

# THE PACKAGING OF FLUID MILK

JACQUES CASALIS \* & JACQUELINE VAN DE PUTTE \*\*

---

The objective of all workers in any way concerned in the collection, transport and treatment of milk should be to deliver to the consumer a product that has preserved, as far as possible, the nutritive properties and natural qualities of milk as it leaves the udder. The work of specialists from various countries—dietitians, health workers, physicians, veterinarians and zoologists—has shown: (1) that on leaving the udder milk taken from a healthy animal is free of pathogenic bacteria; (2) that it possesses a bacteriostatic quality that protects it for a varying period of time against the proliferation of lactobacilli; (3) that the more carefully it is treated the better are its nutritional and therapeutic properties.

There can be no doubt that the ideal is to supply man with a raw milk, for consumption in its natural state, taken from healthy animals, collected and handled with the utmost hygienic care, and distributed under refrigeration (so as to prolong its natural keeping quality) from the factory to the consumers' table.

Unfortunately, this can rarely be done in present conditions of the world dairy industry. The big urban centres of Switzerland have central depots for consumer milk where milk is simply cooled and packaged before being put on sale. The essential factors in the success of this technique are the proximity of production zones to consumption centres, a relatively colder climate than in most temperate countries, and a method of procedure strictly observed by the milk producers.

However, in most countries, climatic factors, lack of co-operation on the part of producers, and long transport distances make it necessary to submit consumer milk to heat treatment of varying degrees before packaging it for distribution. Such treatment is even more necessary when milk and milk products are supplied in countries where climatic conditions do not permit the rearing of dairy cattle.

The protection of milk, whether raw, pasteurized, sterilized, concentrated, or powdered, during packaging and marketing is invariably based on

---

\* Professor, National Institute of Agricultural and Food Products Industries, Paris, France.

\*\* Engineer, Technical Institute of Agricultural Practice, Paris, France.

the same general concepts: milk products are essentially liable to change, either through the action of a wide variety of bacteria, or of physical and chemical factors. The first objective is thus the reduction of these causes of change to a minimum.

#### *Bacteriological causes of change*

Milk contains all the elements necessary for life: proteins, carbohydrates, lipids, mineral salts, vitamins, growth factors, etc. While these substances are of value in human nutrition, they also provide an ideal culture medium for most micro-organisms, the development of which changes the composition of milk and rapidly makes it unfit for consumption. Pathogenic organisms that have entered during packaging retain their virulence and may cause serious illness in the consumer.

#### *Causes of chemical change*

The components of milk, particularly the lipids, are extremely labile and subject to chemical change, especially to oxidation, which in liberating the fatty acids of glycerides imparts more or less unpleasant flavours and odours and changes their nutritional value to a greater or lesser degree according to its intensity. Certain metals (iron and copper in particular), and certain physical agents (temperature and light), accelerate and catalyse these degradation reactions.

## **FACTORS AFFECTING CHANGES IN AND KEEPING QUALITY OF MILK BEFORE AND AFTER PACKAGING**

Before discussing the operation of packaging itself, the factors causing or retarding changes in milk in the course of packaging and during the time between packaging and consumption must be defined. They may have a purely chemical action, such as light; or a bacteriological and chemical action, such as temperature and air.

### **Contact Surfaces**

Surfaces with which milk comes into contact are, in most cases, very difficult to sterilize. The possibility of infection from these surfaces, at the farm as well as at the factory, is great, so that it is desirable to reduce their area as much as possible.

Constant care must be taken during all handling operations to see that surfaces are made free from infection—by cleaning, disinfection, and pro-

tection against recontamination. Surfaces are also a cause of chemical change when they are not absolutely inert in respect to milk and cleaning products. The salts of heavy metals, particularly copper and iron, may form in the course of treatment or from contact with metal containers, and may catalyse oxidation processes.

All new materials (particularly plastics and protective varnishes) destined for use in the packaging of milk must be very carefully examined with regard to their possible solubility in milk at the different temperatures to which they may be subjected when utilized.

Finally, the surfaces of returned equipment and packages must be thoroughly rinsed after cleaning and disinfection, so that no extraneous chemical can affect the composition of the milk.

### Temperature

Temperature may act on milk in two ways, either by encouraging or inhibiting bacterial action or by causing physico-chemical changes that do not involve the activity of living organisms.

Even if hygiene and packaging operations are carried out correctly, bacterial change is to be feared in fresh, raw or pasteurized milk and to some extent in sweetened condensed milks. Evaporated milk and sterilized milk are, by definition, milks that should be devoid of viable bacteria, and powdered milk, although not sterile, does not contain enough water to allow the bacteria it contains to multiply. Physico-chemical changes (by contact with metal or by light) may be produced in fresh milk, but generally there is not time to observe them, since they are masked by changes of bacterial origin; it is in preserved milks that physico-chemical changes may have an effect on quality at the time of consumption.

#### *Changes of bacterial origin*

The relationship between temperature and the rate of multiplication of bacteria is well known. However, care must be taken not to assume refrigeration to be the universal remedy. Cold is a means not of rendering milk more hygienic but of prolonging its keeping quality by retarding the biological processes that lead to its deterioration. Even at low temperatures bacteria continue to multiply, more or less slowly according to species. Lactobacilli are more rapidly inhibited by low temperatures than are proteolytic or alkali-producing bacteria. This emphasizes the necessity of taking all appropriate precautions to avoid recontamination of milk after pasteurization, and confirms the necessity of fixing a time-limit beyond which sale to the consumer is forbidden.

Raw and pasteurized milk must thus be kept in temperature conditions such that the bacteria present are not able to alter the milk composition

between the time of milking, or of pasteurization, and that of consumption. This necessitates systematic refrigeration to preserve milk from the time when it has been cooled after milking or after pasteurization (to a temperature generally between 4° and 8°C) and during the operations which follow, i.e., bottling, storage, transport, distribution and retail storage. It is not merely a question, in the course of these operations, of cooling milk, but of preventing it from acquiring heat from its surroundings. Obviously the methods and amount of refrigeration required vary greatly according to climate and season. The volume and refrigerator capacity of cold stores and refrigeration installations must always be calculated in terms of the extremes of the external temperature.

The refrigeration industry is now able to solve all problems of lowering and maintaining temperatures arising in dairies. The limiting factor in refrigeration is not a technical one, but is the effect of cost of refrigeration equipment on general costs.

### *Bottling*

Cooled milk is put into glass bottles or cartons. The bottles on leaving the washing machine must be rinsed in cold water to prevent excessive reheating of the milk. When bottles are rinsed with water at a temperature of 12°-15°C, the increase in milk temperature is 0.5°-1.5°C according to exterior conditions. It would not be economic to rinse the bottles with chilled water, and if it is impossible to cool the bottles sufficiently in ordinary water, it is preferable to cool the milk.

Cartons paraffined at the moment of filling require a refrigeration device that will reduce them from a temperature of 85°C (temperature of the paraffin bath) to one low enough not to affect significantly the temperature of the milk.

### *Thermal protection of containers*

The conductivity of glass is obviously much higher than that of paper or cartons but, since there is a much greater thickness of material in a glass bottle than in a paper or carton container, the thermal protection contributed by the glass or by the carton is practically equivalent. However, experience has shown that—conditions being equal—milk heats up or cools down a little less rapidly in certain types of carton packaging than in glass bottles. The fact that carton and paper packages are closely packed in crates used for distribution, thus limiting the circulation of air between the containers, gives them a much higher thermal inertia than the glass bottles. For paper and carton packages it is therefore very important that milk be cooled to the appropriate temperature before filling, because a very long period in cold storage would be necessary to reduce the temperature still further.

### *Cold storage*

The period in the cold store is not meant to lower the temperature of the packaged milk but to maintain it. It is important that milk be returned to the cold store as soon as bottling, capping and crating are completed. The cold store should be big enough to contain all the day's production if delivery does not begin before the end of milk treatment.

Insulation must be generously calculated, and the necessary steps taken to avoid falls of temperature at the opening or closing of doors, or at the filling or emptying of the cold store. In particular it is worth while to have an ante-room in front of the cold store, closed by doors or curtains that open at simple pressure and close themselves after the passage of goods or persons. Excellent results have been obtained by putting special ventilators above the doors of cold stores which are automatically set in motion when doors or shutters are opened and create a curtain of air before the entry, thus reducing to a minimum thermal exchanges between the atmosphere of the cold store and the exterior.

The amount of refrigeration necessary to supply the cold store must be calculated in terms of the maintenance of the temperature of cooled milk, taking into account the temperature gains that occur on handling. The cold stores of dairies are very frequently insufficient in size and in degree of refrigeration. They may be connected to a refrigeration plant, using brine or iced-water, that feeds the entire factory. In this case, at peak periods or in great heat, the cold store, which is the last stage of the refrigeration system of the factory, runs the risk of being supplied with a refrigerant that has been insufficiently cooled. On the other hand, when the external temperature is low the cold store consumes little power. For these various reasons, it is the preference nowadays to equip the cold store with individual direct-expansion plant, preferably automatic, thereby permitting operation that is more economic in power and better able to preserve a constant temperature.

### *Transport and distribution*

Depending on the distance from the factory where the milk is treated to the consumption centre, transport may be direct from the factory to the retailer or by rail or road to the place of consumption, distribution being made by delivery vehicles to the retailer. Large road vehicles and railway wagons should be well insulated, and preferably refrigerated with the aid of ice, dry ice or a refrigeration compressor. Usually refrigeration is necessary only during part of the year.

Transport by heavy lorry or rail to the retail delivery vehicles should be carried out under conditions that ensure that the milk does not remain exposed to air temperature or light. Depending on the organizations concerned and the timetables, a cold store may be necessary to hold milk between unloading and reloading.

The delivery lorries must be closed and heat-insulated (see Fig. 1); in the absence of heat insulation the metal body absorbs and concentrates solar heat. It is difficult to assure the maintenance of milk at low temperatures during all the weather conditions encountered during a delivery circuit to the retailers without refrigeration.

FIG. 1  
DELIVERY LORRY



### *Chipped ice*

One of the methods used for maintaining milk at a low temperature throughout delivery consists of filling the crates containing the bottles with chipped ice. This necessitates special crates with solid exterior walls so that the ice surrounds the bottles as far as the neck. This is a very efficient method of maintaining milk at a temperature between 0° and 2°C, and allows for adjustment to the outside temperature.

### **Air and Oxygen**

#### *Bacterial contamination*

From the bacteriological viewpoint, air is an agent of contamination, and constitutes a risk that must not be neglected at the time of drawing-off and in respect of the containers themselves. A room for packaging raw or pasteurized milk must be clean and in good order. The dirty bottles must not be stored there. The floor must be washed and disinfected and kept

damp to avoid dust. The ceilings and walls should be regularly cleaned, whitewashed or treated with anti-fungal paint to prevent the development of mould, particularly in places where condensation occurs. To protect bottles against possible contamination by the atmosphere, the conveyor belt from the bottle-washing machine to the drawing-off equipment should be covered by a casing.

Personnel must be careful not to grasp an empty bottle by placing the fingers in its mouth—bottles must be held by the body or the neck. All personnel in the bottling department must be medically supervised and receive simple instruction on the necessary hygienic precautions. For sweetened condensed milk, in addition to the usual precautions complete disinfection of the room where drawing-off is carried out is necessary. Osmophilic yeasts may develop in the factory and are easily carried in the air. Disinfection of air may be effectively carried out with the aid of aerosols.

When single-service containers of carton or metal are not made at the place where they are filled, they must be stored away from dust, humidity and steam. On reception the containers must be placed with the opening underneath, and during their transport from storage to the packaging room there should be no risk of their contamination.

#### *Oxygen and oxidation*

Oxygen from the air plays an extremely important role in the keeping quality of milk. It is necessary for the development of any bacteria that may remain in sweetened milk. Filling of tins of sweetened milk must be carried out in such a way that a minimum of air remains after closing the tin; filling under vacuum is a good way of preserving sweetened milk.

Oxygen is also the factor which determines physico-chemical changes, and is necessary for the changes caused by light in sterilized milk. It is the chief factor in the ageing of powdered milk.

All oxidation processes are catalysed by the salts of heavy metals that may have entered the milk in the course of treatment, from the farm up to final packaging, by contact with metal surfaces such as badly tinned iron or copper.

#### **Light**

Milk is sensitive to the action of light, above all of direct sunlight. Even a short exposure to light may set off oxidation processes in milk that give it a special taste known as "sunlight flavour". These processes continue after the milk has been withdrawn from the light, and may make it unfit for consumption.

Oxidation leads to a breakdown of milk fats (phospholipids) and of certain non-fatty elements, shown by the destruction of ascorbic acid (vitamin C), riboflavin (vitamin B) and probably other amino-acids. The

milk not only acquires a disagreeable flavour but also loses part of its nutritive quality. The mechanism and extent of this process are still not fully known. This action of light is produced in the presence of oxygen. It has been shown that de-aerated milk does not acquire an oxidized flavour under the action of light; this is the reason why de-aeration and vacuum packaging of sterilized milk improve its flavour and its resistance to oxidation.

Much research has been devoted to this question. It seems that the short waves of the solar spectrum are the active ones. To avoid all oxidizing action of light it is necessary to exclude waves of a length less than 620 m $\mu$ , i.e., all that part of the spectrum which precedes orange and red. Glass coloured green or brown, cartons, and paper containers retard the process of oxidation by absorbing part of the spectrum. Coloured glass bottles, while retarding the process of oxidation by light, do not prevent it completely. Their use is not general in the dairy industry because they cost more and optical inspection of their cleanliness on leaving the washing machine is difficult.

Mattsson<sup>1</sup> has compared glass bottles with Tetrapak. Their relative permeability to light is as follows. At 250 m $\mu$ , light does not penetrate glass or Tetrapak paper. At 350 m $\mu$ , glass allows 70 % of the initial light to penetrate, and Tetrapak paper 1 %. At between 400 and 700 m $\mu$ , glass allows 80 %-90 % of the initial light to penetrate, and Tetrapak paper allows 1 %-2 %.

Research work on the disappearance of ascorbic acid and the appearance of oxidized flavour confirms the protective value of paper packaging—but it is not, however, complete. At present this protection extends only to raw and pasteurized milk, and not to sterilized milk, which because of its long period on the market before consumption is most exposed to the action of light. Precautions are therefore necessary to protect sterilized milk from even diffuse light. Bottle crates of solid wood offer a certain amount of protection as compared with open-work metal crates. Transport of sterilized milk in bottles must be carried out in covered lorries, and warehousing and deliveries must be so organized that the milk is not exposed to the direct action of sunlight. A few minutes' exposure to sunlight is sufficient to set off the process of oxidation. Bottles of sterilized milk must also be protected as much as possible against diffuse light, which acts less rapidly but has the same result.

Warehouses storing bottled sterilized milk should receive appropriate warning, and the retailer should be instructed in the disadvantages of exposing milk, especially sterilized milk, to light.

Metal tins protect sterilized milk against oxidation very efficiently; this is a strong argument in favour of their use.

---

<sup>1</sup> Mattsson, S. (1954) [The effect of light on milk in glass milk bottles and in Tetrapak]. *Svenska Mejeritidningen*, No. 36 (Abstracted in French).

## PACKAGING

### Characteristics of Hygienic Packaging

The developing requirements of health authorities and consumers, in the dairy industry as in all food industries, lead today to a growing tendency to package goods to comply with the following conditions: (1) the container must be tamper-proof, so that between the time of packaging and the time of consumption it is protected against fraudulent practices and the buyer has a guarantee concerning its origin; (2) the container must be of such a shape and size that its contents correspond to the consumer's daily requirements, and its capacity must always be related to the keeping quality of the product.

In such conditions the sale of large-size containers for products for immediate consumption will decline, except in certain special cases to be mentioned later. Progressive disappearance of large-size containers is in contradiction to the idea mentioned previously of the necessity of reducing the size of the surfaces with which milk may come into contact. A reminder of these very general principles will make it possible to formulate the conditions required in a container of good quality.

#### *Bacteriological conditions*

A container of good quality must prevent, or limit to the minimum, all bacterial recontamination. Either it may be used once only (single-service container) or it may be returned to the packaging factory and used more than once. In this case its shape must permit effective cleaning, without inaccessible corners where bacterial deposits difficult to eliminate might form, and with a perfectly smooth inner surface.

#### *Chemical conditions*

A container of good quality should have the following characteristics.

(1) It should be made of materials without any tendency to transmit the slightest trace of their constituents (by dissolving or by melting under heat) to the products which they contain.

(2) It should not be vulnerable to attack by either packaging products or cleaning products. This is essential for two reasons: attack of the internal walls of the container by such products may cause change in milk composition, and may further cause pitting of the walls where bacterial colonies difficult to eliminate could proliferate.

(3) It should be such as to avoid as far as possible all indirect or direct chemical change in the components of milk and, in particular, the oxidation of lipids.

Special care should be taken with all products intended for long storage.

### *Adaptation to type of milk*

Each type of milk requires a container adapted to it, which should accordingly be designed in relation to its function. A bottle of pasteurized milk does not have the same characteristics as a bottle of sterilized milk; nor have the metal tins used for the packaging of concentrated milk and of powdered milk. For raw milk, pasteurized milk, sterilized milk, evaporated milk and sweetened condensed milk, it is necessary to make a special study of the characteristics of hygienic packaging, and how they can be obtained and controlled.

### **Packaging of Raw Milk**

Apart from the exceptional case previously mentioned of dairy plants supplying urban population centres with raw milk (and there the problem of handling is the same as in dairy plants supplying pasteurized milk), the hygienic distribution of raw milk is made by trade or farming undertakings subject to regulations, varying in different countries but generally very strict, concerning the hygiene of cattle, of milk production, and of packaging plants. Bottling, preceded by cooling to 4°C, is generally done by the producer immediately after milking. The bottles are the same as those used for pasteurized milk (see page 580, and Fig. 2). The quantities milked are generally small and do not justify economically the use of automatic machines either for bottle-washing or for bottling and capping. The human factor is thus of primary importance. If milk is drawn from healthy animals, correctly fed, and if the necessary hygienic precautions concerning the stabling of the animals, the milking, etc., are taken, the milk will have a low bacterial content, but it will be all the more susceptible to every risk of bacterial contamination. In addition to cooling of milk as soon as possible after milking, hygienic security rests on the strictest regulation of cleaning, disinfection and filling of bottles.

### *Manual or semi-automatic washing of bottles*

Dirty bottles must be kept outside the place where filling is carried on. Washing of bottles should include the following operations:

- (1) Soaking or rinsing in cold or tepid water containing some disinfectant (e.g., sodium hypochlorite) to retard bacterial growth during the operation.
- (2) Mechanical brushing.
- (3) Soaking in a warm detergent solution.
- (4) Rinsing in clear water.
- (5) Soaking in a disinfectant solution.
- (6) Final rinsing. The bacteriological quality of water used for this operation is obviously one of the essential factors for success. If this quality is not sufficiently high it must be remedied by adding in advance a dose of

suitable antiseptic (sodium hypochlorite, for example, to give a content of 25-50 mg of free chlorine per litre (25-50 p.p.m.)).

(7) Drainage. The baskets and crates in which the bottles are usually put to drain upside-down should also be carefully cleaned and disinfected.

Detergent and disinfectant solutions must be specially examined to ensure that they are efficient but do not attack the hands of the operators. They should not leave residues or traces in the bottles at the time of bottling. Disinfectants with a chlorine base are the most suitable.

### *Capping*

Capping should preferably be carried out with aluminium caps rather than cardboard milk-bottle tops. These caps, which are generally prefabricated, should be stored in a dry place protected from dust and contamination.

If a sterilizing chest for milking, cooling and filling equipment is available, the caps should also receive this treatment.

The recommendations given below for pasteurized milk equipment apply also to automatic equipment for the handling of raw milk.

## **Packaging of Pasteurized Milk**

The equipment used for distribution of pasteurized milk comprises: cans (generally of 20-litre capacity — 4.4 gal.); glass bottles; and single-service containers of cardboard or plastic.

### *Milk cans*

The 20-litre milk can is still used for the distribution of pasteurized milk in smaller centres (in France, centres of less than 20 000 inhabitants) where the installation of bottling equipment would be too expensive; it is also used for supplying milk to institutions (such as boarding-houses, restaurants, barracks, etc.). The question of cans is dealt with elsewhere (see chapter by Ekman, page 557); here it will be sufficient to state that the recommendations concerning their shape, the materials used for their manufacture, and above all their cleaning, should be even more strictly followed when packaging of milk after pasteurization is involved than when they are used for the collection and transport of milk from the farm to the factory.

### *Bottles*

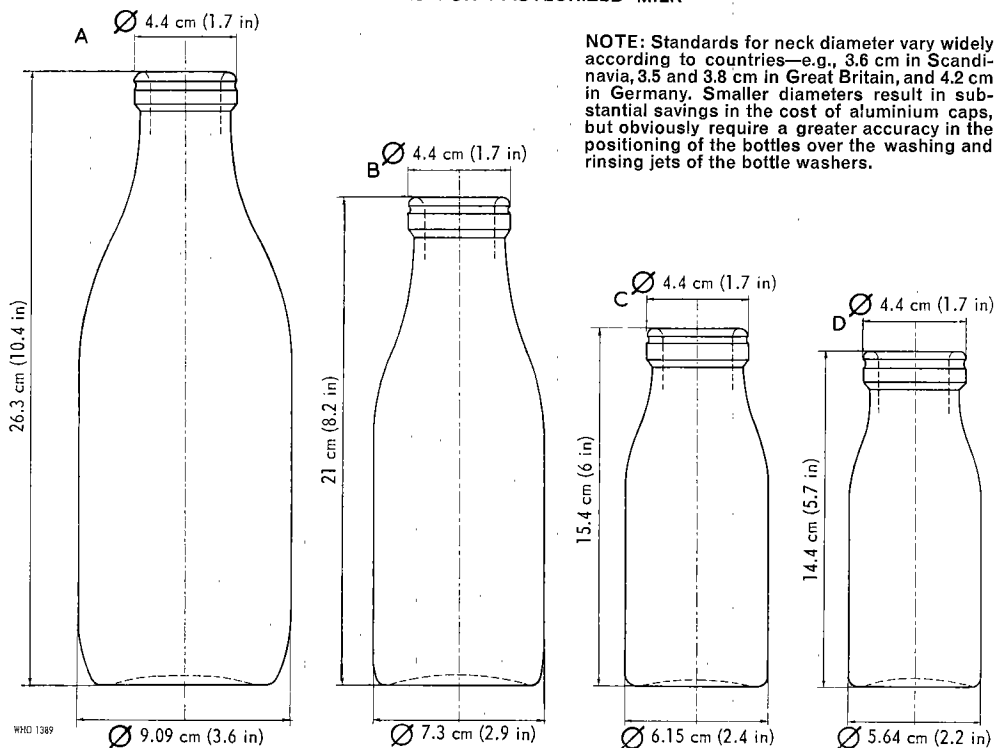
The bottle is gradually replacing the can for distribution of both raw and pasteurized milk in towns as the requirements of health authorities and consumers increase. In spite of its weight and the disadvantages attached to the return and sterilization of empty bottles, the bottle is still the most widely-used container.

Single-service containers are now steadily being developed and improved however, and satisfy the new requirements of the dairy industry and modern selling methods.

*Advantages of the bottle.* The glass bottle has many advantages. Its transparency allows the milk to be seen, and in certain countries quite special importance is attached to a visible cream line. Also, transparency reveals the possible presence of impurities or sediment. Modern bottle-glass is not attacked by milk or cleaning solutions. Bottles may be cleaned and disinfected with caustic products at high temperatures without drawback.

*Shape of the bottle* (see Fig. 2). From the hygienic point of view the shape of the bottle is very important. It must facilitate cleaning, allowing

FIG. 2  
BOTTLES FOR PASTEURIZED MILK



NOTE: Standards for neck diameter vary widely according to countries—e.g., 3.6 cm in Scandinavia, 3.5 and 3.8 cm in Great Britain, and 4.2 cm in Germany. Smaller diameters result in substantial savings in the cost of aluminium caps, but obviously require a greater accuracy in the positioning of the bottles over the washing and rinsing jets of the bottle washers.

	Total capacity	Capacity in use*	Weight**
A	1020 cm <sup>3</sup>	1000 cm <sup>3</sup> (1 litre)	600 g
B	520 cm <sup>3</sup>	500 cm <sup>3</sup> (½ litre)	370 g
C	270 cm <sup>3</sup>	250 cm <sup>3</sup> (¼ litre)	280 g
D	220 cm <sup>3</sup>	200 cm <sup>3</sup> (2 dl)	175 g

\* When filled to within 27 mm from top; 1 litre = 1.76 pints

\*\* 100 g = 3.5 oz.

jets and brushes to act on the entire inner surface. The neck should be joined to the body of the bottle without forming a sharp angle, and should have no bulges or narrow portions. The base should be concave rather than convex so that milk residues collect in the centre rather than at the circumference of the bottom of the bottle where they would be more difficult to reach.

The bottle shape should be adapted as much as possible to the apparatus used for washing, drawing-off, capping and handling, so that there is less risk of breakage during its passage through the plant. Breakages, economically undesirable in themselves, have from the hygienic point of view (glass-splinters, spilt milk, stoppage of the machine) an effect that must not be underestimated.

Studies recently made in different countries, notably in Norway,<sup>1</sup> have resulted in the conclusions that, with regard to the exterior shape of the neck, a straight profile is superior to a bulging profile; the top of the bottle should be not oval but perfectly circular within very small tolerance limits, so that the cap is tight; its optimum thickness is 17 mm.

There was a time when, particularly in the USA, the shape of the bottle affected sales. The manufacturers went to great lengths to find original shapes emphasizing the cream line. Today, in most countries preference for a bottle with a cylindrical body has returned, and a study of the different standards established in various countries would be valuable to achieve international uniformity.

*Capacity of the bottle.* Milk is sold by volume. The most common capacities are the litre, the half-litre, and the quarter-litre for countries where the metric system is used, and the quart, the pint and the half-pint in Anglo-Saxon countries. Filling machines delivering a measured quantity of milk into each bottle are less and less used because of difficulties of cleaning and sterilization; fillers working at a constant level and under a vacuum are preferred. It is important, therefore, that the capacity of the bottles be constant, regular and adapted to the specific filling apparatus. Most countries have regulations fixing the tolerance limits in relation to the exact quantities of milk that should be contained in each bottle sold.

*Resistance of the bottle.* The shape of the bottle affects its resistance to shocks. Manufacture, constancy of quality and thickness of the glass are also factors.

During in-bottle sterilization or pasteurization, bottles are subjected to internal pressures, which they must also be capable of resisting. They must likewise be able to survive the differences of temperature to which they are submitted during washing, and to tolerate sterilization temperatures.

*Quality of glass.* Irregularities in the composition of the glass, the presence of air bubbles, deformations of the surface or extraneous matter in

<sup>1</sup> Hougen, A. G. (1959) *Milk bottle design and quality control*. In: *Proc. XV Int. Dairy Congr.*, **1**, 497.

the glass not only are defects of appearance but affect resistance to mechanical and thermal shocks. The constancy of the weight of the bottle is a factor affecting the constancy of its other characteristics, since it is manufactured from a fixed quantity of glass.

### *Cleaning of bottles*

Cleaning of bottles is one of the most awkward problems in the hygienic packaging of milk. All the precautions taken to destroy the bacterial flora of the milk by appropriate heat treatment are useless if it is not packaged in containers that are as clean as possible. This cleanness has two complementary aspects which are equally important: a macroscopic and a microscopic aspect. Retailing stores return to the factory empty bottles of which some have remained with the consumer or the retailer for a long time, have been used for various purposes, and have contained the most various products: e.g., oil, petrol, paint. There is thus a risk of transmitting odours of varying intensity to a complete consignment of bottles in the washing trough. Even assuming that the bottle has contained only milk, and has been rinsed by the consumer (as unfortunately it has generally not), nevertheless during the time taken for its return to the factory a film of varying thickness has formed on the inside from the dried milk residues or rinse-water remaining in the bottle. This film consists mainly of fat and protein and gradually dries up, adheres more and more firmly to the interior surface and becomes accordingly more difficult to remove. If it were formed only from the chemical constituents of milk it would still have to be removed, but it is invariably the site of a more or less marked bacterial growth, and the bacteria also dry, so that when conditions of temperature and medium are favourable (i.e., when the bottles are again filled with milk) they again multiply.

It is therefore essential, both for commercial and bacteriological reasons, to eliminate these deposits—chemically, by dissolving the fat and by peptization of the dried protein, so that the mechanical action of the washing machine carries them away; and bacteriologically, by destroying the bacterial flora contained in the deposits. These two aspects, detergent and disinfectant, are equally important. It is useless to remove the deposit without ensuring the destruction of bacteria, and the use of disinfectants only would not be effective if the film were not first removed.

In certain countries the regulations allow factories to refuse to take back dirty bottles. It is desirable that similar regulations should be applied everywhere where milk is sold in bottles.

It would also be most advisable to educate the consumer by all possible means, pointing out to him (*a*) the adverse effects on milk quality that may occur as a result of using milk bottles for purposes other than to contain milk, and (*b*) the help he can give towards the improvement of milk quality by returning the bottles to the milk retailer as soon as they are empty, after having carefully rinsed them.

When the bottles arrive at the factory they should be sorted before being placed in the washing machine. Those which are cracked, or are unusually dirty or have a pronounced odour, must be removed, and those which can be recovered are given a special cleaning treatment, while the others are destroyed.

*Types of bottle-washing machine.* Bottle-washing machines are constructed on different principles: spray-type rotary machines; straight-through soaker-hydro machines; and come-back soaker-hydro machines.

A bottle-washing machine, regardless of type, should allow the cleaning and sterilizing solutions to reach all points of the internal and external surfaces of the containers. The contact of bottles with solutions should be sufficiently prolonged. The solutions should not be allowed to mix or to be diluted with rinse-water or steam injections.

Washing operations must be in the following order:

Pre-rinsing with tepid water which warms the glass, eliminates particles not firmly attached to it, and moistens, but does not bake, the dried impurities.

Mechanical action, by brushing or high-pressure jets.

Spraying or soaking with a detergent solution at the highest temperature possible. A temperature of 80°C is generally considered to be satisfactory.

Rinsing in warm water to remove the detergent solution completely, before the injection of disinfectant solution, which is less effective in an alkaline medium.

Spraying or soaking in a disinfectant solution which is most active when hot.

Final rinsing to remove disinfectant and to cool the bottle before filling (in the case of sterilized milk, the bottles are still hot when filled).

However, whatever the refinements of the machine, it must be correctly used and supervised to give satisfactory and constant results.

*Control of washing solutions.* The concentration of washing and disinfectant solutions should be determined and maintained so as to obtain optimum cleaning and sterilizing action.

The concentration of detergent solutions is generally controlled by titration with hydrochloric acid in the presence of phenolphthalein. This method allows the dilution of solutions to be estimated but gives no indication of the chemical changes produced during aging of the solution in the washing troughs. When the detergent solution is carbonated, or saturated with fat and protein, it must be renewed. The frequency of renewal will be established by experiment in terms of the volume of the trough and the number of bottles treated.

The most frequently used disinfectant solutions have a chlorine base. The amount of free chlorine is controlled. A content of between 100 and 250 p.p.m. is considered satisfactory. There are several methods of titration. Solutions with a chloramine base are more stable than those with a hypochlorite base, the chlorine being more active, having a neutral or slightly acid pH. The pH of hard waters may be reduced provided care is taken not to let it drop below the degree at which it would be corrosive to equipment

*Temperature control of troughs.* This test is extremely important: the effectiveness of the entire washing process depends on a correct succession of temperatures between one trough and another, and a sufficiently high temperature in the detergent trough. These temperatures must be easily controlled at regular intervals by the operator of the machine.

*Cleaning of bottle-washing machines.* Some bacteria may survive in bottle-washing machines which are badly maintained, and covered with scale, or where the detergent solution is neither hot enough nor sufficiently often renewed. These are generally aerobic spores which may cause defects, particularly in sterilized milk. The equipment must therefore be regularly cleaned and maintained, and where necessary must be de-scaled, especially the jets.

*Detergents and disinfectants.* The very wide range of detergents and disinfectants provided by the chemical industry for use in dairy factories cannot be reviewed here. An excellent study of them has been published by Mohr.<sup>1</sup> However, it must be recalled that detergents and disinfectants are not polyvalent. Their chemical composition may vary according to the nature of the surfaces to be cleaned and the deposits to be removed, but they must comply with the following general specifications:

- (a) they must not be toxic in the amounts used;
- (b) they must not be dangerous to handle;
- (c) they must not act on the surfaces to be cleaned;
- (d) they must be perfectly soluble in water, so that a careful rinsing will remove them completely;
- (e) they must be effective, regardless of the quality of water used for cleaning.

To these general characteristics must be added those specific to detergents:

- (a) they must have low surface tension in order to moisten the impurities to be removed and penetrate into all the interstices of the surfaces to be cleaned;
- (b) they must promote peptization and swelling of the protein matter contained in the deposits;
- (c) they must promote emulsion and saponification of fat;
- (d) they must keep the impurities to be eliminated in suspension in the cleaning solution.

*Control of cleanliness of bottles after washing.* The control of the cleanliness of the bottles after washing is a delicate operation for which a perfectly satisfactory solution has not as yet been found. Trials for the detection of imperfections in washing using photo-electric cells have not, as yet, given

<sup>1</sup> Mohr, W. (1954) *Die Reinigung und Desinfektion in der Milchwirtschaft*, Hildesheim, Th. Mann (Translated into French by J. Pien).

any conclusive results. The method most usually employed is the "candling" of bottles. The worker in charge of this operation makes a visual examination which may be facilitated by lighting devices, white backgrounds, lenses and mirrors reflecting the image of one surface of the bottle. Nevertheless, the observation of each bottle which passes (at an output which may attain 12 000 per hour) is a delicate and tiring operation, and it is estimated that the same person cannot carry out this work properly for more than half an hour at a time.

It is possible to judge from the appearance of the bottle whether it is really clean or whether there is still a film of organic matter on the inside. The presence of a persistent film of organic matter may be demonstrated by simple methods. In a clean bottle the rinse water forms a continuous smooth film, while on the sides of a dirty bottle it flows in irregular streams. A colorimetric method is very instructive to the personnel; organic matter invisible to the naked eye can easily absorb certain dyes. The dye generally used is fuchsin. A specific quantity of the dye solution is poured into the bottle and the bottle is shaken so that the dye comes into contact with the whole of the inner surface. The rest of the dye is emptied out, the bottle is rinsed, and any remaining organic matter will appear coloured. This method also shows up traces of mineral salts caused by hard water.

Visual methods of examination show the effectiveness of macroscopic cleaning, but the effectiveness of treatment by disinfection can only be measured by laboratory examination. However, a macroscopically soiled bottle is almost certainly a bottle contaminated with bacteria.

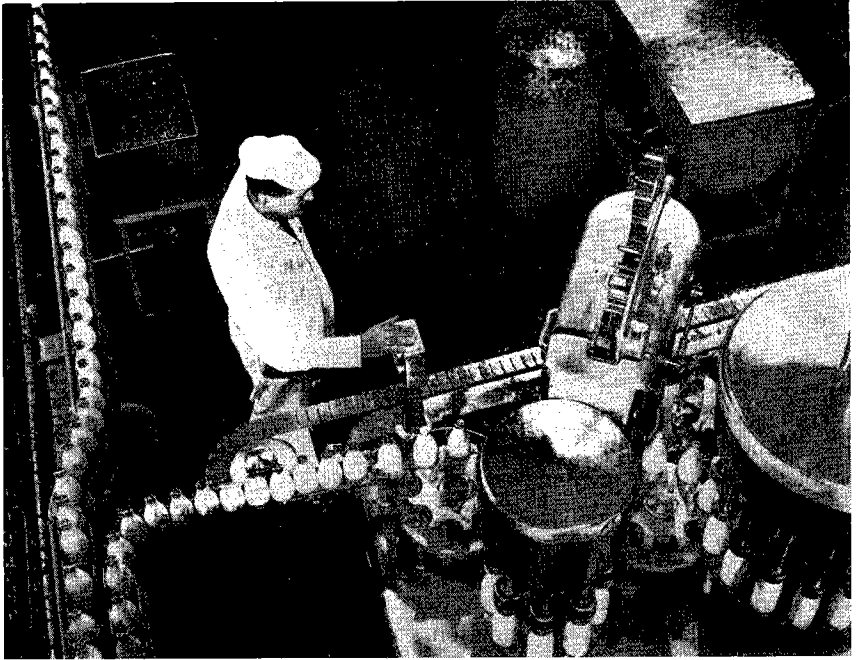
### *Bottle filling and closing*

Level fillers are easier to take to pieces, clean and sterilize than measured-quantity fillers. Bottles of a constant height and capacity are necessary for their smooth functioning.

The three most commonly used methods of sealing bottles are cardboard tops, aluminium caps and crown corks. The *cardboard top* is less and less used. It is placed inside the neck of the bottle in a mouth difficult to clean, which is a source of bacterial contamination difficult to avoid, and which lessens the resistance of the neck. It is not tamper-proof but is easy to remove and replace. It is not leak-proof, does not protect the entire internal surface of the neck with which the milk comes into contact when emptied from the bottle, and thus does not offer full hygienic security.

*Aluminium caps.* Aluminium was first used for bottle-capping shortly after the First World War. At first caps supplied to bottling factories were utilized: these prefabricated caps are still in use for bottling or in fermented milk factories (yoghurt) of small output. Now, however, most bottling systems use machines which cut caps from aluminium strips, stamp them, place them on the bottles, and crimp them on (see Fig. 3).

FIG. 3  
FILLING AND CAPPING BOTTLES



Reproduced by courtesy of United Dairies Ltd.,  
London, W.2, England

The first caps had a thickness of 0.08-0.1 mm. They were heavy, and often lined with paper to reduce the price. Machines for cutting and forming the caps were difficult to run, the cutting instruments blunted quickly, and greasing of the aluminium was a problem. All these difficulties have gradually been solved. The present caps have a thickness of 0.04-0.06 mm and capping machines are able to keep up with bottling equipment with a capacity of from 6000 to 12 000 bottles per hour. The aluminium cap covers the whole mouth of the bottle. It must also be sterile, leak-proof and tamper-proof.

*Sterility of the cap.* Sterilization of the cap just before placing it on the bottle is recommended, but is very difficult to carry out effectively. It must not be forgotten that the caps may sometimes be a source of contamination, and bacteriological tests should be made in the laboratory at regular intervals.

*Resistance to leakage and tampering.* The resistance of the caps to leakage may be tested by placing the capped bottle in water. It is, however, preferable to test it over a period of time by leaving a full bottle upside down for 24 hours. It is considered to be satisfactorily leak-proof if there is no

leakage of milk during this period. It should not be possible to turn a tamper-proof cap round the mouth or remove it without tearing it or making it unusable. The bottle itself is often responsible for faults in crimping, arising from variations in the diameter, height and centring of the mouth. In most countries regulations require bottles of pasteurized milk to bear the date of manufacture, marked on the cap at the time of use. The date stamp is often a movable part of the matrix used in manufacture.

*Dimensions of caps.* The dimensions of the cap are obviously adapted to the bottle mouth. A large number of different types, diameters and sections of bottle-mouth exist; and should be reduced so that manufacturers may simplify their plant and improve precision. It must be emphasized that regularity of operation and output is a necessary condition for the hygienic functioning of bottling equipment.

### *Single-service containers*

Appreciable progress in the use of single-service containers for the packaging of pasteurized milk has been made in recent years. The advantages of single-service containers as compared to bottles may be briefly summarized as: resistance to tampering, reduction in weight carried by distribution lorries, less bulk, no records of containers (crates excepted), no return of empties and, above all, none of the heavy labour and drawbacks of cleaning. Their development is hindered by factors of various kinds: a higher price than bottles, and their opacity, entailing a change in consumer habits, especially for those who attach great importance to the cream line. In certain countries their use has been made compulsory by regulations which forbid the sale in the same shop of bottled milk and milk in single-service containers.

Opacity protects the milk against the action of light, which catalyses oxidation processes that may alter the flavour. From the bacteriological point of view, there is no great difference between a well-washed bottle and a single-service container. The hygienic value of these containers is determined by their leak-proof and stable inner lining. This lining should not contain toxic products, and should be proof against attack by milk constituents. At present two types of single-service container are used: prefabricated packs and those manufactured at the time of use.

*Prefabricated containers* (see Fig. 4). Cardboard containers impregnated with paraffin cannot be heat-treated before use. Certain manufacturers treat the prefabricated containers in a way that protects them from contamination. The user should take care to keep opened lots of containers away from dust and moisture, and the manufacturer should make sure that the containers are not contaminated by mould or other spores during manufacture. Agreement about the bacteriological state of the containers should be reached between the user and the manufacturer. An intermediate solution

FIG. 4  
SINGLE-SERVICE CARDBOARD CONTAINER



consists of paraffining the containers at the time of use. The temperature of the paraffin bath (85°C) is sufficient to ensure sterilization.

*Containers manufactured at the time of use.* The first apparatus designed for manufacturing and paraffining cardboard bottles at the time of use was perfected in the USA. Since it is very expensive it is usually hired out, together with the corresponding filler.

The development of the Swedish Tetrapak recently has given new impetus to single-service packaging. The principle of this package is to form a tetrahedron

from a single strip of paper. The strip is sealed along its parallel edges to form a tube, the base of which is cut and joined to form one edge of the tetrahedron. The required quantity of milk is introduced, and the other end of the tube is cut and sealed by a clamp to form an edge perpendicular to the preceding one. Within the same category of containers, mention must be made of the Zupack.

Pure polythene is used as an impermeable lining. It is considered to be inert and insoluble in milk. Experiments carried out in France have confirmed its harmlessness and it has been officially authorized for the packaging of food.

Tests on the bacteriological state of Tetrapak containers at the time of use have given satisfactory results—complete absence of indole-producing coliform bacteria in the container and an average of less than two viable bacteria per cm<sup>2</sup> of the surface in contact with the milk. In the USA the accepted bacteriological standard is five bacteria per cm<sup>2</sup>.

Tetrapak was first used for quarter- and half-litre containers and is now being developed for one-litre containers.

In countries where milk is already being packaged in bottles, the use of single-service containers is developing for schools, factory canteens and self-service stores, and is just beginning to be general in dairies. In countries where the places of production and treatment of milk are far from consumption centres, and where the disadvantages of bottles (weight, return of

empties) have made the distribution of pasteurized milk impossible, the single-service container is developing direct.

Within a few years Tetrapak equipment has spread to the five continents, and paper factories have been established to supply it. Continual improvements are being effected in the plant for making single-service containers, and although at present they are used only in dairies of a certain size, there is every reason to believe that equipment will be rapidly perfected that will meet the needs of smaller establishments.

*Plastic containers.* Packaging of milk in plastic bags (see Fig. 5) is still in its infancy, and it is not yet possible to judge its hygienic value. The problem is to find a plastic material that is absolutely inert and non-absorbent with respect to milk and is able to withstand the temperatures needed for effective sterilization.

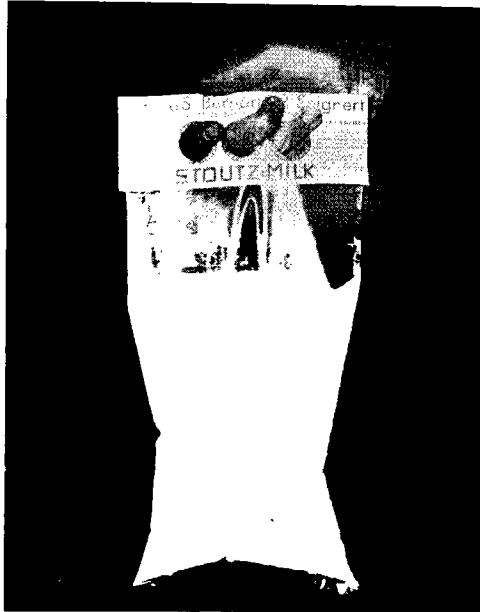
Polythene is inert to milk up to a temperature of about 50°C. Untearable bags of polythene are available which can be individually filled either by an automatic valve (patent W. P. de Stoutz), or by a small-flow filling machine. Current research may result in the development of plastics resistant to high temperatures, which will change the situation.

### Packaging of Sterilized Milk

Sterilized milk should contain no viable bacteria. The principle of milk sterilization is to transport milk in hermetically sealed containers to a chamber under pressure and keep it at a temperature and for a time sufficient to destroy all existing bacteria. Theoretically, it could then be kept indefinitely.

In fact, the term "sterilized milk" is accepted in certain countries for milk which can be kept longer than pasteurized milk, but nevertheless only

FIG. 5  
PLASTIC CONTAINER



Reproduced by courtesy of de Stoutz Actini-France S. A. R. L., Larringes-sur-Evian, France

for a specific limited period. Thus in Great Britain the accepted minimum keeping time is seven days.

The sale of sterilized milk (which does away with daily distribution and justifies a certain amount of storage) has begun to spread with the development of sterilization plant that takes the organoleptic characteristics of milk into account, and of a hermetically sealing system that enables capping to be done automatically.

Sterilized milk is packaged only in bottles or tins. The most widely used method consists of sterilizing the milk within the tin or bottle, filling being carried out immediately before sterilization with warm milk that is sometimes pre-sterilized. The other method is to draw off and fill aseptically with milk previously sterilized in thin layers. The most common method is Martin's (USA). It requires a large amount of cumbersome equipment, and can be used only for the packaging of metal tins, which are sterilized at a temperature of 215°C immediately before filling. Perfectly aseptic filling into glass bottles poses problems which have not been solved by industry.

#### *Metal tins*

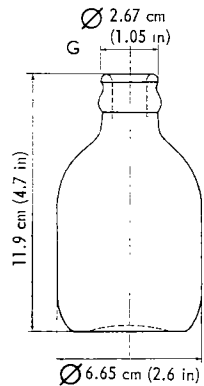
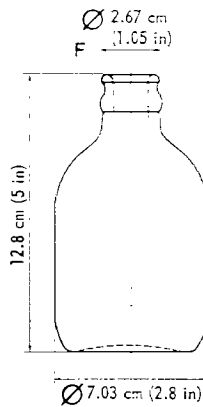
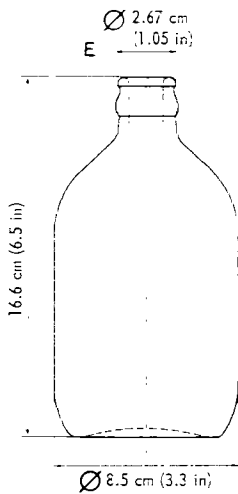
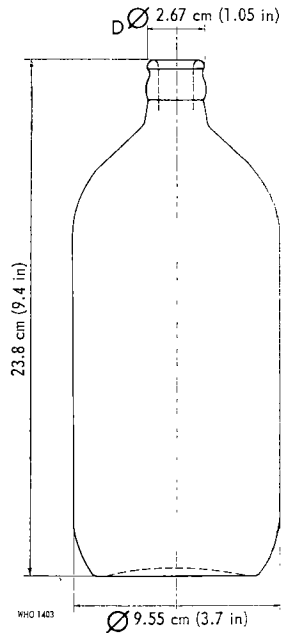
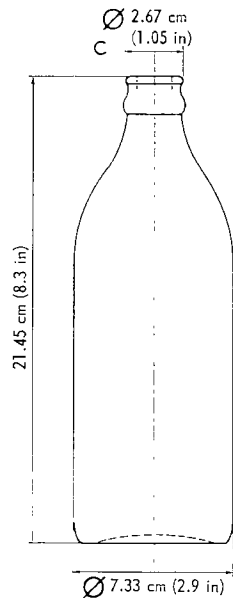
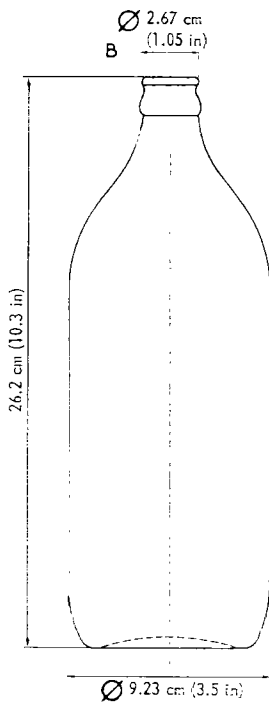
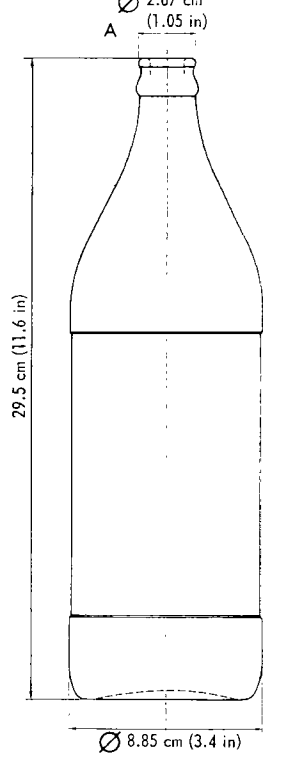
Metal tins for sterilized milk present the same problems as those for evaporated milk (see page 339 in chapter by van den Berg). Tins are dearer than bottles, and their use is economically justified only for transport over long distances, where the return of containers is impossible.

#### *In-bottle sterilization*

In-bottle sterilization may be carried out in autoclaves with or without stirring. Modern machines are continuous sterilizers in which the pressure required to reach the sterilization temperature is maintained by columns of water in equilibrium with a steam chamber under pressure. The bottle is filled with milk, which has been preheated at about 70°C, and hermetically sealed. It then passes into the sterilizer through one of the columns of water, where it is gradually heated, and so to the steam chamber, where it remains long enough for the whole of the milk to reach the required sterilization temperature. This temperature may vary from 110° to 130°C, according to the previous treatment of the milk and the duration of heating. The bottle leaves the sterilization chamber through another column of water in which it is gradually cooled. The milk receives some stirring as a result of the movement and changes of direction of the conveyor belt. This facilitates the distribution of heat and lessens the risk of caramelization of the lactose.

#### *Characteristics of the bottle*

Because of the heat treatment they undergo during sterilization, bottles should fulfil certain standards of resistance to thermal shock and internal pressure.



WHO 1403

	Type	Total capacity	Capacity in use*	Weight**
A	Tall	1100 cm <sup>3</sup>	1000 cm <sup>3</sup> (1 litre)	650 g
B	Medium	1100 cm <sup>3</sup>	1000 cm <sup>3</sup> (1 litre)	630 g
C	Medium	550 cm <sup>3</sup>	500 cm <sup>3</sup> (½ litre)	350 g
D	Short	1100 cm <sup>3</sup>	1000 cm <sup>3</sup> (1 litre)	610 g
E	Short	550 cm <sup>3</sup>	500 cm <sup>3</sup> (½ litre)	320 g
F	Short	275 cm <sup>3</sup>	250 cm <sup>3</sup> (¼ litre)	275 g
G	Short	218 cm <sup>3</sup>	200 cm <sup>3</sup> (2 dl)	170 g

\* 1 litre = 1.76 pints    \*\* 100 g = 3.5 oz.

*Shape.* The bottle for sterilized milk is characterized by the diameter of the rim, which should not exceed 30 mm. The shape of the mouth should be adapted to the method of closing the bottle. The shape of the bottle varies, three types being distinguishable (see Fig. 6):

(1) the high narrow bottle, which has the biggest surface area for a given volume;

(2) the average bottle, which can be used in crates of the same size as those for pasteurized milk;

(3) the short, wide bottle, the shape and size of which is very similar to that of preserving jars, so that it can be used in preserving autoclaves with the minimum loss of space.

From the hygienic point of view, there is nothing to choose between these different types. Particular importance must, however, be attached to standardization of their dimensions. To enable the top to be hermetically sealed and resistant to the pressures of pasteurization, careful attention should be paid to the relative specifications of the diameter and section of the mouth; similarly for the bottle height—variations in height between bottles make it difficult for the capping machine to work properly.

*Closure.* Originally bottles of sterilized milk were closed with swing stoppers provided with rubber seals. This method has several disadvantages. The metal part and the seals deteriorate rapidly and make mechanical cleaning difficult; moreover, closing cannot be done mechanically. Thus the swing-stopper has been practically abandoned in favour of the crown cork.

The crown cork allows the entire process of bottling sterilized milk to be mechanized. It is a fairly strong metal cap provided with a cork insert. The crown cork is prefabricated, placed on the bottle and crimped on by machines, the output of which should be worked out to correspond with the output of the bottling machines. The closure is hermetic and tamper-proof. The hermetic seal is ensured by the cork insert being tightly compressed over the bottle mouth in such a way that it fits exactly over the upper part of the rim. The seal is maintained by crimping the cap on so that the serrations grip the lower part of the rim (see Fig. 7).

#### *Washing of sterilized milk bottles*

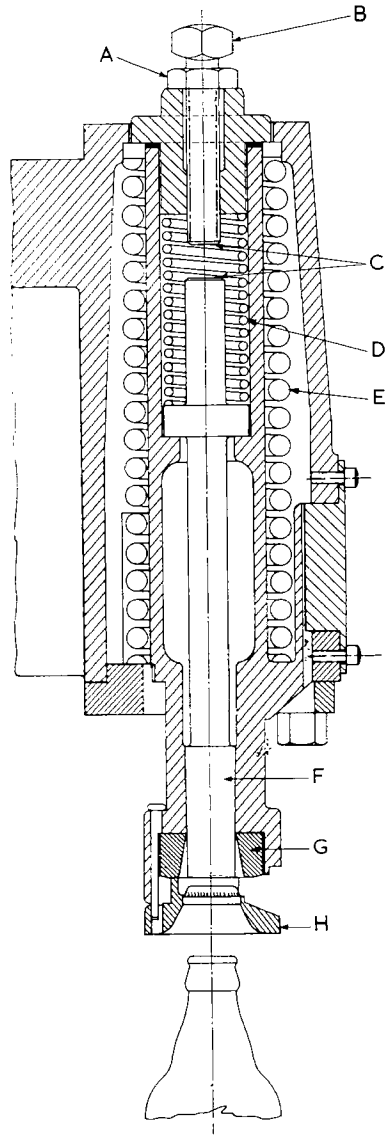
The methods and apparatus are identical to those used for the washing of pasteurized milk bottles.

The operation is more difficult for various reasons.

(1) During sterilization, and particularly when the bottles are not sufficiently agitated, deposits may form on the inside and are more adhesive because of the higher sterilization temperatures.

FIG. 7  
CROWN CORK CAPPER

- A = Lock nut
- B = Adjustable stop
- C = The space between these points controls the rise of the plunger
- D = Plunger spring
- E = Compensating spring
- F = Plunger
- G = Throat
- H = Crown cork support



(2) Bottles of sterilized milk are often stored in the factory for some time before marketing; and—most important of all—they remain on the market longer than bottles of pasteurized milk. Thus contamination of bottles previously mentioned presents a greater danger, and the desiccation of deposits and film on the inner surface of the bottles makes them very difficult to remove.

(3) Finally, the narrowness of the bottle neck makes washing jets less effective.

Bottles must be soaked first in detergent and then in disinfectant tanks.

There is no reason to fear the survival of pathogenic bacteria, common lactic enzymes or moulds in sterilized milk in view of the heat treatment it receives. Failures in keeping quality are almost always due to bacterial spores. All sources of contamination by these organisms must be carefully investigated. They may, in particular, be found in detergent washing solutions if these are not maintained at a sufficient temperature and concentration, or in rinse water. The presence or absence of bacterial spores in cleaning solutions should be regularly checked in the laboratory, and washing machines must be carefully cleaned and, when necessary, de-scaled.

