TALAT Lecture 3710

Case Study on Can Making

31 pages, 23 figures

Advanced Level 1

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Objectives:

1. To give a background of the design and manufacturing processes of food and beverage cans, which are produced by drawing and drawing & ironing of rolled aluminium alloys.
2. To draw attention to the challenge for materials and production engineers to fulfill contradicting demands and requirements for the production of cans and easy-open lids in a very competitive market.
3. To demonstrate that optimization of all parameters, i.e. design, manufacturing and materials, has resulted in sheet metal forming processes of extremely high productivity and reliability.

Prerequisites:

A good general knowledge of engineering practice and a familiarity with sheet metal forming and properties of aluminium alloys

Target Group:

Materials and production engineers in sheet metal industries, research departments and universities

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3710 Case Study on Can Making

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3710.01 Introduction: 2-Piece vs. 3-Piece Food and Beverage Cans

Although this case study deals specifically with food and carbonated drink beverage cans, the techniques described are equally applicable to other sheet metal components of similar proportions. **Figure 3710.01.01** shows different methods of making cans.

| | Methods of Making Cans from Sheet | 3710.01.01 |
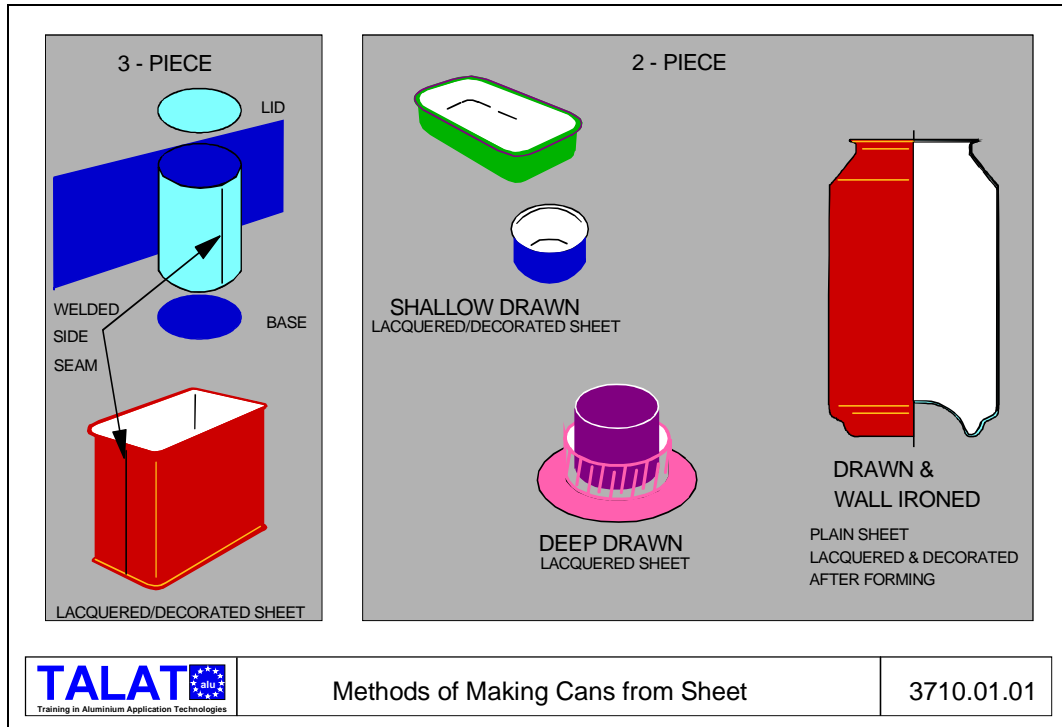
In 3-piece cans the body is rolled or folded from pre-cut lacquered (and sometimes decorated) blanks with the seam-edges left clear. The longitudinal seam is welded, and the ends of the cylinder flanged to take a separate base and lid (i.e. 3 pieces). As the seam edges have been left clear a lacquer stripe has to be applied over the weld zone to complete internal protection and, of course, there is a gap in the external decoration adjacent to the seam.

The 3-piece technique is used with steel (tin-plate or TFS-tin free steel) for fruit, vegetable and meat cans, and some beer and soft-drink beverage cans although these are now being replaced by 2-piece steel cans. A few aluminium 3-piece cans were made with an adhesive bonded side seam, and also a welded side seam (a continuous tube subsequently cut into individual can lengths) but these techniques were abandoned as the 2-piece cans were developed.

Today all aluminium cans are of the 2-piece version with integral wall and base, which avoids the necessity for an internal lacquer repair stripe, permits all-round decoration, and has an inherent higher integrity than the welded-seam can. The separate lid is attached by double-seaming immediately after the can has been filled.

Aluminium cans are produced by two different methods. Food cans, which after filling and processing have negligible internal pressure, have base and wall of approximately the same thickness. These cans are produced by blanking and drawing from

prelacquered (and sometimes predecorated) sheet. The press produces a finished can body. Equipment is relatively simple with a degree of versatility. On the other hand, beverage cans have to retain pressurised beers and soft drinks; they have a thick, inwardly domed base, but can have very thin walls as adequate rigidity is provided by the high pressure within the can. Beverage cans are produced by drawing a cup from plain aluminium sheet and thinning, or ironing, the walls to about one third of the base thickness. The shell is then chemically cleaned prior to internal lacquering, external decorating, and subsequently some mechanical finishing operations such as flanging (see later). The tooling demands a high standard of precision and the equipment is dedicated to one size of can but this is justified by the market demand for billions of aluminium beverage cans annually.

It will be seen that, relative to the 3-piece can, the prime requirement of material for both types of 2-piece can is formability which in the case of the food can applies not only to the metal but also to the lacquer coatings and to the adhesion of the lacquer to the metal. Aluminium is ideally suited to fulfil both formability and lacquer adhesion requirements. This applies not only to the can body, but also to the lid. Scored aluminium tears more easily than scored steel, so aluminium is the preferred choice for easy-open lids for both food and beverage cans. With aggressive products an aluminium body combined with an aluminium lid avoids any possible bimetallic effect which would accelerate corrosion and cause premature failure of the can.

Furthermore, an all-aluminium can facilitates collection and segregation for recycling. Ingot produced from scrap aluminium requires only 5% of the energy required to produce primary metal from bauxite, and the quality is such that used cans can be recycled to produce new cans or at least new products of similar value. Typically, aluminium from used beverage cans is turned into can body stock and is back on the supermarket shelves in around 8 weeks. In most countries there is now a financial incentive for the consumer to collect and return used aluminium cans before they enter the waste stream of household waste and litter, and so effect a closed loop which is both ecologically and economically sound.

Aluminium food cans drawn from prelacquered strip, drawn and wall-ironed beverage cans, and easy-open lids, are described in more detail in the following sub-sections.

3710.02 Food Cans

- Shallow-drawn cans
- Deep-drawn cans
- Food can stock
- Sheet decoration
- Food and can handling and processing

Shallow-Drawn Cans

The familiar rectangular and oval fish cans, and shallow-drawn round cans for various food products **(Figure 3710.02.01)** are produced in a single draw from prelacquered strip or sheet (sometimes predecorated).

Source: Alcan Deutschland

TALAT	Varieties of Aluminium Food Cans	3710.02.01

The lacquered strip or sheet is lightly lubricated (e.g. food grade petrolatum 50 mg/m^2) before feeding into the press where the blank is cut and held between blankholder pads to prevent wrinkling as the central punch draws the material over the drawing die radius to form the can to the required shape and depth **(Figure 3710.02.02)**. The cup does not pass completely through the die but is left with a narrow flange which is trimmed for the subsequent seaming of the lid.

The outer area of the blank has to be reduced from the cut circle diameter to the can body diameter. The metal thickness changes only slightly so this circumferential reduction is accompanied by a radial extension which appears as a longitudinal increase towards the top of the can wall - as illustrated by the progression of the equi-spaced lines on the blank (see **Figure 3710.02.02)**. Obviously this distortion applies also to the

lacquer coating, demanding flexibility and a high integrity bond to the metal surface; it also applies to any external printing or decoration which has to be predistorted so that it will finish in true proportion on the can wall (**Figure 3710.02.03**).

| | Drawing Operation | 3710.02.02 |
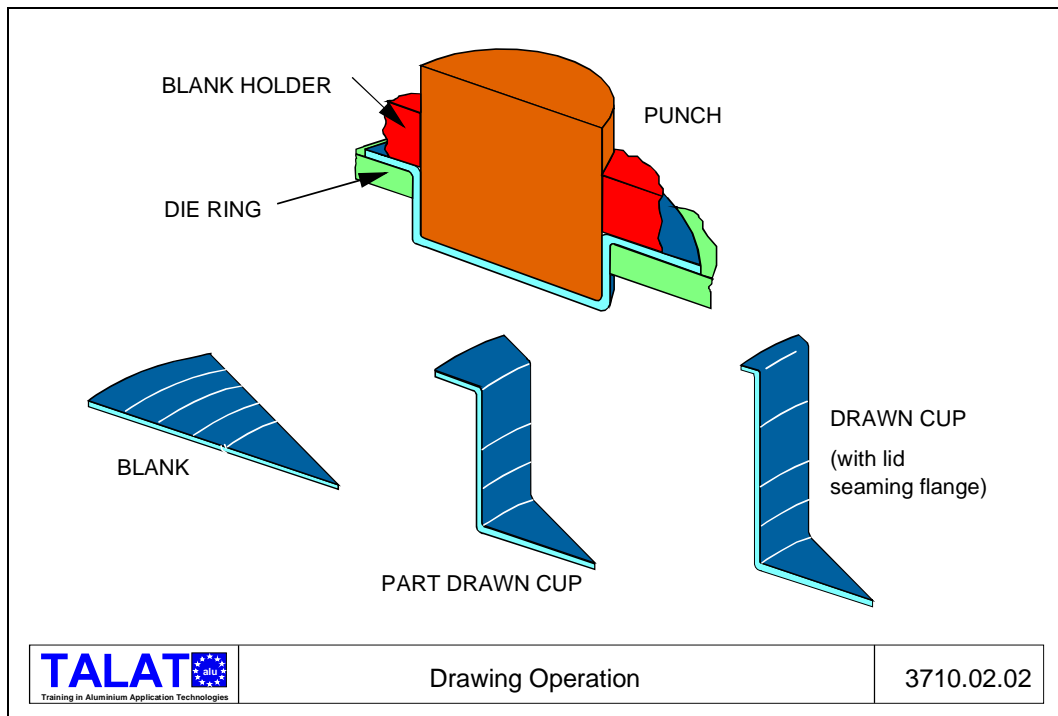
The metal thickness can change slightly during drawing but this is influenced by factors such as the drawing die radius and blankholder pressure. Usually there is a slight thinning of the wall adjacent to the punch nose and slight thickening towards the top of the can body. This is negligible with shallow cans but may be significant with deep, multi-stage, drawn cans (see later).

The press tool may also incorporate features for trimming the flange, and embossing a profile in the base of the can, but sometimes these operations are carried out in a second press.

The shallow-draw presses are usually simple single action presses with the blankholder load applied via springs or rubber cushions, and run at up to 200 strokes per minute. The presses are usually inclined so that the can bodies and trim shreds fall away from the tool area, and tumble through a rotary cage to separate the shreds from the cans. Double-dies or multiple dies can be used to increase productivity and, if practical, staggered to improve metal utilization.

A typical drawing die radius is about seven times the nominal strip thickness. The punch nose is usually the same as the drawing die radius but is less critical although it should always be highly polished.

The force necessary to draw the blank into a cup must be transmitted from the punch via the walls of the drawn shell. Strip lubrication and blankholder pressure are important variables. If the lubrication is too low or the blankholder pressure too high the metal will not flow sufficiently freely and the cup wall, unable to transmit such a high load,

will fracture around the punch nose. On the other hand, inadequate blankholder pressure will allow the blank to wrinkle and the effort required to pull the wrinkles over the die radius will be too high for the cup wall to transmit and fracture will again occur. Excessive lubrication can build up on the blankholder surfaces to form such a thick film that the blank is no longer under precise control and wrinkling will again occur.

Conditions are more critical for containers drawn from thin, strong alloys, and in these cases double-action presses with independent control of blankholder pressure are sometimes used.


WALL DECORATION PRE-DISTORTED TO FINISH TRUE

Source: Cebal

| TALAT | Printed Sheet for Can Drawing | 3710.02.03 |

Deep-Drawn Cans

Single-drawn cans can be produced with height/diameter ratios of up to 0.7:1 (i.e. a drawing reduction of the blank diameter D to the cup diameter d of up to 50%):

$$\frac{D-d}{D} \cdot 100 \quad [\%].$$

However, such a deep draw may exhibit high earing which in the case of a can drawn from pre-decorated strip may give an unacceptable level of local distortion to printed characters. High earing also puts additional local strain on the lacquer coating. In such cases, and with cans with height/diameter ratios greater than 0.7:1, the cans are produced in two or even three drawing stages. This method of production is called Draw-Redraw (DRD) (see **Figure 3710.02.04**).

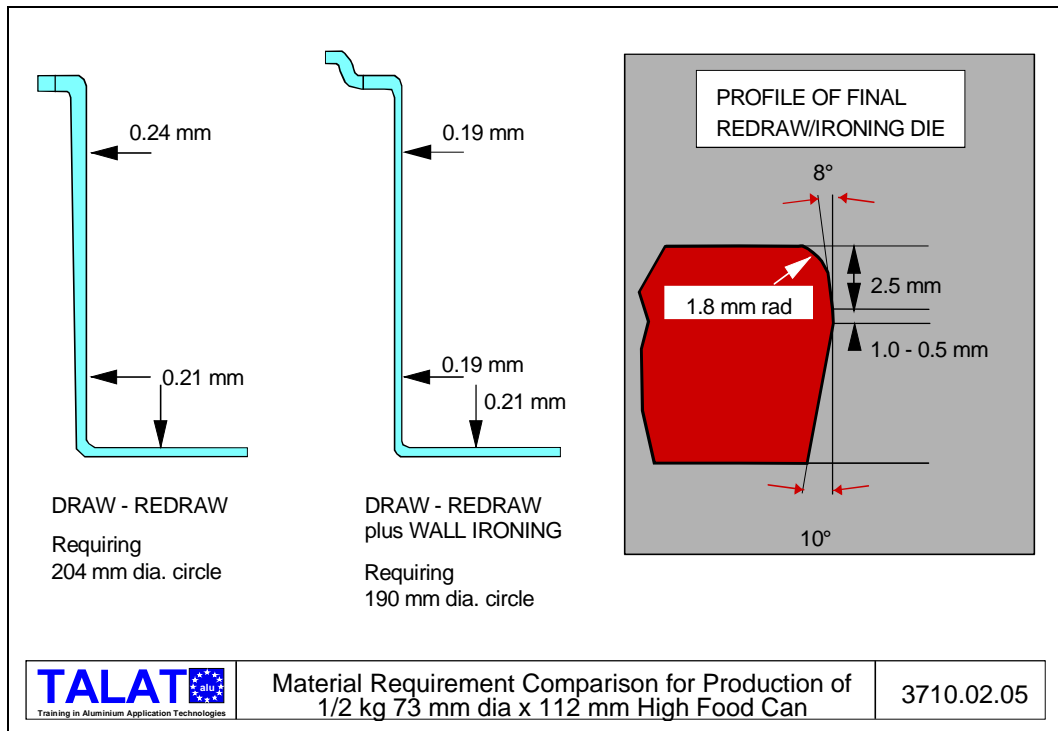| | Draw, Redraw Method of Can Manufacture | 3710.02.04 |
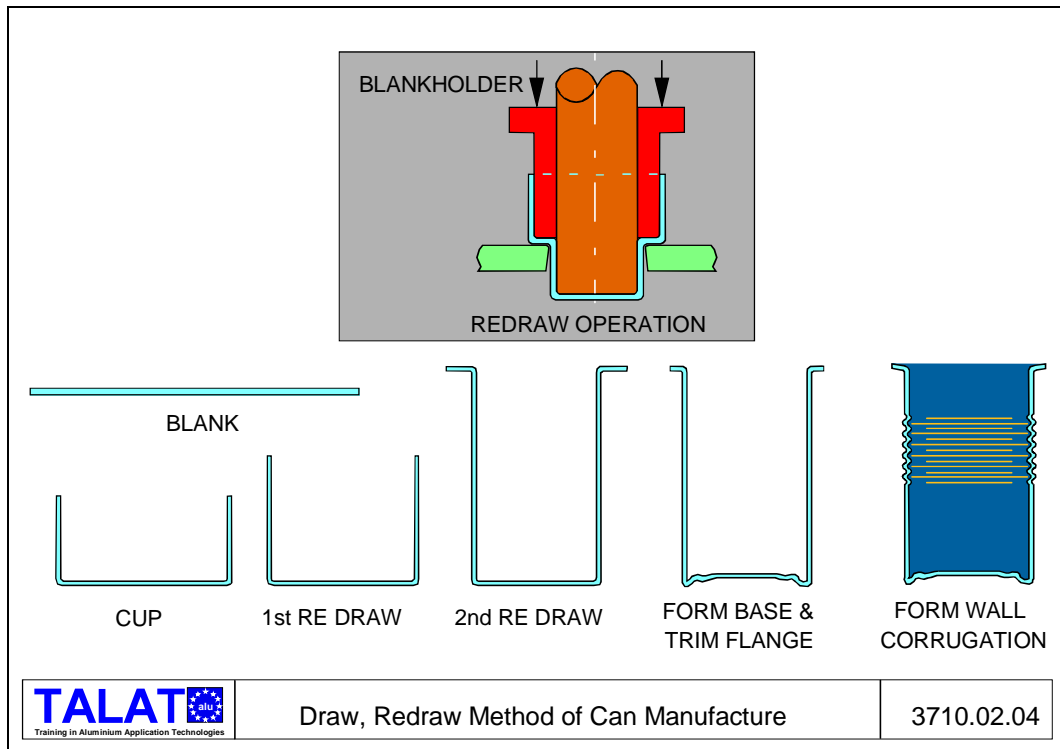
The first operation produces a shallow cup and this effectively locks in the earing profile. The second operation redraws the cup to the finished height. The draw reduction

$$\frac{D-d}{D} \cdot 100 \ \ [\%]$$

of the first operation (blank and cup) should be limited to 40% and of the second operation (first redraw) to 25%. If appreciably higher reductions are envisaged it is preferable to introduce a third operation, i.e. a second redraw, and to redistribute the draw reductions accordingly. The second redraw reduction percentage should be slightly less than that of the first redraw.

In the case of these taller cans the wall thickens appreciably towards the top of the can. For example, with a 1/2 kg food can 73 mm dia x 112 mm tall, 0.21 mm starting thickness would increase to around 0.24 mm. This would require a 204 mm diameter starting circle. However, it is possible to reduce this wall thickening by "wall-ironing" using a special profile in the final drawing die and a reduced radial clearance. This can either size the wall to the original 0.21 mm or reduce the complete wall to 0.19 mm thickness.

The latter would reduce the starting circle diameter to 190 mm, thus giving appreciable metal savings (**Figure 3710.02.05**). This technique has been successful with organosol-lacquered strip and is now being evaluated with the new generation modified polyester coatings.

		PROFILE OF FINAL REDRAW/IRONING DIE

DRAW - REDRAW

Requiring
204 mm dia. circle

0.24 mm

0.21 mm

DRAW - REDRAW
plus WALL IRONING

Requiring
190 mm dia. circle

0.19 mm

0.19 mm

0.21 mm

8°

2.5 mm

1.8 mm rad

1.0 - 0.5 mm

10°

TALAT Training in Aluminium Application Technologies	Material Requirement Comparison for Production of 1/2 kg 73 mm dia x 112 mm High Food Can	3710.02.05

The taller food cans usually have circumferential corrugations roll-formed in the wall to resist „panelling" during processing (see later).

Coil-fed presses are usually sufficiently wide to accommodate multiple tools. These are staggered so that the cut blanks are ″nested″ across the strip with no more than 1 mm shred between the blanks, thus obtaining maximum metal utilization. In the case of sheets, these can be scroll-cut to approach the continuous strip utilization factor (**Figure 3710.02.06**). There is also a sheet feeding attachment for a single or double-tool press, which will stagger feed a sheet to achieve the ″nesting″ obtained on a multi-tool press.

In the case of rectangular containers, the blank shape has to be developed to accommodate the metal requirements for drawing into the corner radii. The blank is usually oriented on the strip so that the earing of the metal provides some of the material required for the corners. Of course, this demands that earing levels are similar not only between batches of coils but also between different suppliers.

Drawn food cans frequently have a stepped flange so that the body of the can is a smaller dimension than the score line on the easy-open lid. Consequently, when the lid is opened there is no lip to impede the emptying of the contents. This feature is referred to as a ″full aperture opening″. In some cases, especially where empty cans have to be transported overseas from can maker to filler, the cans have a tapered body (usually around 7°) so that the empty cans ″nest″ to give a considerable volumetric saving in bulk transport.

In contrast to the beverage can, food cans come in a wide variety of shapes and sizes. Some are still referred to by their traditional names such as ¼ dingley and ¼ club for rectangular, and Hansa for oval, fish cans, while many round cans are known by their overall imperial measurements expressed to the nearest inch and sixteenth fraction, e.g.

301 x 307 refers to a round can 3 $\frac{1}{16}$ inch diameter and 3 $\frac{7}{16}$ inch tall, measured over a seamed can; this is the $\frac{1}{2}$ kg food can.

| TALAT | Scroll-Cut Sheet to Improve Metal Utilisation | 3710.02.06 |
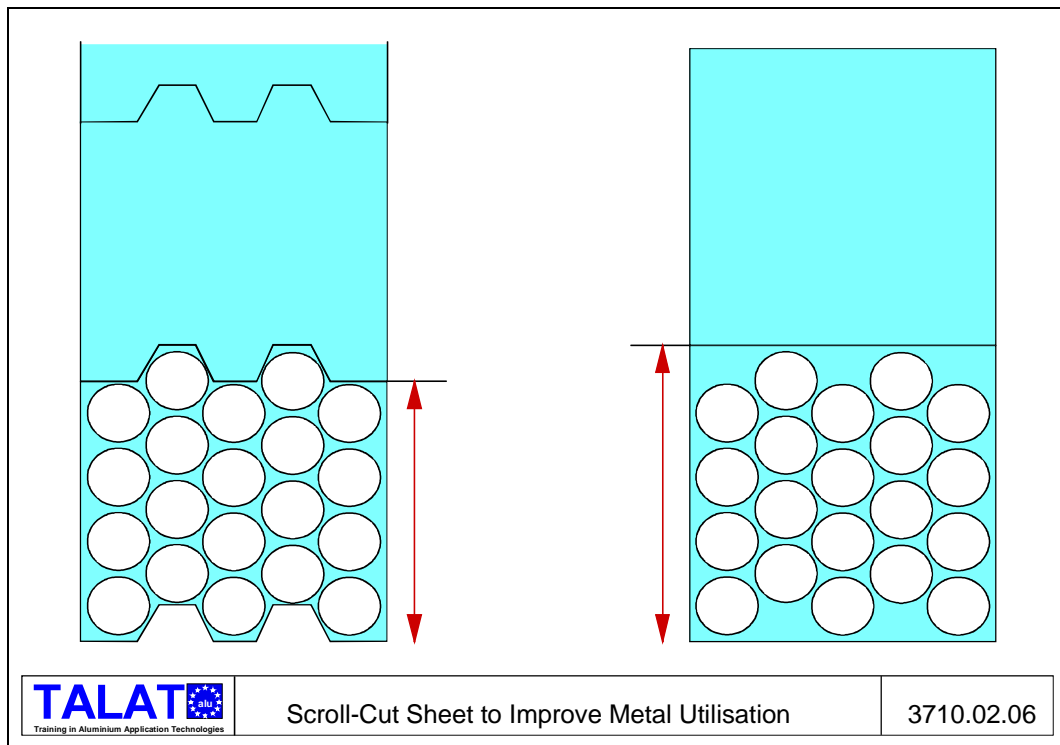
Food Can Stock

A number of different alloys and tempers has been used over the years, but rationalisation has concentrated on three of these (**Figure 3710.02.07**).

Shallow-drawn can bodies are made from a manganese, low magnesium alloy with the designation AA 3005 and in the H46 (lacquered, $\frac{3}{4}$ hard) temper.

Deeper-drawn can bodies requiring a higher degree of formability than 3005 and lower earing, but with similar strength, are made from the medium magnesium (and slightly more expensive) alloy AA 5052 in the H44 (lacquered, $\frac{1}{2}$ hard) temper.

Lids requiring high formability, such as a deep countersink, or an integral rivet for ring-pull opening (see later) are also made from 5052 in the $\frac{1}{2}$ hard temper, but in the case of a simple non easy-open, relatively flat lid, a manganese alloy, AA 3207 in the H48 (lacquered, full-hard) temper, but with lower formability (and lower price), is used.

Today, can bodies are made from 0.22-0.25 mm thick material. It is possible to draw most can bodies from material as thin as 0.15 mm, but these are too light and fragile to handle on most can filling and processing lines without extensive modification to the lines. In spite of can makers carrying out gauge reduction studies, each can maker is supplying several packers, not all of whom are prepared to refine their equipment to handle the lighter cans, and the can maker is reluctant to stock two gauges of material for the same size of can so they continue with this compromise gauge.

Large diameter can lids, i.e. greater than 100 mm, are made from 0.28 mm thick material but the usual gauge is 0.25 mm thick. Thinner material would make the forming of the opening aperture score line, and the lid seaming operation, more critical.

Can Type	Alloy	Composition %						Properties		
		Si	Fe	Cu	Mn	Mg	Cr	U.T.S. MPa	0.2% Proof MPa	Elong % min
Shallow drawn can bodies	AA 3005 H46	Min 0.00	0.00	0.00	1.00	0.20	0.00	190	170	
		Max 0.06	0.70	0.30	1.50	0.60	0.10	230	210	3
Deep drawn can bodies also easy-open lids	AA 5052 H44	Min 0.00	0.00	0.00	0.00	2.20	0.15	240	190	
		Max 0.25	0.40	0.10	0.10	2.80	0.35	280	240	6
Plain lids	AA 3207 H48	Min 0.00	0.00	0.00	0.40	0.00	0.00	180	160	
		Max 0.30	0.45	0.10	0.80	0.10	0.05	230	210	1

TALAT Training in Aluminium Application Technologies	Principle Food Can Alloys (Properties According to Euronorm)	3710.02.07

As mentioned earlier, all food can bodies and lids are drawn from prelacquered or decorated material. Decoration is carried out on pre-cut sheets which are supplied pretreated for good coating adhesion, and the forming operation is carried out on sheet-fed presses. Some high-speed presses are coil fed, and here the supplied material is in the form of lacquered coil. In this case the can would have a plain lacquered body, with the decoration supplied in the form of a printed lid, or in some cases a paper label or even a card carton.

Lacquered material is supplied as coils which are pretreated (to optimise lacquer adhesion) and lacquered on a continuous coil coating line. Today, to meet increasingly stringent environmental requirements, the pretreatment is usually a chrome-free version of a chemical conversion process, or an electrolytic process, to modify the natural oxide film. The lacquers are selected to give adequate drawability for the envisaged can, and adequate chemical resistance for the agressivity of the product. Typical food can lacquers are given in **Figure 3710.02.08**. A laminated plastic film is also under consideration. (Organosol lacquers are now out of fashion because of the chlorine content which leads to additional cost for scrubbing exhaust gases when decoating or melting scrap to comply with new, stringent regulations). Before the strip leaves the coil coating line it is lightly lubricated on both sides to assist the subsequent press forming operation; typical is to use food grade petrolatum applied at 50 mg/m^2, which is compatible with most food products.

	LACQUER TYPE	COLOUR	DRY FILM WEIGHT g/m²
OUTSIDE	EPOXY AMINE	CLEAR, GOLD, or WHITE AS BASE COAT FOR PRINTING	2
INSIDE — Shallow drawn cans	EPOXY PHENOLIC	GOLD	3 - 4
INSIDE — Deep drawn cans	MODIFIED POLYESTER	GOLD or WHITE	7 - 10

TALAT Training in Aluminium Application Technologies	Typical Food Can Body Lacquers	3710.02.08

Unless a special control is specified, lacquered strip is tested prior to despatch to the customer by drawing $\frac{1}{4}$ club fish can bodies and processing at 121 °C for 1 hour in the following solutions:

1. tap water
2. 2% tartaric acid
3. 3% acetic acid
4. 3% sodium chlorate
5. 1% lactic acid + 2% sodium chlorate,

following which the lacquer should show no deterioration in either appearance or adhesion. Only the first test (tap water) is applicable to the external lacquer.

The usual mechanical tests are carried out to ensure the material has adequate strength and formability to produce the specific design of can.

Sheet Decoration

It is not practical to print or decorate coils because of the wide range of designs required for food cans, and the relatively small runs per design. Instead, decorating is applied to sheets. For these, coils are pretreated (as above) then given a thin coating of dioctylsebaccate (DOS) at around 8 mg/m^2. The coil is then slit and cut-to-length to the precise sheet size and supplied in stacks of around 1000 sheets for coating and decorating on the customer's equipment. The DOS film ensures the sheets destack and feed smoothly into the first sheet coater and the level of DOS is carefully regulated to ensure it is compatible with the subsequent lacquer coatings.

Sheet lacquering and decorating involves several passes through roller coaters, decorators and stoving ovens. If the decoration can be achieved in 4 colours (on a coloured base), a typical schedule would be:

- Coat first side (can inside) and stove
- Coat second side (decorative base coat) and stove
- Print 2 colours (2-stand decorator) and stove
- Print 2 colours (2-stand decorator) and stove
- Overprint varnish and stove
- Lightly lubricate with a food-grade wax.

The coated sheets are transported through the stoving ovens standing on edge and supported by open wire frames (wickets). Sometimes with large, thin sheets in hard temper material, internal stresses can be released during the stoving operation and cause the sheet to buckle. This can be avoided by supplying the sheets thermally stabilised. After cutting to size, stacks of sheets are placed on flat pallets and loaded with flat heavy weights. They are then placed in an oven for 2 hours at a temperature just in excess of the sheet stoving temperature (usually 220 °C). Internal stresses are relieved, but the sheets are restrained from buckling by the flat weights. DOS is not applied to this material as it would be evaporated during the thermal stabilisation process. In such cases the customer must ensure that the sheets are never stored more than 4 pallets high (excessive pressure can cause destacking difficulties) and that the guide rails on the first coater are in good condition and well-polished.
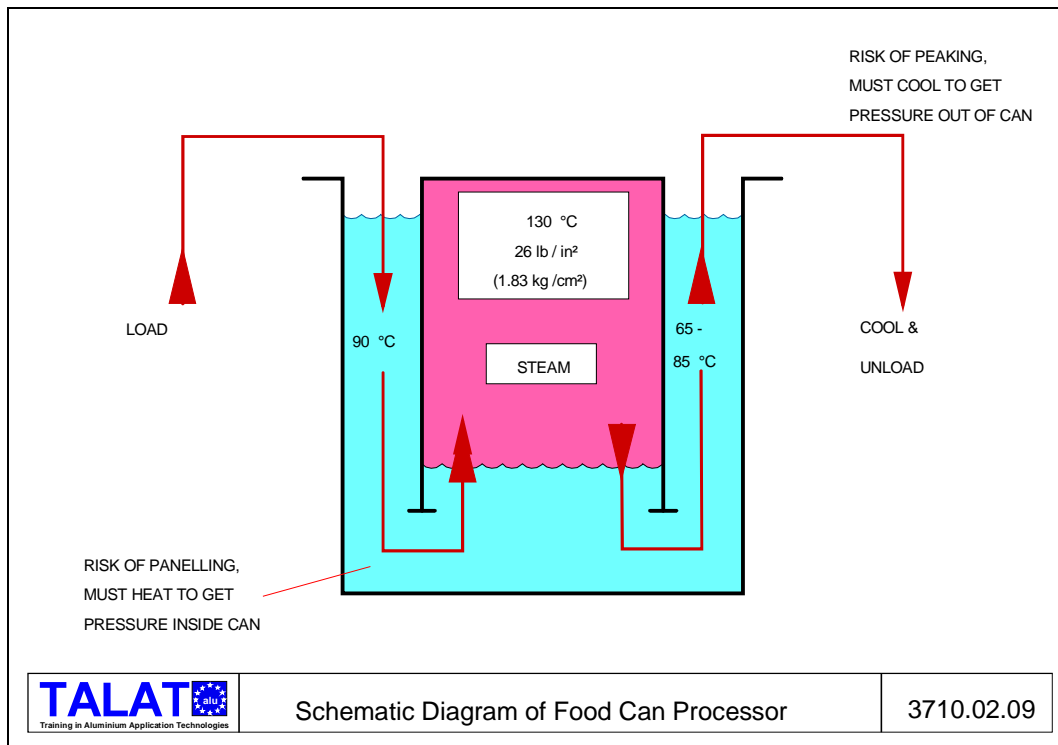
Sheet coater and decorator machines can run up to 100 sheets per minute.

Food and Can Handling Processing

The can must be designed to give the anticipated shelf life specified for a particular product, ranging from fish-in-oil to quite aggressive packs. lt must also withstand mechanical handling on the filling lines, internal pressures during processing, and possible careless handling during transport and storage, yet still present an attractive package to the customer.

As an example, the $^1/_2$ kg round food can, 73 mm dia x 112 mm high, should withstand an axial load of around 200 kg to cover recorded loads of 130 kg from pallets stacked 4-high, 120 kg shock load when snatched during lifting with a fork truck, and 200 kg when rocking whilst cornering during road transport. Of course a lower axial strength would be acceptable if the cans could be guaranteed more protection during transport. The can should also withstand an external pressure of 1.5 kg/cm^2 (21 lb/in^2) without "panelling" and an internal pressure of 2.7 kg/cm^2 (38 lb/in^2) without "peaking", during processing.

A typical continuous processor transports the filled cans on chains through a vertical tower which consists of a central section with steam at 130 °C at a pressure of 1.8 kg/cm^2 (26 lb/in^2). The steam chest is hot-water sealed, with the entry leg preheating and the exit leg cooling the can (**Figure 3710.02.09**).

| RISK OF PEAKING, MUST COOL TO GET PRESSURE OUT OF CAN |

LOAD

90 °C

130 °C
26 lb / in²
(1.83 kg /cm²)

STEAM

65 - 85 °C

COOL & UNLOAD

RISK OF PANELLING, MUST HEAT TO GET PRESSURE INSIDE CAN

TALAT Training in Aluminium Application Technologies

Schematic Diagram of Food Can Processor

3710.02.09

The water in the preheat leg is around 90 °C. The contents of the can heat up slowly, depending on the product. Liquids or gravy heat up quickly, but chunks of meat take a long time. Consequently, with relatively cold products, the contents have not expanded to balance the external pressure by the time the can enters the steam chest, and here is the greatest risk of "panelling".

The cans are in the central stage (steam chest) for about one hour by which time it is calculated that all of the product has reached the sterilizing temperature. Some products can expand by as much as 30 cc in a 500 cc can, and pressures of up to 4.2 kg/cm^2 (60 lb/in^2) can be reached inside the can. This pressure is of course counteracted by the 1.8 kg/cm^2 (26 lb/in^2) steam chest pressure, but still leaves a residual 2.4 kg /cm^2 (34 lb/in^2) maximum.

The water in the cooling leg is in the range 65-85 °C. The objective is to cool the can as quickly as possible but also to reduce the pressure within the can. This is not so easy because due to thermal inertia, the centre of the can with some products is still increasing in temperature as the can progresses through the cooling leg. Here is the greatest risk of "peaking".

A deliberate can volume change during processing will reduce the pressure differential so that a lower resistance to panelling and peaking can be tolerated. Cans are designed with base and lid profiles that can expand during processing but with sufficient mechanical strength that they will return to their original profile on cooling.

Many products are "hot-filled" which reduces the risk of panelling in the entry stage and also results in a slight vacuum in the cooled can to pull the lid and base flat and give a tight pack.

Many packers still use batch processing, and here the cans may be loaded in frames which mechanically constrain and limit their expansion during processing.

3710.03 Beverage Cans

- Cupper press
- Bodymaker press
- Can washing
- Base coating and printing
- Internal lacquering
- Mechanical finishing
- Beverage can stock

Whilst many food cans (particularly fish cans) are required in relatively small quantities to meet seasonal supplies or demand, and are produced on simple presses with tools changed for the production of different cans, the beer and carbonated soft drink beverage can is required in vast quantities mainly in only two sizes, 33 cl (12oz) and 50 cl so that dedicated high-speed, high-precision lines are justified. In fact, these two sizes have the same body diameter (and hence use the same lid) and are merely of different lengths.

The success of the aluminium beverage can is attributable to two factors. First, the introduction of the aluminium ring - pull easy-open lid around 1964 offering convenience, and second the development of recycling facilities making the can ecologically attractive. But, in addition, there have been continuing technical improvements to maintain the can's quality and cost advantages.

The can has to withstand an internal pressure of 6.7 kg/cm^2 (95 lb/in^2). It has a relatively thick inwardly domed base but a very thin wall as adequate rigidity is provided by the high pressure within the can (**Figure 3710.03.01**). Considerable lightweighting of the body has been achieved by attention to detailed design (in particular the base profile) and by fine - tuning the alloy metallurgy and process route to achieve maximum strength yet retain adequate formability. The lid thickness has also been considerably reduced by "necking-in" the top of the can body to accept a smaller diameter (hence stronger) lid. The can body is 211 diameter (the traditional imperial measurement of approximately $2^{11}/_{16}$ inches over a seamed can). Prior to the introduction of the easy-open feature, lids were also 211 diameter. The first easy-open beverage can lids were 209 diameter, these were later reduced to $207^1/_2$, and now 206 ($2^3/_8$ inches) diameter lids are standard. Machinery is being developed for 204 lids and even 202 lids are under consideration. This has been made possible by the development of both technique and machinery to neck in the can body to these smaller diameters. However, the can's stackable feature has to be retained, so a can with a 204 or 202 lid must have a modified base profile (a smaller base rim diameter) to stack on the appropriate lid.

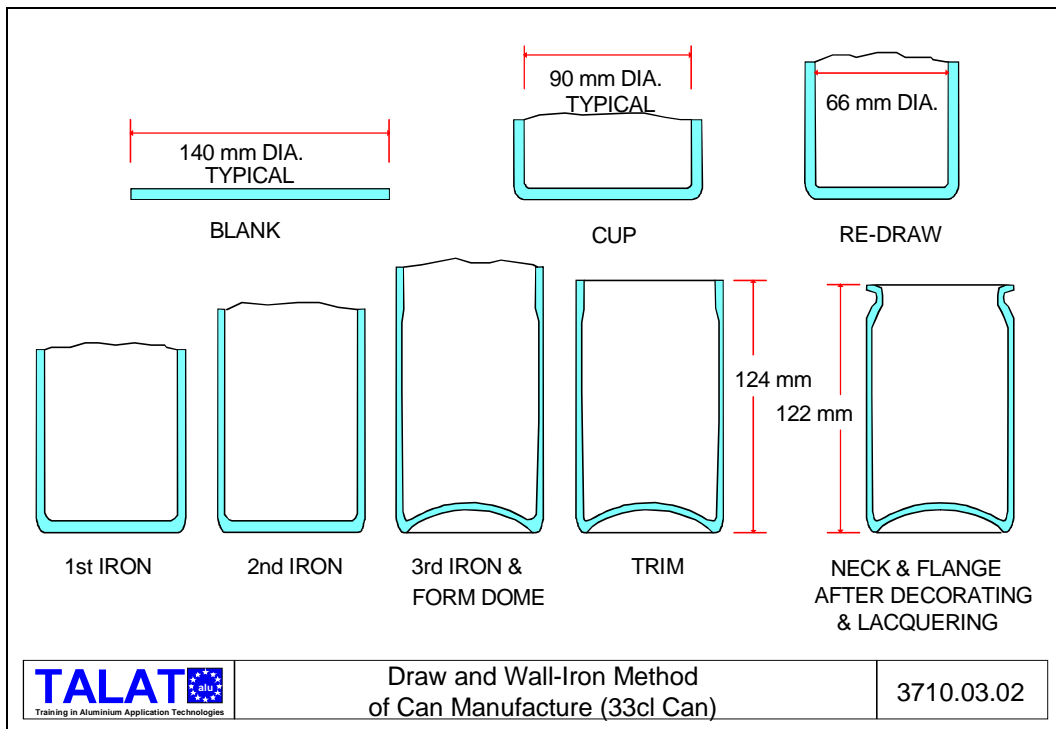| TALAT | Typical Beverage Can Body Profile | 3710.03.01 |
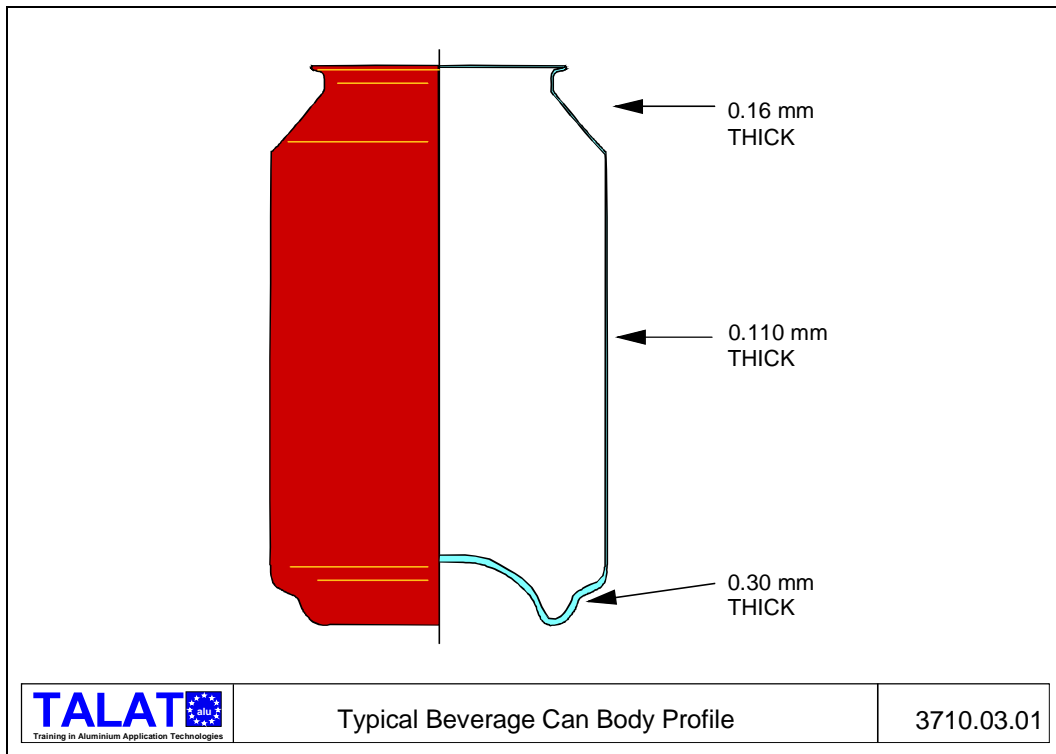
The beverage can is produced by drawing and wall-ironing (DWI) plain strip, then washing, decorating and lacquering the shell prior to mechanical finishing (necking, flanging, etc). All of this is done on a high-speed integrated line. Generous inter-unit storage accumulators ensure that minor interruptions (such as clearing a jammed can) do not result in a complete line shut-down. The individual machine centres usually run just below their maximum so they have the ability to speed up and "catch-up" following any temporary stoppage.

Figure 3710.03.01 shows a typical can body. Typically it is produced from 0.30 mm thick strip and this dimension is substantially preserved in the can base, which is profiled not only to withstand the high internal pressure but also to ensure the base is stackable on the appropriate lid. The wall is ironed down to 0.110 mm thickness over most of body length but the top of the can is not ironed to the same extent and finishes at around 0.16 mm thickness. This facilitates necking, and the thicker flange assists the subsequent lid seaming operation.

The body is produced by blanking, drawing, redrawing and wall-ironing (**Figure 3710.03.02**). The first operation is blank and cup on a ″cupper″ press, and the second operation is redraw to the finished can diameter and wall-iron on a ″bodymaker″. Typically the cup is given a 35-40% draw reduction

$$\left(\ \frac{D-d}{D} \cdot 100 \ \right) \ [\%]$$

and the redraw 25-27%, these reductions balanced to suit both material and equipment preferences.

| TALAT | Draw and Wall-Iron Method of Can Manufacture (33cl Can) | 3710.03.02 |

In the figure: BLANK (140 mm DIA. TYPICAL), CUP (90 mm DIA. TYPICAL), RE-DRAW (66 mm DIA.), 1st IRON, 2nd IRON, 3rd IRON & FORM DOME, TRIM (124 mm / 122 mm), NECK & FLANGE AFTER DECORATING & LACQUERING.

Specific details vary from company to company but typical for a 33 cl can would be a 140 mm diameter circle drawn into a 90 mm diameter cup and redrawn to the 66 mm diameter finished can; a 50 cl can would use a 155 mm diameter circle drawn into a 93 mm diameter cup.

Cupper Press

The cupper is a coil-fed multi-die press where circles are cut and drawn into the first-stage cup. **Figure 3710.03.03** shows a 10-out cupper which blanks 10 circles, staggered for optimum metal utilisation across the width of the strip. Until recently 12-out cuppers were the largest machines, requiring 1478 mm wide strip for a typical 33 cl beverage can, and 1550 mm for a 50 cl can, as wider strip was not available. However, the latest aluminium strip rolling mills can supply material up to 2 m wide, and 14-out cuppers are now running.

Cupping Press | 3710.03.03
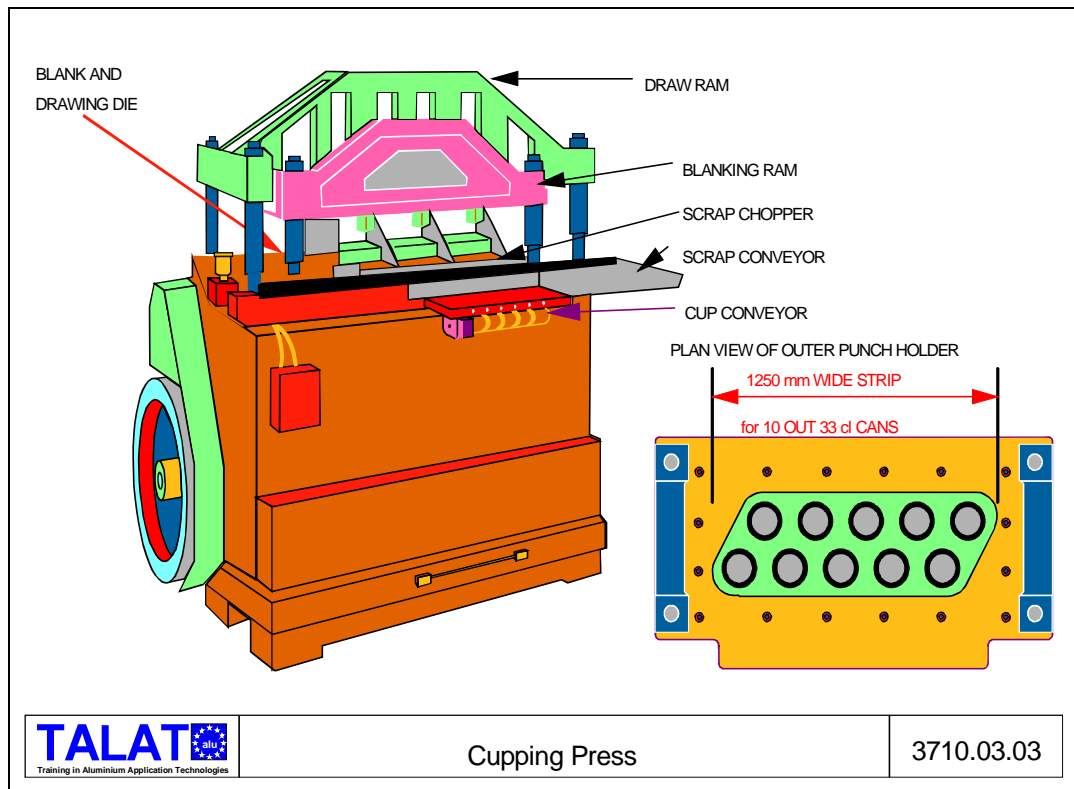
It should be pointed out that a reduction in the thickness of the can base (down-gauging) requires thinner strip and if the wall thicknesses are to remain the same, then a larger starting circle will be required to provide adequate material for the can body. In turn these larger circles will require a wider strip (for the same ″out″ configuration). This strip width may be beyond the capacity of that particular cupper press, and the restriction to a fewer ″out″ configuration and hence lower productivity, would have to be balanced against the economic advantages of the down-gauged can base.

The cupper is fed with coiled strip which is coated with a drawing lubricant as it enters the cupper. The as-rolled strip has a slight amount of residual rolling lubricant present on the surface, and the cupper lubricant applied on the press has to be compatible with this rolling lubricant and achieve, in a very short time, good wetability on the strip. This is ensured by applying a thin but uniform film of a typical cupper lubricant to each side of the rolled strip at the mill during the final slitting operation so that the customer receives pre-lubricated coils, and the lubricant required on the press is less critical.

The blanking and cupping operation is similar to that described previously for shallow drawn food cans (**Figure 3710.02.02**) except that in this case the cup passes through the die so there is no flange. Care must be taken to ensure the blankholder does not clip any slivers of metal from the rim of the blank as the edge passes through the blankholder draw die gap, so a double-action press is used with the blankholder moving independent of the punch, applying reduced pressure towards the end of the draw, and with a ″stand-off″ to maintain a positive gap from the die face so that undue metal thinning is avoided. This is particularly important with higher-earing material.

The face of the blankholder is usually grooved, this increases the unit pressure and is claimed to reduce the effect of thickening during the draw by localising the blankholder

force. In addition, the radial clearance between the punch and the drawing die is usually restricted to about 5% above nominal metal thickness, so that the thickening at the top of the cup wall which occurs during drawing is lightly ironed or "sized". This reduces the apparent earing on the cup and facilitates handling, and also presents a more uniform cup wall for the subsequent ironing operations.

Drawing reductions of up to 40% are sometimes used in the cupper, this reduces the redraw reduction necessary in the bodymaker. However, it is more usual to limit the cupper to around 37% reduction to minimise any earing effect and give a relatively level top to the cup to facilitate handling.

Modern cuppers run at up to 180 strokes/min thus a 12-out cupper will produce over 2000 cups per minute. Usually the speed is regulated to suit the demands of the bodymakers. Such a cupping press would be integrated through suitable storage accumulators with seven bodymakers of which six would be running at any one time with the seventh machine down for planned tool change and maintenance. Bodymakers run at up to 320 cans/min (the latest machines are rated much higher and it is claimed that in the future 500 cans/min will be possible). At present the "front end" of the beverage can making line can be supplying nearly 2000 cans per minute to the "back end" finishing section.

Bodymaker Press

The bodymakers are long-stroke presses for successively redrawing and 3-stage wall-ironing the can body, and finally inwardly doming the base before the can is stripped from the punch. **Figure 3710.03.04** shows the successive stages. As mentioned before, the cup is redrawn to the finished can diameter involving a reduction of some 25-27%, depending on the size of cup. The wall is then reduced from the nominal starting metal thickness (say 0.30 mm) to around 0.110 mm by passing through 3 successive ironing rings. These rings are spaced so that the shell is clear of one ring before it enters the next. Usually the top of the wall (0.16 mm) is thicker than the mid-wall. The second ironing ring should not reduce the wall to less than this thickness. The thickness differential is then achieved by reducing the diameter of the punch at the appropriate point so that the final ironing ring reduces this part of the wall by a lesser amount (**Figure 3710.03.04**). The ironing rings can move slightly in their mountings so that they effectively self-align with the punch. At the end of the stroke a sub-press inwardly domes the base before the can is stripped from the punch.

Redrawing & Wall-Ironing Stages in Bodymaker — 3710.03.04
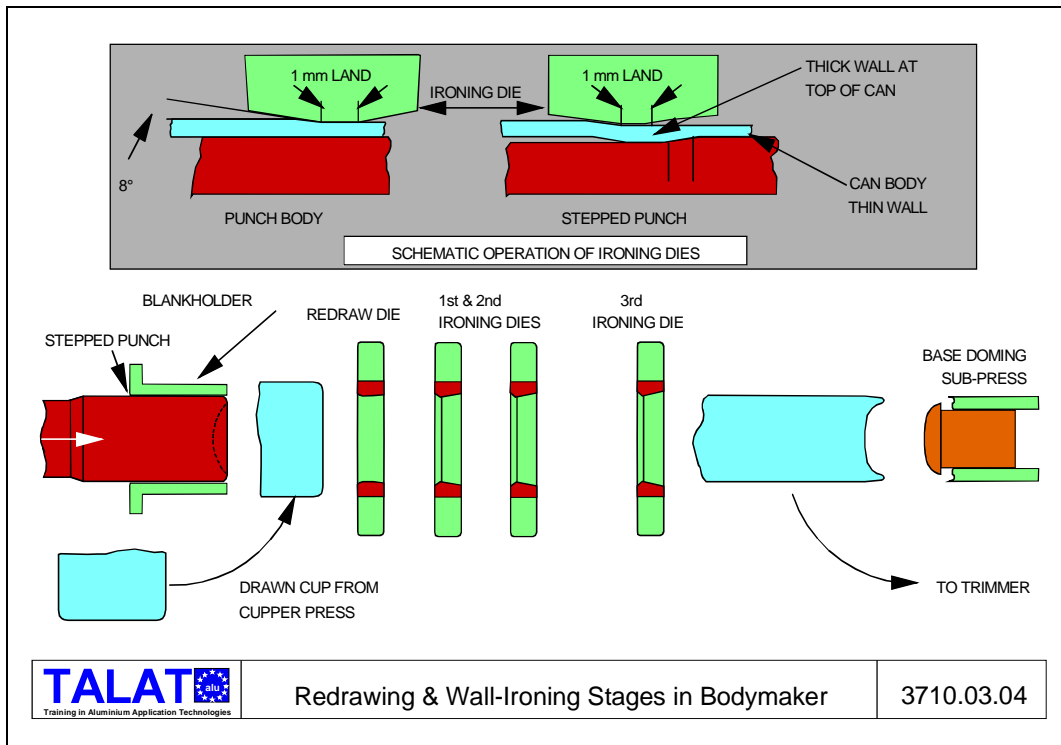
While the strip entering the cupper is only lightly coated with a drawing lubricant, the die box in the bodymaker is flooded with a dilute version of the same lubricant. Its prime function here is as a coolant for the wall-ironing operation. In fact the cup relies to a great extent on the residual lubricant from the cupping operation acting also as a drawing lubricant for redrawing and wall-ironing in the bodymaker. Inadequate lubrication in the cupper may not be evident in the cup production, but may well cause problems subsequently in the bodymaker.

The surface of the punch is usually lightly cross-hatched to carry some lubricant. This assists the sliding of the can shell over the punch during ironing, and the stripping of the shell from the punch at the end of the stroke.

The ironing dies must be maintained to a very high surface finish. Typical is an entry (ironing) angle of 8° and a parallel ″land″ of about 1 mm. It is most important that the junction between these two faces is a sharp corner (**Figure 3710.03.04**).

Following the bodymaker, the shells are trimmed to the precise body length and are ready for the finishing operations.
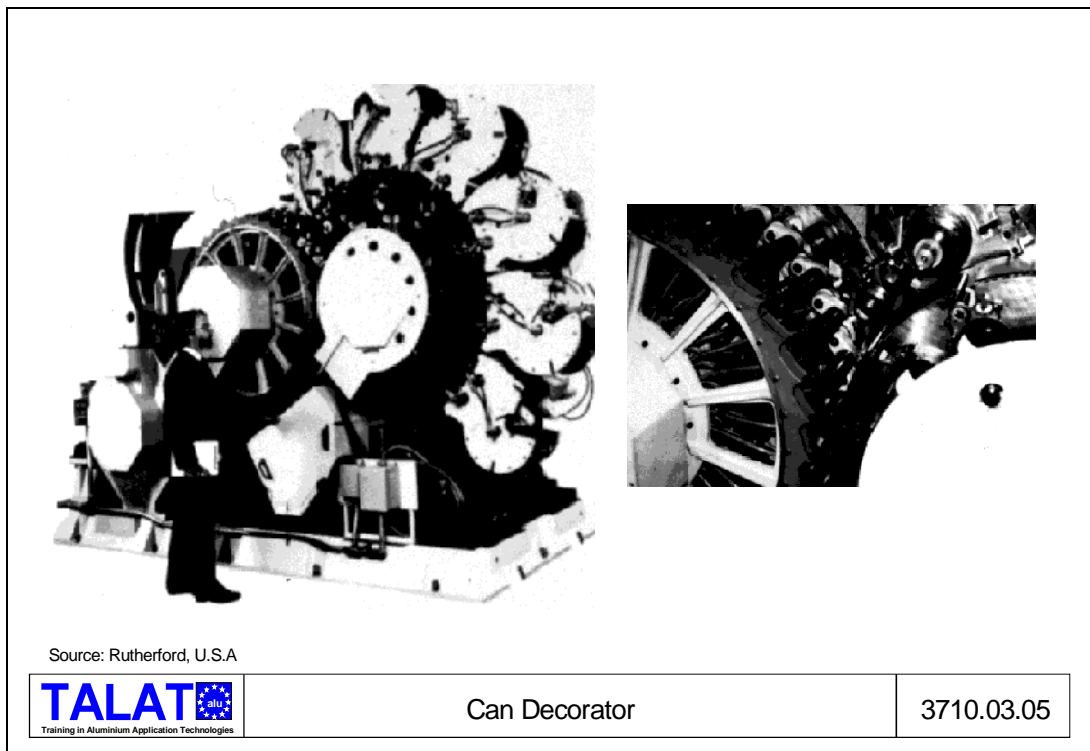
Can Washing

The first finishing operation is a chemical spray degrease and rinse, followed by a chrome-free chemical pretreatment, rinse and dry to ensure good adhesion of the subsequent internal and external coatings. The cans are conveyed through the washer in the inverted position on a broad, open mesh, wire belt. The cans are held on the belt by the upper sprays exerting a slightly higher force than the bottom sprays.

Base Coating and Printing

The next operation is an external base coat for the subsequent printed decoration. The cans are supported on a mandrel and the coating applied by roller. A clear coating is used if the metallic effect of the can is to be preserved in the decoration, otherwise a white base coat is used to form a good surface for the printing inks. The cans are then dried before being transferred to the printing machine.

The printing machines employ the dry-offset technique and are usually 4colour or 6-colour versions. Printing plates for the individual colours are fixed to rollers arranged around the periphery of a drum carrying a rubber blanket. The printing rollers are synchronised to apply the individual colours in register onto the blanket as it travels past them, and revolves to the can station to transfer the complete printed design to a can body which itself is rotating at synchronous peripheral speed (**Figure 3710.03.05**). Most can printers run at up to 1 200 cans/min (the latest are rated at 1 600 cans/min) and there are usually two per line, sometimes producing different designs for separate orders. Most printers can also apply an over-print varnish.

Source: Rutherford, U.S.A

| **TALAT** Training in Aluminium Application Technologies | Can Decorator | 3710.03.05 |

As the can exits the printer a coating of lacquer is applied either by roller to the rim of the can base or by spray to the complete domed base. The prime function of this coating is to improve the mobility of the can on the guide rails through the following forming and subsequent filling operations. However, sometimes an overall base protection is requested to guard against possible external corrosion under long-term storage conditions in a warm, humid atmosphere. This ″secondary corrosion″ is most infrequent and is usually initiated by a can being damaged by careless handling during transport, and leaking to contaminate most of a pallet with a possibly aggressive product. If unprotected other cans may become externally corroded so that they are no longer saleable, or, at worst, even perforate and therefore exacerbate the damage. With overall base protection this problem does not arise.

As the two printing machines may be producing different decorations, the cans subsequently follow separate lanes.
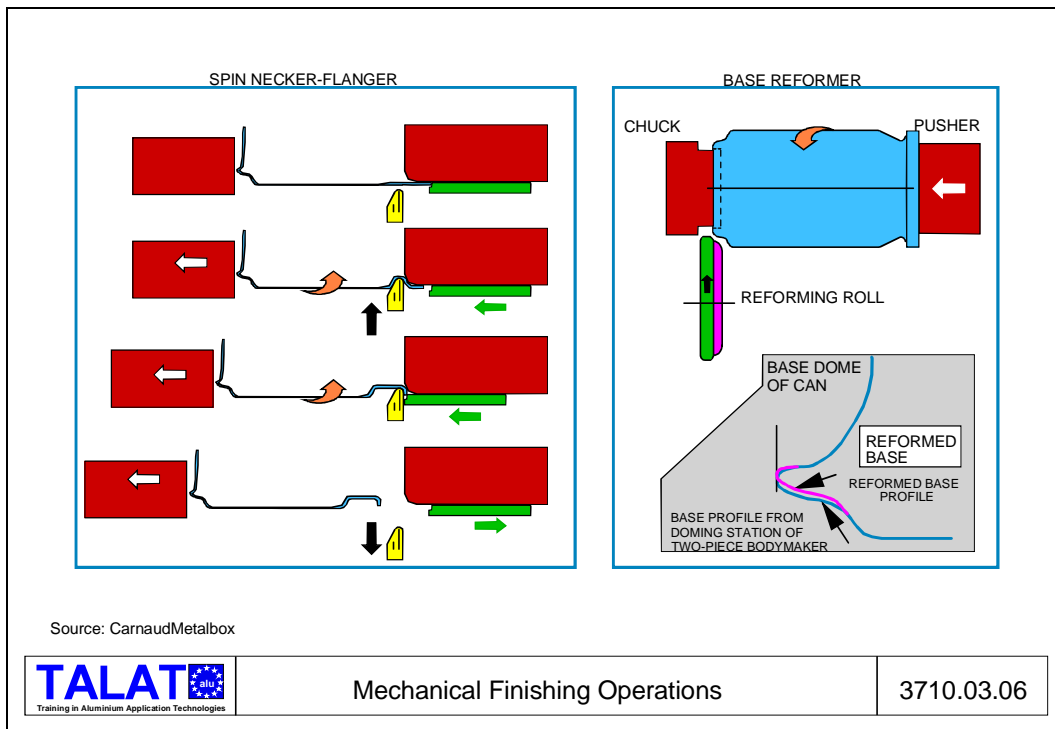
Internal Laquering

The cans pass through an oven to dry the external printing and base coating applications, and then go to a battery of usually four machines in each lane for spraying with an internal lacquer, following which they pass through another oven to cure the internal lacquer. Each spray lacquering machine will run at up to 250 cans per minute although faster machines up to 400 cans/min are now available. The cans are rotated and twin spray nozzles enter the can and spray as they are withdrawn.

Mechanical Finishing

Up to this stage the can has a parallel, un-flanged body. The next operation is to roll in the tapered neck and form the flange (**Figure 3710.03.06**). Although this can be done in a single operation, with the higher reductions now required to reduce the 211 body shell to the 206 or even 204 neck, this is usually done in separate operations, such as die pre-necking followed by spin necking, then flanging.

The next operation is to reform the base profile (**Figure 3710.03.06**). Usually the doming of the base profile at the bodymaker deliberately leaves the flank angles of chime and countersink, and the rim radius, slightly generous to ensure good coverage during internal lacquering. This base profile is now reformed in a rotary operation to give a near vertical countersink flank, and a smaller rim radius, which is a more pressure-resistant profile and hence permits the use of a slightly thinner base.

The cans finally go through a light tester which automatically rejects any damaged cans (e.g. bent or split flanges), and are then palletised for dispatch to the filling plant.

SPIN NECKER-FLANGER		BASE REFORMER

Source: CarnaudMetalbox

TALAT	Mechanical Finishing Operations	3710.03.06

Beverage Can Stock

The alloy used for beverage can bodies is AA 3004 in the H 19 temper. This specification is sufficiently wide to permit suppliers to offer, in addition to their standard material, versions which have higher formability or higher strength properties to suit the specific requirements of their customers and their production equipment (**Figure 3710.03.07**).

Over the past 10 years there has been considerable development of the beverage can, aimed at producing a lighter, cheaper can but with the same body strength. This "downgauging" has been possible chiefly through re-design of the base profile, and necking-in of the flange (to permit the use of a smaller-diameter, hence thinner, lid), but it has also entailed fine-tuning of the metallurgy and process route to achieve maximum strength yet retain adequate formability.

Whilst formability for drawing beverage can bodies is dependent on the mechanical properties of the strip in the as-rolled condition, final can strength is dependent on the properties after stoving the lacquered can. A small addition of copper to the alloy composition minimises the loss of properties on stoving.

Increase in material strength has been achieved by gradually increasing the magnesium content from the nominal 0.9% of 10 years ago, to nominal 1.1% today, and copper from nominal 0.06 to 0.15%. This is probably the limit in this direction as a magnesium content of 1.3% and greater gives rise to pick-up on the ironing dies which produces unacceptable levels of scoring on the can walls, and usually tear-offs in the bodymaker.

In any case, the alloy composition, in conjunction with casting and subsequent thermal and mechanical processing conditions has to produce a uniform, random distribution of second phase particles of the appropriate size, morphology and physical properties to achieve a tool-cleaning action, but not large enough to cause significant weakness where they occur in the very thin wall of the can. For this reason, too, grain size must be uniform and not exceeding 50 microns.

Alloy / Version	Composition % (AA Spec.)						Properties (Euronorm Spec.)					
							As Rolled			After simulated stoving, 200 °C for 10 min		
	Si	Fe	Cu	Mn	Mg	Cr	U.T.S. MPa	0.2% Proof MPa	Elong % min	U.T.S. MPa	0.2% Proof MPa	Elong % min
AA 3004 H19 Min	0.00	0.00	0.00	1.00	0.80	0.00	290	270	2	270	250	3
Max	0.30	0.70	0.25	1.50	1.30	0.05	330	210		310	290	
AA 3104 H19 Min	0.00	0.00	0.05	0.80	0.80	0.00	290	270	2	270	250	3
Max	0.60	0.80	0.25	1.40	1.30	0.05	330	210		310	290	
High Formability	AS ABOVE						290	265	3.5	275	250	4.5
High Strength	AS ABOVE						320	280	1.5	305	265	2.5

| TALAT Training in Aluminium Application Technologies	Beverage Can Body Alloy Properties	3710.03.07

In addition to magnesium and copper, manganese (up to 1.5%) is the principal alloying element for increasing strength. Careful control of the level of iron, and the iron/silicon ratio, assists in reducing the level of earing; it also assists in controlling the grain size, which is beneficial to formability.

Sample finished cans are tested to ensure they withstand the 6.7 kg/cm^2 (95 lb/in^2) internal pressure, and an axial load (vertical crush) of 115 kg (250lb). Routine checks are also carried out at various stages in production, for example to ensure that the printed design is correct to colour specification, and that the internal lacquer is pin-hole free and has adequate chemical resistance.

3710.04   Easy-Open Lids

- Easy-open can lid stock
- Lid seaming

The trigger to the success of the aluminium beverage can was the introduction around 1964 of the easy-open lid. This was the result of a technical development of the means of attaching a ring-pull tab to the lid by an ″integral rivet″, and of machinery to perform this operation at high speed. Though initially applied to the beverage can, the ring-pull tab principle was soon applied to food cans to give virtually full-aperture opening and more convenience than the key-opening or hand-operated can-opener machines (**Figure 3710.04.01**).

Source: SLW, Germany
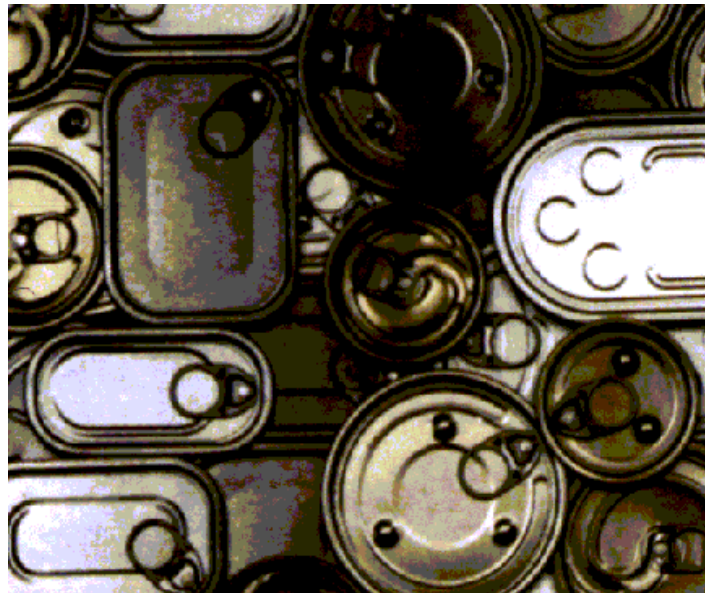
TALAT Training in Aluminium Application Technologies	Variety of Food Can Easy-Open Lids	3710.04.01

Steps in the formation of the integral rivet are shown in **Figure 3710.04.02**. The first stage is to form a bubble. This is usually the most critical operation; if a split rivet problem occurs a fault is often already apparent in the bubble. Highly polished tools and correct strip lubrication are essential. The flank of the bubble is thinned (coined) slightly to assist local metal distribution. The bubble is then redrawn to form the button (i.e. the rivet). The base of the lid around the button is thinned (coined) to extend more metal into the button. Finally, when the tab has been placed over the button, the riveting operation takes place during which the top of the rivet is thinned to extend the metal in the finished rivet head.

The score line is in the form of a truncated ″vee″ (**Figure 3710.04.02**) usually to a depth leaving about 0.085 mm residual metal in the vicinity of the rivet, but thickening slightly to about 0.110 mm on the opposite side of the lid. This is to satisfy the lid

opening criteria of ″pop″ value around 3 kg and ″tear″ value around 7 kg. Obviously limits are fixed to ensure that the score-line is not so weak that it fractures prematurely e.g. during processing or in-store handling, yet does not require so much force to open that the tab or rivet fails.


| TALAT | Steps in Forming an Integral Rivet and Section on Scoreline | 3710.04.02 |
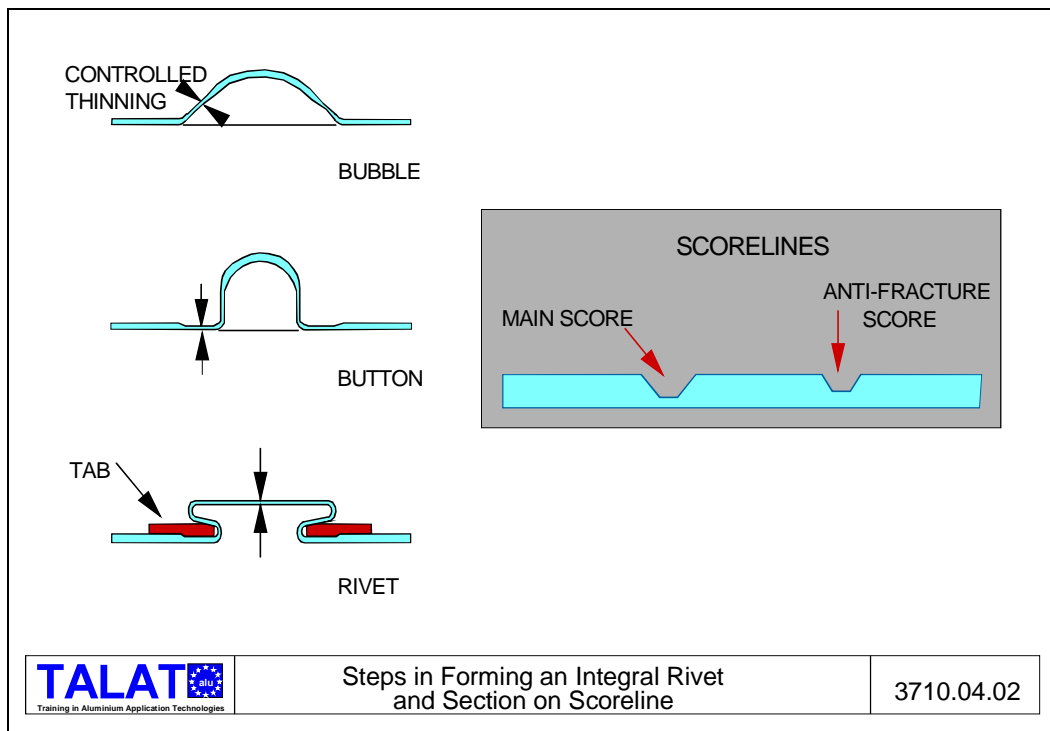
A secondary score line is usually formed at the same time as the main score line. This is a shallow score located just inside the main score line and is claimed to slow down the flow of metal from the main score and prevent score-line fracture during forming.

Today, virtually all beverage cans have an easy-open feature, either the original ring-pull tab or the later ″ecology tab″ (a stay-on tab) (**Figure 3710.04.03**). They are required in vast quantities of virtually one size, justifying the investment in high-speed, high-output machinery. On the other hand, not all food cans have easy-open lids, but rely on the use of a can-opener. Easy-open lids are restricted to those cans where convenience is a marketing factor, such as single-portion packs, or delicatessen products where the high value of the contents can carry the slightly higher cost of an easy-open lid. Easy-open lids for food cans are required in several shapes and sizes (e.g. rectangular fish cans) and are required in smaller quantities than beverage can lids, and are produced on less sophisticated (cheaper) equipment, but the basic stages are the same.

The usual method is to make easy-open lids in two steps.

1. Blanking and forming the plain lid (the shell press) plus curling the edge and applying lining compound; these are termed ″shells″,
2. Transferring the shells to a multi-tool transfer press (the conversion press) for embossing panels, forming the rivet, scoring and finally attaching the ring-pull tab.

Source: Alcan Deutschland

| TALAT | "Stay-on Tab" Version of Beverage Can Easy-Open Lids | 3710.04.03 |
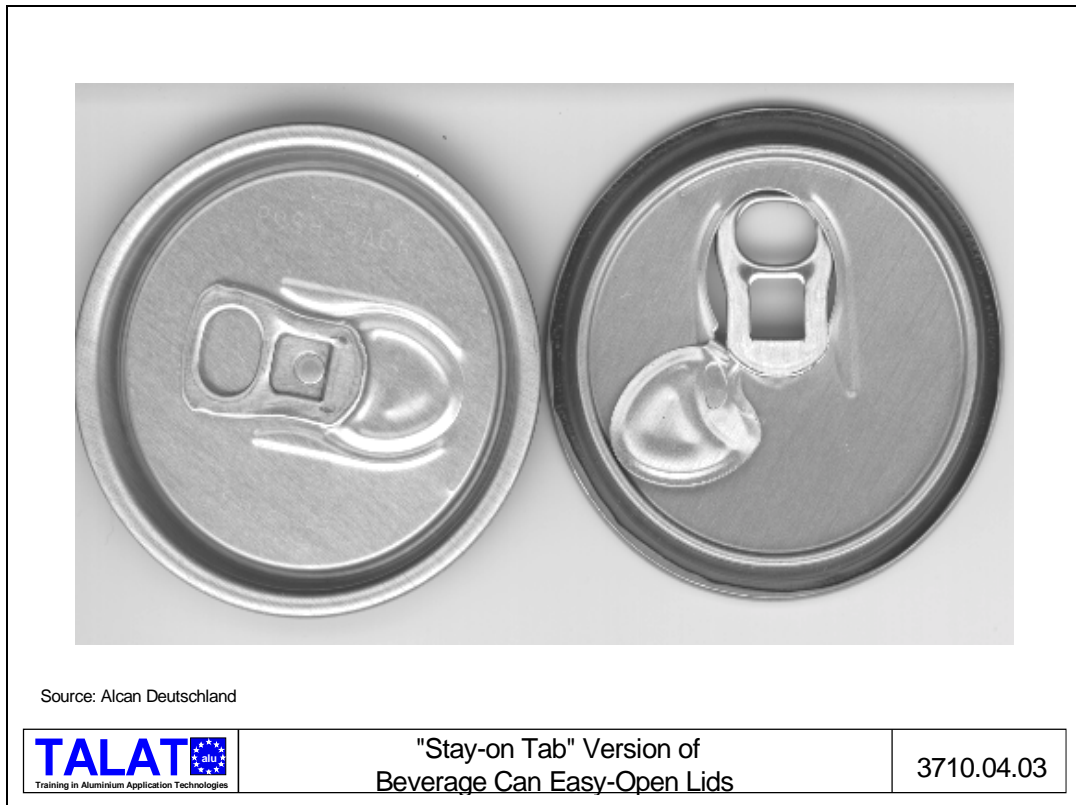
All easy-open can lids are produced from pretreated and lacquered coil. In the case of the beverage can lids, wide coils are used on 24-out shell presses, which can run at up to 300 strokes/min.

The second stage (conversion) press runs at 600 strokes/min, but can have 2, 3 or even 4 lanes (**Figure 3710.04.04**). The conversion press is a multi-stage transfer press, usually with seven stations although not all may be used. Typical is:

1. Form bubble (first stage rivet)
2. Form button (second stage rivet)
3. Form strengthening beads and panels
4. Form scoreline
5. Feed and locate tab over button, and rivet
6. Possible light panelling to remove buckles from centre of lid.

At the same time, the tab is being formed in another multistage transfer press situated adjacent to and synchronised with, the conversion press. The tab is formed in successive steps (**Figure 3710.04.04**) but is not detached from the strip which carries it transversely into the conversion press and locates the tab precisely over the rivet button. The riveting operation detaches the tab from the strip so that the completed lid with tab continues through the conversion press whilst the tab strip skeleton is fed across the line of the press and coiled for recycling.

Beverage can lids have to withstand 6.7 kg/cm^2 (95lb/in^2) internal pressure. As mentioned previously, down-gauging has been achieved by necking the can body and thereby reducing the diameter of the lid. Further gauge reduction has been achieved by drawing the central panel of the lid in two stages. The panel is a reverse redraw and when produced on a single tool resulted in stretching (thinning) of the panel wall. By

separating the drawing operation into two stages, the panel can be drawn without wall thinning, and the countersink can have a steeper (near vertical) flank, giving a stiffer profile and permitting the further gauge reduction mentioned.

Source: Stolle, USA

| TALAT | Multi-Lane Conversion Press Showing Tab Progression | 3710.04.04 |
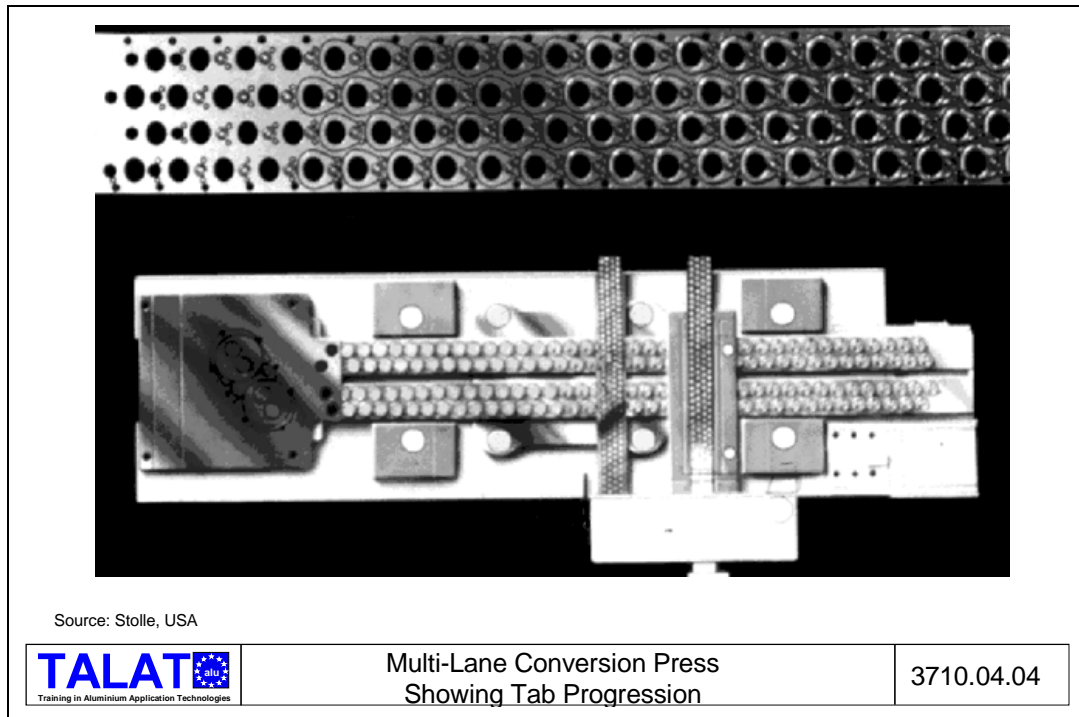
Easy-Open Can Lid Stock

Beverage can easy-open lids are manufactured from AA 5182 H48 lacquered strip, 0.26 mm thick for the reformed 206 lid. Food can easy-open lids are produced from AA 5052 H44 lacquered strip, usually 0.25 mm thick but sometimes 0.28 mm thick for the larger lids. Tabs for beverage can lids are manufactured from AA 5042 H18 (as rolled) strip 0.45 mm thick. Tabs for food can lids are manufactured from the same material but in the H48 (lacquered) condition as plain material may discolour during the food can steam processing operation (**Figure 3710.04.05**).

Internal lacquers for easy-open lids have to possess good formability for the integral rivet and good pressure resistance where the score-line is formed, as well as good overall adhesion and compatability with the product. Organosol lacquers have performed well in the past but, as mentioned previously, organosols are now going out of fashion. Non-PVC lacquers (such as epoxy-modified polyesters) are under intense development but at present (January 1993) non satisfies all requirements, so 2-coat organosol systems at 12-15 g/m^2 film weight are still the main coating used for the inside of easy-open lids. The external lacquer is usually a clear epoxy-amine at around 3-5 g/m^2 film weight.

Alloy		Composition %							Properties		
			Si	Fe	Cu	Mn	Mg	Cr	U.T.S. MPa	0.2% Proof MPa	Elong % min
FOOD CAN LIDS	AA 5052	Min	0.00	0.00	0.00	0.00	2.20	0.15	240	190	
	H44	Max	0.25	0.40	0.10	0.10	2.80	0.35	280	240	6
FOOD CAN TABS	AA 5042	Min	0.00	0.00	0.00	0.20	3.00	0.00	330	280	
	H48	Max	0.20	0.35	0.15	0.50	4.00	0.10	370	320	5
BEVERAGE CAN LIDS	AA 5182	Min	0.00	0.00	0.00	0.20	4.00	0.00	355	310	
	H48	Max	0.20	0.35	0.15	0.50	5.00	0.10	400	350	5
BEVERAGE CAN TABS	AA 5042	Min	0.00	0.00	0.00	0.20	3.00	0.00	330	300	
	H18	Max	0.20	0.35	0.15	0.50	4.00	0.10	380	350	3

TALAT	Easy-Open Lid Alloys (Properties according to Euronorm)	3710.04.05

Lid Seaming

Both beverage and food can lids are fitted to the can body after filling by a double lock seam (**Figure 3710.04.06**). There are basically two stages. First, the rim of the lid is curled under the body flange which is then bent down, and second, the seam is closed tight. Today, beverage can filling lines, with integrated lid placement and seaming, run at up to 2,600 cans per minute.

TALAT	Steps in the Formation of a Double Lock Seam	3710.04.06
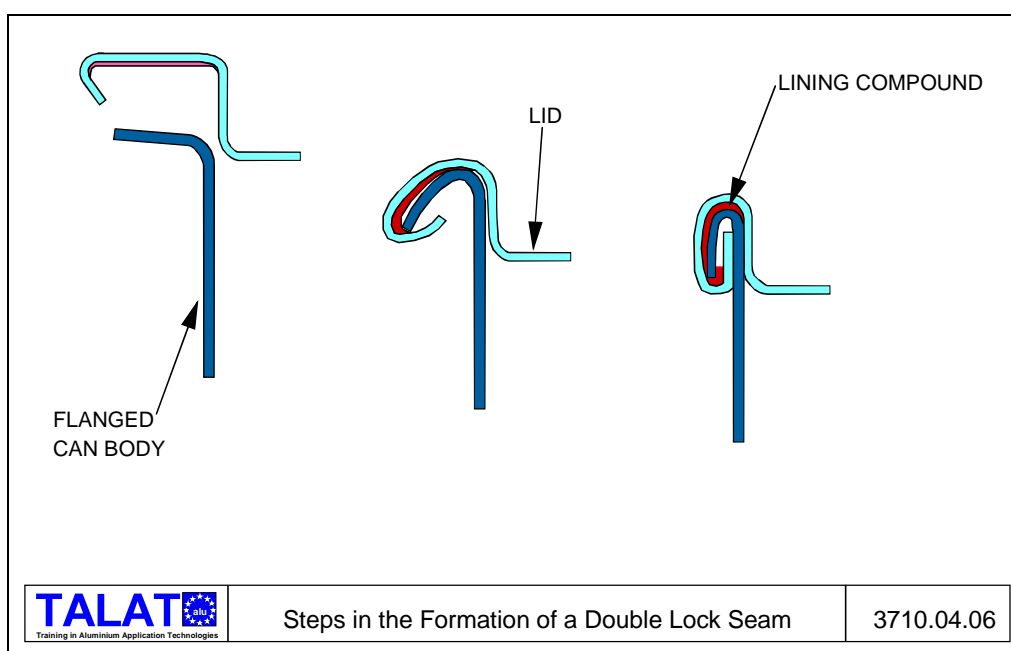
3710.05 Future Developments

Aluminium food cans are at present used where the customer appreciates the convenience of an easy-open container, or where a very long storage life is required such as for military or emergency stores. The first factor (convenience) could lead to some future growth in the demand for aluminium food cans. However, a third factor, recyclability, which has been such a dominant factor in the acceptance of the aluminium beverage can, has been virtually unexploited in the case of the food can. Ecological pressure (even legislation) could well provide the future motivation for aluminium cans replacing steel cans for a wide range of food products.

Concerning the beverage can, this will increase its dominance over the steel competitor as other countries develop used can collection schemes and install recycling centres. The present beverage can body alloy, AA 3004, has a strength limitation imposed by the pick-up on ironing dies if the composition exceeds 1.3% Mg. The development of a coating (lacquer or laminate) which could withstand the severe wall-ironing operation would enable precoated aluminium of virtually any alloy to be used, as die pick-up would no longer be a problem. The use of, say, a high magnesium alloy would lead to considerable gauge reduction for the same strength of can, and could offer a cost saving which would improve even further aluminium's advantage over other beverage container materials.

3710.06 List of Figures