METAL PACKAGING

Contents of article

Part 1: Aluminium Manufacturing & Foil

i. Background for metal packaging

Appearing in the early 1800s, metal was one of the oldest packaging used in the world. This embraces packs for food, drink, aerosols, dry and technical products. Metal is usually used for primary packaging under container type, the world market for specific metal containers is a little over 400 billion units.

Figure 1. Some specific packaging manufactured by metal.

The advantages of metal packaging include:

- The significant aesthetic value of decorating aspect when they serve for the label, food cans.
- Good barrier (gases, humidity or odors, ultra-violet) characteristics so they are especially suitable for preserving food and beverage, sensitive products to ambient around.
- High-temperature resistance and heat transfer capacity so that food or retort products can be canned, pasteurized or sterilized with appropriate modes to ensure safety and hygiene.
- Light weight, high mechanical strength convenient for transportation.
- …

Especially, metal packaging produced from iron, tin-iron or aluminium that are abundant and available in the earth's crust. It's similar to glass, metal can be recycled endlessly without a loss of quality so it was classified in the group of sustainable packaging. In this article, we will learn about packaging made from aluminium and steel (ETP & TFS) because they are widely used and have significant demand from the market.

ii. Raw material – Aluminium, Steel Manufacturing

Aluminium is the most abundant metal and the 3rd most element popularity found in the earth's crust (approximately 8%), after oxygen and silicon. It's never found as a pure metal in nature due to its reactive behaviour but combined with hundreds of minerals. The chief source of commercially manufactured aluminium today is bauxite.

Bauxite is a reddish-brown clay-like deposit containing iron, silicates and aluminium oxides, the latter comprising the largest constituents. At present, bauxite is so plentiful that only deposits containing a content of aluminium oxides greater than 45% are selected to manufacture aluminium. In order to produce commercial-graded aluminium from bauxite, essentially two processes must be employed:

- The bauxite ore must be refined to remove impurities (*this is called the refining step*).
- Aluminium metal is extracted from aluminium oxide using electrolysis (*this is the smelting stage*).

Following these initial steps, two further processes are required:

- The aluminium is processed into varied thicknesses based on application purposes and rolled into coils. (*alloy casting step*)
- Special surface finishes are applied to enhance appearance, decorate, strengthen, protect, or provide specialist functions (*decoration step)* A flow process diagram for the aluminium manufacture process from bauxite encompassing the chemical extraction process (A), electrolysis (B) and alloy casting (C) operations, is shown below:

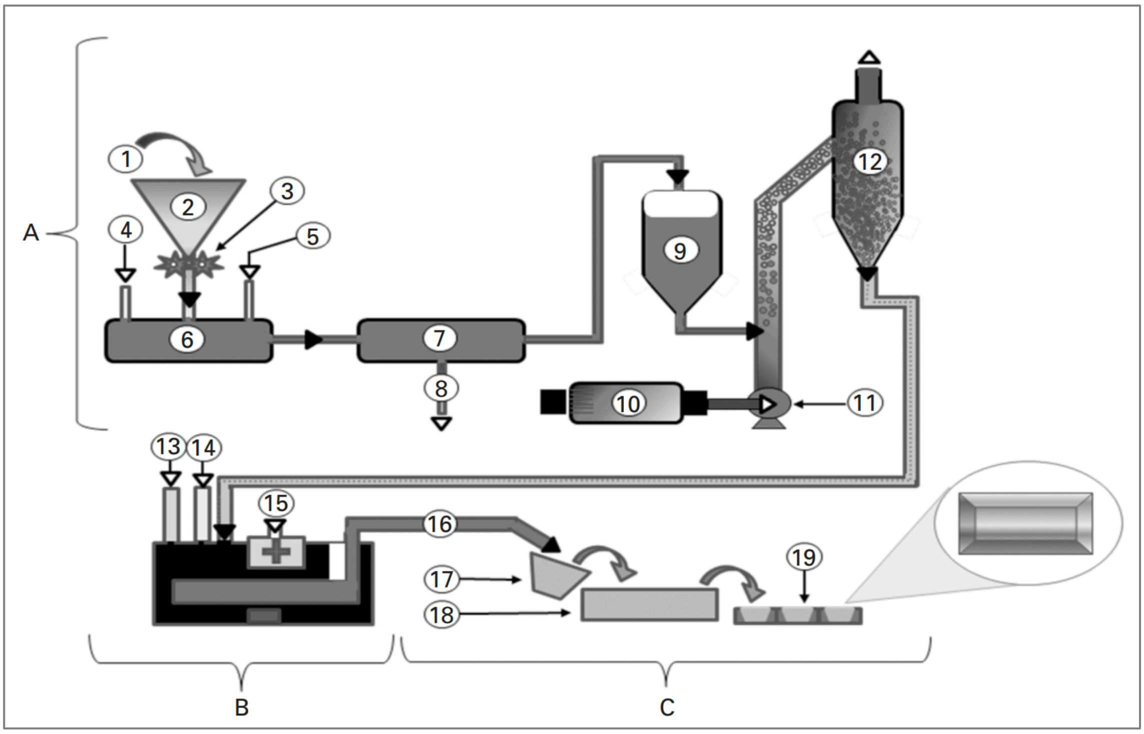


Figure 2. Illustration of the aluminium manufacturing

1-2. Bauxite feeds into the hopper. **3.** Mechanical crusher employed to reduce bauxite particle size and increase surface area for chemical extraction. **4.** Input chemical (sodium hydroxide). **5.** Input chemical (lime). **6.** Aluminium oxide is effectively released from bauxite in the presence of caustic soda solution within the primary reactor (digestion) tank. **7.** The aluminium hydroxide is then precipitated from the soda solution. **8.** Spent solids/tailings discard a red mud residue generated as a byproduct of the process.

9. Precipitation tank: aluminium hydroxide is precipitated from the soda solution. The soda solution is recovered and recycled within the process. **10.** Drying system (air heater system). **11.** Drying system (hot air blower system). **12.** Drying system (cyclone fines recovery system): post calcination, the anhydrous end product, aluminium oxide (Al_2O_3), is a fine-grained free flowing, white powder.

13. Input chemical (aluminium fluoride – AlF3). **14.** Input chemical (cryolite – Na_2AlF_3). **15.** Fuel source (e.g. coke, petroleum and pitch). **16.** Molten aluminium: the reduction of alumina into liquid aluminium is operated at around 950°C in a fluorinated bath under high-intensity electrical current.

17. At regular intervals, molten aluminium tapped from the pots is transported to the cast house crucible. **18.** The aluminium is alloyed in holding furnaces by the addition of other metals (according to end user needs) and cleaned of oxides and gases.

19. The liquid metal is then cast into ingots. These can take the form of extrusion billets, for extruded products, or rolling ingots, for rolled products, depending on the way it is to be further processed. Aluminium mould castings are produced by foundries which use this technique to manufacture shaped components.

2.1. Refining (or *Chemical extract process*)

The refining step, which is also known as the Bayer Chemical Process, is carried out in four stages:

- Digestion (1-5)
- Clarification (6)
- Precipitation (7-8)
- Calcination. (9-12)

Raw material (bauxite) is processed into pure aluminium oxide (alumina) prior to its conversion to aluminium via electrolysis, four tonnes of bauxite are usually required in order to generate two tonnes of finished alumina which ultimately produces approximately one tonne of aluminium at the primary smelter.

2.2. Smelting (*or Electrolysis*)

The smelting step is employed to process the alumina. Its primary function is to separate alumina into metallic aluminium and oxygen utilizing electrolysis, a procedure that was originally devised by Charles Hall and Paul-Louis-Toussaint Héroult in the late nineteenth century. The modified electrolytic method used today requires that the alumina is first dissolved in what is described as a smelting cell.

A smelting cell is made from steel, lined with carbon and filled with heated cryolite, in that Cryolite is an aluminium-based compound that has strong conductive properties. Once the smelting cell is filled with cryolite, an electric current is passed through the cryolite and this causes a surface crust to form on the alumina. This crust is not a permanent feature and is broken regularly through further alumina additions and via stirring.

At this point, other elements may be added to the aluminium. The addition of other elements is dependent on the characteristics required from the aluminium alloy. Elements added include copper, zinc, magnesium, manganese and/or chromium.

Aluminium alloys containing small amounts of these elements have excellent strength properties. For some examples:

- Alloy 3003, which contains manganese, has greater

stiffness as well as improved processing properties for cans or containers for pastries and pies.

- Alloys 1100, 1145 and 1235 are most commonly used for rerolling stock for foil.
- Alloy 1200 is commonly used for packaging applications. Aluminium foils are made in several tempers (i.e. degrees of hardness), dependent on their application.

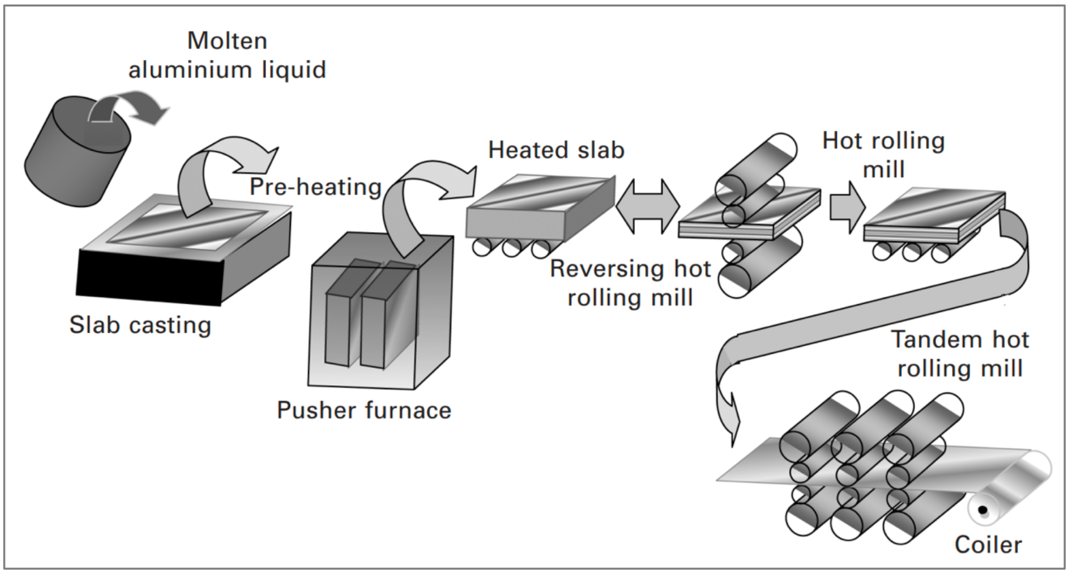
The modified molten aluminium is then poured into chilled casting moulds where it cools and sets to form large aluminium blocks or slabs called ‘rolling ingots’ which typically range in weight between 10 and 25 tons. These ‘rolling ingots’ are reduced to ‘reroll stock’ or sheets approximately 3–6 mm thick. The tempers of reroll stock (stiffness) will depend on the aluminium packaging manufacturer's needs.

2.3. Alloy casting operations

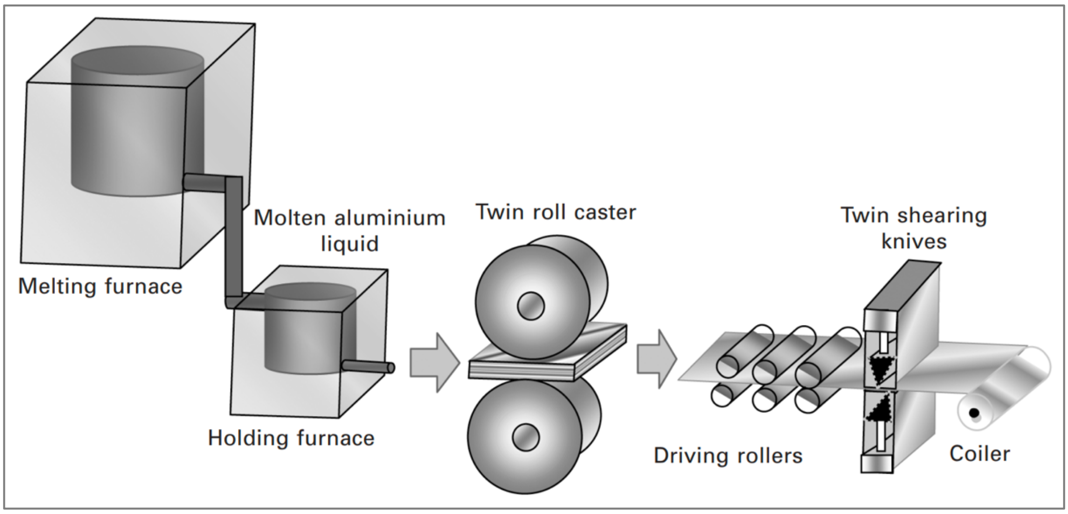
Aluminium alloy coils are classified based on application purpose and their specific thickness, in that the container or beverage cans require usually more than 150 mm in thickness whilst aluminium foil is less than 150 mm.

In fact, foils are available in gauges as low as 6.3 mm. Heavier foil gauges (> 17 mm) provide an absolute barrier to gases and liquids. A typical water vapour transmission rate (WVTr) for 9 mm foil is 0.3 g/m^2 per 24 hours at 38°C and 90% RH. As thickness is reduced, foil becomes more vulnerable to tearing or pin holing. Aluminium coil is produced by two basic processes:

- The traditional method of rolling aluminium slabs, ingots or thick plates into a narrow gauge aluminium web stock using heavy rolling mills (Fig. 3)



- Continuous casting or hot-strip casting (similar to an extrusion process) takes place immediately after the aluminium has left the furnace (Fig. 4)



When using the conventional rolling mill method, the ingot-rolled stock must be re-annealed (reheated) between mill passes to overcome work hardening and restore workability. While the 'hot-strip' casting uses a system continuously feeds, casts, chills, and coils the reroll stock. Since it is heated during production, continuous cast reroll stock does not need to be re-annealed when being made into foil.

After the aluminium stock has been manufactured, it must be further processed on a rolling mill. The work rolls have finely ground and polished surfaces to ensure a flat, even foil with a bright finish. The work rolls are paired with heavier backup rolls which exert very high pressure on the work rolls to ensure stability. This pressure ensures a uniform gauge (thickness) across the resulting aluminium sheet (known as a web). each time the foil stock passes through the rolling mill, it is squeezed, its thickness is reduced and its length increases, but its width remains the same so that the required width for the final foil product must be set at the beginning of the process.

2.4. Steel Manufacturing

Steel (sheet or coil) manufacturing is the same in some steps when compared to the aluminium coil manufacturing process. Steel results from the purification of liquid iron, there is a differences in the melting process due to different material aspects and finishing processes. Compared to aluminium with a protective layer of aluminium oxide, steel after the manufacturing process often has a rough surface, more susceptible to corrosion and oxidation by oxygen and moisture in the air. Steel must undergo many processing and machining processes including tinning process or coating (0,15 – 0,4 µm) to make it suitable for its intended use. In that tinning process include two methods: hot-dipping and electroplating. Most of the tin-plated steel or tin free steel made today are then further electroplated with a very thin layer of chromium (~0.05 µm) by ECCS method – electro chrome coated steel to prevent dulling of the surface from oxidation of the tin.

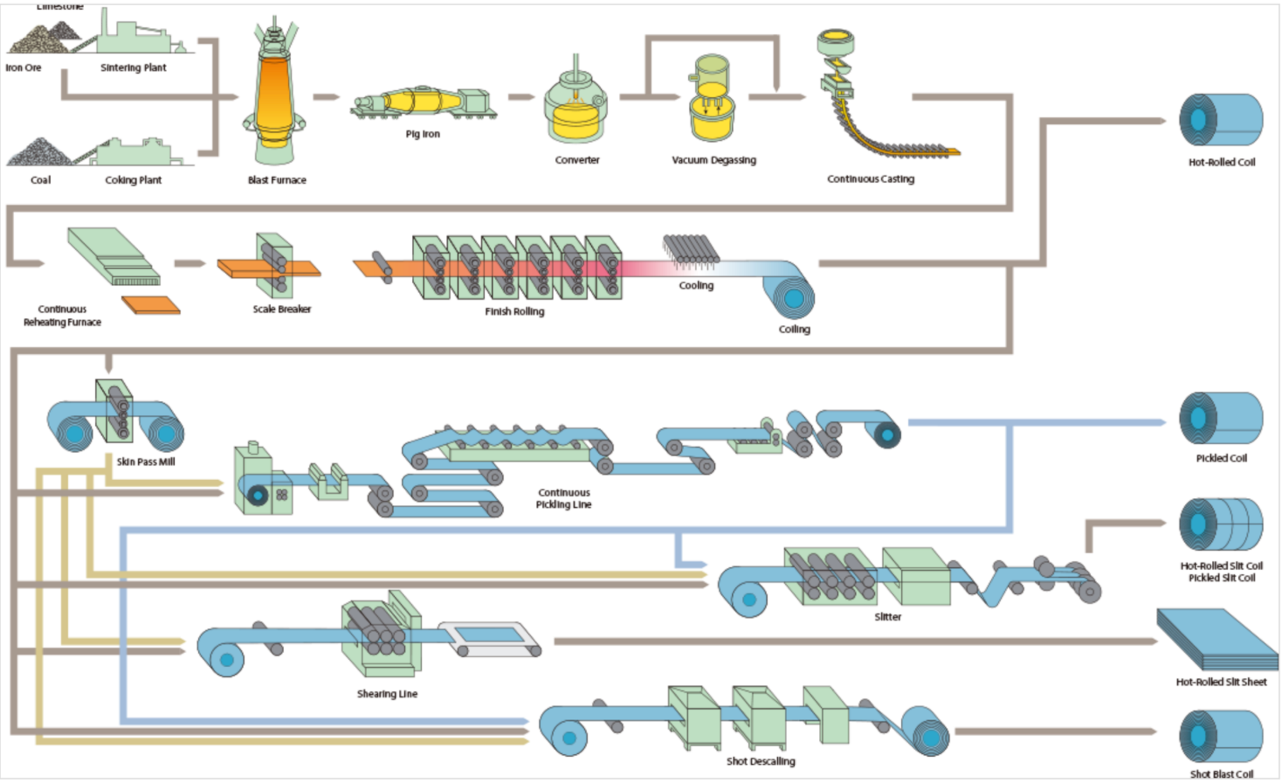


Figure 5. Illustration of the steel manufacturing

iii. Foil Label finish

3.1. Foil treatment, Coating & lacquering

Rolling produces two natural finishes on foil: bright and matte. Finishes can be produced with special patterns on the work rolls or, more commonly, by using separate or in-line mechanical finishing machines.

Type of finish	Description
Bright both sides	Uniform bright specular finish, both sides
Extra-bright both sides	Uniform extra-bright specular finish, both sides
Matte one side	Diffuse reflecting finish, one side
Matte both sides	Diffuse reflecting finish, both sides
Embossed	Pattern impressed by engraved roll or plate
Annealed	Completely softened by thermal treatment
Chemically cleaned	Chemically washed to remove lubricants
Hard	Foil fully work-hardened by rolling
Intermediate temper	Foil temper between annealed and hard

In most packaging applications, aluminium foil can be solely applied or combined with other materials such as coatings, inks, papers, paperboards and plastic films to create decorating labels. A very useful characteristic of aluminium foil is that it has the capacity to readily accept many different types of coating materials such as inks (for printing), varnishes and lacquers (for embossing), adhesives and polymers (for heat sealing, etc.). The selection of foil alloys, gauges and tempers needs to take into account the type of coating or lacquer required. Where a coating is needed, gravure coating is used for most low-viscosity materials. Heavier coatings require some forms of roll coater. Coatings generally can be classified as protective or decorative. Protective functions for coatings include:

- making the foil more heat-resistant
- increasing tensile strength
- increasing resistance to potentially corrosive agents
- enhancing the barrier properties of low gauge foil
- increasing resistance to scratching or scuffing
- increasing the UV resistance of a printed foil.

Decorative and other functions include giving additional gloss and depth to a decorated or printed foil, or improving the adhesive quality of the foil for other coatings or printing inks. *Some general properties and characteristics of typical aluminium foil coating materials will be shown in part 2.*

3.2. Foil printing and embossing

The popular printing method for foil is gravure whilst flexo printing is less popular than one. Because the foil base is very thin and two sides have different treatments, a primer or wash coat should be applied to ensure a clean surface and to provide a foundation for the ink before the foil label is to be printed. Vinyls is common primer for gravure and flexographic printing. If a thicker coating is required, e.g. for lithographic printing, vinyl copolymer or nitrocellulose may be used. A second film coating may then be applied on top of printed images to protect it from scuffing as well as to reduce surface friction

Aluminium foil is particularly suited to embossing. This gives both a three-dimensional quality to a design and increases the number of reflective surfaces able to reflect light to create a more eye-catching effect. Besides, it also increases stiffness and allows cut pieces of foil to be easily separated, e.g. stacks of pre-cut lids.

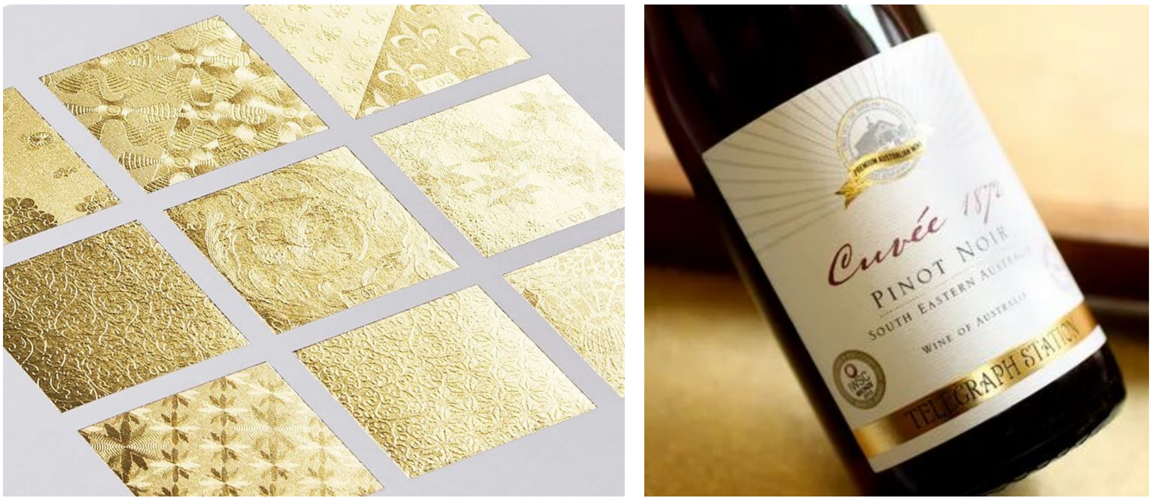


Figure 6. Some instances for foil embossing (left) and stamping (right)

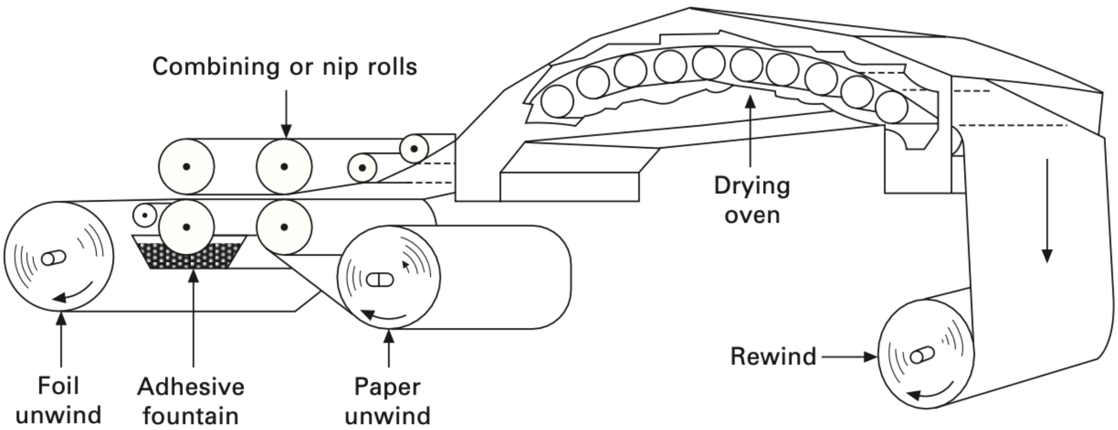
3.3. Aluminium foil used as a laminate

Lamination involves combining sheets of different materials into a single layer, using a mixture of adhesives, pressure and sometimes temperature to bond the materials together. Adhesives are selected on the basis of their suitability for the materials to be joined as well as such issues as any toxicity or contamination risk they might present, potential odour or colour issues, moisture and heat resistance. The main types of adhesives used are:

- heat-sealable adhesives
- water-soluble emulsions and dispersions
- thermoplastics in lacquer-type solvents
- hot melts (natural or synthetic waxes)
- extruded-film adhesives.

Four methods are used to laminate aluminium foil:

❖ ***Wet bonding*** involves combining the various layers before the adhesive is dry. A water- or solvent-based adhesive is used and is normally applied to the foil. Further layers are then applied on top and the laminate passed through a combining or nip roll at varying drying temperatures, depending dry bonding. This method is suitable for a smoother, denser and less porous materials such as paper.



❖ ***Dry bonding*** use both natural and synthetic sealing agents and can be either water or organic solvent based include vinyls, epoxies, polyesters and urethanes. These layers are aligned and passed through a heated combiner roll which reactivates the adhesive to create the bond. This method is well suited to non-porous materials such as polyester films, which add strength and flexibility when combined with aluminium foil.

❖ ***Extrusion bonding*** involves extrusion of one or two molten plastic films which are then combined with the aluminium foil. As the aluminium foil web approaches the combiner roll, an extruder die deposits a layer of hot extrudate across the width of the web. The laminate then passes through the chilled nip of the combiner roll, cooling the plastic layer which solidifies. No drying is required.hot-melt bonding.

❖ ***The hot-melt bonding*** is used for high-speed lamination since there is no need for a drying stage. Hot melts include polymer resins, waxes, and resin-wax combinations. They can be melted at a lower temperature than extruded coatings, applied to the web, and chill-set in the nip of the combiner roll. The plastic nature of the hot melt improves heat-sealability and the dead-fold characteristics of the foil.

3.4. Aluminium metallised films

Vacuum metallising or metallisation involves depositing a metal layer onto a substrate (e.g. paper or plastic film) in vacuum conditions. Aluminium is the only metal used for vacuum metallising. This approach is now widely used in flexible packaging since it improves gas and moisture barrier properties, heat resistance, light reflectance and electrical conductivity. Metallised films are often a component in a laminate.

Product	Type of laminate
Coffee	12 µm metallised BON/50 µm LDPE
Savoury snacks	18 µm OPP/adhesive/18 µm metallised OPP
Condiments/spices	12 µm metallised PET/38 µm MDPE
Bag-in-box wine	50 µm ionomer/12 µm metallised PET/75 µm EVA
Biscuits	OPP/18 µm metallised OPP
Medical products	paper/adhesive/18 µm metallised OPP/ionomer
Cold meats	metallised PET/PE

Batch processing is the most widely used approach to metallising which can handle reels of over 20,000 m per hour. It involves a horizontal tubular chamber, up to 2 m in diameter and 3 m long.

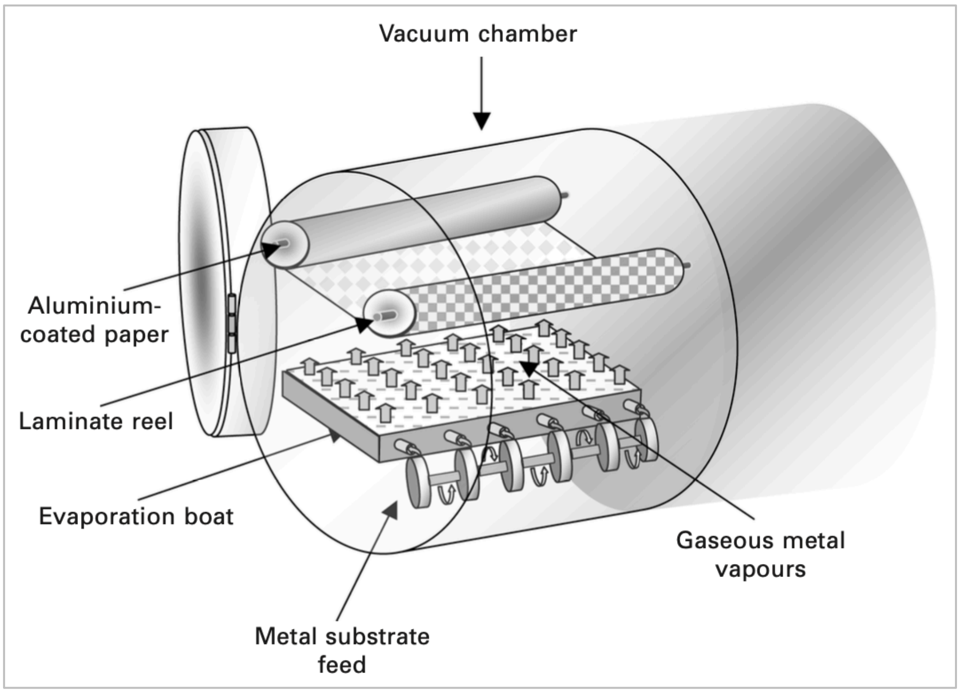


Figure 7. Vacuum metallising process which operates at approximately 1,500°C (2,700°F)

A series of rollers carry the substrate through the chamber from which the air has been evacuated by vacuum pumps. Pure aluminium wire is fed into containers ('boats') which are electrically heated to vaporise the aluminium. (The vacuum reduces the vapourisation temperature of the aluminium). As the vapour rises, it condenses on the underside of the substrate as it passes over a chilled drum. The thickness of the metal deposited is controlled by a combination of web speed, wire feed rate and boat temperature. Electrical resistance and optical density are the two main methods for testing deposition and layer thickness.

iv. Some applications of aluminium foil as Packaging materials

Packaging Application for	Products	Illustrating images
Rigid smooth wall containers – *Aluminium foil with sufficient thickness was compressed into container form.*	Meat joints for roasting, large portioned ready-meals and convenience-style food products	
Semi-rigid wrinkle wall containers – *A harder material such as paper or plastic wrapped around by aluminium foil*	Take-away meals, savory pies, bakery products, frozen and chilled ready-meals	
Closure systems	Milk, beverages, instant coffee, dried powders, health foods and pharmaceutical products, cosmetic creams	

Flexible packaging – *Most aluminium foil applications are laminated with other materials to create a multi-layer structure.*	**Dairy products**: milk, cheese, butter and ice cream **Beverages**: wines, juices, soft drinks, liquors, beer; **non-beverage products:** soaps, shampoos, conditioners, detergents, cosmetics **Dessicated and powdered products**: coffee, tea, cocoa powder, custard, fruit, concentrates, vegetables, dehydrated powders, soups, herbs and spices, yeast and other powdered extracts, salt, sugar, pharmaceuticals, tobacco products **Cereal and baking foodstuffs**: cake mixes, cereals, frosting mixes, pasta-based products, rice-based products, biscuits, crackers, snack foods, breads **Confectionery**: chocolate, hard and soft sweets, all products containing volatiles contributing to flavours such as mint, orange, coffee, aniseed, clove, etc. **Muscle-based foods**: meat, poultry, fish, game, casseroles, stews, soups and broths, general muscle-based retorted products, chilled and frozen products, pet foods	    
Labels	Used widely from foodstuff to beverage packaging	
Composite cans	Powdered drinks, snack foods, juice-based beverages, instant biscuit/ cookie dough, chilled and frozen foods	

Part 2: Modern Metal Containers

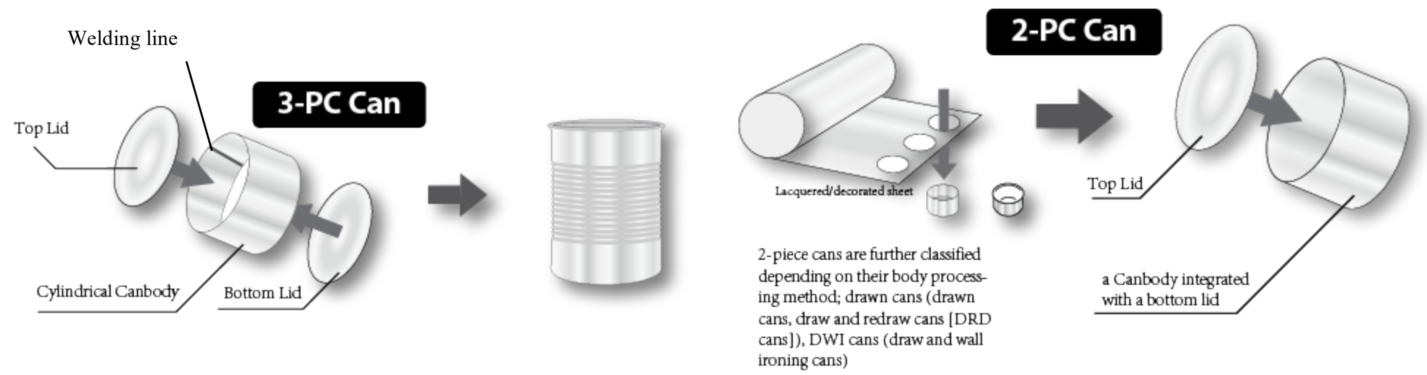
i. Overview of metal containers

1.1. Common format for metal cans

Metal containers are manufactured from either packaging steel or aluminium. The choice will depend on the duty that the can has to perform as well as the can geometry and the method of production. Metal cans or bottles are mostly constructed by one of the following two basic methods:

- Three-piece can (3-Pc) – comprising a cylindrical body rolled from flat rectangular sheet with the side seams overlapped and joined using electric resistance welding and two ends mechanically joined to produce a closed container.
- Two-piece can (2-Pc)– comprising a seamless cylindrical can body with one integral end (base) shaped from a flat disc and the other end mechanically joined to produce a closed container.

3-pc cans and 2-pc cans, depending on the structure.



Most metal containers are designed to hold liquid, or solids in liquid, at pressure, vacuum or normal atmospheric pressure, the exceptions being those designed for dry products or as decorative containers only. The geometric relationship between can diameter and height were to define which can format is most appropriate for which manufacturing process. This relationship may be described as:

- Tall cans - Height greater than diameter (e.g. beer can)
- Short cans - Height equal to or slightly less than diameter (e.g. tuna can)
- Shallow cans - Height significantly less than diameter or width (e.g. sardine can).

Most cans for food, drink or for use as aerosols or collapsible tubes have circular cross sections because these can be made, filled and ends seamed on at much higher speeds than those having non-round cross sections.

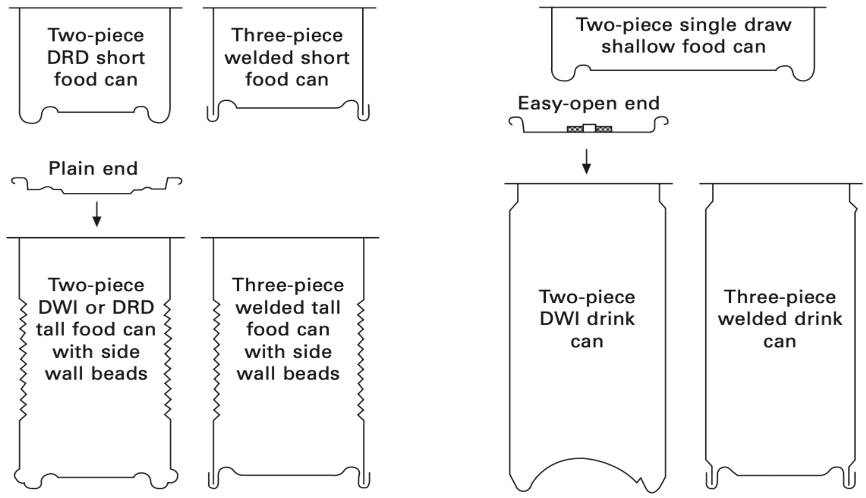


Fig 1. Typical processed food and drink cans. (DRD: Draw re-draw can; DWI: Draw wall-ironing can)

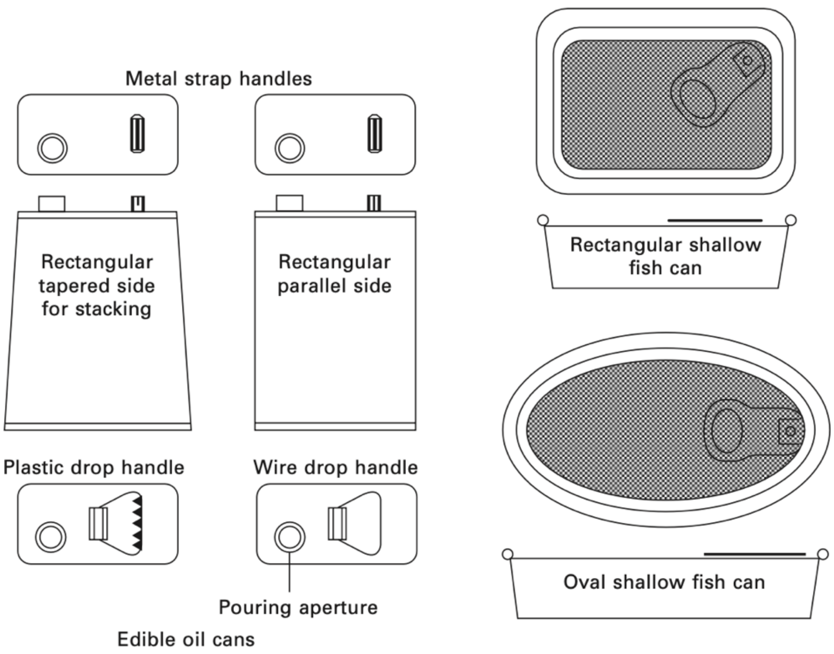


Fig.2 Typical non-round food cans.

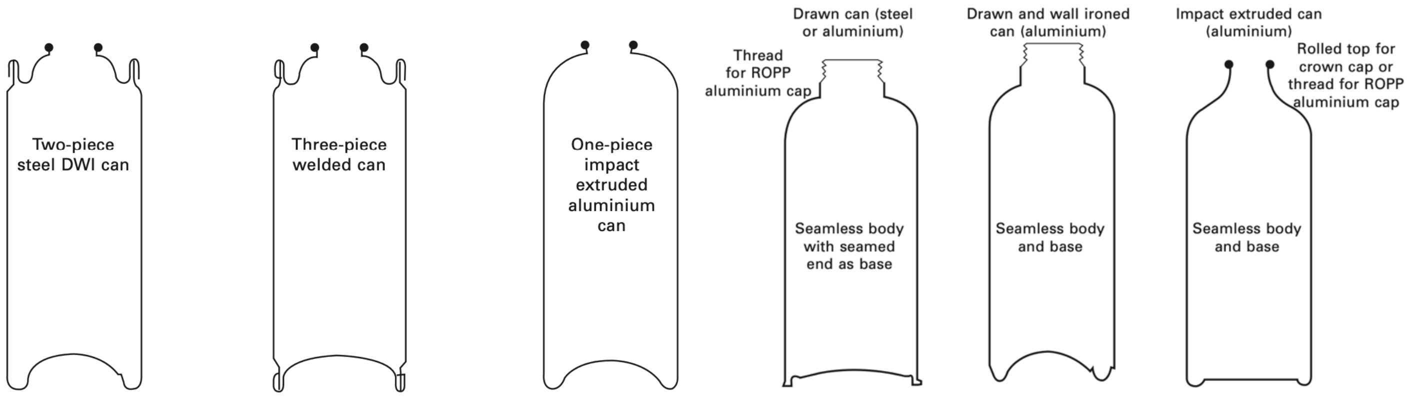


Fig.3 Typical aerosol cans (or bottles) prior to fitting of valve mechanism and/or closure

A range of standard can diameters has been developed for each of the food, drink and aerosol markets. This was necessary in order to limit the number of different tool sets to can makers and fillers and to limit the number of different end diameters that need to be manufactured.

In the drink sectors, the various size ranges have been developed to produce a set of can volume capacities to provide varying portion sizes to suit the demands of the consumer markets, while minimising the number of containers having similar or nearly similar capacities. The suitable explaination of this is to two-piece systems, the can-making processes are less flexible in terms of making different can sizes because the investment in tooling dedicated to one can diameter and height is greater than that for three-piece can making whilst the three-piece can-making process may be used to form any shape or size of container.

Fig 4. Some popular two-piece can sizes for the drink on market. (Source: TBC)

Metal caps and closures are initially formed as shallow drawn containers before special shapes and lining/sealing materials are added to provide the necessary functions of the finished component. Because of the large quantities produced, these are generally made in standard diameters to suit the range of container neck sizes.

1.2. Raw materials management used to produce metal containers

As presented in Part 1, the main raw materials used in metal can making for packaging are steel, aluminium and organic coatings in either liquid or solid form. The coatings are used to protect the metals from chemical interaction with the products packed in the containers and, where necessary, the external environment. The coatings also help to prevent dissolution of unwelcome elements and taint from the metals into the product.

1.2.1 Management of corrosion

When using steel or aluminium containers for packing wet products, some of which may also be subject to heat processing, consideration must be given to the likelihood of corrosion taking place on the inside walls of the cans due to chemical action of the product and how this may be prevented. Additionally, the external surfaces may be subject to corrosion due to excessive humidity in the atmosphere or during heat processing in steam/water systems.

For steel-based containers the presence of metallic tin on the surface always improves the corrosion resistance whether or not organic coatings are also in place. ECCS (tin-free steel) will give excellent corrosion prevention provided that an adequate layer of organic coating is in place as a seal coat. While the oxide which forms naturally on the exposed surfaces of aluminium does provide some resistance to corrosion but this is insufficient for wet products, so all internal surfaces of these containers must normally be coated.

Organic coatings are applied to the internal container surfaces to form an inert barrier between product and metal to prevent chemical actions due to the nature of the product and to prevent dissolution of metallic elements into the product. The weight of coating and, where appropriate, the weight of tin applied to steel may be varied to suit the specific conditions in the can.

For three-piece welded side seam cans, it is necessary to leave the surfaces of tinplate forming the weld overlap free of any coating to ensure the weld is sound. The internal lacquer and external coating are then applied on welded sides after the weld has been made to finish. This process is called side striping, the coating being applied by spray, roller or as a powder and then cured by a blast of hot air applied to the outside of the can body. There are some can material/product combinations where a side stripe lacquer is not necessary.

Besides, bi-metallic corrosion can take place between aluminium and steel under certain circumstances if the drinks experience full heat-processed after filling, reverse for cans where only low-level pasteurization takes place, there is no problem when using aluminium ends on steel can bodies.

1.2.2 Food contact issues

When packing food or drink into metal containers, it is very important that the product packed and the container's internal surfaces are compatible with one another so that no unwanted or uncontrollable chemical reactions take place between the two. This is most important with wet foods and liquids. Internal lacquers on the can body and ends are used to prevent basic chemical actions from taking place.

Many food items, particularly meat and fish, contain sulphur. During the heat processing cycle, low-level reactions can take place between sulphur and tin or iron to create black sulphides. These can take place across the surfaces of the coating if the weight is insufficient or if an incorrect coating specification has been used. While the sulphide products are not hazardous, they can impart stains to light-coloured foodstuffs.

1.2.3 Coating materials and their application

Coating materials are applied to the metal surfaces either in liquid or solid form (as powders, laminates or hot extrusions). This may be done before the metal forming operations, i.e. as the coil or cut sheet, or after forming when the container or end has a three-dimensional shape.

Liquid coatings are organic-based materials comprising resins with combinations of solvent and/or water-based carriers to ensure good control of applied weight together with satisfactory wetting, adhesion, and curing properties. The resin forms the hard coating that remains on the metal surface after the curing has been completed. Depending on the chemistry of the coating, curing may be achieved by the application of heat or by subjection to ultraviolet (UV) light. However, the method of curing is designed for the coating and cannot be changed later. The choice of curing method is dependent on many factors such as the product packed, the type of heat processing employed, the type of can, and how it is used by the consumer.

Liquid coatings may be applied by roller coating or airless spray and generally form part of the can-making operation, then the product passes through a tunnel oven system where the liquid carriers (solvent) are first evaporated leaving the residual resin to be cured within heat-curing treatment, formed by chemical cross-linking, into a hard but flexible surface.

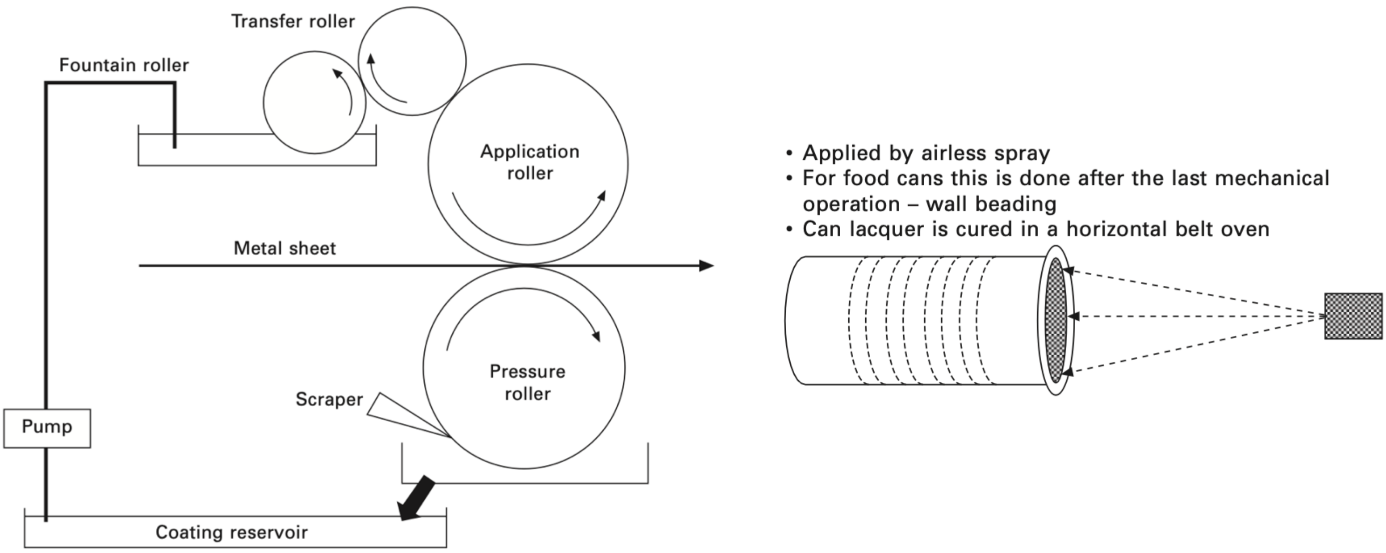


*Fig 5. Coater for applying lacquer to sheets (**left**) and DWI food can internal lacquering (**right**)*

Coating type	Acid	Alkali	Water	Solvent
Acrylics	Fair	Fair	Fair	Good
Alkyd	Fair	Fair	Good	Good
Butadiene-styrene	Excellent	Excellent	Excellent	Good
Butyrate	Fair	Fair	Fair	Fair
Cellulose acetate	Fair	Fair	Fair	Fair
Chlorinated rubber	Excellent	Excellent	Excellent	Fair
Epoxies	Excellent	Excellent	Excellent	Excellent
Ethyl cellulose	Fair	Excellent	Good	Fair
Melamine	Excellent	Excellent	Good	Good
Nitrocellulose	Good	Fair	Excellent	Good
Polyamide-epoxy	Fair	Excellent	Excellent	Good
Polyester	Good	Fair	Good	Good
Polystyrene	Excellent	Excellent	Excellent	Fair
Polyvinyl acetate	Fair	Fair	Good	Poor
Polyvinylidene chloride	Excellent	Excellent	Excellent	Fair
PVAC chloride copolymer	Excellent	Excellent	Excellent	Fair
Styrenated alkyd	Fair	Good	Good	Fair
Urea	Excellent	Excellent	Excellent	Good

Fig 6. Chemical resistance of some typical resins used in coating system

The choice of coating is mainly based on the purpose of the application, the properties of coating and types of can-making processes, and economics. In particular, polyester or acrylic is often used for external coatings of 2-piece and 3-piece cans whilst epoxy compound is for interior lacquer. In some cases, Epoxy-ester or epoxy-phenolic coating, which sometimes will be mixed with zinc oxide, internal lacquering for 3-piece cans. **e.i.** tuna or meat cans are going to release hydrosulfit within preservation times causing a dark colour, so the presence of zinc oxide helps to neutralize this gas without affecting to product inside.

ii. Manufacture of rigid metal containers

2.1 - Two-piece cans making process.

Two-piece cans are also known as seamless cans because the base and side walls are constructed from one piece of metal without any joins in the open-top container. They're assembled with ends via a joint called a flange (or double seams).

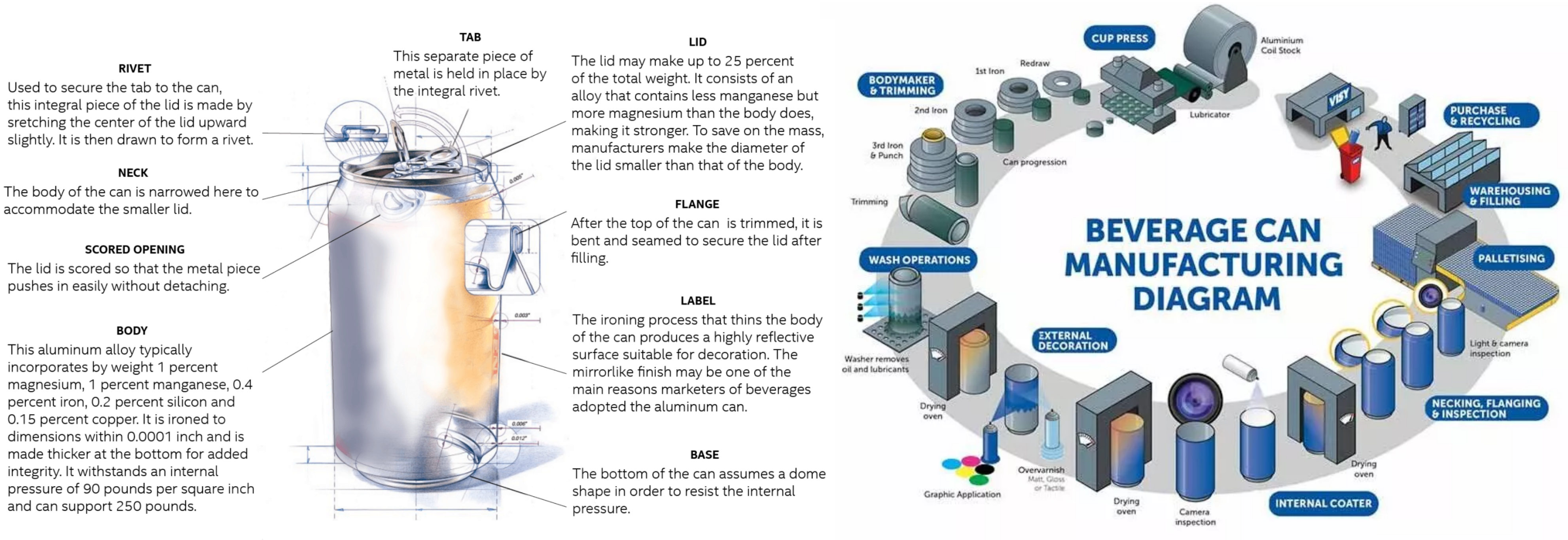


Fig 7. A typical instance for the terminologies of 2-pc cans and its general manufacturing process.

A general metal packaging production process normally includes 8 steps (including DRD and DRI cans): Cupper, Bodymaker & Trimmer, Washer, Decorator (Printing, Varnishing and/or Lacquering), Necking & Flanger, Inspecting, palletizing and finally can-ends.

2.1.1 Cans forming stage

Drawn and redrawn (DRD) cans are used for food (particularly processed fish products) while Draw wall-ironing (DWI) cans widely used for food, drink and aerosol, and general line cans and may be made from steel, tinplate or aluminium. There are differences between these two can types, while they have almost similar formation processes in can forming, may derived from:

- DRD can: Aluminum alloys can be used under master sheets which can be printed former or not, and coated adequately to withstand to forming process; the height and dome of cans were formed not too tall and deep.
- DWI can: Aluminum alloys are often packaged in rolls, facilitating continuous "flat disc" cutting at high speeds. In addition, DWI cans often go through more ironing rings to reduce wall thickness body and higher dome.

This stage mainly focuses on the can-forming process. First, the aluminum roll is fed into the cupper, where the cup press machine will hold and cut the aluminum into "flat discs" and press them into shallow cups (or blank cup) with many punching tools. Two steps above were performed at the same time by die-cut rings and punching tools. Can body-forming requires calculating the flange angle of the ironing rings to minimize friction as well as surface uniformity, and lubricants are indispensable throughout this process.

Next, blank cups will be placed into the suitable body maker if the redraw-forming or parallel wall-ironing ring tools required depending on the type of can are selected to be formed. After passing through the body maker, cans will be trimmed to remove uneven top edge and leave a clean edge with the correct overall height proceeding to create the neck and flange. In another process, the flange of DRD can be created through cup-making.

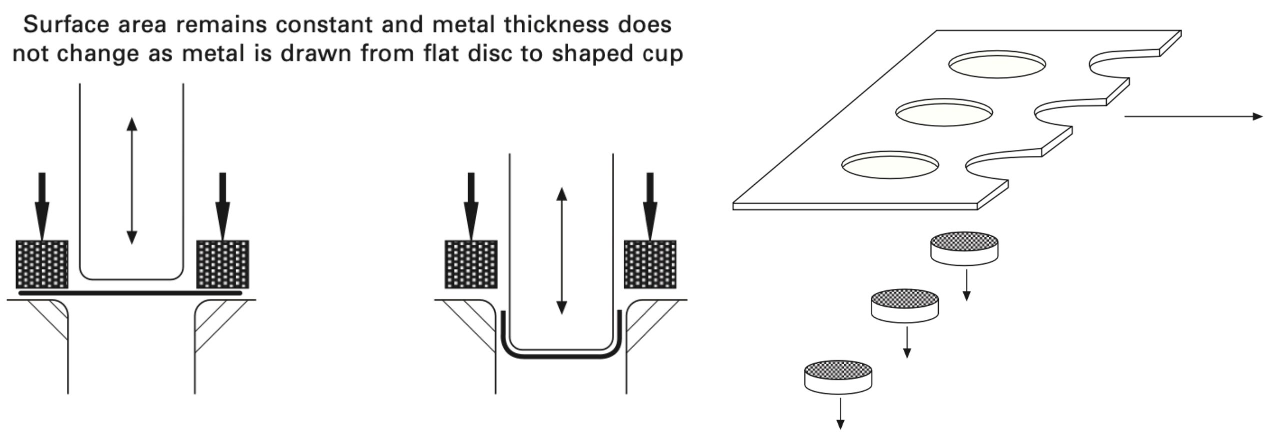


Fig 8. Cup making for DRD and DWI cans.

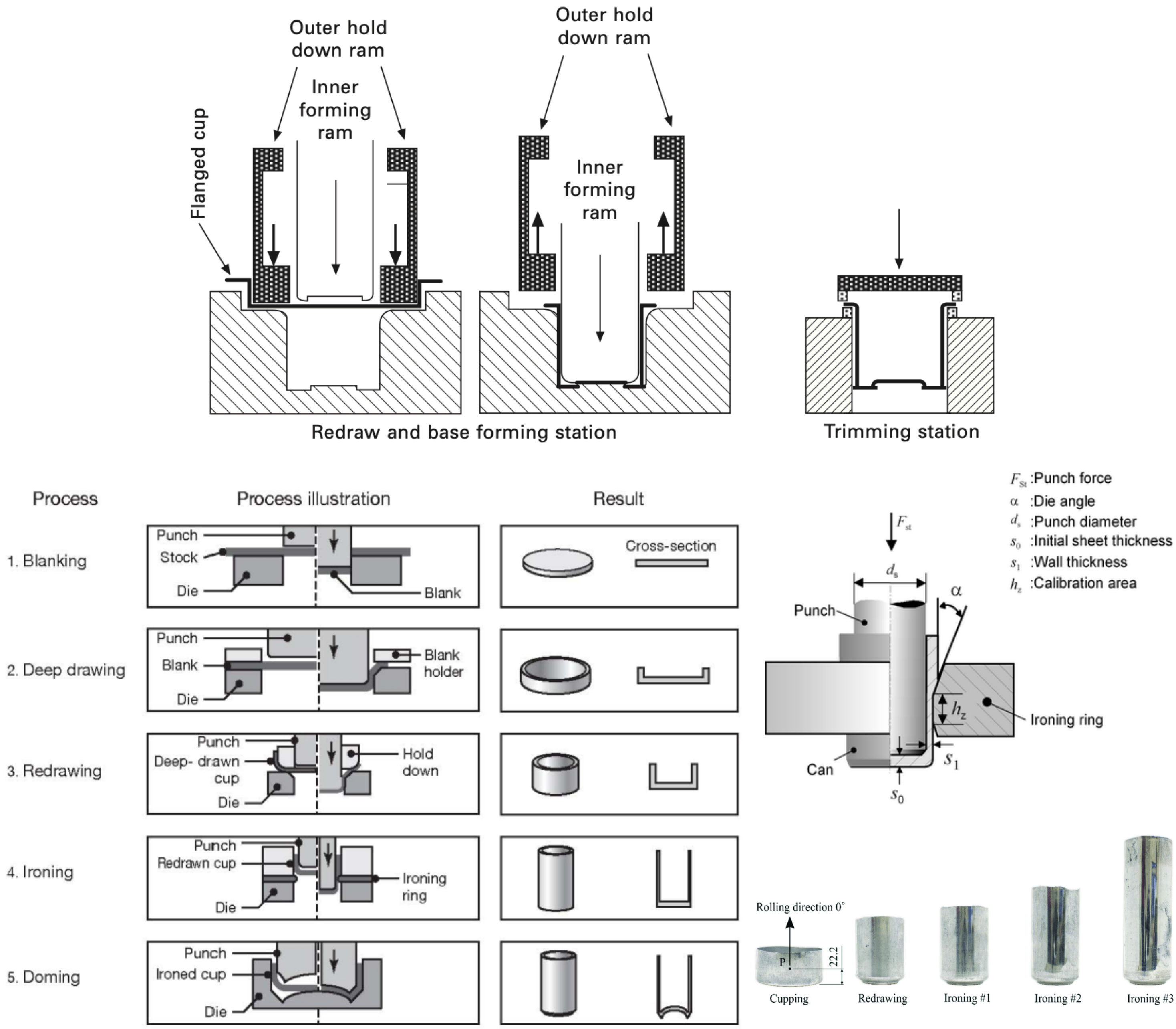


Fig 9. DRD can forming (above) and DRW can forming (below)

The main purpose of forming the dome below the can is to reduce the contact surface coefficient between itself and the conveyor belt through the can-making process and filling of the can at the end-user manufacturer. At bottom dome, manufacture will be convex curving of a number which serve for shift-production traceability. In addition, dome helps allocate the axial load on the can base, its hemisphere structure also distributes internal pressure which prevents the buckle of shape.

2.1.2 Cans washing stage

The nature of TFS (tin-free steel) or tin-steel (ETP) is normally an oil layer above, this can usually come from lubrication for coil roller in its making process. Besides, lubricants used in the can-forming stage will deposit on can surface, which generally reduces the adhesive ability to apply inks and overvarnish at the decorating stage and some food safety aspects from lubricants used.

In aluminium can making process, Cans are usually covered with a very thin layer called a baffle coating before leaving washer, the tension surface of the can will increase to easily apply inks without base coating as in steel cans.

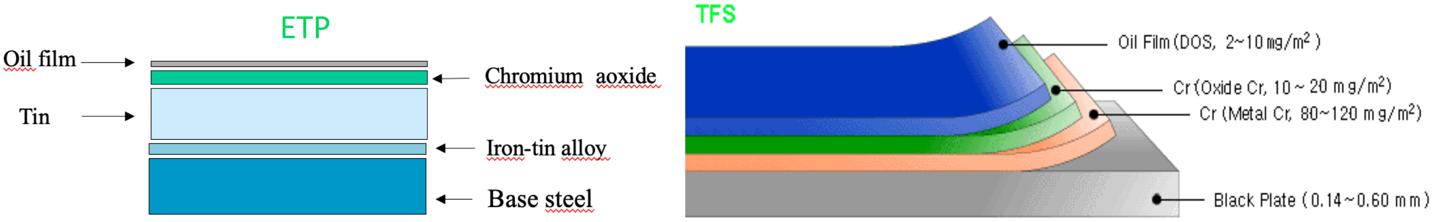


Fig 10. The metal structure of ETP (Electrolytic Tinplate - left) and TFS (Tin Free Steel – right)

2.1.3 Can decorating & finishing stages

Printing on metal packaging provides decoration to attract the consumer and reinforce the image of the product brand while also giving information about the package and its contents.

- ***ETP & TFS base***: These metal sheets after coming out washer will be dryer and then coating on both sides. Can produced without imagine will be known as general cans, the paper or plastic label can be used for decorating purpose. Printing on to metal for packaging, usually offset printing method, may be undertaken with the metal in flat sheet form, prior to metal forming (for three-piece, general line lock seam and drawn containers), over-varnish applied for protect printed images. Flat sheet printing allows an unlimited number of colours to be laid down, regardless of the number of printing machines/colour heads installed, because sheets can be re-fed through these machines for additional colours to be added.

Fig 11. A typical CMYK offset printer used to print on metal sheet.

- **Aluminium base**: As mention above, can before releasing washer will apply a thin baffle and then dry. Cans were transportation by vacuum conveyer to CPP station to reject these can doesn't meet requirements such as dome finish, trim height, and they're hooked by pin chain later to drive to decorator system. Printing method used on aluminium cans surface is lithography with the maximum number of colours is determined by the design of the machine (normally 6 units). However, techniques for printing on formed circular bodies have to overcome the restriction that it is not possible to register individual colours onto a continuous surface. This issue is solved by first laying down all the colours in sequence, as a reverse dry offset image, on an intermediate rectangular surface (rubber blanket) which has the same dimensions as the external surface of the can.

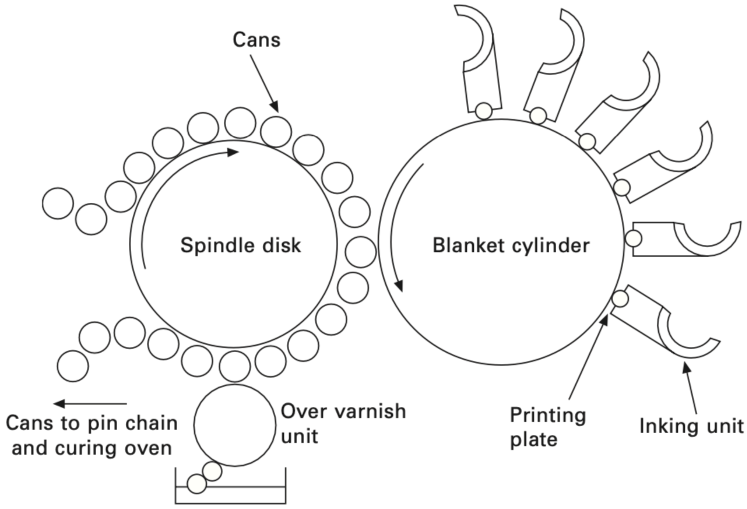
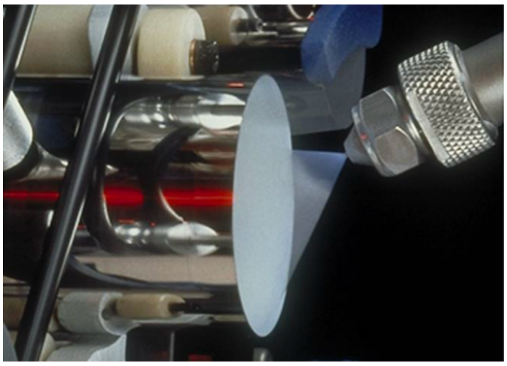


Fig 12. Cylindrical can decorating machine

Digital technology is now being developed and brought into production for circular printing of drinks cans. This will allow virtually instant change of design to take place with no set-up time or wastage of ink and containers. It will also permit topical information to be included on can label designs for sale of filled product within say 24 hours of the can being made. Moreover, it's actually suitable for small-sized containers to be printed on base of can, now when all the required information may be difficult to contain on the side wall of limited area.

For drinks can, over-varnish also applied on can surface after printing is for imagine protection and rim varnish at base for reducing coefficient friction. Inks for both flat sheet and circular print systems are waterless types and available in heat cure or UV forms. They are not absorbent, so all liquids on the surface must be removed by evaporation in dry-oven or curing by UV lamp systems.

❖ **Internal spray coating step for DWI can only**



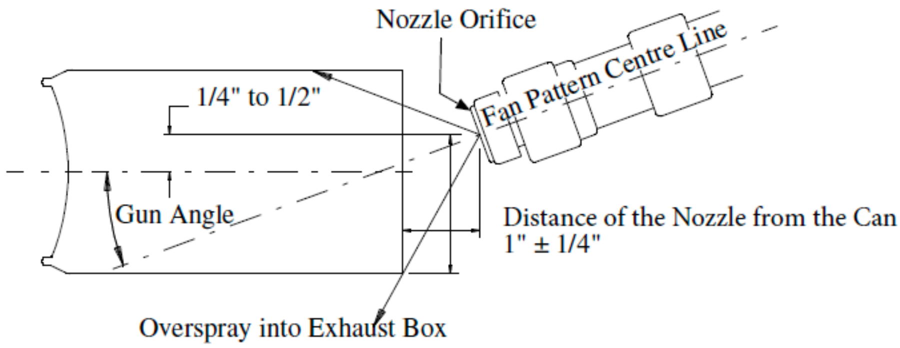


Fig 13. Illustration for Internal spray gun

DWI cans often go through the process of thinning the can body, so internal lacquering before body forming is not as common as the DRD cans. In almost modern techniques of the drinks can-making process, the internal coating is usually sprayed under high pressure by double single-nozzle guns or a dual-nozzle gun.

General principles of the above these gun types must ensure the lacquer-covered interior surface of can. The double single-nozzle gun is the popular used type in the world and a clear illustration of this principle. Specifically, Gun 1st will spray to cover the dome and reverse side whilst Gun 2nd will spray on the body can with high pattern-width and remaining dome. The thickness of the coating can be adjusted by pattern width which the nozzle gun can apply to ensure uniformity and even distribution of the coating inside the can interior.

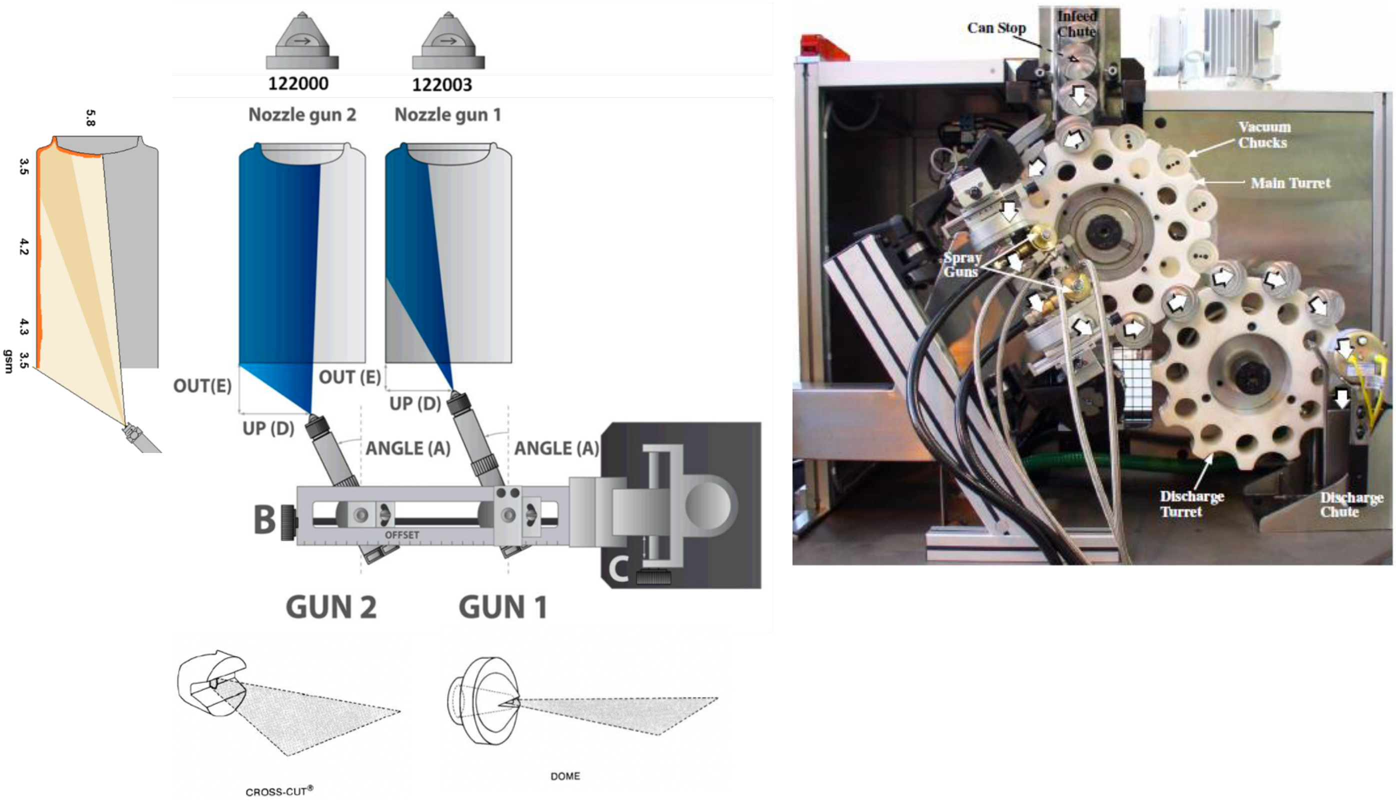
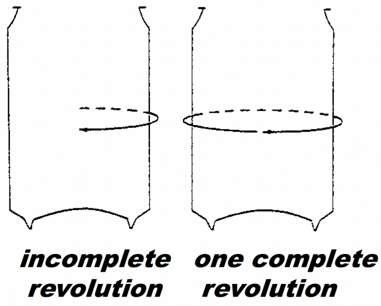


Fig 14. Illustration for operation of internal spray gun

To ensure that the interior can is covered by lacquer, almost all cans will spin by vacuum chucks to get double or triple layers of coating. Firstly, cans will move along the infeed chute to come into the turntable. Next, they will be held by vacuum chucks which spin cans when they come near ISM (internal spray machine). Based on time duration and the revolutions of cans being set up, the spin speed of vacuum chucks can be up to 2500 rpm. Excepting these above parameters, the pressure of the gun (normal up to 600 psi) and liquid flow's lacquer, and also the speed of cans feeding (range of 300-350 CPM) is one of the other important elements. Finally, the coated cans will be moving out of LSM (line spray machine) by these turrets and vacuum chucks before coming into IBO (interior bake oven).

Spin Speed vs Revolutions

Spin Speeds		1 Wrap	2 Wraps	3 Wraps
	1500 rpm	40 ms	80 ms	120 ms
	1750 rpm	34 ms	68 ms	102 ms
	2000 rpm	30 ms	60 ms	90 ms
	2250 rpm	27 ms	54 ms	81 ms
	2500 rpm	24 ms	48 ms	72 ms



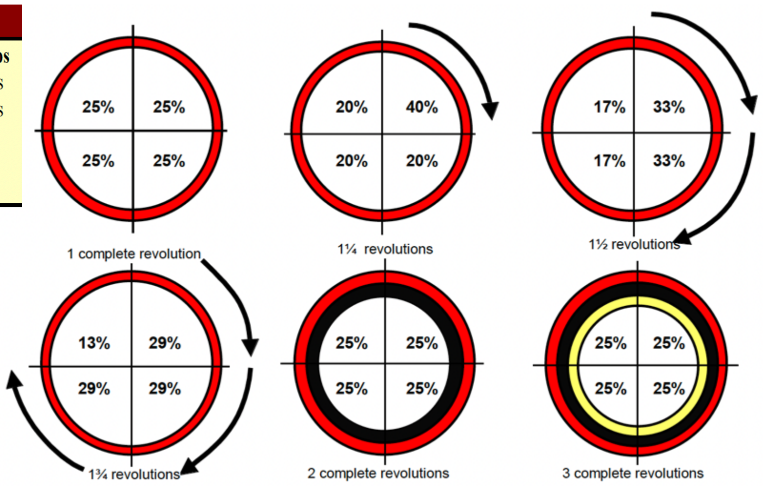


Fig 15. Can revolutions set-up at internal spray machine system.

- **Dry cans by Internal Bake Oven.**

After going through LSM, cans will drive in IBO for drying and curing internal lacquer inside cans. The drying mode depends on the weight of the applied coating, and each type of used coating in the specific products. Almost all internal coating types used for lacquer is water-based epoxy or modified epoxy that must be cured at high temperatures because they are related to these curing agents of the polymer can interact or cause spoil the contained product inside after pasteurization if coating isn't cured adequately. In fact that most all UV coatings were banned from use as internal barriers for the food field by regulations of FDA and relative food safety agencies worldwide.

E.g. Beer/Beverages need to exist in IBO at 188°C for at least 60 secs while retort products/energy drinks need higher temperatures up to 199/193°C for at least 45 secs.

After leaving the IBO, the dried cans must ensure that the residual solvent of the coating isn't contained, and the coating is not discoloured or has unusual spots inside the cans. Cans will then have to go through the neck and flange-making process, so the wet cans will lead to many risks related to losing the coating or depositing a residual on the Necker machine.

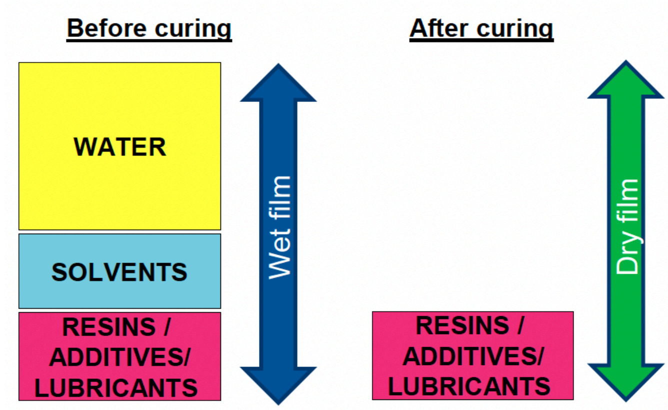


Fig 16. Evaporate mechanism of aqua coating and illustration for IBO with convection fan.

2.1.4 Can Necking stages

The necking process is to narrow the shoulder of cans and create a flange which helps cans and ends connect each other to form double-seal seams. On the other hand, it also creates an aesthetic appearance and balance for cans. The formed neck diameter and flange width will depend on diameter and flange types of ends which will seal at seamer.

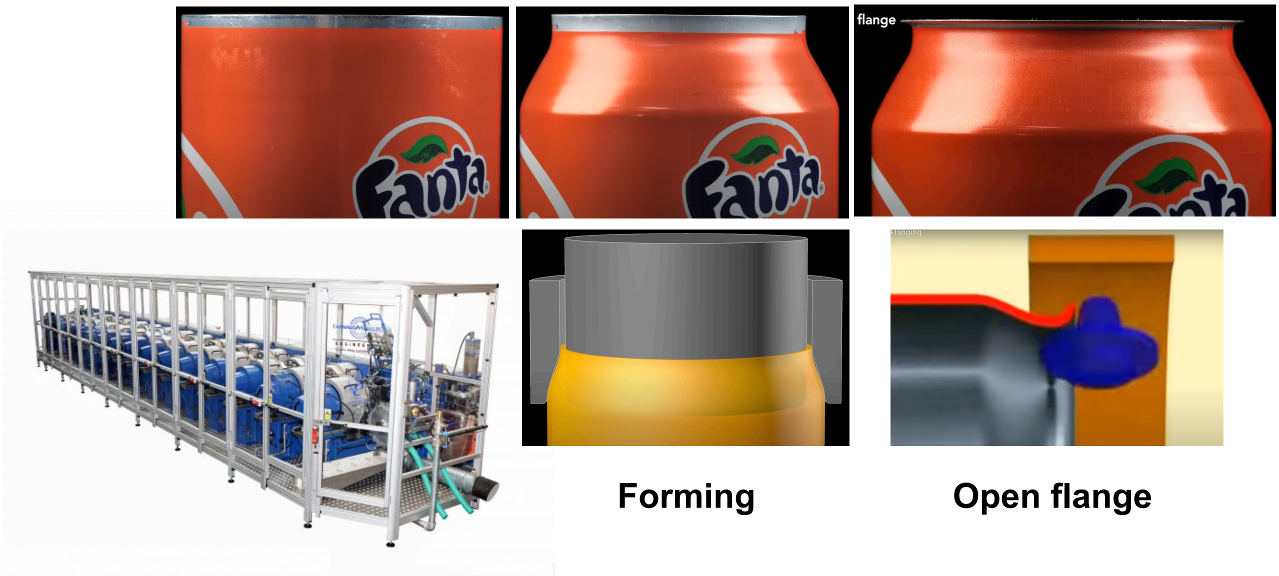


Fig 17. Necker machine & its necking & flanging mechanism.

2.2 - Three-piece welded cans making process

Three-piece welded cans for food, drink, general line decorative and industrial cans, as well as aerosols, are only constructed from steel-based materials as thin gauge aluminum cannot be welded by this process. Most of these are made from tinplate or tin-free steel ECCS (electro chrome coated steel) is difficult to weld with consistency without first removing the metallic coating. Coils of tinplate, after receipt from the steel maker, are cut into sheets approximately one-meter square to suit the dimensional capacity of the downstream equipment for coating and printing.

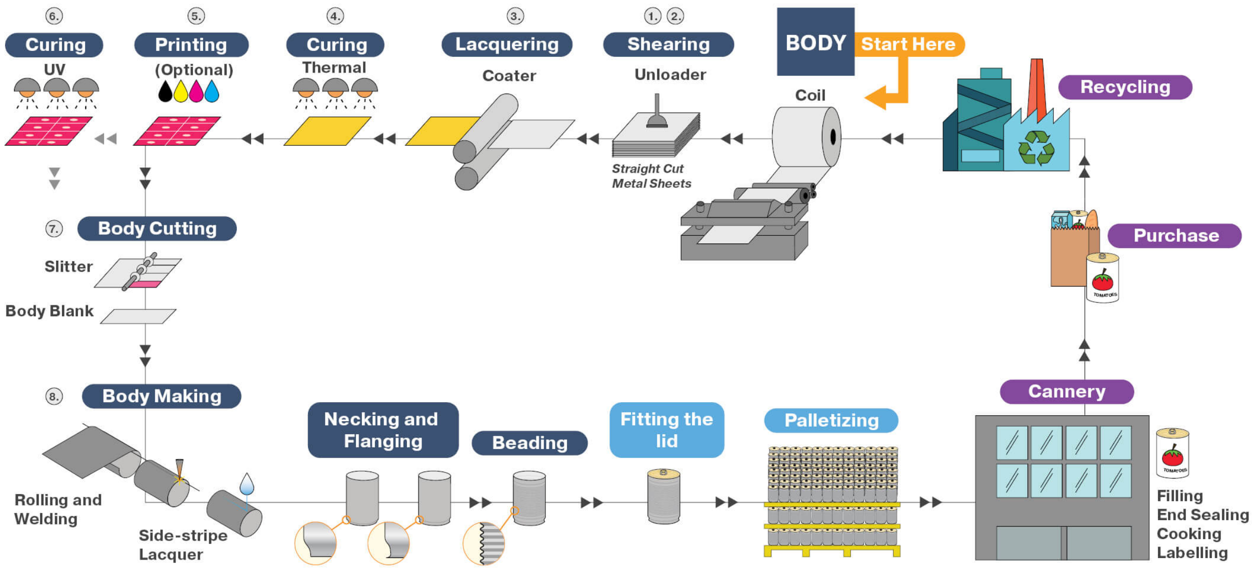


Fig 18. A typical instance for 2-pc cans manufacturing process

After this process, the sheets are cut, by slitting, into rectangular blanks from which individual can bodies are made. Normally, the area in the vicinity of the weld is left without coating or print to ensure that a sound weld is made. In the welding body forming machine, each blank is rolled into a cylinder with two longitudinal edges overlapping by approximately 0.4 mm. Using electric resistance spot welding, where alternating current passing through the metal seam heats the material, the tinplate is softened sufficiently for the two edges to be squeezed together to form a sound joint. Each peak of electric current creates a spot of weld. As the length of the cylinder passes between the electrode rollers, a series of overlapping spots is created to form a continuous weld. If necessary, a side stripe coating is applied over the weld area at this time.

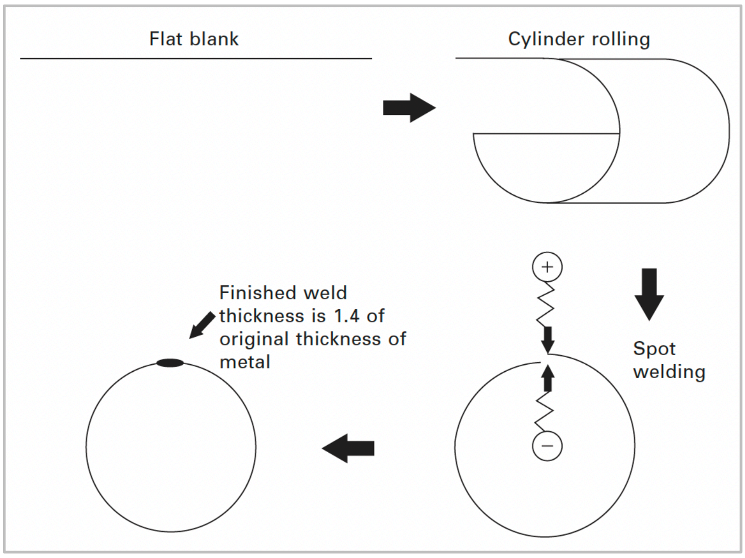


Fig 19. Three-piece can forming and welding mechanism.

All three-piece cans now pass through a flanging process where both ends of the cylinder are flanged outwards to accept the can ends. Drinks and aerosol cans are usually necked in prior to flanging. This process reduces the diameter of both ends of the cylinder, before the flange is formed, which in turn allows ends to be fitted which, after seaming, are smaller in overall diameter than the can body. This in turn reduces the cost of the end and the space taken up by the seamed body. Some three-piece food cans have the bottom only necked in to permit safe stacking of one filled can on top of another.

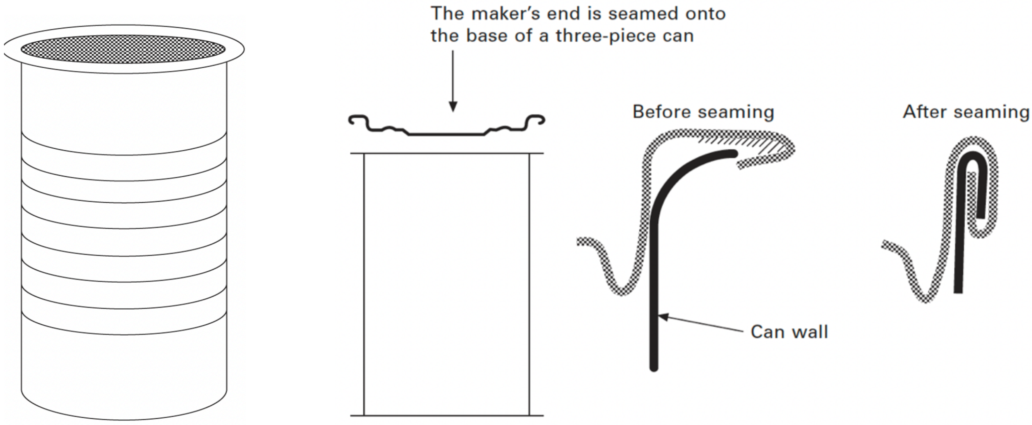


Fig 20. Can wall beading and flange ends fitting process

Where the can height is greater than its diameter, most tall food cans are passed through a beader where the walls of the cans have circumferential beads formed in them to give added strength to resist heat processing conditions after can filling

2.3 - Two-piece impact extruded cans and tubes

The process of impact extrusion is restricted to containers made from aluminium only as it is not possible to form steel cans in this way. Historically, this process has been used for aerosols, rigid cans, and collapsible tubes. In recent years shaped bottles for drinks have been introduced where the forming process has been based on that used for aerosol production.

Fig 21. Some types of two-piece aluminum bottles & collapsible tubes

In this process, a thick disc equal in diameter to the outside of the finished container is punched out from aluminium plate. The disc thickness is such that its mass/volume is equal to that of the untrimmed can body. The disc is placed in the bottom of a die and a reciprocating punch having maximum diameter equal to the inside diameter of the container is driven into the disc at high speed. The cold metal is forced out of the die block and flows up the side of the punch until the end of the stroke. The same process is used for forming collapsible tubes. However, in this case the base of the die is modified to allow formation of the tube nozzle with or without a sealing membrane and the starting disc shape is also modified as shown in **Fig. 22 (*right*).**

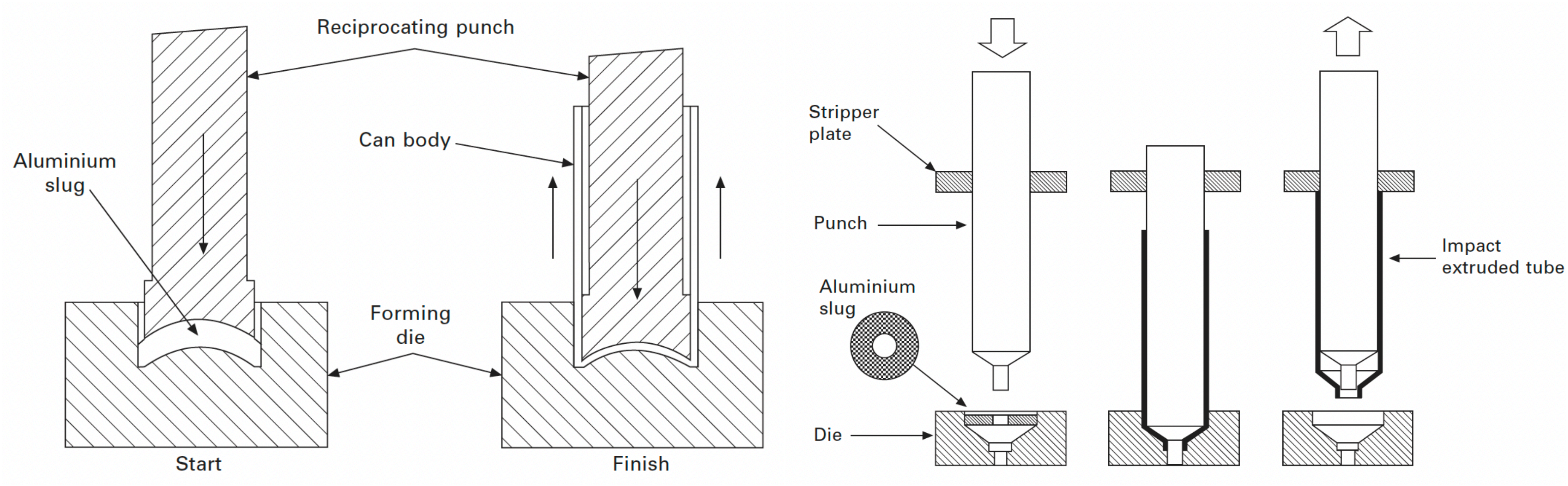


Fig 22. Impact extrusion process of aluminum bottles(left) and collapsible tubes (right).

As the forming process work hardens the tube wall, it is necessary to soften this by application of heat (annealing), after forming, so that the finished tube is capable of being squeezed and rolled up during use. Further manufacturing steps, including coating and printing, are similar to those used for DWI drinks cans. The only exception to this is that necking and flanging are replaced by a multi-step forming process, which can be up to approximately 15 steps to shape the top of the container from full body diameter to that required to accommodate the ultimate can closure device. This could be a flange on which to crimp an aerosol valve mechanism, a rolled edge to accept a crown end, or a screw neck to accept a ROPP™ (roll-on pilfer proof) cap.

2.4 - Ends making process.

Can ends for mechanical double seaming are constructed from aluminium, tinplate or tin-free steel (TFS). Aluminium and TFS are always coated on both sides with organic lacquer or film laminate whilst the metal is still in coil or flat sheet form. For tinplate these coatings are optional, upon the product being packed in the container and the specified external environmental conditions. The base of a three-piece can will always be a plain end (non-easy-open). For food cans, the top may be either plain (requiring an opening tool), full aperture easy-open or peelable membrane design.

Historically, tapered rectangular solid meat cans have employed a key opening device to separate the two scored body sections; these are now gradually being replaced by containers having rectangular panel full aperture easy-open ends.

Fig. 23. Some bottom plain & top can-ends for food cans.

For drink cans, the top is usually referred to as a stay-on-tab (SOT), enabling the opening tab and pierce-open end section to be retained on the can. The SOT end has largely superseded the traditional ring-pull end (RPT).

Fig. 24. Two popular types of ends used for drink cans with these different diameters.

All ends for processed food cans have a number of circular beads in the centre panel area to provide flexibility. These allow the panel to move outwards, as internal pressure is generated in the can during the heating cycle of the process and so reduce the ultimate pressure achieved in the can. During the cooling process, this flexibility permits the centre panel to return to its original position. Whilst can ends for beer and carbonated drink cans do not require the above feature as the can's internal pressure is always positive. The plate thickness and temper have to be appropriate to level of carbonation of the product and, if applicable, pasteurisation treatment; otherwise excessive internal pressure may cause can ends to peak or distort.

2.4.1 Plain food can ends and shells for food/drink easy-open ends

The initial processes for making bottom plain can ends and easy-open ends for food and drink cans are the same. The body of an end that will ultimately be converted into an easy-open end is referred to as a shell. Plain ends/shells may be stamped directly from wide metal coils or sheets/strips cut from coils. When using coil or sheet, the metal is fed through a press that produces multiple stampings for every stroke. After removal from the forming tool, the edges of the end shells are then curled over slightly to aid in the final operation of mechanical seaming the end onto the flange of the filled can. After curling, the end shells are passed through a lining machine that applies a bead of liquid-lining compound, which can be PVC or Polyester, around the inside of the curl. The compound lining is a resilient material that, during mechanical forming, will flow into the crevices of the double seam and thereby provide an airtight seal. This process is described in Fig. 17.

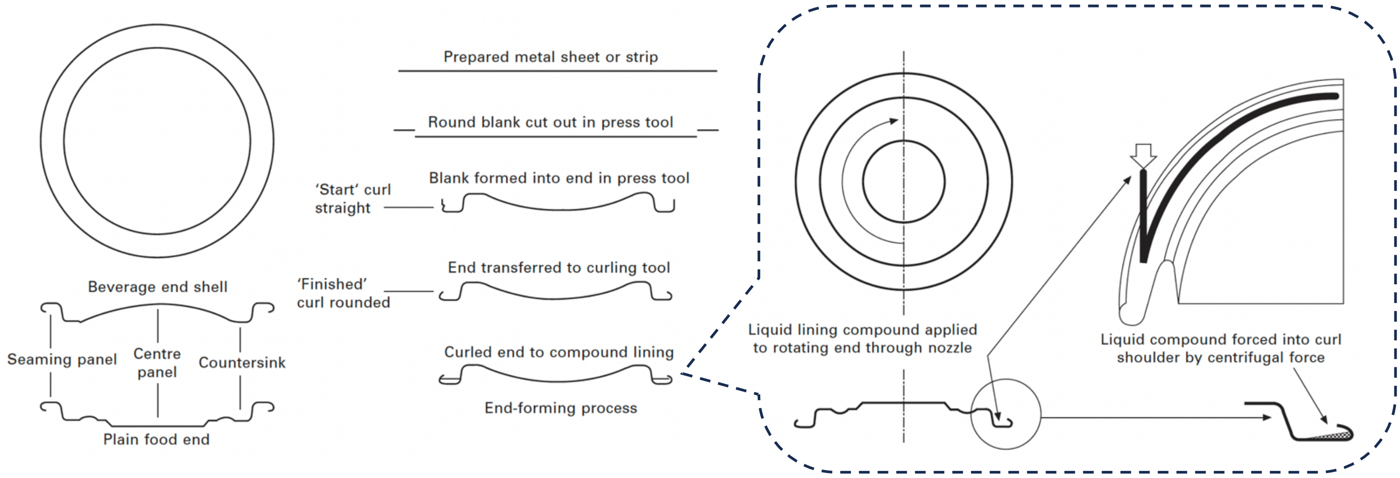


Fig. 25. Plain food and beverage end shell formining along with lining compound application.

2.4.2 Conversion of end shells into easy-open ends

The principles used in the conversion of end shells are the same for both full aperture food easy-open ends and small aperture drink easy-open ends. The conversion operations comprise scoring (partially cutting through) the perimeter of the opening panel and attaching a metal tab with which to tear open the panel. Scoring is necessary to reduce the force required to open the end to an acceptable level and to determine where the break will occur. These operations are described in **Fig. 26.**

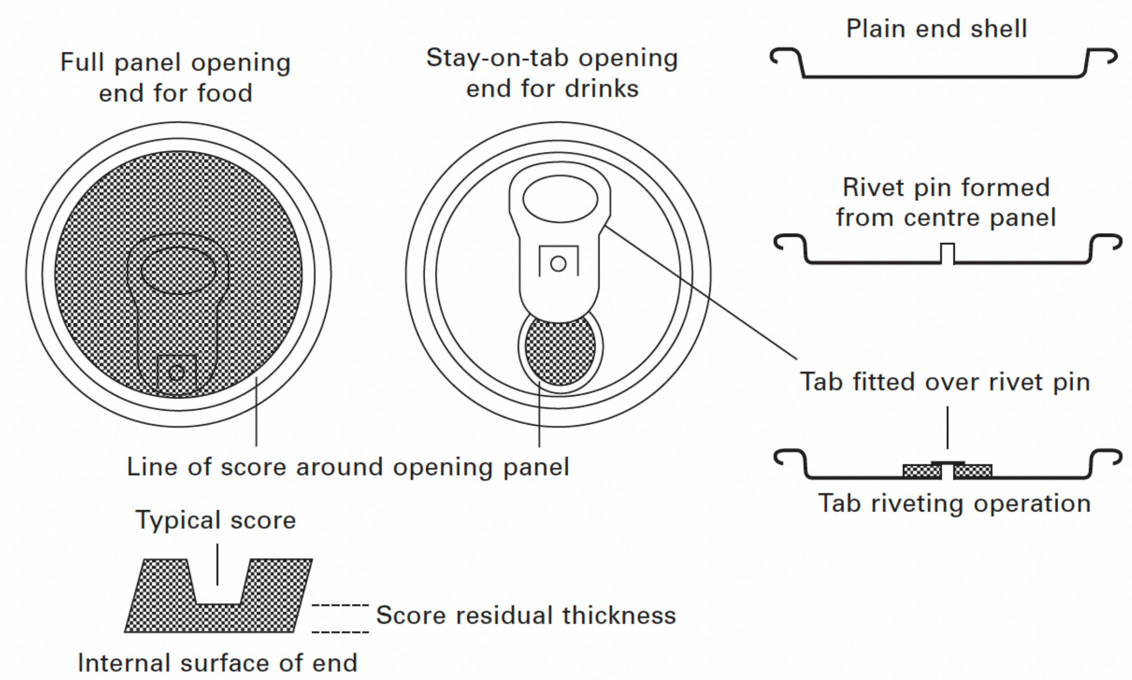


Fig. 26. Conversion of plain end/shell into easy-open end

The pull-tab is made from a narrow strip of pre-coated aluminium or steel, which is in coil form. The strip is first pierced and cut, and then the tab is formed in two further stages shown in **Fig.18.** At this point, the tab is still attached to the strip by bridges to facilitate feeding over the rivet formed in the shell. The shells pass through a series of dies that score them and form a hollow upstanding rivet in the centre panel of the shell. The tab is then placed over the upstanding rivet on the shell, and the rivet is deformed to make a joint between the two components. The finished ends, ready for capping the filled cans, are packed into paper sleeves and palletised for shipment to the can filler.

2.4.3 Peelable membrane ends for food cans

A peelable membrane end is essentially a plain aluminium or steel food can end with part of the centre panel removed as a disc and replaced by a pre-cut aluminium or polymer membrane which is heat-sealed to the remaining part of the centre panel. This can easily be seen in some cans containing dry products such as powdered milk or snacks, and nuts... A recent design of this type of end is capable of withstanding full heat processing conditions without the need for overpressure in the retort to prevent rupture of the membrane due to high internal pressure.

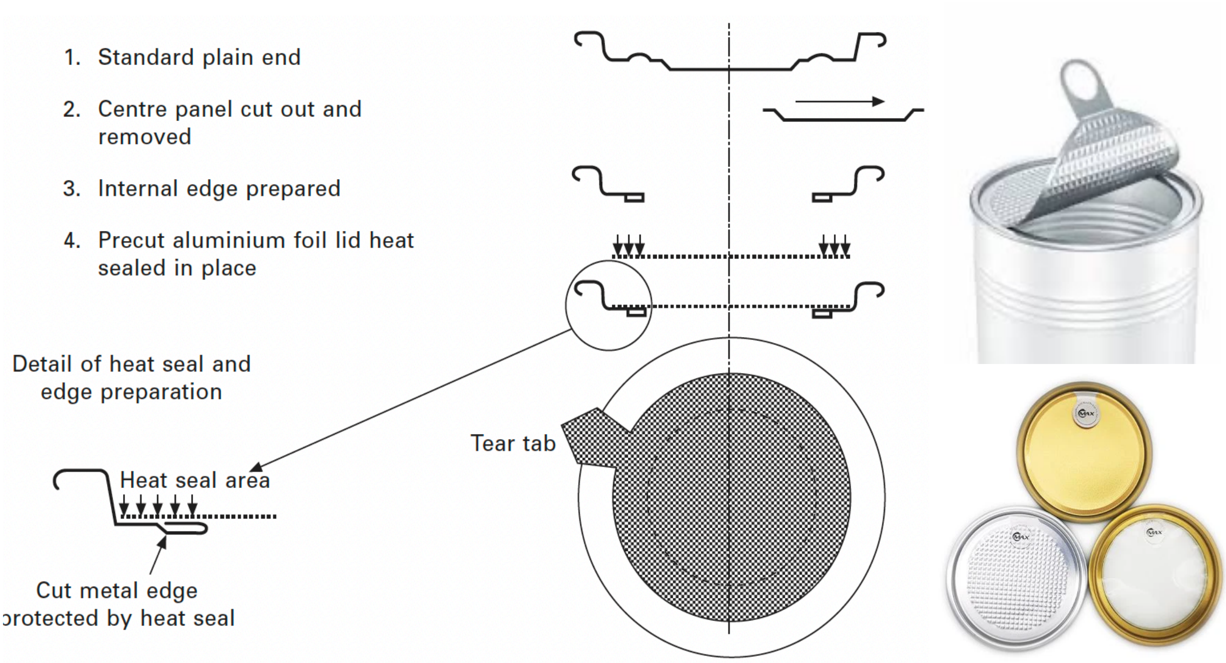


Fig. 27. Forming of peelable membrane end.

2.5 - Mechanical seaming of ends onto can bodies

After the filler, cans enter the seamer where a lid is placed and the can is sealed. A good seam must be achieved consistently to preserve the quality of your products. Seaming a can requires two operations.

- Firstly, The inside diameter of the end curl is just sufficient for it to drop cleanly over the flange of the can, the operation roll bends the lid over and under the lip of the can. If the end were not curled the two components would not lock together as the seam was made.
- Secondly, the operation roll pounds the metal into place. The end is mounted on a round (or non-round) chuck which fits the external surface of the countersink wall and supports this wall during the seaming process.

When considering a canning machine, look for an all-mechanical seamer rather than a seamer powered by pneumatics and seaming tools suited to can ends. This ensures that critical seaming operations are the same every time leading to more consistent seals and lower air consumption.

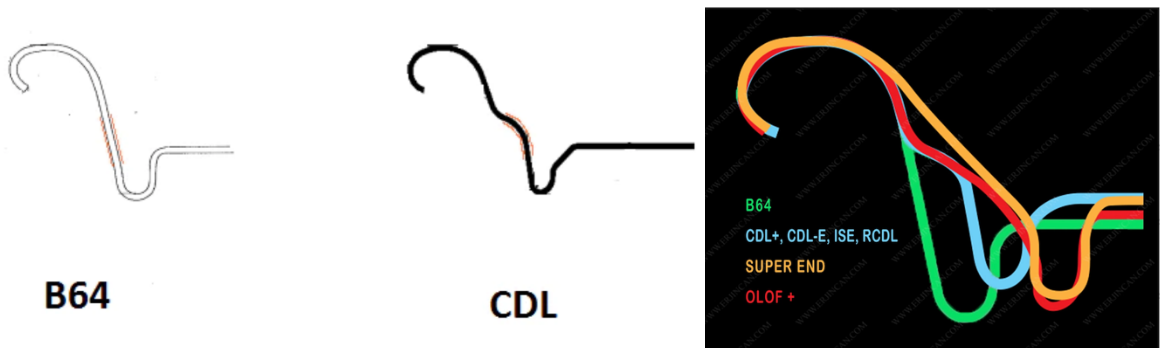


Fig. 28. Countersink wall types used popular for 2pcs & 3pcs cans

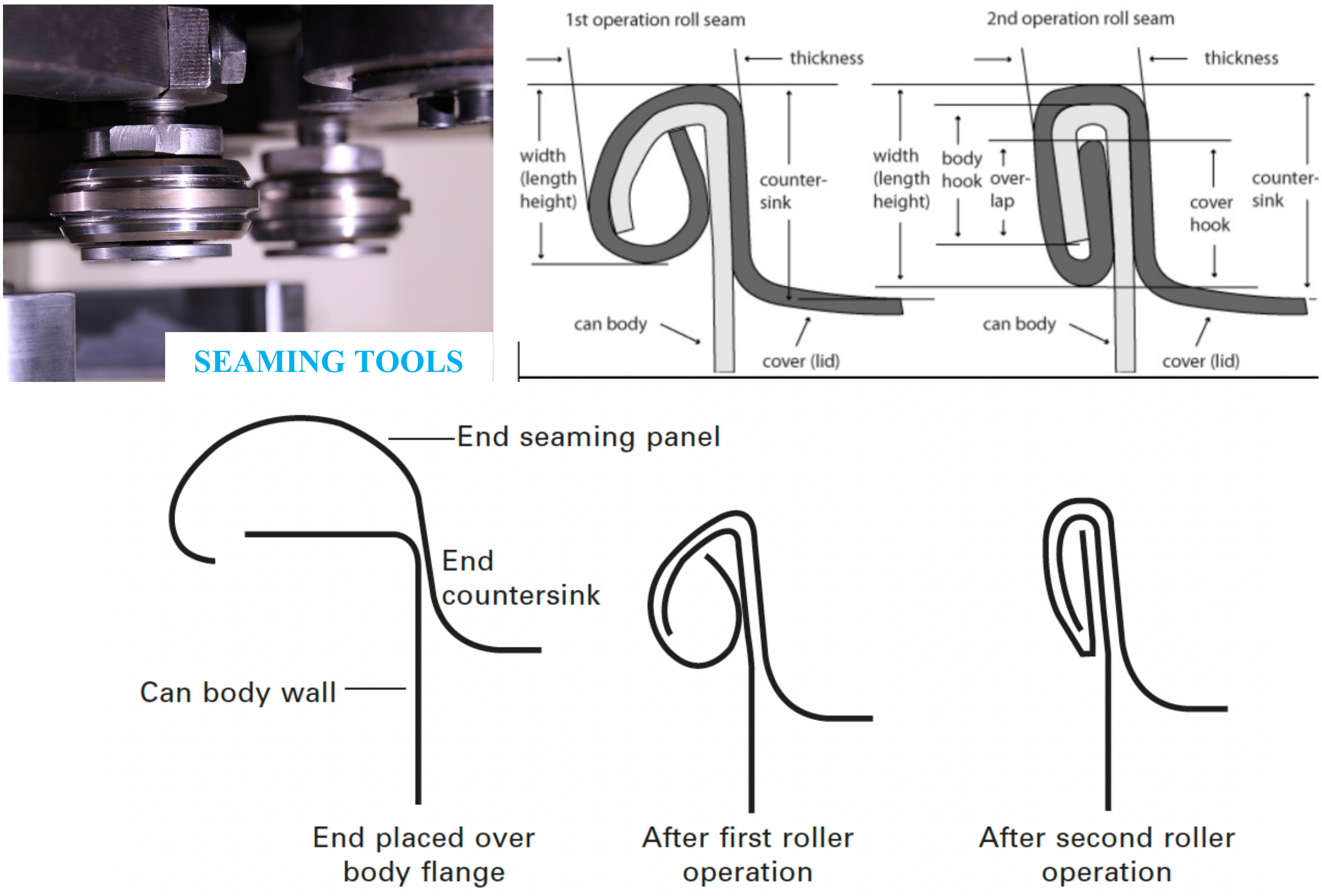


Fig. 29. Mechanical seaming operations

The speed of the seamer is also an important feature. The seamer must outpace the filler to minimize the amount of time the beverage is absorbing DO (Dissolved Oxygen) while exposed to the atmosphere. Finally, establishing a routine for checking the seams on cans every 45 minutes will help to catch any bad seams before distributing to the masses.

To evaluate the seam, some of the dimensions can be taken from the outside of the finished seam while others can only be measured from a cross-section view. This view may be obtained either by cutting through the seam or by using X-ray technology. Some parameters cannot be measured directly from the seam cross section but require simple mathematical calculations to deduce the result.

2.6 - Basics of heat processing of food (retorting)

It is necessary to kill all living organisms within the can after filling and seaming on the closure if the canned food products need to be for long-term storage at ambient conditions. This is achieved by sterilisation using heat by sufficient heat within the required minimum amount of time satisfied. The advantage of liquid products is convection currents within the can allow more rapid temperature increase time than compared to solid products where heating the centre core of the product may only be achieved by conduction. The operating principle of the heating method used is similar to that of the domestic pressure cooker with steam at a higher pressure than the atmosphere one. A pressure relief valve fitted to the lid controls the internal pressure and prevents it from rising above this level. In these systems, achieved temperatures will usually be in the range of 113–132°C with processing times ranging from five minutes to periods above one hour, depending on the type of product being sterilised and the can dimensions.

When cans were designed, they needed to be calculated internal pressure can increase quickly through sterilisation or pasteurisation due to thermal expansion and expanding headspace gases of liquid inside cans. The effect of this is imploding the can's body because of the imbalance of internal pressure inside the can. In some cases, some food products need to be sterilised for a longer time cans are usually added circumferential beads providing the body cans with sufficient hoop force to resist internal strength and supplement expanding space.

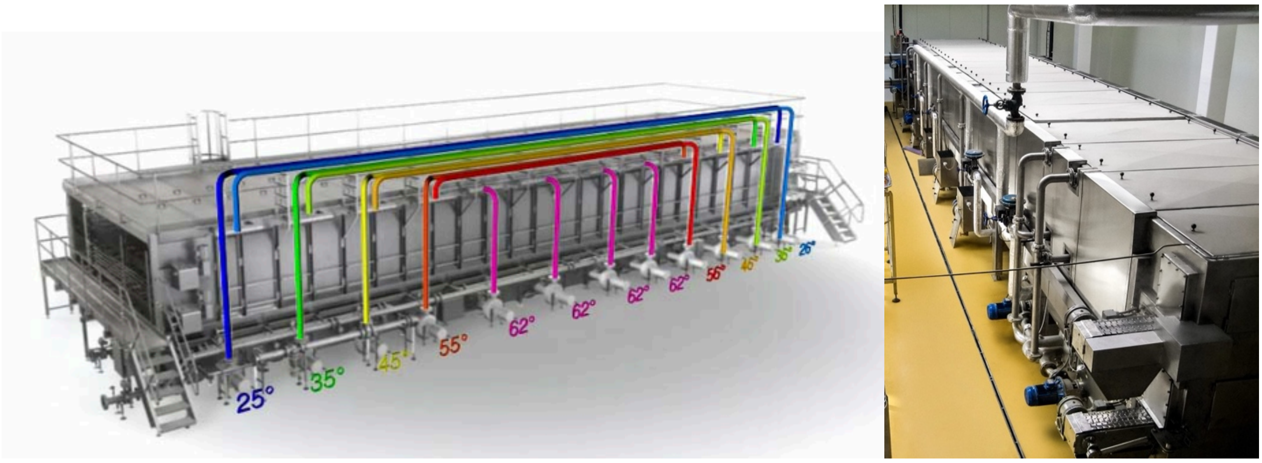


Fig. 30. The pasteurization system used popular for drinks cans.

iii. Quality control of semi-finished and finished components

3.1 Quality Assurance.

Quality assurance checks on semi-finished and finished components are carried out both in-line as part of the manufacturing process, and off-line in a laboratory. Some in-line processes such as pressure or light testing for cracks and pinholes, video inspections of can internal surfaces or external decoration and are carried out on every component produced.

Most other checks use predetermined sampling plans where components are removed from the line either automatically or by hand. Statistical analysis is then used to determine the performance of the various processes. This method of control is required because the line production rates are so high, being in the range of 50–2500 items per minute. E.g. for imensional checks, automatic measuring stations are often used. The equipment produces the results of each sample in a statistical format and delivers the results to the central laboratory.

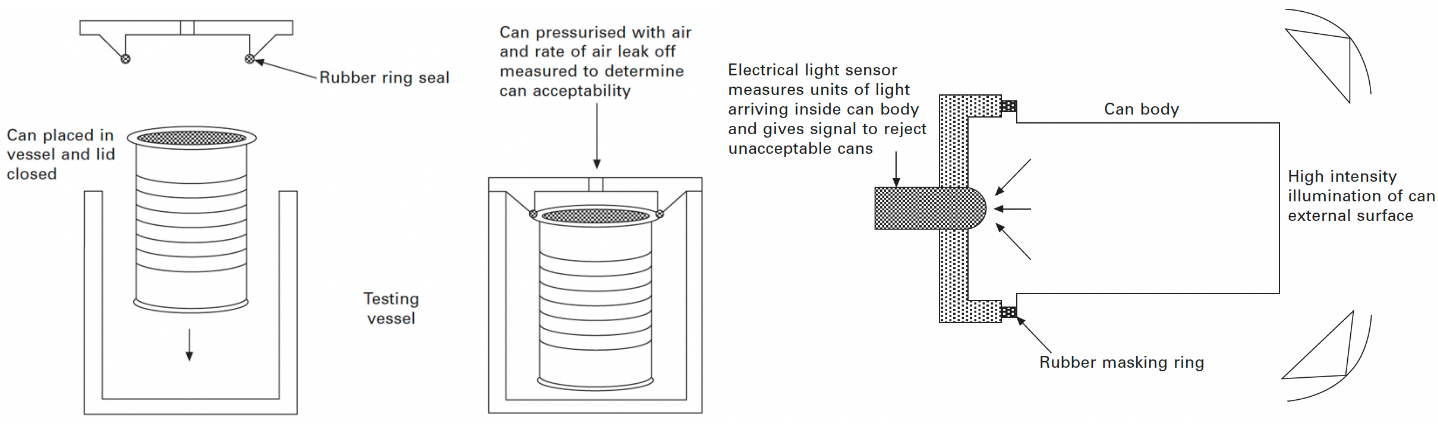


Fig. 1. The testing principles of Three-piece can air (right) and Two-piece can light testing (left)

Whereas off-line tests usually carried out in following instances

- **Dimensions** – height, diameter, wall thickness range, flange width, flange outside diameter, Neck height, etc.
- **Strength** – axial compression, resistance to implosion (food cans), base dome buckle (drinks cans), Brimful capacity .
- **Coating integrity** – Dry film weight, distribution (freedom from pinholes), adhesion
- **Ends** (in addition to above tests), deflection due to internal pressure changes, lining compound placement and weight
- **Easy-open ends**, additional tests to determine ‘pop’ and ‘pull’ loads to open and tear the tab, rivet strength and integrity.

Attribute sampling for off-line testing is normally carried out on randomly selected pallets of finished cans or ends before these are conveyed to the warehouse for onward shipment to the customer. Traceability of raw materials through to the finished components is assured by the recording of the coil numbers, sheet pallet numbers where these are used, and the time over which these are fed into the production line. Likewise, container, dome number or batch numbers of coating materials are recorded in the same way. For customer, barcodes are generally applied to the labels on pallets of finished goods to give both fixed information such as customer name, container specification, number of items, etc., and real-time information such as pallet serial number, date, time pallet packed, etc. For drink cans externally printed in-line, a code is embodied into the label design, at the overlap area which indicates the maker's name, factory, date, and shift of manufacture or other encoded way such as end-user name, year, line production time and shift of manufacture.

❖ **Online quality assurance**

Parameter	Value
Variable non-conformities (including dimensions)	Standard Cpk requirement is > 1.33,
Attributive non-conformities	Based on AQL value agreement
Metal exposure inside (enamel rating)	For steel cans: - Beer: average < 2 mA and individual < 10 mA - Others: average < 0.5 mA and individual < 2mA For aluminum cans: - Beer: average < 10 mA and tolerance < 40 mA with Cpk > 1.67 - Others: average < 2 mA and tolerance < 15 mA with Cpk > 1.67 - Hard to hold: average < 0.5 and tolerance < 10 mA with Cpk > 1.67
Metal pick-up	Iron: ≤ 0.2 mg/l/6 month Aluminum: ≤ 1 mg/l/6 month
Color deviation decoration	Normally refer to the approved "light & dark" samples
Outside coating and ink adhesion by cross-cut test	Class 1: detachment of small flakes of the coating at the intersections of the cuts i.e. a cross-cut area not significantly greater than 5 % is affected
Placement accuracy	For embossed and shaped cans horizontal and vertical positioning of the register vs. profile < 1 mm
Profile depth for embossed cans	0.23 ± 0.07 mm at the deepest points
Compound placement *(ends only)*	Aluminium cans: standard/panel placement or high-on-shoulder (HOS) Steel cans: high-on-shoulder (HOS).
Opening force *(ends only)*	Pop force ≤ 27 N Push force ≤ 36 N When opening the can-end of finished product it should tear properly along the score, the score panel should remain attached to the can-end and the tab should not break of.

❖ **Off-line quality assurance**

Parameter	Value
Dimensions	According to Technical Standard for the relevant can
Buckle resistance: dome reversal pressure	- Standard can & ends; printed/cured can-end: **≥ 620 kPa** - Widget can: **≥ 690 kPa** (only required in case the buckle resistance of a standard can is insufficient such as the addition of liquefied nitrogen) - Can-ends for widget cans with addition of liquid nitrogen: **≥ 650 kPa**.
Dome impact resistance	No dome reversal should occur
Can growth	< 1.5 mm at 6 bars
Axial load	Straight wall cans: individual can: ≥ 675 N
Free board / Head space	minimum 3.5%, maximum 5%
Flange ovality at point of delivery	≤ 2 mm
Mobility sidewall	Sidewall dynamic friction coefficient: ≤ 0.12 μd Bottom dynamic friction coefficient: ≤ 0.12 μd
External bottom/rim coverage: placement of varnish	For steel cans: full bottom coverage For aluminum cans: full rim coverage The coverage should be done in such a way that: 1. No blisters are observed 2. No metal exposure should be evident on the covered area 3. UV based rim coats are preferred
Dome design	Dome design should be such that full stackability of filled cans with both CDL and ISE is assured.
Tab-over-chime (*ends only)*	Not allowed for filled cans at pasteuriser exit.

3.2 Quality control and identifying some normal defect

The most common defects that may be found in metal packaging components are:

- All can bodies – low tin coating weight, badly formed flanges, leaking can, big dent or deform, ppside-down,…
- Coated surfaces – pinholes, poor adhesion, undercuring, underfilm staining, cracks coating after necking in drink cans and after curling can ends, rim coat not present, rough or insufficient, causing considerable line efficiency losses
- Decoration – Miss printing or colour, decoration shifted, printing damaged (dirt, glue, stains),…
- Three-piece can bodies – poor weld strength, badly formed/incomplete weld
- Two-piece draw and wall ironed can bodies – pinholes in body or flange area
- Can ends (plain) – lining compound incorrect weight or missing, and bad placement
- Can ends (easy-open) – broken/leaking rivets, residual score out of specification, pop and pull loads out of specification.

Part 3: Metal closures

Metal closures for fitting to glass and plastic containers are highly specialised products. Depending on the different strength requirements, the closures for drinks containers are made from aluminium, whilst those for processed food are made from steel. It will be seen that the threads on closures can be formed during the initial metal-forming process, or as an off-line molding process, or during the filling/closing process or even during the (food) heat processing operation. In all cases, the dimensions (finish) of the neck of the glass/plastic container need to be specified very accurately and, for this reason, the specifications are usually set by the closure manufacturer and not the container maker.

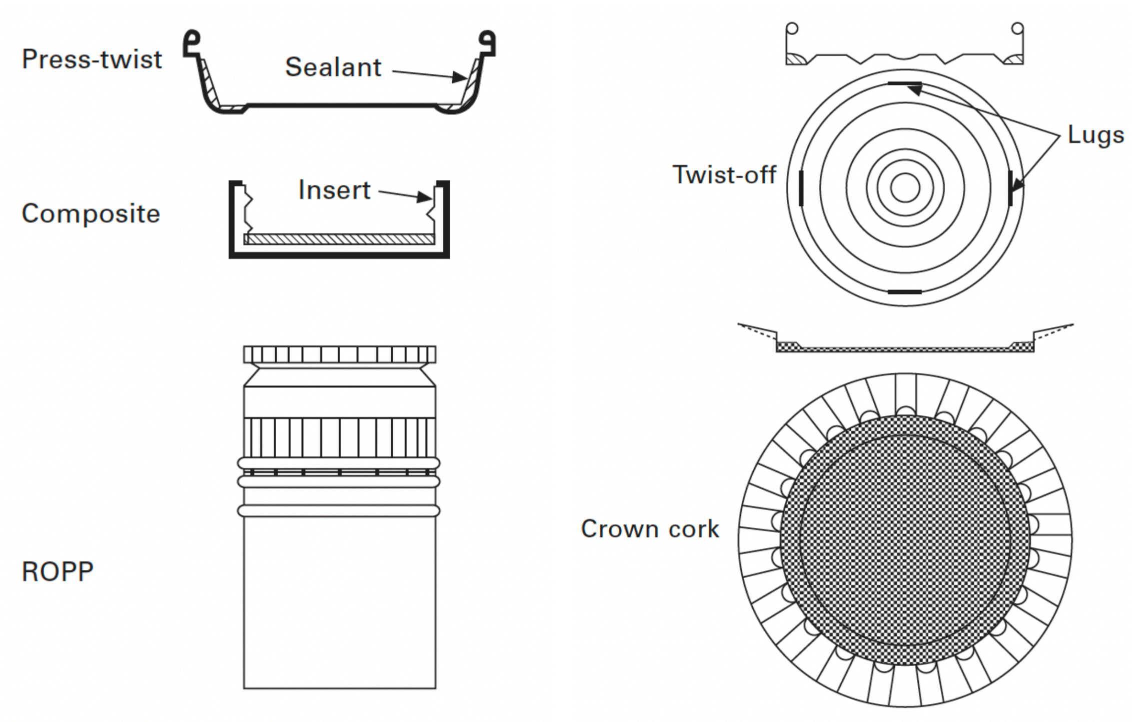


Fig. 1. Outlines of metal closures.

1.1 Roll-on pilfer proof (ROPP™) caps

Roll-on metal closures are made only from aluminium, because it is necessary to have a soft material for the thread rolling process. This type of closure is initially produced as a printed and internally coated deep-drawn two-piece can. After the addition of special mechanical features, and a wad or flowed-in liner to provide the seal to the surface of the bottle, the closure is complete and ready for shipment to the filler. When the bottle has been filled, the closure is slipped over the neck of the bottle, and the threads are rolled into the closure to conform to the profile of the neck of the bottle.

The manufacturing process for the roll-on closure is the same as that for a draw/redraw cans made from printed and coated sheet aluminium. If the end of the closure is to be printed, this is done whilst the metal is still flat. The closure liner is either a wad cut and inserted into the metal shell, or a flowed-in polymer applied to the inside top surface of the shell. Where the latter is used, the flowed-in material can be applied over the whole of the inside top surface or just to the circumference.

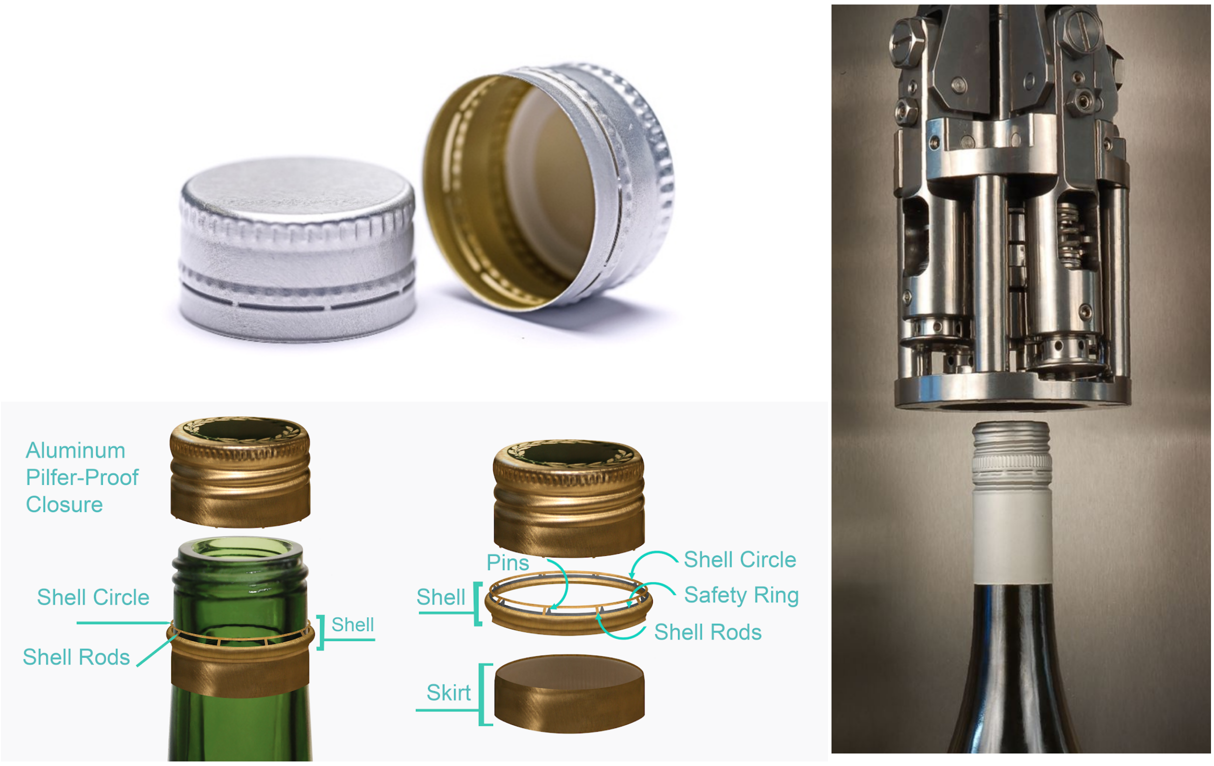


Fig. 2. ROPP Cap and its capping machine along with the opening mechanism.

1.2 Composite closure

A composite closure comprises the aluminium body of a roll-on closure with a plastic moulded insert which is pressed in to give a tight fit between the two components. The low-density polyethene plastic insert has internal threads moulded into the side walls and is designed to accept a standard wad liner. This type of closure can be made with or without a tamper-evident feature. A composite closure provides two additional features to the standard ROPP™ closure.

- The thread of the closure is internal and provided by the insert so that the external side wall of the closure has no threads in evidence after it has been sealed onto the bottle. This closure is used to improve the external appearance of the filled package.
- As the internal thread of the closure is made from moulded plastic, it is more suitable for use with products which have a high sugar content, such as liqueurs.

When an all-aluminium closure is used with these products, there is a tendency for the sugar, which remains on the thread after the bottle has been used for the first time, to form a sticky deposit between the aluminium and glass threads. This makes the bottle difficult to re-open. When one of the thread components is made of plastic, this problem does not occur.

1.3 Twist-off closures

Twist-off lug closures require less than one turn to apply and remove. For this reason, they are often referred to as 'White' caps. The product inside the glass jar is packed under vacuum, by packing the product hot and flushing the headspace with steam; the vacuum increases as the product cools to ambient temperature. The seal between the closure and the top face of the glass jar is produced by a combination of the internal vacuum and the mechanical force produced when the cap is tightened in the capping machine. Many twist-off closures are now fitted with 'vacuum buttons' which indicate to the consumer, before opening, whether there is still a vacuum inside the headspace. The internal vacuum produced during the packing operation is sufficient to pull down the vacuum button. For the light metal packaging industry, the combination of a twist-off closure fitted to a glass jar is unique, it being the only time that a fully preformed metal component is fitted to a fully preformed container made from a non-metal product.

Fig.3. TW and CT caps along with thier closing mechanism.

1.4 Press-twist (PT) closures or screw

The PT closure developed for heat-processed baby food in glass jars necessitated t a high-speed closing system for the filled package, which needs only to be pushed over the threads in the neck of the glass jar to make the initial closure. The heat of the processing system does the rest, by softening the sealant and allowing it to flow into the threads in the neck of the glass jar. A vacuum button is created during the metal-forming operations to indicate to the consumer, prior to opening, whether there is still a vacuum inside the headspace. In some cases, a plastic molded tamper-evident ring is often incorporated into the closure. This is held in place by a curl on the wall of the closure.

1.5 Crown cork closures

Crown corks are used for sealing glass bottles containing carbonated or non-carbonated drinks. The cap is pre-formed during the manufacturing process and clinched onto the top of the bottle manually or automatically after the bottle has been filled. A tool is required to remove the closure from the bottle, which may be hand-held or wall-mounted. This closure is manufactured from tin-free steel with suitable coatings on both the inside and outside. The process is identical to that used for plain can-ends until the press-forming operation. At this point, the blank is cut from the sheet in the same press station where the cap is formed. After forming, a liner is introduced into the top of the cap to make the seal across the top of the neck of the bottle.

Fig.4. Some type of crown cork and its normal design