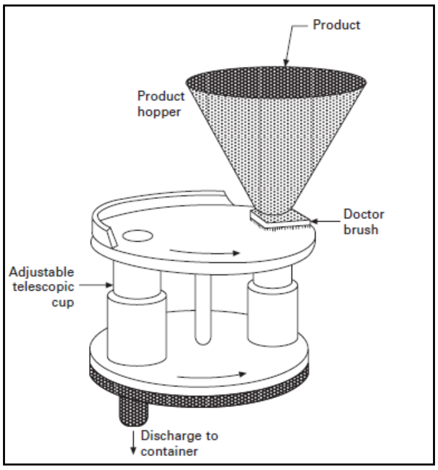


Fig. 27. Filling by volume using a cup filler (source - Anne and Henry 2012).

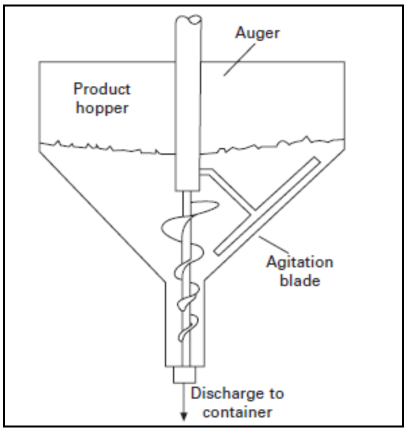


Fig. 28. Filling by volume using an auger filler (source - Anne and Henry 2012)

Filling by weight. Weigh filling typically involves the use of weighing buckets. The product is fed from a hopper into the bucket. Once a certain weight is reached, the hopper is closed, and the bucket tips the product into a discharge chute or directly into the container. In older machines, this would be done using a mechanical balance system that would trip a mechanism to stop the feed of the product when the required weight had been supplied. The container supply mechanism would then release the filled container and position an empty one ready for filling (Anne and Henry 2012) one potential problem with weighing is the risk of the surplus product reaching the bucket after the bucket has reached the desired weight but before the product flow has been halted. This can be dealt with by having separate bulk and 'dribble' feed lines. The bulk feed line supplies the product to the bucket until the required weight is nearly achieved. The bulk feed line is closed, leaving the slow-flowing dribble line to top up the bucket. These systems ensure greater accuracy but make weight filling a relatively slow process.

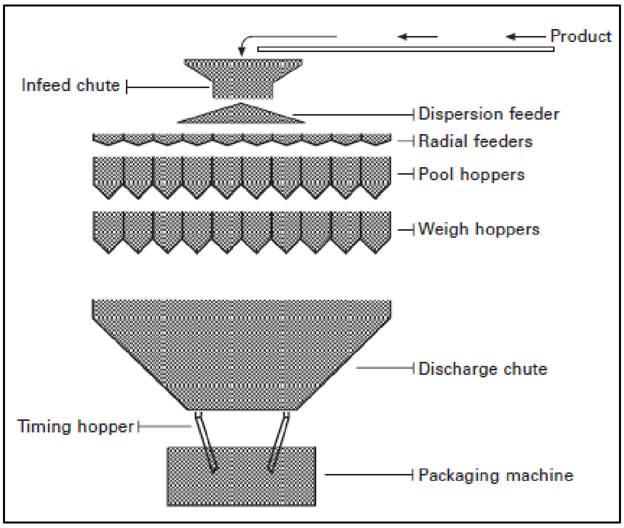


Fig. 29. Multi-head filling by weight (source - Anne and Henry 2012).

The development of electronically controlled magnetic force balances has made it possible to have much more sophisticated, rapid, and flexible systems. It is now possible to have a multi-head machine that simultaneously fills products into several containers (Fig. 29). These systems often use several weighing stations to fill each container, selecting which stations to fill the container to the exact weight.

As with more traditional systems, they use bulk feeders to fill containers near their final weight and fine feeders to top up the container to an exact weight. The machines weigh each container to allow for slight variations in container weights. This will enable them to weigh the product without packaging (net weight) or the product plus packaging (gross weight).

The machine can then calculate how much each container requires, weigh each piece being supplied, select which container to place it in, and continuously calculates how much more needs to go into each container as it fills.

Any packs with the wrong weight are rejected. Free-flowing powders can be measured by volume using a telescopic measuring section of the machine, filled before the product is transferred to the container.

CHEESE PACKAGING MACHINES

Chamber Packaging Machines. Chamber machines are commonly used in film purses to seal meats and cheeses. The object is put into the machine, and the deck is locked. A seal is created when the top and the lid of the machine meet. Vacuum evacuation starts at this point, followed by a vacuum process. The product is ready to be removed if the deck is lifted. Then are, the chamber packaging machine forms

— Small Chamber Machine (Desk Model) – Chamber up to 50 liters, rotary vane pump 3 to 25 m^3/hr.

— Double Chamber (Mobile) - Two chambers, each up to 150 liters, rotary vane pump 40 to 300 m^3/hr

Fig. 30. Cheese packaging machine (source www.agrimoon.com).

— Big Chamber Machine (Non-Mobile) - Chamber up to 400 liters, pump combination rotary vane pump 340 to 1000 m^3/hr. Booster pumps 500 to 2000 m^3/hr

— Rotating Chamber Machine (Non-Mobile) - Multiple rotating chambers (step evacuation) rotary vane pump160 to 630 m^3/hr

— Tray Sealing Machine - Small packagers typically use these skin pack machines

— Inert Gas-Flushed Packaging (Snorkel Machines) - 80% Nitrogen- 20% CO_2 mixture.

CONCLUSIONS

The packaging line combines materials science and industrial engineering, and advancements in these fields have aided packaging innovation. Flexible wrappers and bags with tear strips or laser cut to make them easy to open or innovative tamper-evident technologies to provide the brand owner and the consumer certainty about the integrity of the goods are now commonplace. Bottles are currently being molded from resin, filled, sealed, marked, cartonned, and palletized on complete packaging lines with a high automation control and inspection level. As a result of these advances, a wide range of packaging machinery is now required.

Conflict of Interest. None.

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