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STERILIZABLE SEMI-RIGID ALUMINIUM CONTAINERS FOR FOOD PACKAGING 1/

by

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SUMMARY

This paper deals with the introduction of the sterilizable semi-rigid aluminium foil food container as a viable product available for use with a wide range of food products. This introduction has been the culmination of 5 years' research work by Alusuisse, dealing with such aspects as selection of materials, both of the aluminium foil and the interior lining that serves as the heat-seal medium for the lid and that provides an inert barrier to foodstuffs, methods of forming, development of heat-seal machinery and establishment of sterilization procedures. These matters are discussed in the paper, and a conclusion is reached that a plastic coated, or in some cases, lacquer coated aluminium foil container can be successfully sterilized with many products. Easy-opening is a particular feature of this type of container, which thus offers advantages over many designs of tin-plate can and glass jar. Economically, the product competes with glass jars and in some cases, dependent on size, with drawn tinplate cans. The body-seamed tin-plate can remains cheaper, but this new aluminium container is worthy of consideration where other factors, such as design flexibility, attractive appearance, easy-opening and stackability are important. The container has had particular success in the continental fish-canning industry, but has wide application for meat and paste products, baby foods and perhaps even pet foods.

INTRODUCTION

Over the years the tin-plate container has proved a safe and efficient vehicle for food preservation and one that is extremely economical to produce. Standardisation, the price we have had to pay for these benefits, seemed of little account in the past compared with the advantages of cheap long-term storage for a great variety of perishable foods.

Today, there are signs that this situation is beginning to alter: an affluent public with higher expectations of variety and convenience has grown up creating new demands on the product and its container. New developments in heat-and-serve meals and the widening choice of luxury foods are aspects of a trend towards higher quality and service that are reflected in packaging as well. Features such as easy-opening, novel shapes and attractive finishes are no longer inessentials but factors that are going to repay more attention in the future.

The advantages of aluminium for packaging - light weight, easy-formability, attractive appearance and food compatibility - looked highly suitable for application in many areas and encouraged a number of post-war attempts to replace tin-plate by aluminium. A direct substitution of one material for another proved, however, to be an uneconomic proposition. To utilise aluminium it is necessary to appreciate and use its advantages to the maximum. This appreciation has lead to a variety of possibilities, and the easy-open can end is a spectacularly successful example. In the field of aluminium foil the popularity of the semi-rigid, wrinkle-wall container over the past ten years, for a variety of food packaging applications, was the starting point for work undertaken by Alusuisse to develop a foil container suitable for sterilized foods. This search has led to the introduction of a smooth-wall foil container having a heat-seal coating of either lacquer or plastic film that could be lidded and sterilized and that offered a smooth attractive outside surface for printing and lacquering coupled with immense design possibilities regarding container shape.

In other areas this search to utilise aluminium's advantages fully, has led to the establishment of the principle that a foil pouch, comprising a complex foil/film laminate could provide a sterilizable container.

"STERALCON"

Five years ago the Swiss Aluminium Group embarked on a programme of research and development to establish techniques and materials for producing a smooth-wall foil container that could withstand commercial high temperature sterilizing processes and would be suitable for the widest range of applications.

From the beginning the concept was adopted that as the aluminium required a protective coating to withstand attack from a number of food-stuffs, it would be desirable to have a double-purpose coating - namely, one that would protect and would also provide a sealing medium. Thus work centred on providing a heat-seal coated container and lid material.

It was also appreciated that one of the main draw-backs of the tin-plate fish can (to take one example) was the extreme difficulty of opening. A prime requisite of the ultimate pack was, therefore, one that not only provided a perfect tamper-proof seal but that gave a means of being easily opened. Much work had to be done before this apparent contradiction of requirements could be provided.

At the starting point no work had been done on high-speed forming of thermoplastic-coated foil materials, and there was no experience to indicate what combination of foil/film materials, lacquers and heat sealing techniques would give the best all-round performance at a realistic cost.

Research was, therefore, centred mainly on six requirements:-

1. Foil gauges and alloys had to be selected that would be strong enough to resist puncturing and impacts, yet were capable of forming well at high speed in conjunction with a thermoplastic coating.

2. An inert, high temperature resistant inner coating was needed to form a bacteria-resistant seal and a complete barrier between the foil and the contents.

3. A method has to be found of bonding this plastic film to the aluminium foil so that it would not delaminate during forming, under impact, or as a result of flexing under pressure at high temperatures in the autoclave.

4. A special heat-resistant protective lacquer was needed for the outside of the container that could be coloured and printed, would withstand forming, and would not be affected by the high temperatures of sterilization or pressure sealing.

5. The lid had to satisfy "easy-open" requirements.

6. Commercial sealing machinery had to be developed and the necessary sealing and autoclaving conditions had to be established to produce packs that were 'commercially sterile' for a wide variety of products.

The successful outcome of these researches was the "Steralcon" (= sterilizable aluminium container) known in the UK as "Stera-Pak", which proved itself in laboratory trials and has now been tested for over 4 years in a number of medium-scale commercial applications.

Basically, a smooth-walled semi-rigid heat-sealable container, the Steralcon consists of a 0.060 mm - 0.14 mm foil body with a 0,015 - 0,050 mm polypropylene or polythene liner and a lid of 0.50 mm - 0.110 mm foil with a polypropylene or polythene liner. (Fig.1). The lid is applied by pressure and heat-sealing to form a fully sterilizable, hermetic and bacterial-resistant pack with the following advantages:-

a. <u>Easy Opening and Disposal</u>

No key or can-opener is needed. The lid can be quite easily cut open with a knife, or can be supplied in a tear-tab version that simply peels off. There are no sharp corners and the container can be crumpled up for disposal.

b. <u>Individual Shapes and Sizes</u>

Containers from 10 ml.- 600 ml. capacity can be made in round, oval, triangular, square or asymetric shapes, and can also be contoured to the shapes of individual products. (28.4 ml. = 1 fl.oz).

c. <u>Attractive Appearance</u>

The good looking, smooth-walled, seamless container can be produced in a range of colours that retain their attractive finish after exposure to the high temperatures of sealing and sterilization. Work is in progress to extend the range of colours, and to develop decorative printed finishes.

d. <u>Good Display Features</u>

Conical shapes permit stable stacking of filled containers with consequently better use of valuable display space.

e. <u>Lightweight</u>

Size for size any number of Steralcon containers weigh approximately one-fifth the same number of tin-plate cans.

f. <u>Space Saving</u>

Nested, when empty, containers occupy only a fraction of the space needed for straight-sided cans. Handling, transport and storage costs are thus lower than with glass or tin-plate.

g. <u>Improved Shelf Life</u>

The inner coating is chemically inert and communicates no odour or off-flavour to the contents, even after prolonged storage. The number of products for which the container is unsuitable is very few. In the case of certain foods, tests have shown that flavour and/or appearance are better after 2½-3 years' storage, than when the same foods are stored in tin-plate.

h. <u>Storage in Use</u>

Because of (g), products can be stored in containers after opening without the development of odours or tainting.

i. <u>Impervious to Light and Odours</u>

The outer foil skin makes the container completely impervious to light and odours.

j. <u>Non-corroding</u>

Corrosion, due to temperature fluctuations and condensation, which can be a problem with tin-plate containers, does not occur with the aluminium container.

k. <u>Shorter Processing</u>

Due to rapid heat penetration of the shallow foil container, it may be possible to cut sterilizing time for certain products, with resulting improvements in flavour and colour.

l. <u>Resistance to Breakage</u>

The foil container, although easily deformable, does not break.

FOIL STRIP DEVELOPMENT

When work on the Steralcon began, the techniques of forming aluminium foil into various container shapes were still in their early stages and no work had been done on forming foil laminates. Various problems had to be overcome. In particular, aluminium foil had to be provided in the correct metallurgical condition to give the required forming characteristics and in addition a thermo-plastic coating had to be found that had matching properties and could withstand high-speed forming and subsequent container processing without cracking or delaminating.

At the same time as the container materials were being evaluated, various forming techniques were being considered and initially tests were carried out with air-forming techniques as well as with the conventional deep-drawn method.

Early experimentation aimed at observing the effect of forming on the various container materials used and a careful study was therefore made of deep-drawing practice and theory. In particular, relationships were established between the size of blank (or plain foil shape) and the diameter of the container produced. The blank size was found to be critical and ratio factors between the blank diameter and the internal container diameter were established for a wide range of metal thicknesses.

Air-forming techniques showed early promise but severe limitations regarding container shape (only shallow sides proved possible) led to this particular forming method being discarded. It was considered that it could not offer any advantages over the traditional mechanical forming method.

Deep drawing tooling has been developed to offer a choice of several different shapes of container, including some with fluted sides. These have been produced to indicate the wide range of possibilities and show that individually tailored shapes and profiled containers present no problem.

CHOICE OF THE LAMINATE

The choice of the plastic heat-seal material may be made between a lacquer and a film. Work has been, and continues to be done on both, but in this paper the main references are to the film variety which formed the starting point of the research. At the present stage of development it is considered that the plastic laminate is the most universally applicable and has a greater margin of safety. The lacquer version is suitable for a much more limited range of products and may be more critical in use. Its advantage over the plastic laminate, however, is its lower cost and so development on this material will continue.

ESTABLISHMENT OF THE POLYPROPYLENE LINING

Originally the thermoplastic coating was a low pressure polythene laminated to the foil by a high pressure polythene extrusion. Two main technical disadvantages became apparent; firstly, the material suffered from built-in stresses that gave rise to stress cracking unless a stress relieving operation was performed on the containers, and secondly, the extruded polythene had a low melting point and tended to weaken during the heat of sterilization, thus setting up a risk of delamination. A third problem was commercial in as much as an uncertain supply situation arose. These three reasons led to the material being dropped in favour of a polypropylene that could be laminated with a different formulation of adhesive.

STORAGE TESTS

To test various laminate combinations many different products were filled, sealed and sterilized in the containers and then stored for varying periods ranging from 1 to 3 months and for the more promising materials 12 months. In addition to such tests at room temperature accelerated tests at both 35 °C and 50 °C were carried out.

MATERIALS

Alloys

Most experimental work has been carried out using a 98.75% aluminium alloy. This has good forming characteristics, and also slightly higher strength than 99½% (commercial purity).

Soft temper alloys have th best drawing characteristics, but work is in hand to develop containers in hard and intermediate tempers to give increased strength and rigidity.

Range of material thickness

Aluminium	Container	.060 mm - .140	mm
	Lids	.050 mm - .110	mm
Polyethylene/Polypropylene		.015 mm - .050	mm

The figures quoted above are not absolute minima and maxima but represent the range on which successful results have been achieved so far. The particular choice of thickness depends on the container size and strength requirements.

Aluminium/Inner Coating Bond Strength

Using the current choice of adhesive (a special two component adhesive) delamination tests on a strip 15 mm wide showed a tear strength of 500-1000 grammes. Similar tests after heating to 121 °C showed that a slight reduction of tear strength occurred; the value, however, does not fall below 400 grammes. These results have appeared satisfactory in practice, being sufficient to withstand the stresses of mechanical forming as well as the deformation effects that occur when filled containers are subjected to impact tests.

Outer Stove Lacquered Surface

Steralcon has an outer coating of a specially formulated stoving lacquer. The lacquer has both a decorative and a functional purpose:
firstly it provides an enhanced appearance and secondly it protects the foil from staining and discoloration by food juices or the effect of high-temperature steam sterilizing. Like the interior lining, this coating is applied to the foil strip.

SEALING

Steralcon containers are closed by the welding of two heat-seal surfaces. The actual seal area is an annular ring 2-3 mm. wide between the horizontal rim of the container and the superimposed lid. At temperatures of about 150°C, the plastic begins to flow and at this point the pressure that is applied round the rim during the sealing operation results in the formation of a continuous bead at both the inner and outer edges of the seal. Provided temperature, pressure and dwell times are accurately adjusted, a completely fused, hermetic and bacteria-resistant seal is obtained.

For best results the seal area should be free from product contamination and for this reason filling equipment with absolutely clean cut-off is needed. Laboratory tests and commercial experience has shown, in some cases, however, that fully reliable seals can be obtained even through a portion of the packed product. As an example of this it can be stated that in extensive laboratory trials on the packing of sardines in olive oil, completely hermetic seals were obtained even though in all cases the seal area was 100% contaminated with olive oil.

The low failure rate (not greater than 0.05%) during the commercial packing operations at a fish-canning plant in Germany also speaks for itself, for all containers are deliberately overfilled before sealing, so that seal area contamination is unavoidable.

Pressure, temperature and dwell times are functions of the container size, foil thickness and product temperature.

Considerable experimental work was carried out on plastic flow during varying conditions of sealing temperature and pressure. It was found necessary to have differential heating on the top and bottom tools and to control pressure accurately so as to avoid too much flow of the sealing compound.

The following figures indicate the range over which effective sealing takes place for different sizes of container:-

Top tool temperature	230° - 280°C
Bottom " "	120°C- 150°C
Sealing pressure	80-150 Kp/cm^2
Dwell time	0,5 - 1.5 sec.

To prevent build up of internal pressure due to rapid heat transfer by the foil to the inside of the container, lids should be cooled during sealing, and the cooling extended for fractionally longer than the duration of the seal. Figure 2 shows a schematic cross section through a sealing tool.

TEST PROCEDURES

A number of procedures have been developed for testing the quality of Steralcon seals. These are briefly discussed as follows:-

a. Seal Sections

Sections taken through the seal area show the amount of plastic flow and by experience the requirements for a good seal have been established. (See fiqure 3).

b. Pouch remain test

A second experimental test is to etch away all the aluminium from the container until just the plastic 'pouch' remains. Visual examination determines the film thickness throughout the seal area and enables the effect of pressure, temperature and dwell time variations to be observed and plotted.

c. Burst pressure test

Experience has shown that for a container to withstand sterilization successfully, a seal strength of 4-8 kg/cm^2 is required. This test measures that strength.

The procedure consists in placing the container in a frame so that it is supported at all sides except at the seals. An air-inlet needle pierces the bottom of the container, the unit is closed, immersed in a water bath and the air pressure turned on. This pressure is increased until seal failure occurs. A schematic representation is shown in figure 4.

d. <u>Seal thickness test</u>

The earlier three tests are all destructive and hence of value in research but not for providing a quality control procedure in a production plant. This particular test is non-destructive and so has a commercial value.

The technique consists in measuring the thickness of the foil/plastic/foil rim of the container at eight places. For any given thickness of foil and plastic coating there is a given deformation that must take place for a good seal. This instrument (patented by Alusuisse) can therefore be set-up to show the after-seal thickness of the rim and to indicate when the required thickness is not obtained. The system is currently only used for checking a percentage of output but there appears to be no reason why such a system could not be incorporated on high-speed automatic machinery in order to give 100% inspection.

SEALING MACHINES

For test purposes, laboratory scale sealing machines were developed and later adapted for semi-automatic pilot and medium-scale operations. One of these models is the F.2, a compact, mobile unit which handles any of the several standard container shapes at an output of 800 packs an hour. In a fish canning line, in which the containers are overfilled, a station has to be incorporated for pressing down the lids of the containers and rinsing before the sealing cycle begins. A combination of two semi-automatic units was designed for this purpose and integrated into a single system which is successfully processing around 1,000 containers an hour. (See figure 5).

For large scale commercial operations several leading machinery manufacturers are offering automatic sealing machines which can reach an output of up to 100 containers per minute.

PACKAGING LINES

The whole process from the coil to the closed containers is illustrated in figure 6. As shown, this process can be divided into the following 6 steps:

1. The containers are formed from the coil by punching and deep drawing.

2. The containers are filled manually or automatically.

3. The filled containers are covered with a lid which is also punched from the coil.

4. The containers are sealed by applying heat and pressure.

5. The closed containers are sterilized in autoclaves.

6. The sterilized containers are prepared for shipment.

All these steps can be carried out by special machines which have proved their reliability in several years of application. These machines can be set up in a way which to a high extend allows automatic transportation of the containers between the single steps.

On the other hand, there have also been developed special machines which combine several of these steps. Thus, as an example, figure 7 shows a machine for forming, filling, lidding and sealing. Such a machine can produce up to 80 - 120 sealed containers per minute, depending on the size of the container.

EASY OPEN LIDDING

Easy-opening has been part of the marketing-oriented brief for Steralcon throughout all the development of the containers. Indeed, the obtaining of a really good easy-open system that was also fully secure has proved to be the last problem to be solved.

Although, with very little effort, the Steralcon container (particularly of the fish can size, 188 cc.) can be readily cut open with a knife, something more convenient was considered desirable. This was in spite of market research carried out in Germany that indicated full consumer acceptance of the knife-opening method (See Figure 8).

In 1963 development work began on a variety of tear string devices used in conjunction with polythene-coated lid. All attemps to produce a 100% bacterial-proof seal in this way, however, failed.

Finally, various foil/film combinations were tried out to obtain a peel-open seal. In the majority of cases it was found that either the foil delaminated from the plastic, leaving a diaphram inside still requiring piercing to open, or the seal was too strong to be pulled apart. However, in 1967 it was found that successful results could be obtained under particular sealing conditions if for the lid a laminate of foil and thin, biaxially prestressed polypropylene film was used in combination with a normal foil/polypropylene container. (See figure 9).

It is evident that the burst strength of such a seal, if it fulfills the easy-open requirements must be lower than that of a normal seal. Nevertheless, a sufficiently high strength has been obtained to enable the container to withstand sterilization with an adequate margin of safety.

STERILIZATION

Because of the tendency of the thermoplastic material to soften and weaken during high temperature sterilizing, counter-pressure autoclaving for Steralcon containers is essential. The build-up of internal pressure in the sealed container depends on a number of factors, of which the most important are:-

a. the nature and rate of expansion of the fill

b. the expansion of the container

c. the deformation of the container and lid

d. the amount of headspace

e. the effect of gases driven off when the filling is heated,

To prevent deformation and seam failure, head space must be kept to a maximum of 5% or lower, and counterpressure, ideally, to 37 p.s.i. applied at 120°C - 121°C. Adequate, though borderline results have been achieved using a lower pressure of 32 - 30 p.s.i., whereas below 30 p.s.i. failures occurred.

For good results, counterpressure must be applied as soon as heating starts and maintained during cooling down to a temperature of at least 40°C. It is also important that containers are firmly packed in the sterilizing chamber and separated between layers.

A schematic representation of the required pressure/temperature variations during the sterilization of Steralcon containers is given in Figure 10.

For specific containers and fillings the counterpressure figure will vary considerably so that the curve can only serve as a rough guide. The upper curve shows a counterpressure which is constant throughout the sterilization process, which has also been found to give satisfactory results (Figure 10).

Sterilizing cycles, of course, must be worked out individually and will depend on such factors as the pH value of the fill, the Fo value required, the heat transfer properties of the fill and the shape and size of the containers.

Aluminium has rapid heat-transfer properties and these combined with the relatively shallow depth of the containers suggest that it may be possible to shorten sterilization times for some products generally packed in squatter containers of glass or tinplate. Work still remains to be done on this aspect of relative heat transfer properties. Any shortening of sterilization time that is possible should have the effect of improving the flavour and/or colour of the product.

PRODUCT ACCEPTABILITY

Tests have been carried out on a wide range of products and good results achieved for all but a few products.

Even for products with pH factors below 3, Steralcon has been used successfully. The packaging of products having such a low pH value, however, is subject to prior testing, as some of these acids might attack the plastic lining and cause delamination.

The range of products that can be used with an interior lacquer lining rather than a polypropylene liner is more limited and a pH value of 5 to 9 is needed. In practice this allows the use of Steralcon with meat and fish pastes, which are two products of particular interest for this type of packaging.

CURRENT COMMERCIAL SITUATION

At the present a substantial amount of Steralcon-foil is being produced by Alusuisse and converted into containers by several users.

In one of the largest operations, herring fillets in four different sauces are being produced at a high rate. The container used for this operation is an oval, non pull-tab type of 188 cc. capacity. Very often the containers are packed in a full-colour printed carton to provide shelf appeal and a measure of container protection.

In Switzerland the Steralcon packaging system has found broad application for all kinds of meat products and prepared meals (see Figure 11). Five large manufacturers of this kind of food are now using Steralcon for their products.

The amount of interest generated by the success of these operations has attracted the attention of leading international food manufacturers, some of whom are now introducing Steralcon for their products.

The economics of Steralcon versus tin-plate, glass and other competing packaging materials varies from country to country and is not the subject of this paper. However, it seems obvious that the Steralcon initially at any rate, must be more expensive than tin-plate, where the latter is used for seamed cans. Where, however, a one-piece can - such as the fish can - is involved, then a cost parity exists for small sizes with the disparity in favour of tin-plate increasing as the container size increases above 150 cc. Tin plate with easy opening device also comes about to the same price level as Steralcon.

Price alone, however, cannot be the sole determining factor, equally important are appearance, appeal and ease of opening.

CONCLUSION

For selected applications where there is a demand for attractive, easy-open containers, the semi-rigid sterilizable aluminium foil container offers advantages not possessed by other materials.

It is not a universal alternative to the tin-plate can but one which is likely to command considerable interest for the packaging of fish and meat products.

Extensive research followed by experience in commercial operations has helped to [illegible] the Steralcon system to the point where it can be confidently offered to food processors in the whole world.

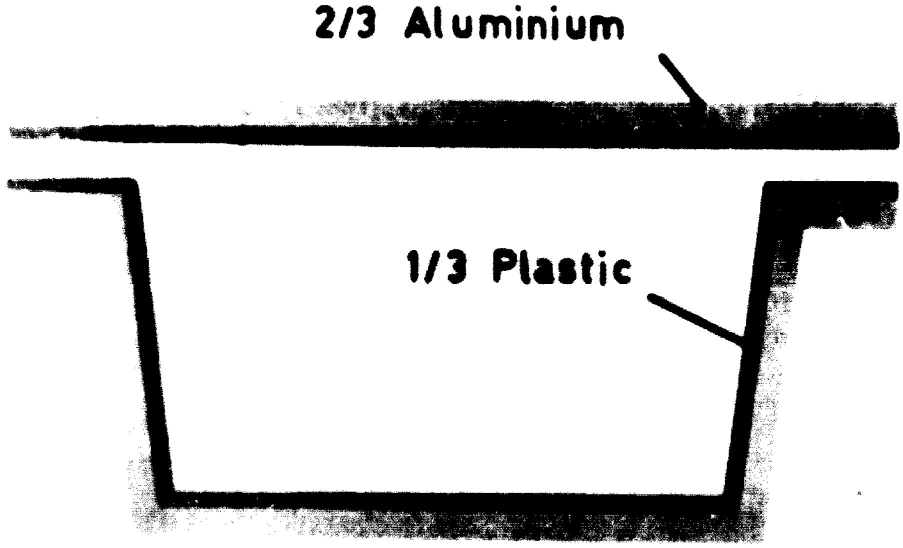


Figure 1: Section through the Container (schematic)

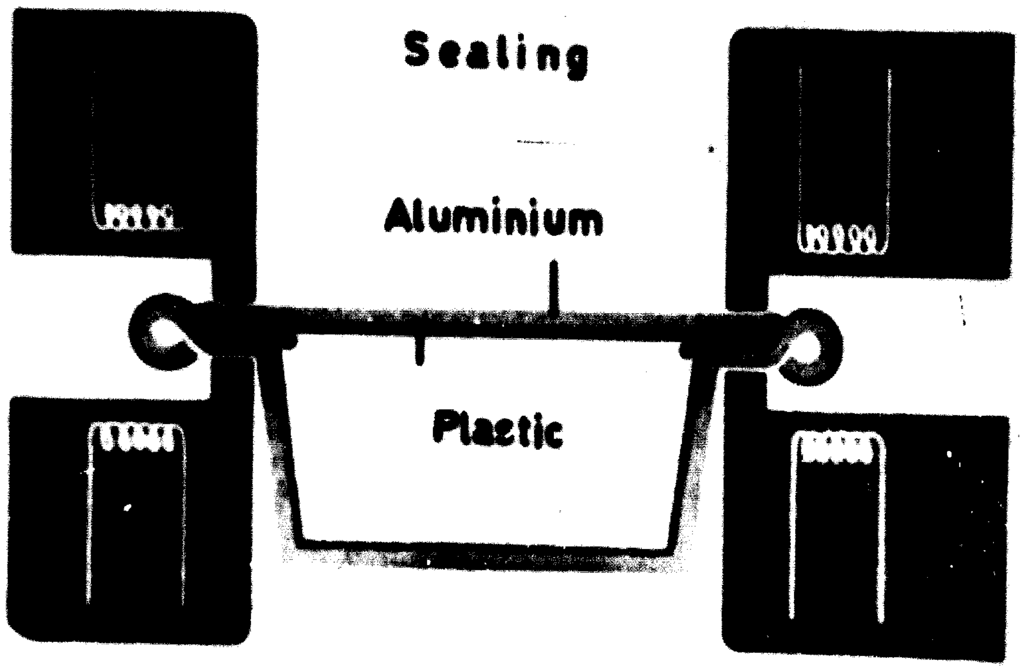


Figure 2: Section through Container and Sealing Tool

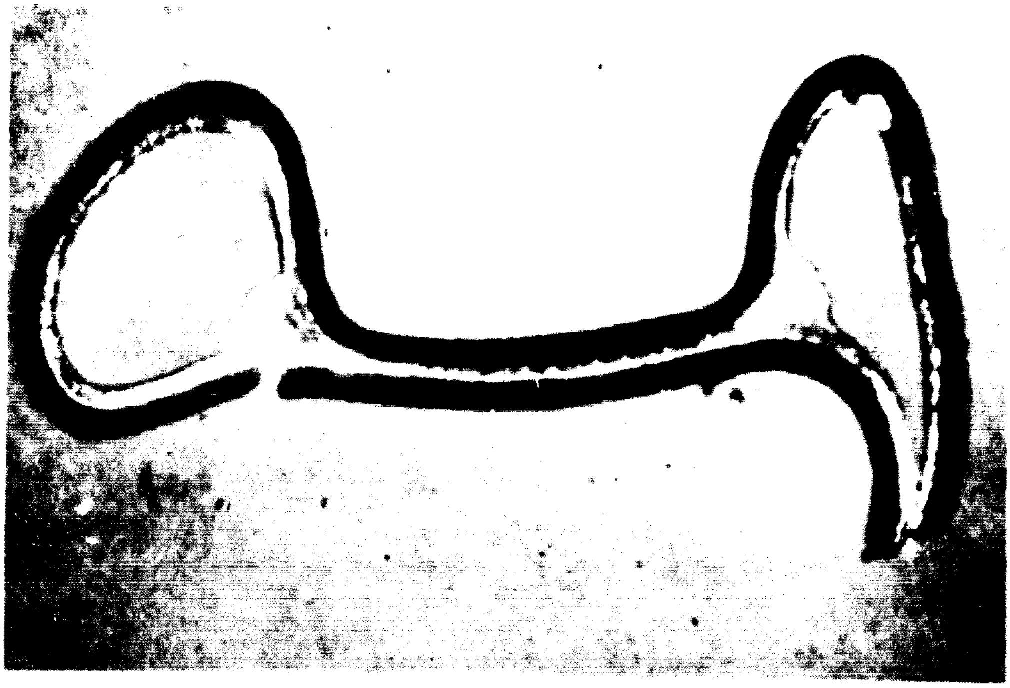


Figure 3: Flow of the Plastic Layer during the Sealing Process is revealed by this magnified Section through the Seal Area

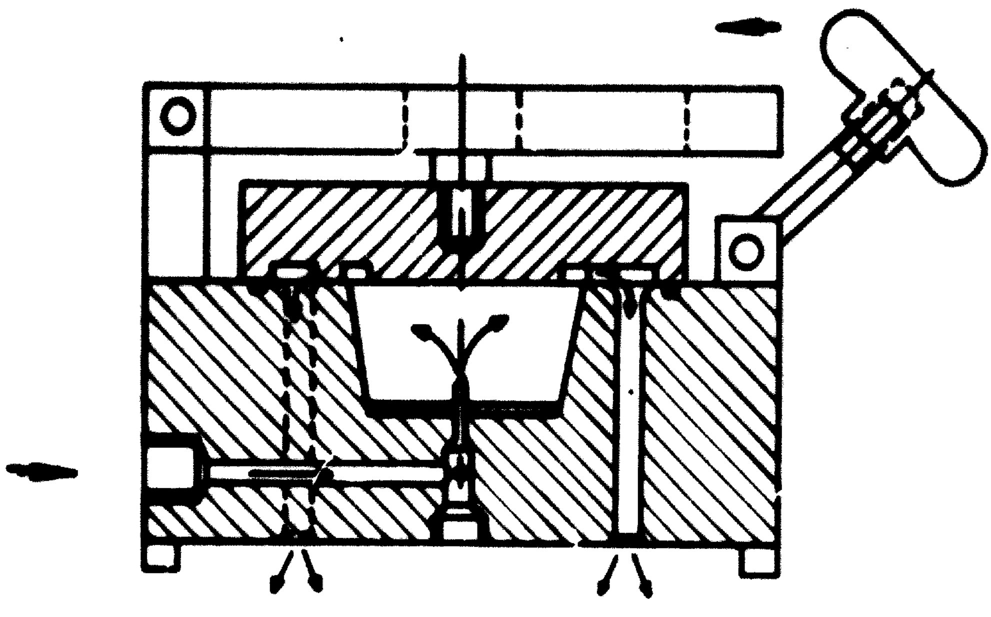


Figure 4: Seal strength measurement Test

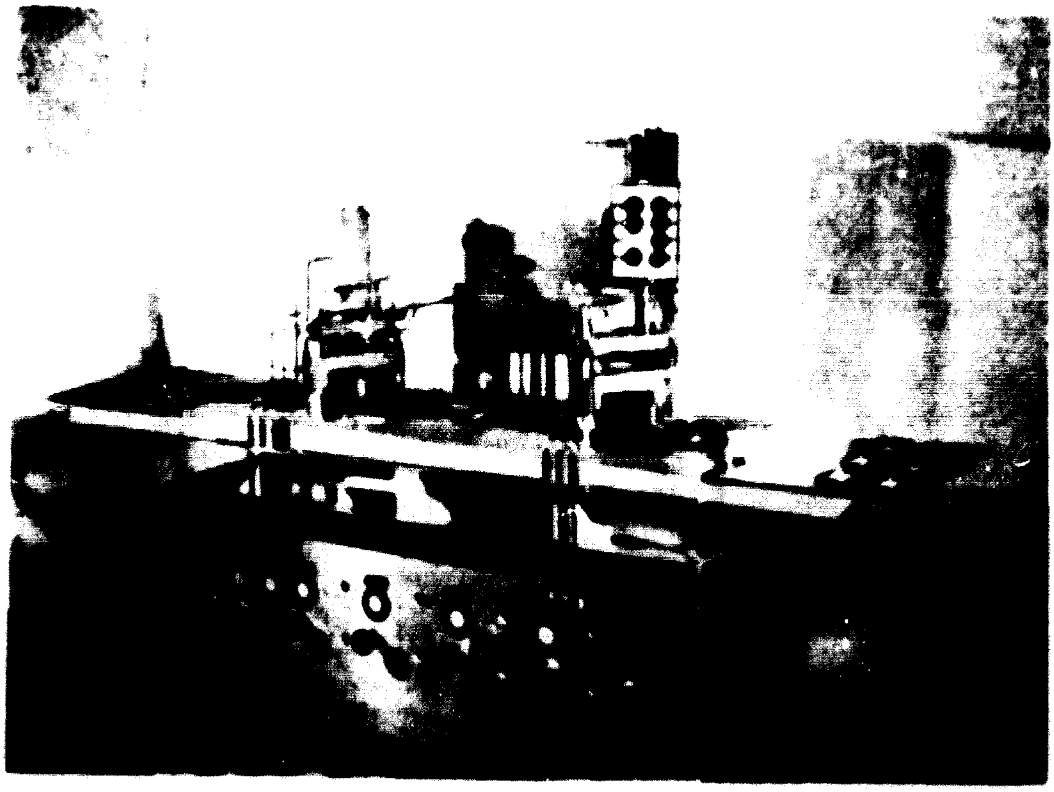
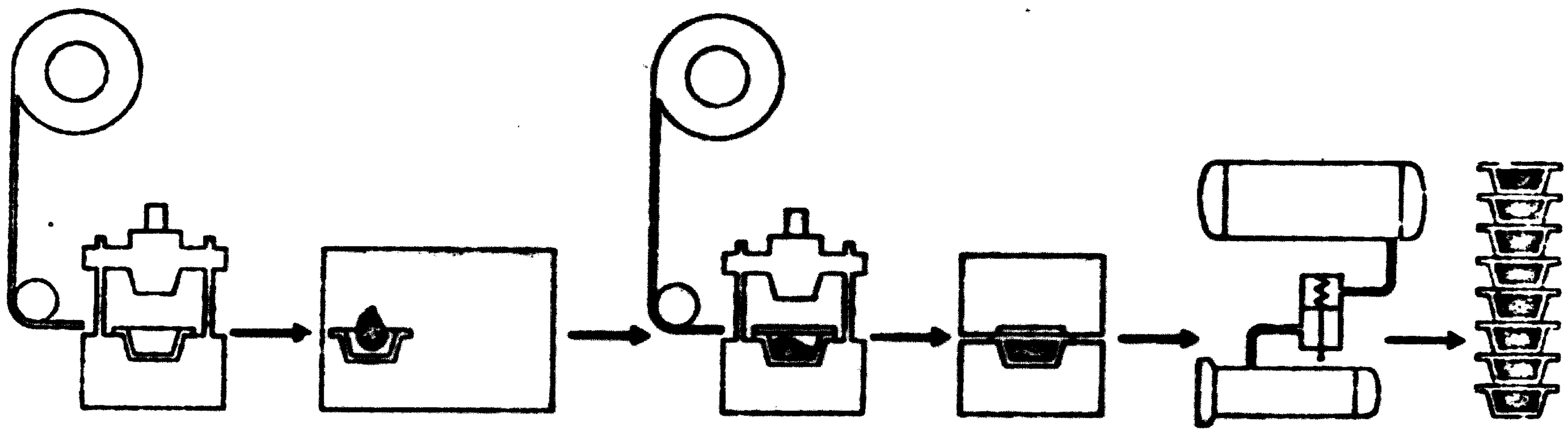


Figure 5: Washing and Sealing Machine used in packing fish

Packaging Line with Steralcon



1 Forming of the containers from the coil

2 Filling by hand or automatically

3 Lid-punching and container lidding

4 Sealing

5 Sterilizing applying counter pressure

6 Preparing for shipment

Figure 6

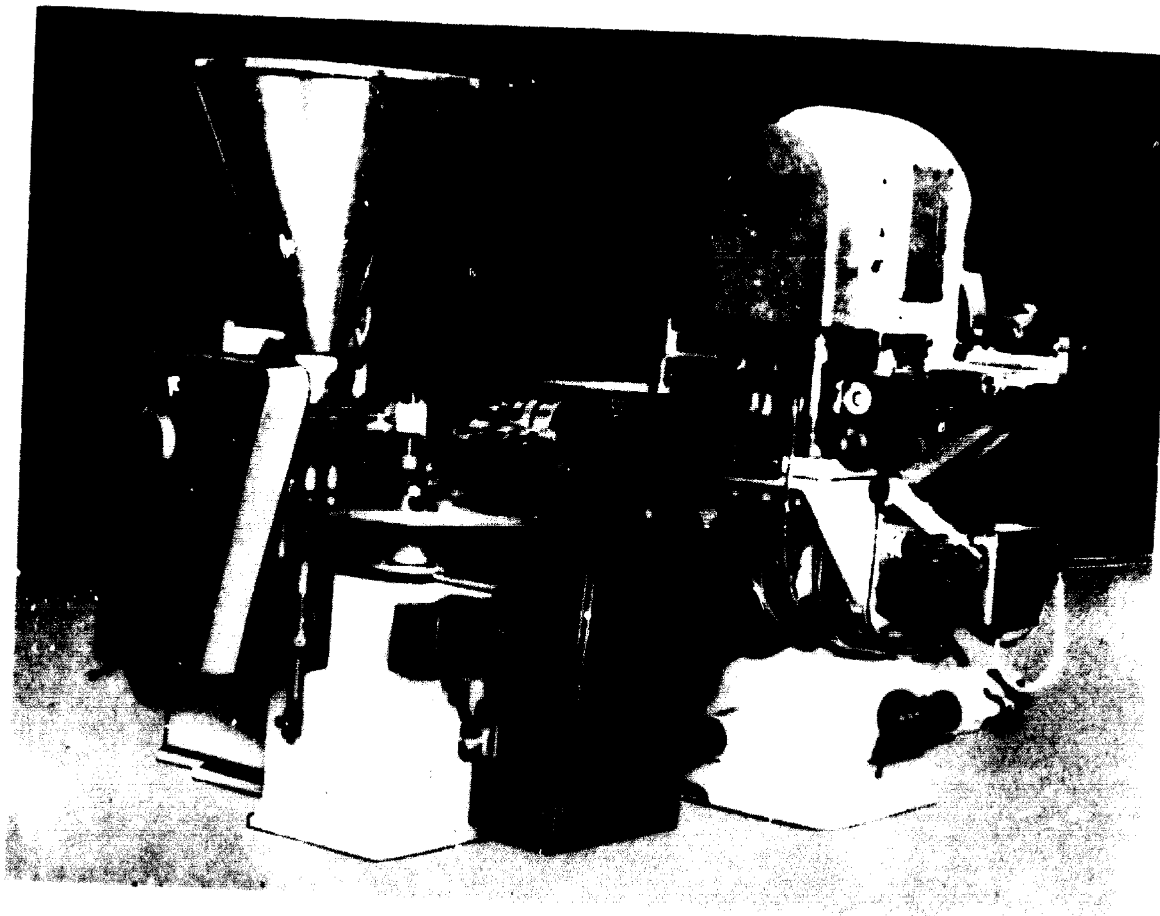
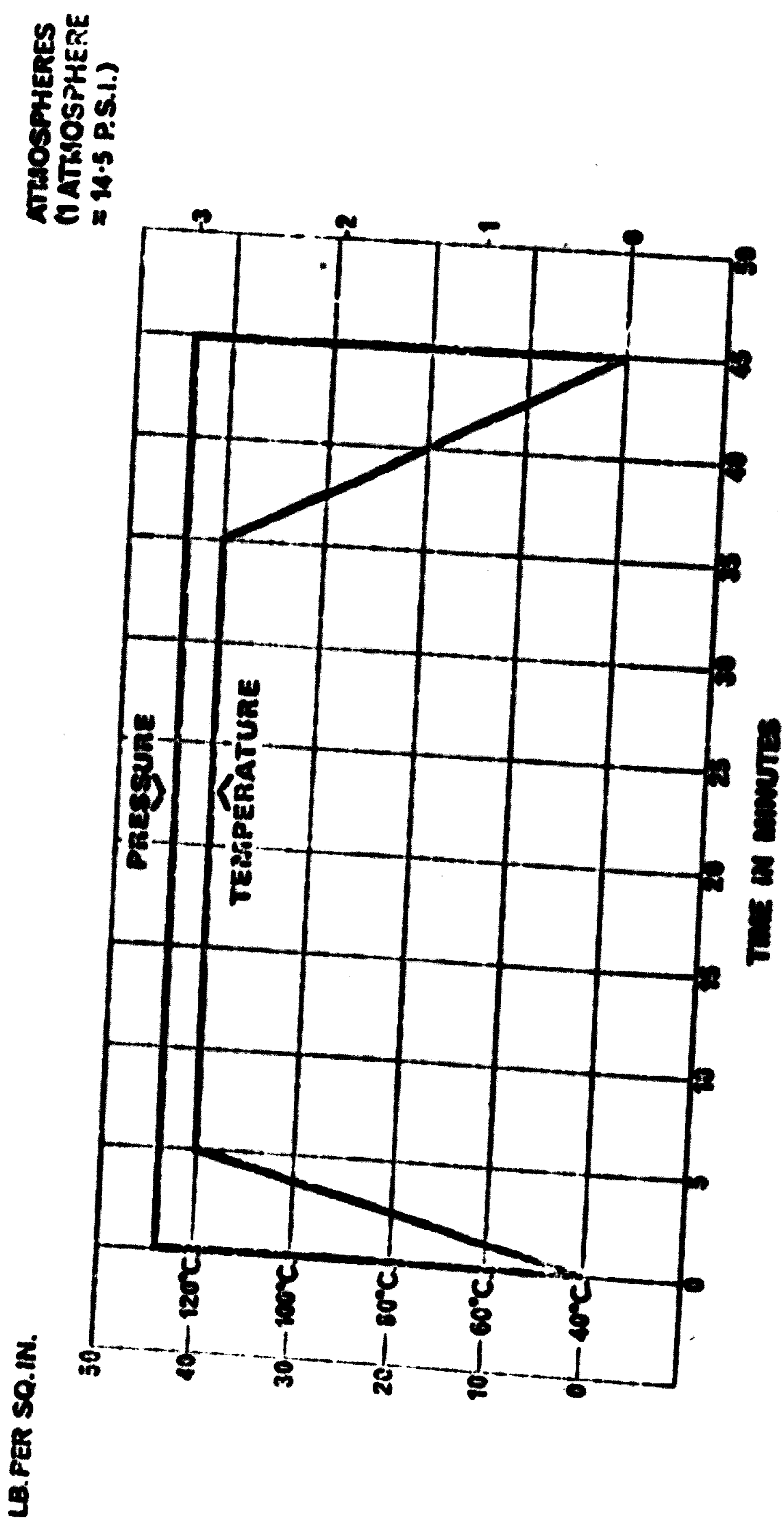


Figure 7: Packaging Machine for Container forming, filling, lidding and sealing

Figure 8: Knife opening

Figure 9: **Tear** opening

SCHEMATIC DIAGRAM OF PRESSURE AND TEMPERATURE VARIATIONS DURING STERILIZATION



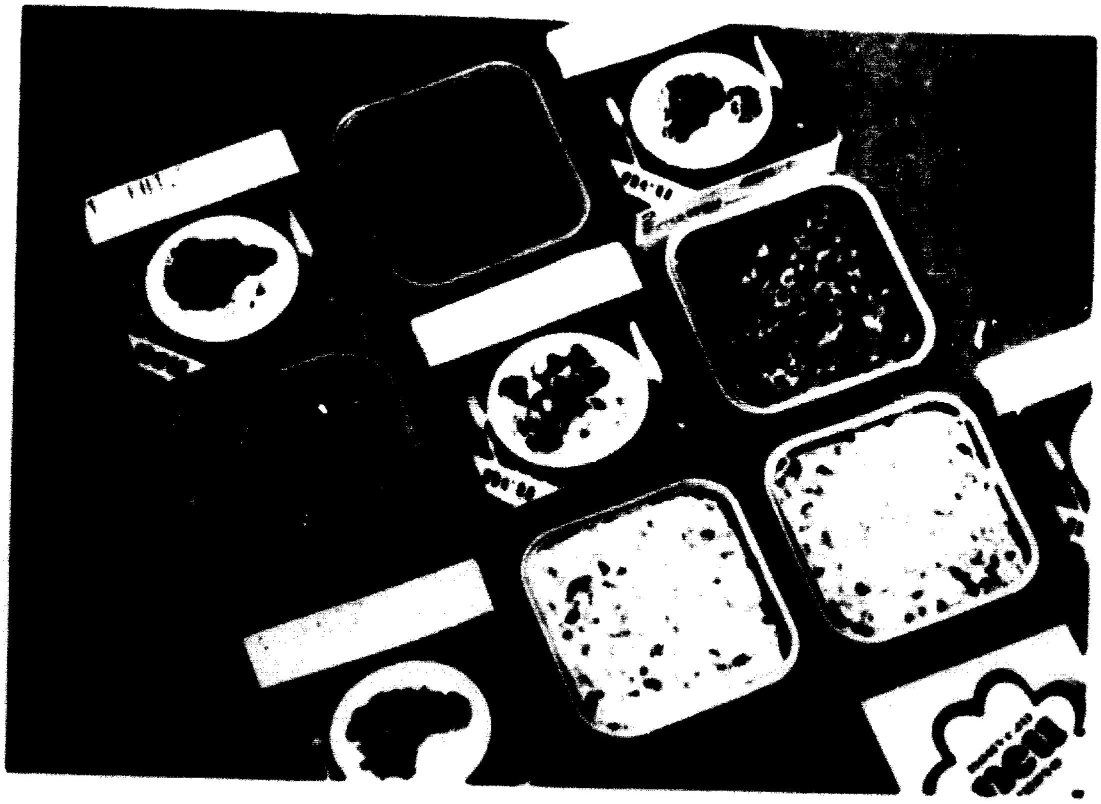


Figure 11: A Selection of recent uses

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