Manual on fish canning

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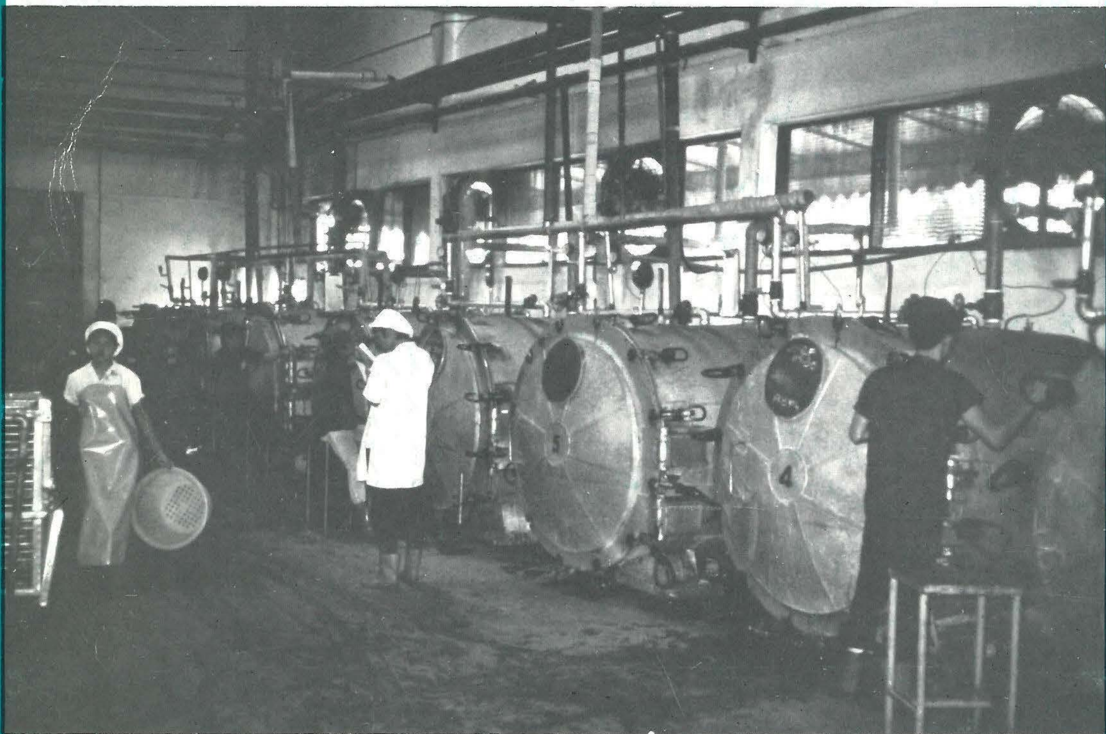

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Manual on fish canning

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PREPARATION OF THE DOCUMENT

This manual on fish canning has been produced to augment the technical information on fish processing put out by the Fish Utilization and Marketing Service of the FAO Fishery Industries Division. As a teaching aid it provides material for a complete course on the canning of fish and will also be of value to those contemplating the establishment of fish canning operations.

ABSTRACT

The manual provides a background to the principles of canning and to the specification and construction of containers for the sterilization of fishery products. After describing the unit operations in fish canning the specific processes for the following types of canned fish products are detailed: sardine, tuna, salmon, crustaceans, molluscs and fish pastes. There is a section on equipment for fish canning and a final chapter on process control in fish canning operations.

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CONTENT

1. PRINCIPLES OF CANNING

The technology for preserving foods in cans was developed at the beginning of the nineteenth century when a Frenchman, Nicolas Appert, won a competition initiated by another great character in French history, Napoleon Bonaparte. Napoleon is better remembered for his feats as a conquering General, than he is for providing the stimulus for the development of a food preservation technique that was to mark the start of the canned food industry. Appert won his prize (12 000 francs) for demonstrating that foods which had been heated in air-tight (hermetic) metal cans, did not spoil, even when they were stored without refrigeration. Once the reliance on the refrigerated and/or frozen food chain had been broken, it was possible to open markets for shelf-stable canned products where no entrepreneur had ventured previously. In the time since Appert's success, the technology of canning has been modified and improved, however, the principles are as true today as they were when first enunciated. The success of the international fish canning industry rests on the sound application of these principles.

1.1 Thermal Destruction of Bacteria

When fish are landed they contain, in their gut and on their skin, millions of bacteria which, if allowed to grow and multiply will cause a rapid loss of the "as fresh" quality and eventually result in spoilage. During post-harvest handling, in transit to the cannery, the fish inevitably become contaminated with other bacteria; these will further accelerate spoilage unless protective measures (such as icing) are employed. The purpose of canning is to use heat, alone or in combination with other means of preservation, to kill or inactivate all microbial contaminants, irrespective of their source, and to package the product in hermetically sealed containers so that it will be protected from recontamination. While prevention of spoilage underlies all cannery operations, the thermal process also cooks the fish and in some cases leads to bone softening; changes without which canned fishery products would not develop their characteristic sensory properties.

In order to make their products absolutely safe, canned fish manufacturers must be sure that the thermal processes given their products are sufficient to eliminate all pathogenic spoilage microorganisms. Of these Clostridium botulinum is undoubtedly the most notorious, for if able to reproduce inside the sealed container, it can lead to the development of a potentially lethal toxin. Fortunately, outbreaks of botulism from canned fishery products are extremely rare. However, as those familiar with the 1978 and 1982 botulism outbreaks in canned salmon will testify, one mistake in a season's production has the potential to undermine an entire industry. It is because the costs of failure are so prohibitive that canned fish manufacturers go to great lengths to assure the safety of their products. Safety for the end-user, and commercial success for the canner, can only be relied upon when all aspects of thermal processing are thoroughly understood and adequately controlled.

When bacteria are subjected to moist heat at lethal temperatures (as for instance in a can of fish during retorting), they undergo a logarithmic order of death. Shown in Figure 1 is a plot (known as the survivor curve) for bacterial spores being killed by heat at constant lethal temperature. It can be seen that the time interval required to bring about one decimal reduction (i.e., a 90% reduction) in the number of survivors is constant; this means that the time to reduce the spore population from 10 000 to 1 000 is the same as the time required to reduce the spore population from 1 000 to 100. This time interval is known as the decimal reduction time, or the "D value ". The D value for bacterial spores is independent of initial numbers, however, it is affected by the temperature of the heating medium. The higher the temperature the faster the rate of thermal destruction and the lower the D value - this is why thermal sterilization of canned fishery products relies on pressure cooking at elevated temperatures (>100°C) rather than on cooking in steam or water which is open to the atmosphere. The unit of measurement for D is "minute" (the temperature is also

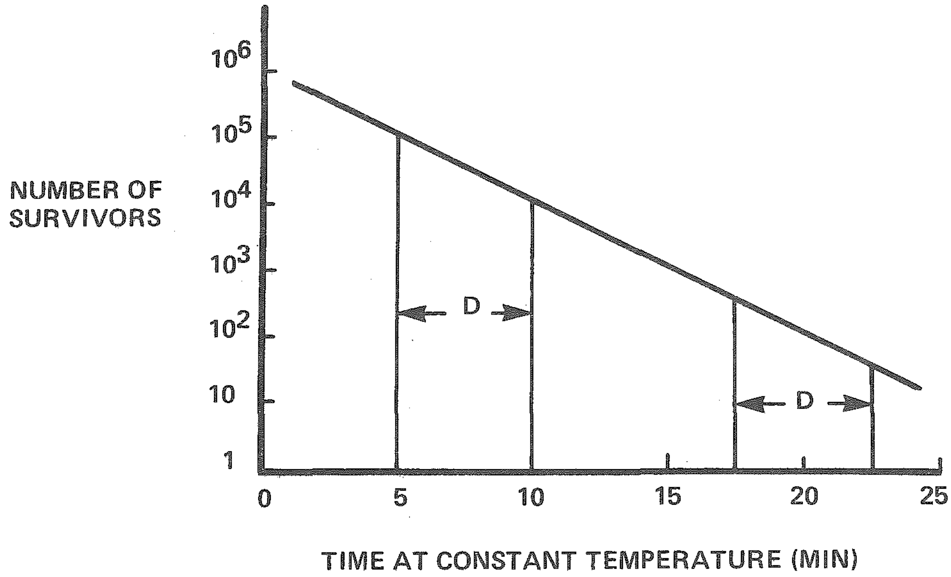


Figure 1 Survivor curve for bacterial spores, characterized by a D value of 5 min, subjected to heat at constant lethal temperature

specified, and in fish canning applications it can be assumed to be 121.1°C). Another feature of the survivor curve is that it implies that no matter how many decimal reductions in spore numbers are brought about by a thermal process, there will always be some probability of spore survival. In practice, fish canners are satisfied if there is a sufficiently remote probability of pathogenic spore survival for there to be no significant associated public health risk; in addition to this they accept, as a commercial risk, the greater probability of there being some non-pathogenic spoilage.

Shown in Table 1 are the reference D values for bacteria commonly found to be important in canning. Since it can be seen that not all bacterial spores have the same D values, a thermal process designed to, say, reduce the spore population of one species by a factor of 10^9 (i.e., 9 decimal reductions or a 9D process) will bring about a different order of destruction for spores of another species. The choice for the fish canner therefore becomes one of selecting the appropriate level of spore survival for each of the contaminating species. Thermophilic spores (those which germinate and outgrow in a temperature range of between 40° and 70°C and have their optimum growth temperatures around 55°C) are more heat resistant, and therefore have higher D values, than spores which have mesophilic optimum growth temperatures (i.e., at 15° to 40°C). This means that raw materials in which there are high levels of thermophilic spores will require more severe thermal processes than will products containing only mesophilic spore formers, if the same degree of thermal destruction is to be achieved for each species.

1.2 Thermal Processing Requirements for Canned Fishery Products

From the point of view of preventing microbial deterioration in the finished product, there are two factors which must be considered when a fish canner selects thermal processing conditions. The first is consumer safety from botulism, and the second is the risk of non-pathogenic spoilage which is deemed commercially acceptable.

Table 1

Decimal reduction times (D values) for bacterial spores of importance in fish canning

Organism	Approximate optimum growth temp. (°C)	D value (min)[a/]
B. stearothermophilus	55	$D_{121.1}$ 4.0 - 5.0
C. thermosaccharolyticum	"	" 3.0 - 4.0
D. nigrificans	"	" 2.0 - 3.0
C. botulinum (types A & B)	37	" 0.1 - 0.23
C. sporogenes (PA 3679)	"	" 0.1 - 1.5
B. coagulans	"	" 0.01 -0.07
C. botulinum (type E)	30 - 35[b/]	$D_{82.2}$ 0.3 - 3.0

a/ D values quoted are those at the reference temperature of 121.1°C, with the exception of that for *C. botulinum* type E, the spores of which are relatively heat sensitive, being killed at pasteurization temperatures (e.g., 82.2°C)

b/ Although the temperature range for optimum growth of *C. botulinum* type E is 30-35°C, it has a minimum of 3.3°C which means that it is able to grow at refrigeration temperatures

Safety from botulism caused by underprocessing means that the probability of *C. botulinum* spores surviving the thermal process must be sufficiently remote so as to present no significant health risk to consumers. Experience has shown that a process equivalent to twelve decimal reductions in the population of *C. botulinum* spores is sufficient for safety; this is referred to as a 12D process and assuming an initial spore load of 1 spore/g of product, it can be shown that, for such a process, the corresponding probability of *C. botulinum* spore survival is 10-12, or one in a million million. This implies that for every million million cans given a 12D process, and in which the initial load of *C. botulinum* spores was 1/g, there will be only one can containing a surviving spore. Such a low probability of survival is commercially acceptable, as it does not represent a significant health risk. The excellent safety record of the canning industry, with respect to the incidence of botulism through under-processing, confirms the validity of this judgement. In the United States over the period 1940-82, in which time it is estimated that 30 billion units of low-acid canned food were produced annually (and of these approximately one billion per year were canned seafoods), there have been two outbreaks (involving four cases and two deaths) of human botulism attributable to delivery of inadequate thermal processes in commercially canned food in metal containers. This corresponds to a rate of botulism outbreaks due to failure in the selection or delivery of the thermal process schedule of under 1 in 10^{12} ($0.6/10^{12}$).

Spoilage by non-pathogenic bacteria, although not presenting as serious a problem as botulism will, if repeated, eventually threaten the profitability and commercial viability of a canning operation. It is because of the commercial risks of product failure that canners ought to quantify the maximum tolerable spore survival levels for their canned products. As with the adoption of the 12D minimum process requirement for safety from botulism, experience is the best guide as to what constitutes an acceptable level of non-pathogenic spore survival. For mesophilic spores, other than those of *C. botulinum*, a 5D process is found adequate; while for thermophilic spores, process adequacy is generally assessed in terms of the probability of spore survival which is judged commercially acceptable. In other words what level of thermophilc spoilage can be tolerated bearing in mind the monetary costs of extending processes to eliminate spoilage, the quality costs arising from over-processing and finally the costs of failure in the market place, should surviving thermophilic spores cause spoilage. All things being considered, it is generally found acceptable if thermophilic spore levels are reduced to around 10^{-2} to 10^{-3}/g. There are two reasons why higher risks of spoilage (arising through survival, germination and outgrowth of thermophilic spores) can be tolerated. First, given reasonable storage temperatures (i.e., <35°C) the survivors will not germinate; and secondly even if spoilage does arise it will not endanger public health.

If a thermal process is sufficient to fulfill the criteria of safety and prevention of non-pathogenic spoilage under normal conditions of transport and storage, the product is said to be "commercially sterile". In relation to canned foods, the FAO/WHO Codex Alimentarius Commission (1983) defines commercial sterility as "... *the condition achieved by application of heat, sufficient,* alone or in combination with other appropriate treatments, to render the food free from microorganisms capable of growing in the food at normal non-refrigerated conditions at which the food is likely to be held during distribution and storage". Although this definition specifically refers to "non-refrigerated" conditions and thereby excludes those semi-preserved and pasteurized foods in which refrigerated storage is recommended (and in many cases is obligatory in order to prevent growth of the pathogenic psychrophile C. botulinum type E - which can grow at temperatures as low as 3.3°C), publications by the Department of Health and Social Security in the United Kingdom and the Standards Association of Australia do not exclude refrigerated foods. According to these less restrictive interpretations, commercial sterility may then also encompass those foods which are intended to be stored at refrigeration temperatures; this implies that commercially sterile canned foods will be free from microorganisms capable of growing at ambient or refrigeration temperatures, whichever is considered normal. Whether the product is intended to be stable under refrigeration or at ambient temperatures, the attainment of commercial sterility is the common objective when manufacturing all canned fishery products. There are, however, circumstances in which a canner will select a process which is more severe than that required for commercial sterility, as for instance occurs when bone softening is required with salmon or mackerel.

1.3 The Concept of Thermal Process Severity (F_o Value)

A mathematical equation describing the thermal destruction of bacteria can be derived from the survivor curve shown in Figure 1. If the initial spore load is designated N_o and the surviving spore load after exposure to heat at constant temperature is N_s, then the time (t) required to bring about a prescribed reduction in spore numbers can be calculated and is related to the D value of the species in question by the equation,

$$t = D(\log N_o - \log N_s)$$

From this equation it is apparent that the time required to bring about a reduction of spore levels can be calculated directly, once the spore level before, and the desired spore level after, the heat treatment are specified, and the D value of the spores under consideration is known. For instance, considering the generally recognized minimum process for prevention of botulism through under-processing of canned fishery products preserved by heat alone (which assumes that initial loads are of the order of 1 spore/g, and in line with good manufacturing practice guidelines, final loads shall be no more than 10^{-12} spore/g), the minimum time required to achieve commercial sterility (i.e., a 12D process) can be calculated from,

$$\begin{aligned} t &= 0.23(\log 1 - \log 10^{-12}) \\ &= 0.23 \times 12 \\ &\simeq 2.8 \quad \text{min} \end{aligned}$$

This means that the minimum thermal process required to provide safety from the survival of C. botulinum is equivalent, in sterilizing effect, to 2.8 min at 121.1°C at the slowest heating point (the SHP) of the container. This process is commonly referred to as a "botulinum cook".

Having established the minimum process with respect to product safety, it remains to select a processing time and temperature regime which will reduce the numbers of spore forming contaminants (more heat resistant than those of C. botulinum) to an acceptable level. If, for instance, the canner is concerned at the possibility of C. thermosaccharolyticum spore survival (because it is known that raw materials are contaminated with these spores and it is likely that the product will be stored at thermophilic growth temperatures) and the N_o and N_s are 10^2 spore/g and 10^{-2} spore/g, respectively; the time required to achieve commercial sterility can be calculated as before,

$$\begin{aligned} t &= 4.00(\log 10^2 - \log 10^{-2}) \\ &= 4.00(2 + 2) \\ &= 16 \text{ min} \end{aligned}$$

Thus, in order to prevent commercial losses through thermophilic spoilage by C. thermosaccharolyticum the thermal process must be equivalent, in sterilizing effect, to 16 min at 121.1°C at the SHP of the container. This approach to calculating the thermal process requirements tends to be an oversimplification for two reasons:

(a) in practice it is not reasonable to assume that naturally occurring contaminants will be present only as pure cultures. However, because fish and other raw materials contain a mixed flora, canners assume "worst-case" conditions in order to develop a process which always provides adequate protection from all contaminants. It is customary, therefore, to assume that C. botulinum and other heat resistant spore forming bacteria are present, and then to select a thermal process, the severity of which is sufficient to reduce their probability of survival to commercially acceptable levels.

(b) The survivor curve (shown in Figure 1) assumes that the temperature of the heat treatment is constant (and in the cases considered, equal to 121.1°C), whereas during heating in a commercial retort, the SHP of the can experiences a lag in heating and in many cases may never reach retort temperature. Thus the equation that permits calculation of the time required at constant temperature to achieve a desired survivor level (i.e., N_s) cannot be simply applied to the effects of heating at the SHP of a can. Consequently, the total sterilizing effect at the SHP of a can, which by convention is expressed as time at constant reference temperature, is not the same as the scheduled time for the thermal process (i.e., the time for which a batch retort might be held at operating temperature). To account for the influence on total sterilizing effect of heating lags it is necessary to integrate the lethal effects of all time/temperature combinations at the SHP during a thermal process and express their sum as being equivalent to time at reference temperature. In manufacture of shelf-stable canned fish it is standard practice to express the magnitude of the sterilizing effect of a thermal process in "minutes" at the reference temperature of 121.1°C. Following this convention, the symbol for the total sterilizing effect of a thermal process is designated as the F_o value; where F_o is defined as being equivalent, in sterilizing capacity, to the cumulative lethal effect of all time/temperature combinations experienced at the SHP of the container during the thermal process. Taking the examples considered above, this means that a botulinum cook must have an F_o value of at least 2.8 min, whereas freedom from thermophilic spoilage by C. thermosaccharolyticum would necessitate an F_o value of at least 16 min.

1.3.1 Determination of F_o values

The F_o value of a thermal process can be determined by microbiological or physical means. The former method relies on quantifying the destructive effects of heating on bacterial numbers through their enumeration before and after a thermal process; the latter method measures the change in temperature during a thermal process at the SHP of the container and relates this to the rate of thermal destruction at a reference temperature. These techniques can be applied to measure the lethal effects of pasteurization processes (in which the target organisms are usually the relatively heat sensitive forms of bacteria, yeasts and moulds) or they may be used to assess the severity of sterilization processes (in which the target organisms are heat resistant spore-forming bacteria). In this text only the physical method of quantifying the lethal effect of thermal processes will be described.

First, it is necessary to record heat penetration data with thermocouple probes which have been carefully placed to detect changes in product temperature at the thermal centres of the packs. There are many commercial brands of thermocouples available to suit most sizes of fish cans, glass jars and retortable pouches; they can also be constructed with copper/constantan thermocouple wire in which the hot junction is constructed by soldering together the ends of the two wires. The hot junction is coated with a thin laquer layer to insulate the exposed metal surfaces from the product (and thereby prevent surface corrosion which might otherwise interfere with the accuracy of the reading), and then it is carefully positioned at the SHP of the container. Once the thermocouples are in place and the process commenced, the temperature is recorded regularly throughout the heating and cooling phases of the thermal process. The heat penetration data so collected may be treated in a number of ways in order to calculate the F_o value of the process; however, only two of these methods are described in the following sections.

1.3.2 The improved general method of F_o calculation

A plot of temperature versus time is made on specially constructed lethal rate paper in which the temperature (on the vertical axis) is drawn on a semi-logarithmic scale and process time on the horizontal scale; also shown on the vertical axis (but usually, for convenience, on the right-hand side of the paper) is the corresponding lethal rate for the temperature which is on the adjacent left-hand vertical axis. By convention, the rate of thermal destruction (designated L) at product temperature (designated T) for bacteria, or their spores, important in canned fish sterilization is taken to be unity at 121.1°C; and further, the rate changes by a factor of ten for every 10°C that the temperature changes. Mathematically this relationship is expressed by the equation,

$$L = \log^{-1} \frac{T - 121.1}{10} \quad \ldots\ldots\ldots\ldots \text{(1)}$$

This means that the rate of destruction for all temperatures can be related to the rate of destruction at the reference temperature (121.1°C). Thus the cumulative lethal effects, for all time-temperature combinations experienced at the SHP in a container, can be equated to time of exposure at 121.1°C.

Once the plot is drawn, the area under the graph is calculated (by counting squares or by using a planimeter) and divided by the area which is represented by 1 min at 121.1°C, i.e., an F_o value of 1 min. This yields the total sterilizing effect, or the F_o value, of the process. Shown in Figure 2 is an example of a temperature-time plot for a conduction heating pack processed at 121.1°C. In the worked example, the area under the graph is 70 "units", which when divided by the area corresponding to a F_o of 1 min, i.e., 4 "units", yields 17.5 min, which is the F_o value for the process being evaluated.

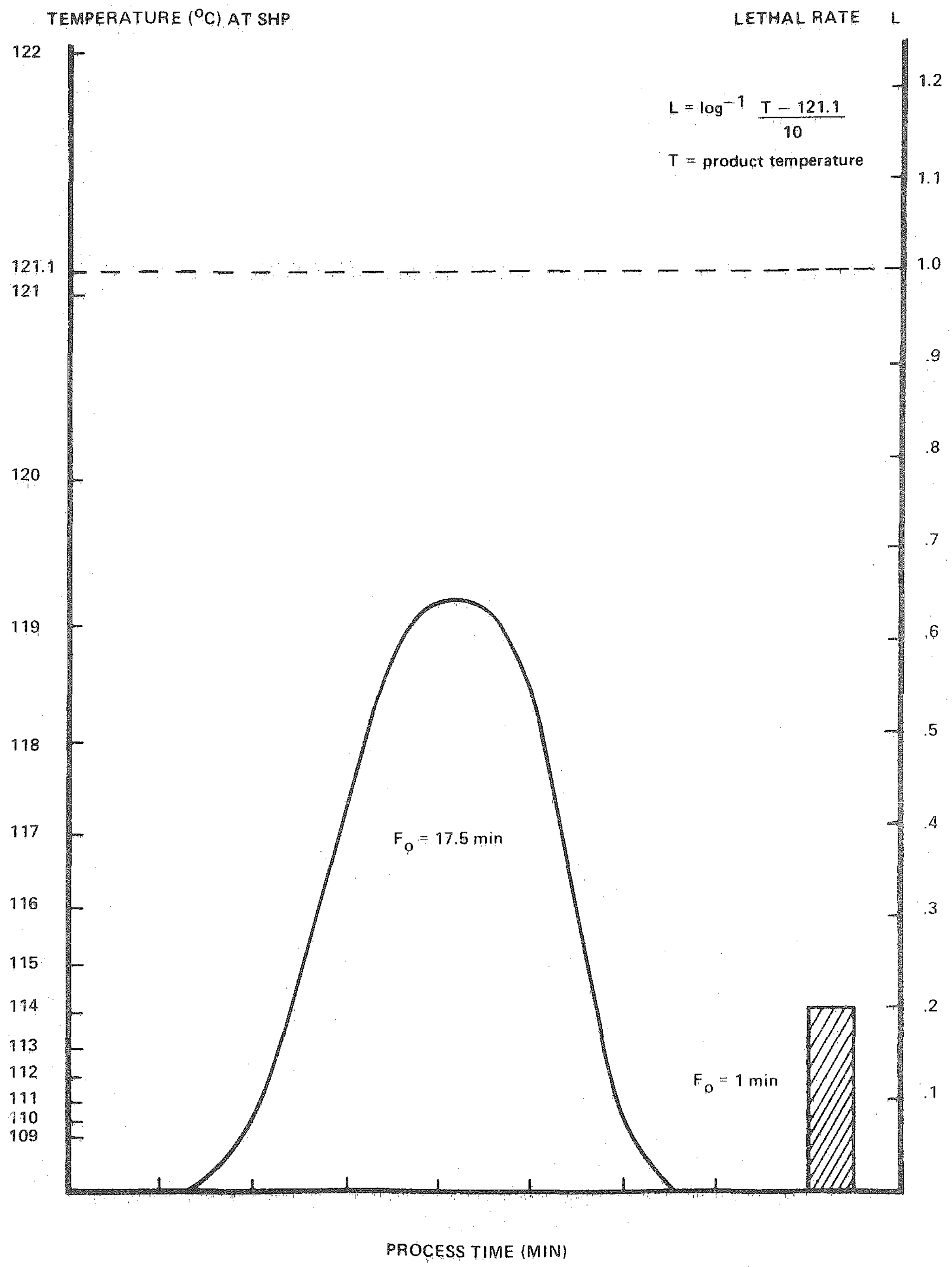


Figure 2 Temperature - time plot for conduction heating pack processed at 121.1°C

It can be seen that the total sterilizing effect of the process is equivalent to 17.5 min at 121.1°C, even though the product temperature never reached 121.1°C, and neither did the retort operate at that temperature. Because it is possible to equate the rates of thermal destruction at any temperature, to the rate of destruction at the reference temperature of 121.1°C, the effects of heating lags can be quantified.

1.3.3 The trapezoidal integration and method

This is a simplified mathematical method in which the time-temperature data are used to record the changes in the lethal rates of spore destruction at the SHPs of containers during heating and cooling. If product temperature is recorded at regular time intervals, and assuming that this temperature is constant for the period between measurements, the lethal rate applying for each time interval can be computed (using equation 1). When the rates (applying over each time interval) are summed and multiplied by the time between measurements, the cumulative F_o value for the entire process can be found without the need for graphical representation of the heating and cooling curves. The trapezoidal method also allows simple calculation of the contribution to total process lethality of the heating and cooling components of the process. In Table 2 is shown a worked example in which the product temperature was recorded at 5 min intervals during a process of 60 min at 121.1°C.

<u>Table 2</u>

Time, temperature, lethal rate, cumulative lethal rate and F_o value for a conduction heating product retorted at 121.1°C for 60 min

Time (min)	Temperature (°C)	Lethal rate	Cumulative lethal rate	F_o value (min)
0	24.0	0	0	0
5	24.5	0	0	0
10	34.2	0	0	0
15	54.7	0	0	0
20	72.5	0	0	0
25	87.0	0	0	0
30	98.0	0.005	0.005	0.025
35	105.1	0.025	0.030	0.150
40	110.5	0.087	0.117	0.585
45	114.5	0.219	0.336	1.679
50	117.2	0.407	0.743	3.717
55	119.0	0.617	1.360	6.798
60 (steam off)	120.3	0.832	(1.776)	(8.880)
			2.192	10.960
65	120.3	0.832	3.024	15.120
70	106.0	0.031	3.055	15.275
75	88.1	0.001	3.056	15.280
80	70.0	0	3.056	15.280

To calculate F_o for the total process: the sum of the L values gives 3.056 which when multiplied by five (the time interval between readings), gives an F_o value of 15.3 min. (Although the theoretical total F_o value for the process is 15.280 min, this can be rounded to 15.3 min as it is unrealistic to quote values beyond the first decimal place.)

To calculate F_o for the heating phase: the sum of the L values at times 25 min and 60 min (i.e., 0 and 0.832) is divided by two and this value (0.416) is added to the sum of the L values from 30 min to 55 min (1.360), so that the total accumulated lethal rate at the time the steam was cut (1.776) can be multiplied by five to give a total F_o value of 8.9 min at steam off. This feature of the trapezoidal method allows for simple calculation of the F_o value during thermal processing, as for instance may be required when the schedule calls for steam to be cut when the F_o reaches an assigned value.

1.4 Specification of the Thermal Process Schedule

Once target F_o values for canned fish products are specified, manufacturers must take steps to ensure that all cans receive the correct thermal process and that all factors affecting the rate of heat transfer to the SHP of every can are controlled. It is by these means that microbiological spoilage arising from under-processing can be prevented and the associated health and/or commercial risks avoided. The technique most frequently adopted to control delivery of the thermal process is to draw up a thermal process schedule which specifies those factors which, in any way, could affect delivery of the target F_o value to the SHP of the container. The Codex Alimentarius Commission (1983) define scheduled process as "the thermal process chosen by the manufacturer for a given product and container size to achieve at least commercial sterility".

Government regulators in many countries adopt similar systems to monitor the scheduled processes of products sold under their jurisdiction, and of these perhaps one of the best known is that implemented by the United States Food and Drug Administration (FDA). In addition to requiring that those processors of acidified and low-acid canned foods sold in the United States register their establishments with the FDA, it is also necessary to file with FDA scheduled processes covering all canned foods which are destined for sale in the United States. Although these requirements will only be relevant for those canners supplying the United States market, the regulations identify several factors which form a useful checklist for canners who are formulating new canned fish scheduled processes, amending existing ones or wishing to review their control procedures. The information which should be specified in the scheduled process is summarized in Table 3.

Not all the items shown in Table 3 will be relevant for a single process. For instance, with some processes the number of retort baskets per retort load will remain constant, whereas with others, it may vary because of delays caused by fluctuations in the supply of fish to the canning line. Under "worst-case conditions" (i.e., with full loads) the steam requirements will be considerably greater than when the retort is only partially full; also, under these conditions steam circulation can be impaired so that the rate of heat transfer to the SHP of the containers is adversely affected. In a case such as this, that steam circulation is influenced by the load size, need be of no consequence, provided the effect is accounted for when calculating the scheduled temperature and duration of the thermal process.

Taking another example, specification of product fill weight may be important when filling solid style tuna or whole abalone into cans which are later to be topped-up with canning liquor; in both instances the convective currents in the brine favour rapid heat transfer to the boundaries of the solid product, there then follows conduction heating during which heat is transferred more slowly to the SHP of the container. However, should fill weight not be controlled, with the result that some cans contain more solid (and therefore less brine, given that the latter is added to a constant headspace), the rate of heat transfer to the SHP of containers will vary, being slower in those packs containing a higher ratio of solids to liquids. The effect of changing the solids to liquids ratio in a pack ought not be underestimated, and alterations should never be adopted without first confirming the adequacy of the process after the proposed change. This point has been demonstrated through trials in which fill weight for solid style tuna packed in 84 x 46.5 mm cans was increased by 10% over the maximum specified. The packs were then processed at 121.1°C, and in order to achieve a constant target F_o value of 10 min (for the standard and the overweight packs), it was found necessary to increase process time by 16% for the heavier pack. In this case, failure to compensate for overfilling would not significantly affect public health risks while the target F_o was of the order of 10 min (or more), although there would be an increased probability of survival for those spores more heat resistant than C. botulinum and, associated with that, an increase in the commercial risk of non-pathogenic spoilage. However, public health risks arising from overfilling can increase for those manufacturers, who,

Table 3

Cheklist of factors affecting delivery of the scheduled processes for canned fishery products

Item	Reason for inclusion
Container dimensions	Affects rate of heat transfer to SHP
Target F_o value	Affects probability of under-processing spoilage
Process temperature	Affects time required to achieve target F_o
Process time	Affects temperature
Product initial temperature	Affects time for product to reach temperatures lethal to spore-forming bacteria
Product fill weight, i.e., extent of conduction or convection heating	Affects mode of heat transfer to SHP
Product consistency (with homogenous packs)	Affects rate of heat transfer to SHP
Liquids to solids ratio and particle size (with particulate packs)	" " " " " " "
Packing style (e.g., horizontal or vertical alignment of pieces)	" " " " " " "
Container stacking patterns in retort or retort baskets	" " " " " " "
Number of retort baskets/retort	" " " " " " "
Retort operation, e.g., venting and/or condensate removal	Affects temperature of heating medium
Cooling method	Affects contribution to total process F_o of cooling phase

being wary of the reduced yields and or losses in sensory quality caused by processing heat sensitive marine products (e.g., oysters, mussels and scallops), select target F_o values closer to the minimum for low-acid canned foods (i.e., F_o = 2.8 min).

The rationale behind preparation of the thermal process schedule is to provide a standard format for identifying and specifying all those factors affecting the adequacy of the thermal process. The checklist, shown in Table 3, is a guide which should be adapted to suit each canner's requirements. It is important that the scheduled process be developed only by those expert in thermal processing and, only then, when the data upon which recommendations are based are determined in a scientifically sound and acceptable manner. Because of the importance that is attached to correct calculation of thermal processing conditions, it is common to find that in some countries the regulators overseeing canning operations maintain a register of those who are "approved" to establish thermal process schedules.

Once a thermal process schedule has been established it must not be altered without first evaluating the effects of the proposed change on delivery of target F_o values. Also, alterations to product formulation must be evaluated in terms of the possible changes they bring about in the product's heating characteristics. Ideally, specification of the thermal process schedule will be based on data from heat penetration trials with replicate packs, processed under the "worst-case conditions" likely to be encountered in commercial production; however, if this is not possible it is sufficient to refer to those standard texts on canning which recommended process times and conditions for a wide range of canned foods.

In summary therefore, the process schedule provides the specifications which are critical to delivery of an adequate thermal process. The times and temperature of the process schedule is usually contained in the process filing form, an example of which is shown in Figure 3. When completed, the process filing form will also contain additional information which should be specified in the process schedule. It is good practice for the details of the scheduled process to be conveniently located close to the retorts and in a position where it can be seen by the operator.

1.5 Application and Control of the Scheduled Process

Once the process schedule is defined, the manufacturer must implement systems to monitor, control and provide records which confirm, after the event, that all stages in production affecting heat transfer to the SHP of the can were within specification. Records provide the means for a continuous assessment of production and an early warning system with which to initiate corrective action if potential problems arise; also they provide valuable and permanent documentary evidence that delivery of the process was in line with details in the process schedule. The value of permanent records becomes apparent at times of product recalls, when the need may arise for the canner to demonstrate that production techniques complied with good manufacturing practice (GMP) guidelines - without this evidence canners risk facing claims of professional negligence should their product become involved in litigation.

Records should be simple to complete, so as not to discourage their use, and easy to interpret. In some cases it may be appropriate to record data on a quality control chart which shows the change in some variable against time (e.g., fill weight, as in Figure 4). The scales can be chosen to show the change in values about the target value and also include permissible maxima and minima (i.e., tolerances); action levels can be included to alert operators of trends that may cause production to move out of control. Quality control charts are well suited to continuous operations where monitoring takes place throughout production, they are less frequently used when the function being evaluated is a batch operation. Some recording systems are completed by the operator at specified stages of an operation (e.g., the retort log sheet, as in Figure 5) while others are automated and require only minimal operator input (e.g., retort thermographs, as in Figure 6).

No matter what form of records are adopted, their function is to provide retrospective assurance that the thermal process schedule and those related factors which affect heat transfer to the SHP of the container have been regularly monitored and controlled during production.

FISH CANNING ESTABLISHMENT — Thermal Process Filing Form for Still Retorts

Establishment Name			Establishment No.	OFFICIAL USE ONLY
Address				Date received
City	State	Postcode	Telephone No.	File No.
Fish Product — Name and form				Approval No.
Type of Retort and heating medium		Container type ☐ Tinplate can ☐ glass jar ☐ Other (specify)		Other critical control factors ☐ Percentage solids ☐ Formula change ☐ Solid/liquid ratio ☐ Hand fill ☐ Mechanical fill ☐ Other (specify)
Heating by ☐ Conduction ☐ Convection Heating Curve ☐ Simple ☐ Broken or complex	Come-up time (from end of venting to operating temperature)	Normal pH (Processed) (1)	Minimum vacuum in container after closing (where applicable) — kPa	

Container Dimensions		Maximum drained weight (where applicable)	Minimum Net Weight	Minimum Scheduled Process (2)						Product Code	Formula Approval No.			Process Approval No.		
Size (mm)	Shape			Min Initial Temp.	Time Mins.	Temp. C	fh (3) Value	j (3) Value	Fo Value		USA	Canada	Other (specify)	USA	Canada	Other (specify)

Process submitted by:

Name ____________________

Signature ____________________ __/__/__
(Approved Person)

This is an ☐ original submission ☐ amended submission in respect of Approval No. ____________

I hereby certify that I have sighted the process and formula approvals as indicated above.

____
(Name)

__/__/__

____
(Signature of Officer-in-charge)

(1) pH may vary under commercial condition by ±.5 units for most products.
(2) Basic data from scheduled process as calculated to be attached for new products, or documentary evidence from approved authority for existing processes.
(3) fh and j values not required with complex or broken heat curves.

Figure 3

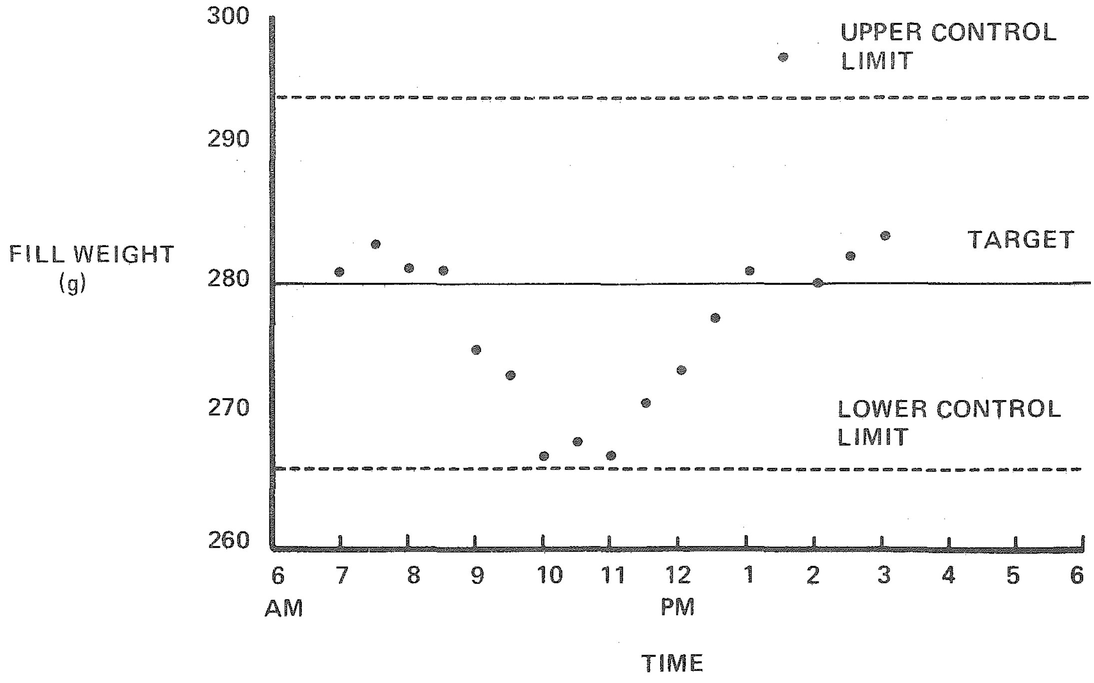


Figure 4 Quality control chart for recording container fill weight

2. PACKAGING MATERIALS FOR CANNED FISHERY PRODUCTS

Containers for thermally processed canned fishery products have several functions in common, whether they are constructed of metal, glass, plastic laminates or composites of plastic and metal laminates. The functions of packaging materials can be summarized as follows:

(a) to hermetically seal the product in the container while delivering a thermal process which will render it "commercially sterile";

(b) to prevent recontamination of the product after processing and during subsequent transport and storage; and

(c) to provide nutritional benefits and marketing convenience, through presentation of preserved fishery products all year round, often far from the source of supply, and in the majority of cases without the need to rely on refrigerated food chains.

2.1 Metal Containers

2.1.1 Tinplate

The most frequently used form of packaging for canned fishery products is tinplate which is fabricated into two and three piece cans of a wide variety of shapes and sizes. Tinplate consists of a base plate of low-carbon mild steel, onto each surface of which is electrolytically deposited a layer of tin. Base plate gauge varies, depending on the size of the cans which are to be manufactured and their intended application; however, it is usually between 0.15 and 0.30 mm thick. Nowadays, for the manufacture of extra light gauge plate, steel sheet is cold rolled twice prior to being tin coated, and in these cases is referred to as double reduced (DR) plate. Tin coating mass varies, according to end use and whether or not lacquers are to be applied; the thickness of the tin coating layers ranges from around 0.4 to 2.5 micron. Shown in Table 4 is the

RETORT OPERATORS LOG SHEET

Date	Product	Code	Container		Min^{m} Initial product temp.	Retort No.	Scheduled Process		Time					Retort Temperature		Signed by
			Size	No/R			Time	Temp	Steam On	Vent Closed	Temp Up	Steam Off	Actual process	Mercury in glass	Thermo-graph	

Reviewed .... Date ....

Figure 5

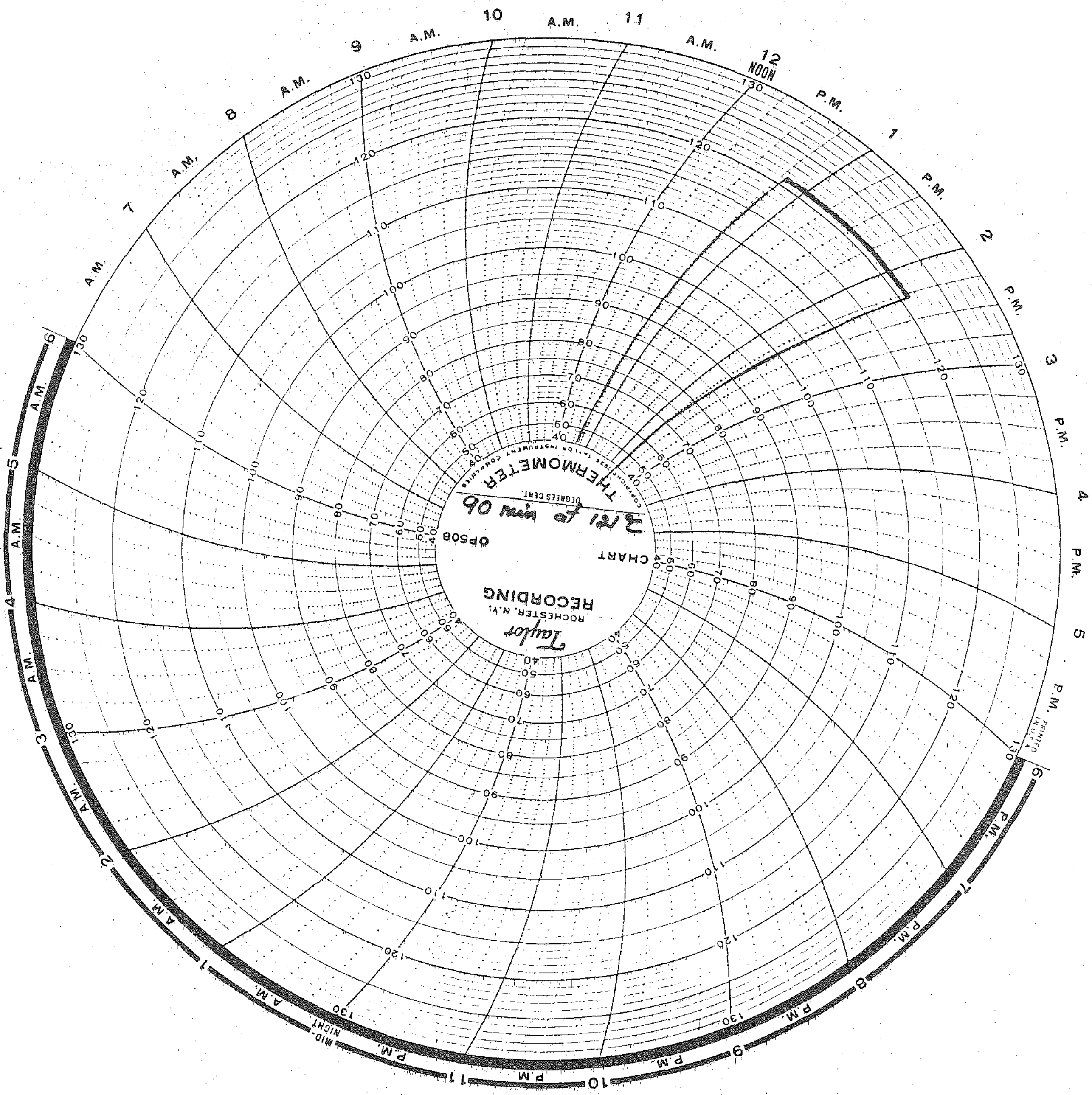


Figure 6 Retort thermograph showing record of 90 min process at 121°C

designation, nominal coating mass and minimum average coating mass for electrolytically coated tin plate. Plate on which the tin coating mass is the same on each surface is known as equally coated plate; whereas plate with different tin coating masses on each surface is referred to as differentially coated plate. When specifying tin coating masses it is customary to quote, for each surface, the nominal mass of tin per square metre of plate. Following the standard nomenclature, the designation E05 means that on each surface, there is 2.8 g of tin per square metre of plate; while the designation D10/05 means that the tinplate is differentially coated and has 5.6 g of tin per square metre of plate on one side, and 2.8 g of tin per square metre on the other surface.

Tin is applied to provide sacrificial protection of the steel base - the tin layer gradually dissolves and passes into the surrounding solution, while the steel layer beneath remains protected. Recently the high cost of tin has made attractive the production of tin-free steel (TFS) in which the conventional tin and tin oxide layers are replaced by chromium and chrome oxide layers. Thus conventional tinplate and TFS consist of multi-layered structures; tinplate comprises an innermost steel layer on top of which there is in sequence, and on each surface of the plate, a tin/iron alloy layer, a free tin layer, a tin oxide layer and an oil lubricant layer, whereas TFS comprises a base steel layer on top of which there is sequentially and on each surface, a chromium layer, a chromium oxide layer and an oil lubricant. Plain TFS cannot be readily soldered, it lacks the corrosion resistance of conventional tinplate (since there is no sacrificial protection of the steel by an overlayer of tin), but it provides an excellent key surface onto which can be applied protective lacquers. Since the introduction of TFS, there has been development of a third system using neither tin nor chromium but nickel as a coating material for the steel base.

In canned fishery products (and with other proteinaceous packs such as meat and corn), it is customary to use sulphur resistant (SR) lacquer systems to prevent the formation of unsightly, yet harmless, blue/black tin and iron sulphides on the plate. Due to the inclusion of white zinc oxide, SR lacquers have a milky appearance. The reason for the inclusion of the zinc is that it reacts with the sulphur compounds, released from the proteins during thermal processing, to form zinc sulphide precipitates which cannot readily be detected against the background of the opaque lacquer. Another lacquer system finding use for meat and fish packs relies on the physical barrier provided by the inclusion of aluminium pigments in an epoxy-phenolic (epon) lacquer. These lacquers, often referred to as V-enamels, are common in pet food cans.

2.1.2 Aluminium

The dominant position of tin plate as the packaging material of choice for canned seafood products has been challenged with the development of aluminium alloys. Alloys frequently lack the chemical resistance of pure aluminium; however, because they possess greater hardness than that of the pure metal, alloys are well suited to the construction of cans. The mechanical characteristics, lacking in pure aluminium yet required in the material for food cans, are obtained by the inclusion of small amounts of magnesium and manganese. Depending on the can size and the alloys used, the thickness of the aluminium in fish cans normally ranges from 0.21-0.25 mm. Care must be exercised when manufacturing "easy-open" ends to control the depth of the scores so as to avoid "cut through"; practically, this restricts the lower limit for the thickness of plate which can be used in ends. Aluminium alloys are widely used for the manufacture of dingley, club, hansa, and a variety of conical and straight sided round cans. Some of the important factors which account for the increasing popularity of aluminium for the construction of fish cans are summarized:

- ease of fabrication. Many fish canners manufacture their own can bodies from pre-coated coil stock, thus saving the costs of transporting the bulky empty containers from the can manufacturing plant;

Table 4

Tin coating mass for electrolytic tinplate sheet[a/]

Designation	Coating mass (g/m^2)	
	Nominal	Min[m] average
Equally coated tinplate		
E02	1.1/1.1	0.9/0.9
E05	2.8/2.8	2.5/2.5
E07	3.9/3.9	3.6/3.6
E10	5.6/5.6	5.2/5.2
E15	8.4/8.4	7.8/7.8
E20	11.2/11.2	10.1/10.1
E27	15.1/15.1	13.4/13.4
Differentially coated tinplate		
D05/02	2.8/1.1	2.5/0.9
D10/05	5.6/2.8	5.2/2.5
D15/05	8.4/2.8	7.8/2.5
D15/10	8.4/5.6	7.8/5.2
D20/05	11.2/2.8	10.1/2.5
D20/10	11.2/5.6	10.1/5.2

a/ Figures quoted show the tin coating mass per square metre for each surface of the tin plate

- attractive appearance;
- good corrosion resistance. Although generally more resistant to external atmospheric corrosion, product induced internal corrosion and sulphur staining, than unlacquered tinplate cans, aluminium cans are coated internally with an epon or polyester lacquer and externally with polyesters and polyvinyl fluoride coatings;
- ease of opening tear-off ("easy-open") ends;
- light weight;
- recyclability (however, this characteristic is of greatest significance with carbonated beverage and beer cans);
- elimination of side seams with drawn cans. (This desirable feature is also available with drawn tinplate cans).

Because of their relatively large surface area and flexibility, many aluminium cans ends (e.g., those on club and dingley cans) are prone to distortion during retorting and early in the cooling cycle (i.e., when the pressure in the cans is greatest). In some cases this will cause peaking, and it is in order to avoid this that these cans are commonly processed in counterbalanced retorts operating with an overpressure.

2.1.3 Can construction

Metallic cans are available in a multitude of shapes and sizes to suit all types of canned fishery products. A selection of the range can be seen in Table 5, in which are shown the common two and three-piece cans used by the fish canning industry.

Three-piece cans are manufactured from a rectangular piece of tinplate (known as a body blank) which is formed into a cylindrical shape and then joined along a vertical seam by either soldering or welding; to this section are added two ends, one by the can maker and the other, after filling by the canner - the former is referred to as the can maker's end (CME) and the latter the canner's end (CE). The seam joining the can end and the body is known as the double seam and it is the formation of this seal which is critical if the container is to function correctly. Errors in "double seaming" can lead to loss of the hermetic seal and the possibility of post-process contamination, giving rise to canned food spoilage. Diagrams illustrating the sequence of rolling double seams, critical double seam morphology and criteria for assessing double seams are presented in section 2.1.4. Experience has shown that the majority of problems arising through faulty double seam formation are associated with errors in application of the canner's ends. This is attributable to the greater difficulty in applying can ends under commercial filling operations, when compared with completing the same operation in the can making plant.

Two-piece cans for fishery products are made by the draw and re-draw (DRD) process using aluminium or tinplate. While it is possible to have two-piece cans using both tinplate and aluminium (e.g., a tinplate body with an aluminium end), they have the disadvantage that bi-metallic corrosion may occur if the two exposed surfaces come into contact. DRD cans are made from circular blanks of pre-lacquered plate which are first drawn into shallow cups and then re-drawn, once or twice depending on the can's final dimensions, causing an elongation of the wall and a simultaneous reduction of diameter. One great benefit of two-piece cans is that they have no side seam, and only one double seam, thus reducing the risks of leakage arising from imperfect seam formation.

Aluminium easy-open two-piece cans enjoy great popularity for canned sardines where the convenience of the tear-off end is well suited to the dimensions of the product; however the functional benefits of the system have to be weighed against the slightly greater costs of the aluminium container and in some cases the need to process in counter-balanced retorts to prevent the light gauge plate from deforming during thermal processing.

Since the mid 1970s tapered two-piece tinplate and aluminium have been available. Here the can body is drawn from a blank and transported while nested with other cans in tiers. The system offers savings in equipment, labour costs and space when compared with un-nested conventional three-piece tinplate cans; it also overcomes the need to complete fabrication in the cannery, as occurs with cans bodies that are despatched in the flat for later erection (reforming) and addition of the can maker's end, prior to normal filling and sealing.

2.1.4 Double seam formation and inspection procedures

The double seam is an hermetic seal formed by interlocking the can body and the can end during two rolling actions. The first action roll curls the edge of the can end up and under the flange of the can body and folds the metal into five thicknesses (seven at the side-seam) while embedding the flange into the compound. During this operation the circumference about the edge of the can end is reduced causing the "extra" metal to wrinkle. The second action roll flattens and tightens the seam so that an hermetic seal is formed. This action causes the wrinkles (formed in the first operation) to be ironed out while the compound is forced into any gaps between the metal surfaces. Shown in Figures 7, 8, 9 are diagrams showing the various stages in the formation of a can double seam; in Figures 10 and 11 are a cross section of a double seam and the major attributes affecting seam quality.

As product safety depends upon maintenance of the hermetic seal, it is important that double seam formation be checked regularly during production, after all jams under the sealing machine, after adjustment to the machine, and after machine start-up following a long delay in production. Good manufacturing practice guidelines indicate that visual inspection of double seams should be at least every 30 min, while full teardown procedures should be followed for each

Table 5

Summary of selected two and three piece aluminium and tinplate cans showing nominal dimensions and capacity, typical products and net and drained weights

Type of can	Material	Capacity (ml)	Length (mm)	Width[a/] (mm)	Height (mm)	Product	Net weight (g)	Drained weight (g)
2 piece								
1/4 Dingley	Aluminium or Tin[b/]	112	105	76	21	Sardines, small fish	106	85
1/4 Club	Aluminium or Tin[b/]	125	105	60	29	Sardines, small fish & tuna	125	95
1/2 Hansa	Aluminium or Tin[b/]	200	148	81	25	Herrings	195	130
1/2 Oblong	Aluminium or Tin[b/]	212	155	61	30	Kippers	225	225
1/3 Oval	Tin plate	200	149	81	25	Mackerel	195	130
1/2 Oval	Tin plate	270	149	81	25	Mackerel	250	180
2 & 3 piece								
2 piece round	Aluminium	225	-	90	40	Shrimp	217	150
2 piece round	Aluminium	115	-	78	32	Shrimp	111	75
2 piece 1/2 round	Aluminium or Tin	245	-	90	44	Fish & vegetables, herring, tuna	230	c/
2 piece 1 round	Tin plate	490	-	120	49	Fish & vegetables, herring, tuna	460	c/
3 piece round	Tin plate	106	-	66	40	Tuna	100	78
3 piece round	Tin plate	212	-	84	46	Tuna	200	155
3 piece round	Tin plate	400	-	99	60	Tuna	377	292
3 piece round	Tin plate	4 250	-	218	123	Tuna	4 000	3 100
3 piece round	Tin plate	8 500	-	218	245	Tuna	8 000	6 200
3 piece round	Tin plate	450	-	74	118	Abalone	425	213
3 piece round	Tin plate	450	-	72	118	Codroe in brine	425	300
3 piece round	Tin plate	450	-	101	64	Fish cakes	400	260
3 piece round	Tin plate	900	-	101	121	Fish balls	800	520

a/ Diameter of round cans shown as width

b/ Cans constructed with aluminium or tin plate

c/ Drained weight affected by proportion of vegetables in pack

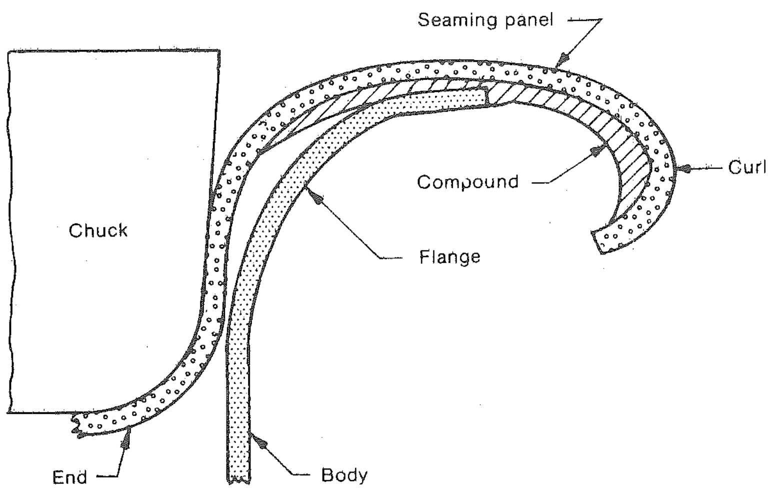


Figure 7 Cross-section showing the positioning of the parts of the can body and loose end which will form the double seam (Courtesy of Standards Association of Australia.)

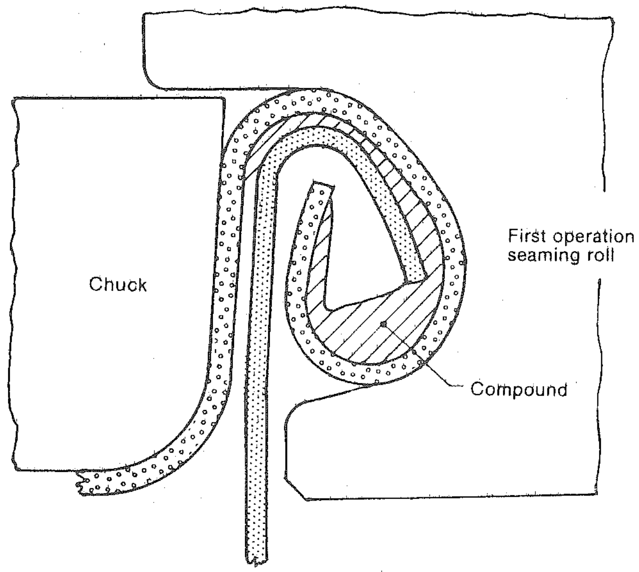


Figure 8 Cross section of the seam after the first operation (Courtesy of Standards Association of Australia.)

sealing head at least every four hours. Can manufacturers and can seaming machine suppliers usually supply directions for seam formation and standards against which double seams are evaluated. As a guide the major quality criteria for assessing double seam quality are summarized:

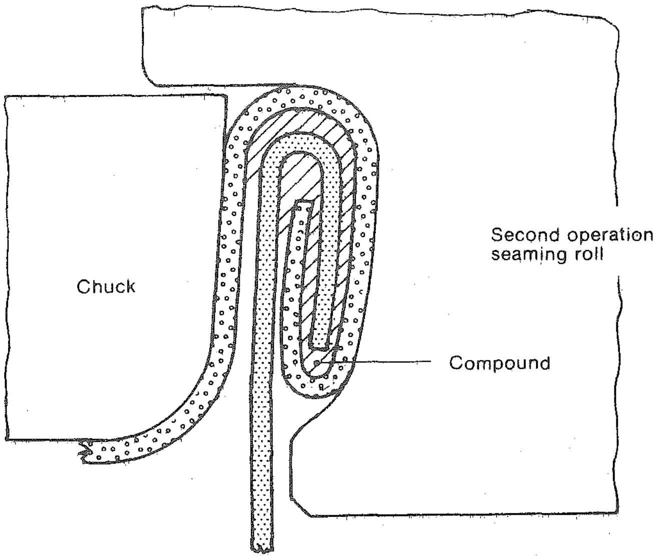


Figure 9 Cross section of the seam after the second operation (Courtesy of Standards Association of Australia.)

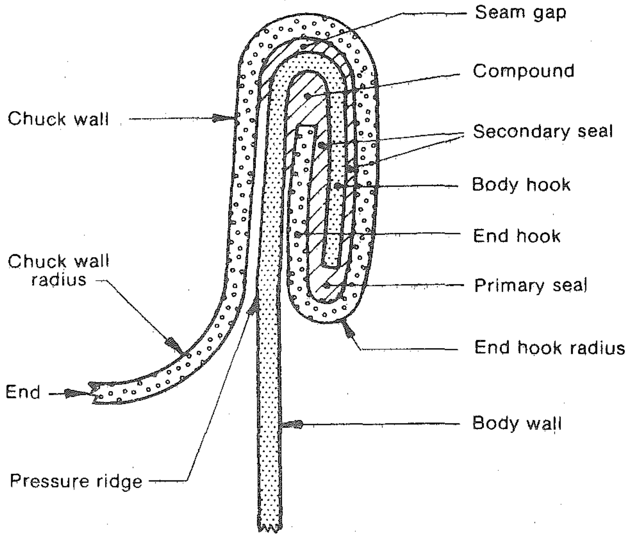


Figure 10 Cross-section of a double seam away from the side seam (Courtesy of Standards Association of Australia.)

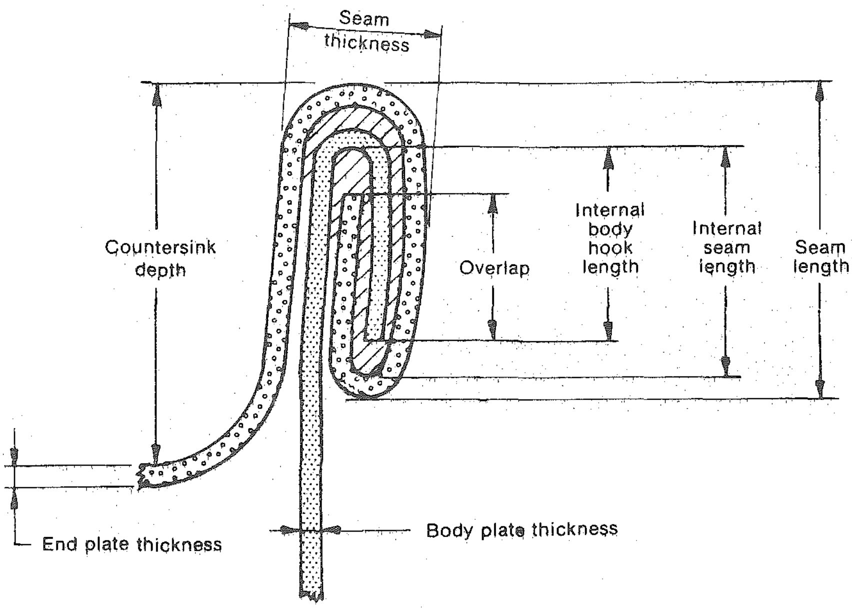


Figure 11 Cross-section of a double seam showing some of the attributes that influence seam quality (Courtesy of Standards Association of Australia.)

(a) External inspection: much information as to the quality of a double seam can be obtained by a visual and tactile examination of the rolled seam. For skilled operators it is often not necessary to strip a double seam and measure the component in order to determine whether the sealing machine is rolling seams which comply with the requirements of good manufacturing practice. Conversely, an alert machine operator can pick up drift in performance before double seam criteria fall below acceptable limits. When conducting these assessments it is necessary to check for the following defects:

- droop at the juncture, spurs and skidders (see Figures 12 and 13);

- seam cut over, seam fracture and cut seam (see Figure 14);

- false seams (a point on the seam where the end and body hooks fail to engage);

- damage to the double seam or can body.

Also shown in Figure 13 are the locations where double seam measurements of the stripped seam components of circular cans should be conducted, and in Figure 15 are shown the positions for component measurements on rectangular cans.

(b) Tear down inspection: a complete analysis of the double seam form and dimensions should be completed at least every four hours of continuous production for each seaming head. At times when there are difficulties with seam formation, these tests should be completed more frequently until satisfactory performance is demonstrated. The double seam attributes to be assessed include:

- body hook butting ($\geq$70%),

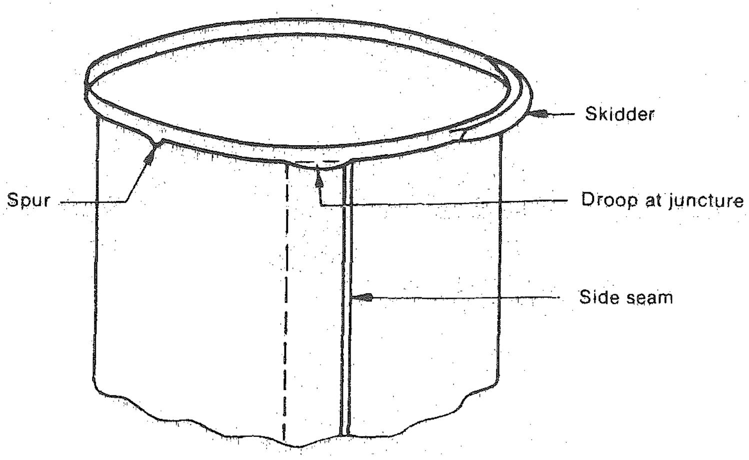


Figure 12 Double seam showing spur, a drop at the juncture and an incompletely rolled region known as a skidder (Courtesy of Standards Association of Australia.)

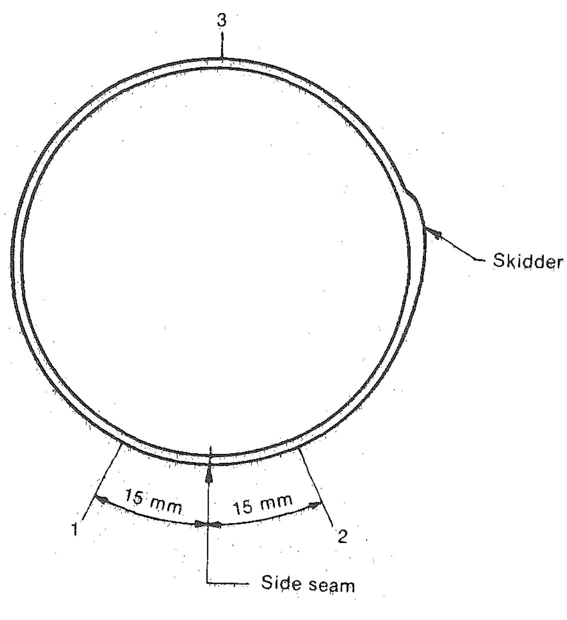


Figure 13 Positions designated 1, 2 and 3 are the points at which to measure the double seam components. Also shown is a skidder resulting from incomplete rolling of the seam (Courtesy of Standards Association of Australia.)

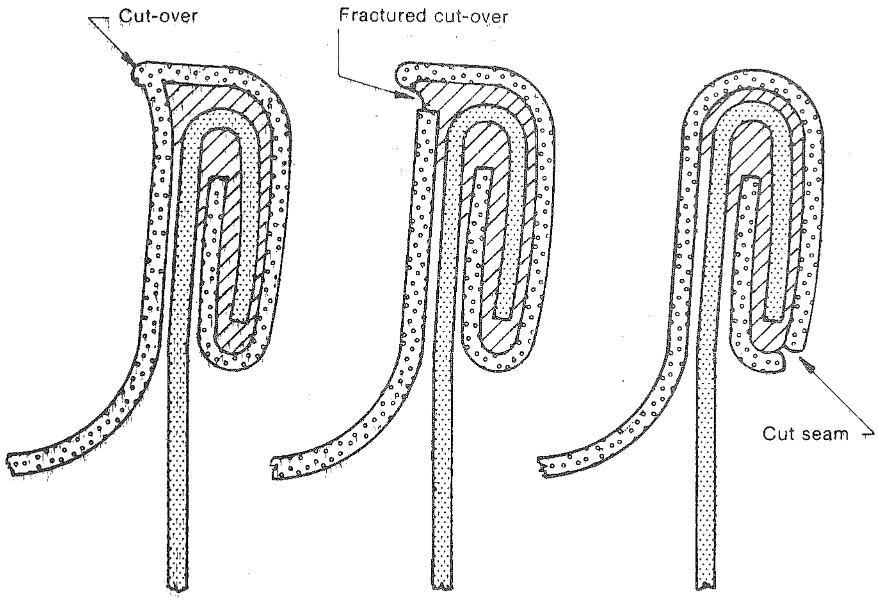


Figure 14 Cross section of a seam showing cut-over, a fractured cut-over and a cut seam (Courtesy of Standards Association of Australia.)

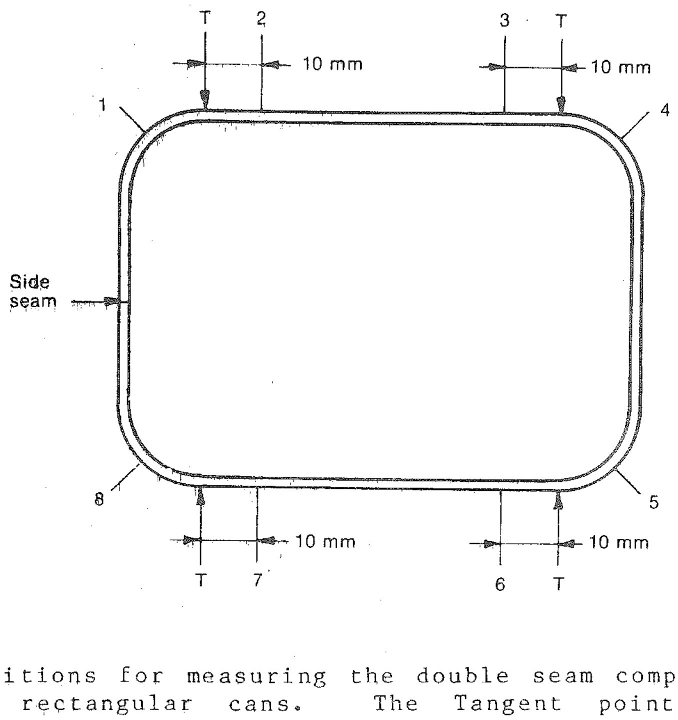


Figure 15 Positions for measuring the double seam components on rectangular cans. The Tangent points are indicated by the letter T (Courtesy of Standards Association of Australia.)

- overlap ($\geq$45%),
- tightness($\geq$70%),
- juncture rating ($\geq$50%),
- countersink depth ($\geq$ seam length at the same point),
- pressure ridge (continuous and visible).

In parentheses are shown the Australian recommended specifications for round cans of 74 mm diameter; however, as these values change for cans of different sizes and shapes, manufacturers ought consult their can suppliers to determine the satisfactory compliance criteria for use with their cans. Shown in Figures 16 and 17 are schematic diagrams for double seam sections of an end hook showing the juncture rating and the tightness rating, respectively. A cross section of a partially stripped seam in which the pressure ridge is visible is shown in Figure 18.

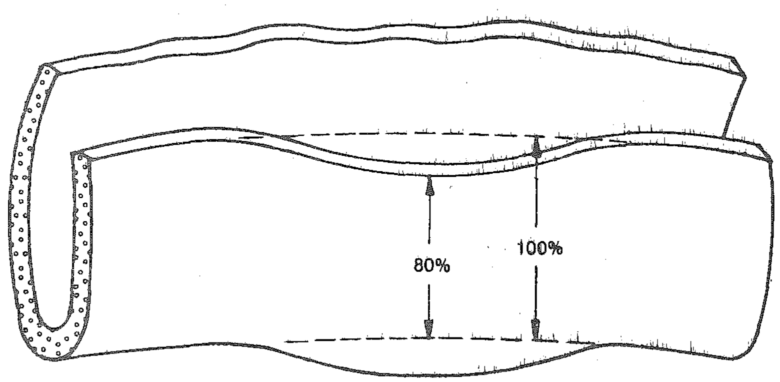


Figure 16 Section showing the juncture rating, which is equal to the percentage of the end hook which is available for overlap; in the example the juncture rating is 80% (Courtesy of Standards Association of Australia.)

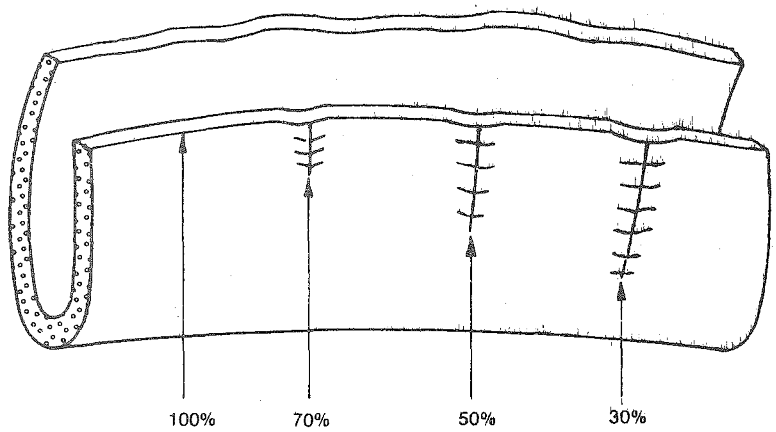


Figure 17 Section of an end hook showing increasing degrees of wrinkle from left to right. The tightness of the different parts of the seam is shown by the figures which indicate the percentage of the end hook length which is not wrinkled (Courtesy of Standards Association of Australia.)

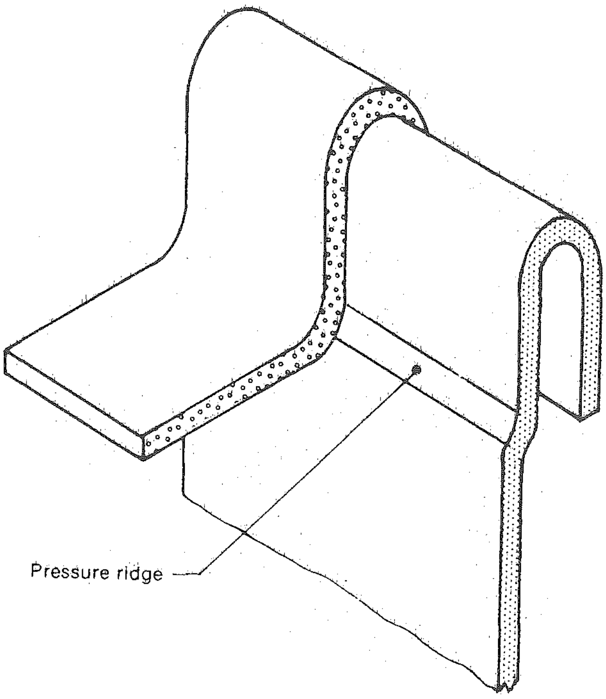


Figure 18 Section of a partly stripped seam showing the pressure ridge on the inside of the can body (Courtesy of Standards Association of Australia.)

2.2 Plastics and Laminates

With the development of plastic and plastic and aluminium foil, flexible, semi-rigid and rigid laminated packaging materials, has come a range of systems suitable for in-container sterilization of fishery products. Of these, the best known is the retortable pouch, which because of its flat profile and correspondingly high surface area to volume ratio (relative to that of cans), heats more rapidly than conventional cans. However, despite certain of their advantages (e.g., greater retention of heat labile nutrients and other quality benefits arising due to rapid heat transfer to the thermal centres of retort pouch packs; the favourable costs of transportation, and the ease of opening and heating contents) they have not replaced, to the extent that was anticipated, conventional packaging materials for heat sterilized fishery products.

In America, problems were encountered with early versions of the flexible retort pouches which typically consisted of a three-ply laminate comprising an outer polyester layer (for strength, scuff resistance and printability), a central foil layer (for excellent barrier properties) and an inner polyethylene or polypropylene layer (for heat sealability). These difficulties arose primarily because of FDA's concern regarding approval of the food contact surfaces used in flexible pouch manufacture, and although they have been overcome, there still remain other disincentives arising from:

- the slow filling speeds (compare with metal cans);
- the difficulty of maintaining seal integrity when closing contaminated sealing surfaces;
- the difficulty of regulating the counter pressure required to assure a uniform profile during processing and cooling;

- the high cost of capital investment; and

- the need for protective outer wrappers.

Semi-rigid (all plastic), pouches (trays) are now available and with some of these systems the problems of slow filling and sealing speeds have been overcome by using integrated form-fill computer controlled equipment. Depending on the heat treatment selected, fish processors may choose trays manufactured to withstand pasteurization conditions (i.e., at <100°C) or sterilization conditions (i.e., at 110°-122°C). Irrespective of the form of the laminated container and the temperature at which it is processed, the function is the same - it must provide a strong hermetic seal, and because of this the seals should normally be at least 3 mm wide and continuous. For heat sealing the sealing surfaces should be plane-parallel to each other and the temperature of the jaws should be uniform across the entire sealing area. Since the integrity of the heat seal is critical to the safety of the product, it should be tested routinely. Typical testing protocols include,

- seal strength tests, normally used to determine the best combination of time temperature and seal pressure;

- burst-pressure tests;

- seal thickness tests;

- dye penetration tests; and

- visual appraisal of seal quality.

Whether considering retortable pouches which are flexible, semi-rigid or rigid, all offer the common attraction of providing a means to minimize the nutritional and sensory quality losses (which often are associated with traditional thermal processing in rigid containers), while simultaneously providing the opportunity to display visually appealing products. This is why developments with pouch packs are establishing a tradition of promoting a high quality image for fishery products.

2.3 Glass

With the exception of some fish pastes, glass is rarely used for fishery products which are preserved by heat alone; however, it is frequently chosen to package semi-preserved items such as salted fish, pickled herrings and caviars. The principles of processing in glass are substantially the same as for cans, but there are certain modifications which are necessary because of the sealing mechanisms used, and the thermal properties of glass, which make it vulnerable to rapid changes in temperature of more than 50°C.

2.3.1 Sealing mechanisms

Like cans, glass must be hermetically sealed to prevent product contamination after sealing and processing. Closures for glass container are made with either lacquered tinplate or aluminium into which has been placed a flowed-in plastisol lining compound (or a rubber ring with a pry-off cap) that acts as a sealant between the glass surface (called the "finish") and the cap. The closure is held in place by the vacuum in the container and/or the friction between the glass finish and the cap. The sealing surface of the glass may be across the top of the finish as with twist caps (Figure 19) or around the side of the finish as with pry-off caps (Figure 20) or around both the top and side seals as with push-on twist-off (PT) caps (Figure 21). It is important that the glass sealing surface be free of defects and protected from damage, as otherwise there is an unacceptable risk that the container will leak and draw in contaminants. It is because of the latter requirement that it is recognized as good manufacturing practice to ensure that the diameter across the finish of the jar is less than

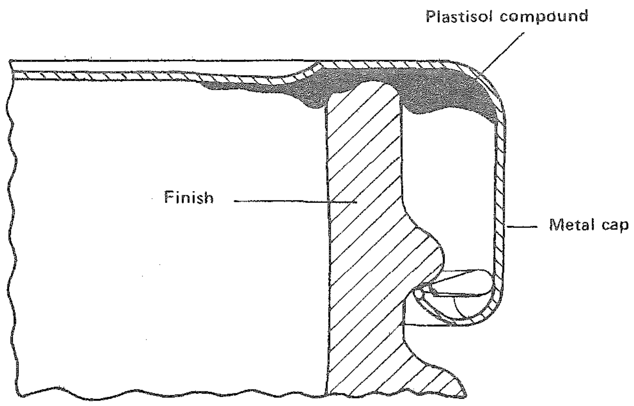


Figure 19 Cross section of twist cap applied to glass finish: top seal

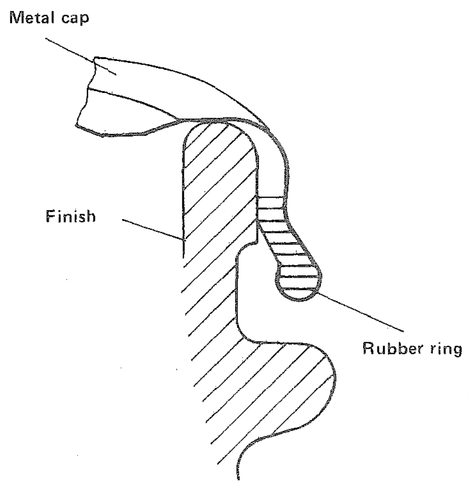


Figure 20 Cross section of pry-off cap applied to glass finish top and side seal

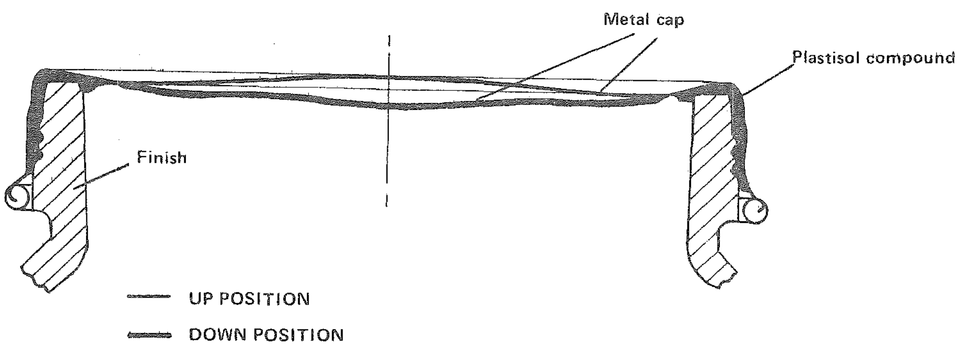


Figure 21 Cross section of press-on twist-off (PT) cap applied to glass finish: top and side seal

that of the diameter across the body of the container. This prevents the closure from suffering undue damage through striking the closures on adjacent containers as they move along conveyors. Fortunately, with most containers that have lost their hermetic seals prior to processing, the caps will fall off during retorting and thus alert operators to pack failure.

In addition to obvious loss of vacuum, other faults to be aware of when using glass include the following:

- cocked caps: usually caused by mis-alignment of lug type closures while passing under the sealing machine so that the lug sits on top of the thread rather than underneath it. Cocked caps are readily visible as part of the top of the closure is raised;

- crushed lugs: occur when the sealing machine forces the lug of a twist cap down over the thread, rather than engaging it correctly, while winding the closure down onto the finish;

- stripped caps: result when the cap is over-tightened so that the lugs strip and splay-out over the thread of the finish;

- tilted caps: occur when pry-off and PT caps do not sit down uniformly on the finish.

2.3.2. Inspection procedures

The frequency of inspecting for adequacy of seals with glass containers should be sufficient to ensure consistent formation of hermetic seals. As a guide, this means that intervals between non-destructive testing should be no more than 30 min, while destructive testing should take place at least every four hours. In addition to this, visual inspection should follow every occasion that the capper jams. The results of all closure examinations should be recorded on the appropriate form.

3. UNIT OPERATIONS

Despite the wide range of canned fishery products that is available, there are relatively few operations which are unique to one manufacturing process. For instance, the correct pre-process handling techniques and refrigerated storage conditions of all fish for canning have much in common. (In fact, there will be very little difference in the handling methods for fish destined for canning, and the handling of the same species destined for refrigerated and/or frozen food chains). Similarly, with can seaming, with retort operating procedures, and with post-process handling of containers, the methods adopted are independent of the type of the product. The purpose of retorting (i.e., to achieve a shelf-stable and safe product by the application of lethal heat) remains the same for all canned fishery products despite there being considerable differences in, say, the severity of processes for abalone and salmon. So too with post-process handling of containers; since the dangers that arise from mishandling canned shrimp are not significantly different from those arising from mishandling canned mussels, or any canned fishery product, it is understandable that there are common guidelines which discourage manual handling of all processed wet containers, and recommend that all retort cooling water be chlorinated. This generalized view of the unit operations in fish canning is simplistic, but nevertheless, it provides a framework for identifying those points in the process where control systems can be implemented to ensure that critical stages of production are effectively monitored. The following is therefore a summary of the major operations in fish canning - a more detailed discussion of the production of each of the main commercial canned fishery items is in Chapter 4.

3.1 Raw Material Handling

There is a direct, and unavoidable, relationship linking raw material quality and end product quality, and this holds as much for the production of canned fish as it does for fish which is bought fresh and prepared in the home. Because handling conditions immediately after catching are responsible for the rapid loss of the "as-fresh" quality, the quality of canned fish suffers whenever the raw material is temperature abused and/or physically damaged between catching and thermal processing. This means that the quality criteria considered desirable by cannery management when they assess their raw materials, ought be the same as those chosen by consumers when they purchase fresh fish. This is not to overlook the fact that, in many cases, fish for canning can be trimmed to remove bruises and other localized flesh defects; however, the provision of trimming operations does not justify the use of fish which has reached an advanced stage of spoilage resulting from poor post-harvest handling and/or storage. Thus, the handling techniques that are recommended for refrigerated and frozen storage of fish apply equally well to fish that is to be canned. As the quality of fish deteriorates from the moment of death, all that can be hoped for by good handling is to retard the rate at which undesirable, quality degrading, changes occur. Techniques which are recommended for the rapid inhibition of temperature related spoilage in freshly caught fish for canning include:

- the use of ice which is applied directly to the fish;
- immersion in chilled sea water (CSW) tanks;
- immersion in refrigerated sea water (RSW) tanks; or
- freezing of fish harvested long distances from the cannery, or for fish which is received fresh or chilled but which is to be held in frozen storage until processing.

Irrespective of which of the above techniques is adopted, the aim of cold or frozen storage prior to canning is to ensure that fish are received in a condition enabling manufacture of a commercial quality product displaying the desirable sensory attributes which are characteristic of the canned species.

For greater detail regarding handling of fish see the following publications:

FAO/WHO, 1977. Codex Alimentarius Commission, Recommended international code of practice for fresh fish. Rome, FAO, Joint FAO/WHO Food Standards Programme, CAC/RCP 9-1976:40 p. Issued also in French and Spanish

FAO/WHO, 1980. Codex Alimentarius Commission, Recommended international code of practice for frozen fish. Rome, FAO, Joint FAO/WHO Food Standards Programme, CAC/RCP 16-1978:58 p. Issued also in French and Spanish

FAO, 1977. Freezing in fisheries. FAO Fish.Tech.Pap., (167):83 p. Issued also in French and Spanish

Löndahl, G., 1981. Refrigerated storage in fisheries. FAO Fish.Tech.Pap., (214):74 p. Issued also in Spanish and Arabic. French version in preparation

FAO Fisheries Circular Nos.:

Myers, M., 1981. Planning and engineering data. 1. Fresh fish handling. FAO Fish.Circ., (735):59 p. Issued also in French and Spanish

Graham, J. (ed.), 1984. Planning and engineering data. 3. Fish freezing. FAO Fish.Circ., (771):126 p.

Brox, J. *et al.*, 1984. Planning and engineering data. 4. Containers for fish handling. FAO Fish.Circ., (773):53 p.

Other factors important in the handling of the raw material include observation of hygienic practices, to avoid excessive contamination with, and proliferation of, spoilage microorganisms, and elimination of rodents, insects, birds or other vermin. Safeguards to control cross-contamination can be particularly important in warm climatic zones where ambient temperatures often are above 30°C, and therefore favourable for the rapid growth and multiplication of bacteria. This means that those canneries allowing their frozen stock to thaw while exposed on the factory floor during the day, and often overnight, do so to the detriment of end-product quality, and under extreme circumstances at the risk of pre-process and/or under-processing spoilage.

Ideally canners will receive fish of uniform and good quality so that the finished product is of a constant standard, however as this is not always possible, it is often necessary to grade fish prior to canning. Grading systems may be for size and/or any of the sensory attributes which reflect fish freshness and ultimately end-product quality.

3.2 Pre-treatment

Pre-treatment covers the range of operations during which the product is prepared for canning. Examples of pre-treatment include, gutting, washing, nobbing, filleting, shucking, shelling (peeling), cutting, brining and dipping. Each of these steps has the common objective of bringing the raw material closer to the size, form or composition required for retorting. Given the advances made with mechanization in fish handling, most of these operations can be carried out using semi-automatic or automatic equipment. While mechanization usually means greater production speeds, common advantages of manual operations include, higher yields and greater versatility, plus a greater opportunity for continuous in-process inspection procedures. The benefits accruing from manual operations must be weighed against the costs of labour. In developed countries, where labour costs are relatively high, there is a tendency to use machines rather than rely on manual operations; but in developing countries, because labour is comparatively cheap, there is a greater dependence on a large labour force.

Each of the pre-treatments listed previously is referred to, in the context of the canning process of which it forms part, in Chapter 4. First, however, some general introductory comments.

All of the pre-treaments (particularly those in which flesh is cut), ought be carried out under conditions of good manufacturing practice; which means that the rudimentary steps of process hygiene should be implemented. Satisfactory control of contamination from operating surfaces, from viscera or from raw materials, is achievable with regular cleaning (i.e., by washing the product and cleaning the line and ancillary equipment) and/or by limiting the duration of exposure at temperatures suitable for growth of spoilage microorganisms.

3.3 Pre-cooking

Pre-cooking is usually carried out in steam, water, oil, hot air or smoke, or a combination of these. It serves a number of related functions;

- to partially dehydrate the flesh and prevent release of those fluids during retorting which would otherwise collect in the container;
- to remove natural oils, some of which have a strong flavour;
- to coagulate fish protein and loosen meat from the frame;
- to develop desirable textural and flavour properties; and
- to make the flesh of crustacea firm and aid their release from the shell.

As pre-cooking conditions affect yield and sensory quality it is important that they be regulated. An excessive treatment tends to reduce yields, whereas inadequate pre-cooking means that the purpose of the treatment is not achieved. Pre-cooking conditions are usually established through pilot trials in which centre temperatures of the product at the completion of a "satisfactory" process are measured, or alternatively, the time (at pre-cooking temperature) required to bring about the desired effect is determined.

Pre-cooking can be combined with a dipping process, particularly for products which require additives to impart flavour or colour, or in order to modify texture through the surface action of brines. Dips may be a source of contamination, and if so, their quality should be monitored so that they can be changed when necessary.

Construction of a time-temperature plot for the product as it moves down the processing line is a simple technique for highlighting those potential danger areas, where delays in production can adversely affect the microbiological status of the product. At stages where the combination of temperature and time favour rapid microbial growth (e.g., immediately after pre-cooking before the product has cooled), process control points can be established and monitoring systems set up, so that the manufacturer can take corrective action should product quality appear to be at risk.

In some cases (e.g., when steaming tuna, when blanching abalone, or when boiling crabs prior to picking) pre-cooking will precede packing the product into containers for subsequent sealing and retorting. There are also processes in which the product is packed into cans prior to pre-cooking. An example of the latter is in the manufacture of Mediterannean style canned sardines, which are packed and then heated in two-stage flash cookers (the fish are steamed and then dried in a continuous operation). Cans are drained of condensate and drip, filled with oil or sauce and then sealed and retorted.

3.4 Filling

Whether filling operations are manual or automatic it is most important that fill weights, and fill temperatures for hot fill products, are monitored because both affect the rate of heat transfer to the SHP of the can during retorting. In processes which go beyond the minimum botulinum cook (F_o = 2.8 min) variations in fill weight and/or temperature are not likely to have public health significance; however in processes where target F_o values are recognized as close to the minimum for safety from botulism (e.g., F_o = 2.8 to 3.0 min), even small variations in fill temperature or fill weight can have significant effects on the adequacy of the process. Because filling can be critical to product safety, it is imperative that it be carried out under strict control.

Apart from the need for containers to appear full, headspace is necessary so that thermal expansion, caused by heating the product from filling temperature to processing temperature, does not result in an excessive build-up of pressure and damage to the hermetic seal. Under normal circumstances seams withstand the strains generated by internal pressure, however, in extreme cases this causes permanent deformation (known as peaking, or buckling) of the can end. Peaking is unacceptable, as it carries with it an associated risk that the seam in the vicinity of the damage will leak and permit ingress of contaminants, particularly during cooling when the cans draw a vacuum. (Excessive pressure build up in glass containers during thermal procressing will usually dislodge the cap.)

Since peaking is a consequence of excessive internal pressure in the can, it can be prevented by controlling a number of factors other than headspace, these include:

- fill temperature; the higher the filling temperature, the less the pressure generated by heating the contents to processing temperature. As a consequence of hot filling a vacuum forms in the container after thermal processing and cooling;

- vacuum closing; cans and glass jars may be closed under a vacuum, which has the effect of counteracting the increase in pressure caused by heating the product in a sealed container. Vacuum closing is achieved by mechanical evacuation of the container headspace gases just prior to sealing, or by steam-flow closing, a process in which super-heated steam is flushed across the top of the container immediately before the can end or jar closure is sealed in place.

3.5 Sealing

Techniques for formation and the evaluation of the hermetic seals with metal cans, glass containers and laminated systems are described in Chapter 2. Central to the success of the entire fish canning industry is the ability of canners to form hermetically sealed containers whether they be made of metal, glass or laminates of plastic and/or plastic and foil. Failure in this critical operation will mean that product safety and shelf stability is at risk. Given the potentially serious implications of seal failure and post-process contamination, manufacturers must be sure that their operations are strictly monitored at regular intervals throughout the entire production. Once sealing machines have been adjusted, suitably trained personnel must confirm their satisfactory performance by examination of sealed containers. There is an abundance of literature available from packaging material and sealing machine suppliers recommending methods of seal formation and criteria for their evaluation. In several countries regulatory authorities have published procedures for the evaluation of seal adequacy; the purpose of this is to ensure that not only local manufacturers have guidelines to follow, but also so that foreign manufacturers can comply with the requirements of the country to which they are exporting.

Since formation of sound hermetic seals is critical, it is essential that records confirming compliance with GMP guidelines are completed during production, and maintained after release of the product. If in the event of a product recall there are no permanent records, manufacturers run the considerable risk of being unable to demonstrate that their operations were in control, and that due care was taken to assure the safety of the finished product.

It is important that sealed containers be indelibly coded with details of the production date and time, product codes, the manufacturing plant and any other information that is necessary to identify the origin and nature of the product.

3.6 Retorting

Procedures for developing and controlling delivery of thermal process schedules are outlined in Chapter 1, and descriptions of available retorting systems are in Chapter 5. However, no matter how well the scheduled process has been formulated, nor how great the capital expenditure for buying top quality equipment, these efforts will be wasted if there is human error in delivery of the process.

3.6.1 Retort operating procedures for cans

In order to reduce the risks of operational errors, it is customary to adopt standard procedures for retort operation. In some countries the regulatory authorities require that supervisors of retort operations in those plants manufacturing low-acid canned foods shall have successfully completed a specialized training course in the principles of thermal process control. One of the objectives of these courses is to provide retort supervisors with standard operating procedures which will reduce the risk of error being made through ignorance or carelessness.

As a guide, and as a means of standardising procedures, it is recommended that retort operations be classified according to the five sequential steps shown in Table 6. Also shown is a checklist of key points for each stage in the

Table 6

The five stages of retorting[a/] and key point checklist

Stage	Checklist
1. Preparation and loading:	Is the retort drained? Are all containers removed? Are air and water injets closed? Are cans loaded and the process commenced within one hour of filling? Are heat sensitive indicators attached to retort baskets?
2. Venting:	Is all the air removed? Does indicating thermometer register retort temperature of $\geq$ 103°C?
3. Come-up:	Is it $\geq$ 10 min for fully laden retort?
4. Processing:	Is retort at scheduled operating temperature for the scheduled process time? Is process timing commenced when retort reaches operating temperature? If there are any deviations from the scheduled process are containers from the batch isolated? Is there agreement between scheduled process time and thermograph record of process time? Are bleeders open during the process? Is condensate drain open and operating?
5. Cooling:	Is steam removed from retort before cooling water enters? Does the cooling water fill the retort within 10 min? Is the retort pressure cooled to prevent cans peaking? Is the pressure cooling controlled to prevent panelling? Is the cooling water of suitable microbiological quality?[b/] Is cooling water chlorinated so that there is a detectable level of free available chlorine at the completion of cooling? Are cans rapidly cooled to centre temperatures $\geq$ 40°C? Are there procedures to preclude manual handing of wet containers?

a/ These guidelines are based on the operation of a static batch retort in which heating is with saturated steam and cooling is with an over-riding air pressure

b/ As a guide, suitable retort cooling water will have no detectable coliforms in 100 ml samples taken monthly, and have a total aerobic colony count of < 100 organisms/ml for samples taken weekly retorting procedure. The five stages of retorting are intended to apply specifically for processing cans (loaded in retort baskets) in steam and pressure cooling in conventional retorts; the sequence will need to be adapted if processing glass (see sections 3.6.2 and 5.3.7) or if processing cans in crateless retorts (see section 5.3.6). As discussed previously, GMP regulations require that the retort operator must record on the retort log sheet (see Figure 5) all processing details for each batch processed.

3.6.2 Retort operating procedures for glass

Although many of the key points identified in Table 6 will apply equally to processing cans and to processing glass in water, it is important to make clear the distinction between the two systems. The two features about retorting glass that make the operation different from that for cans are the use of water as the heating medium and the need for over pressure. It is common practice when using vertical retorts to lower the baskets into pre-heated water. Pre-heating the water reduces the time required to bring the entire system up to operating temperature, and it also prevents thermal shock breakage that could follow if hot filled jars were immersed in cold water. The temperature of the water must be strictly controlled so that it does not exceed that of the product, otherwise the partial vacuum holding the cap in place may be lost, or sufficiently reduced for the seal to loosen or vent if struck. Another reason for controlling the water temperature is that if permitted to fall, it will cause a drop in the initial product temperature and possibly lead to underprocessing.

In horizontal retorts, because the baskets cannot be added directly into pre-heated water, it is necessary to load the retorts while empty and then add the water. If possible the water should be pre-heated so that it is added at approximately the same temperature as the product.

Overpressure is required to hold the caps in place during processing and in the early stages of cooling so that the total pressure in the vessel always exceeds that inside the container. Although the most commonly used technique to generate overpressure is to introduce air through the steam spreaders and/or into the headspace above the water level, some systems rely on steam which is added through an independently controlled steam supply feeding through the top of the retort. Two advantages in using air overpressure are that when entering through the steam spreaders it assists agitation and helps maintain uniform temperature, and secondly, it helps reduce the knocking that often occurs when adding steam to cool water. Without overpressure the pressure generated inside the container, by heating the contents, would eventually cause the seal to vent or the cap to be displaced. The overpressure required is affected by a number of inter-related factors; these are the headspace in the container, the product fill temperature, the vacuum at the time of sealing and the temperature of processing. In most cases it is sufficient to have between 70 and 105 kPa overpressure. This means that when sterilizing in water at 115.6°C, the total pressure in the retort will be that due to the steam (i.e., 68-70 kPa) plus an additional 70 to 105 kPa for the overpressure; whereas when the retort temperature is 121.1°C the total pressure in the retort will be that due to the steam which heats the water to 121.1°C (i.e., 103-105 kPa) plus a further 70 to 105 kPa for the air overpressure. Shown in Figure 22 is a simplified drawing showing the relationship between the pressure in glass jars and that in the retort when processing with a counterbalanced sytems while in Figure 23 can be seen the pressure relationship that would arise if glass jars were processed in a standard (i.e., non-counterbalanced) system. Use of excessive overpressure with large diameter caps can cause panelling, and for this reason it is advisable to gradually reduce the air pressure in the retort during cooling.

It is important that the water level in the retorts be maintained above the top layer of containers throughout the process. Should the level fall, so that jars become exposed to the air/vapour cushion in the top of the retort, there is a serious risk that they will receive an inadequate thermal process. In order to prevent this, sight glasses should be installed to indicate that the water level is held at not less than 10 cm above the top layer of jars.

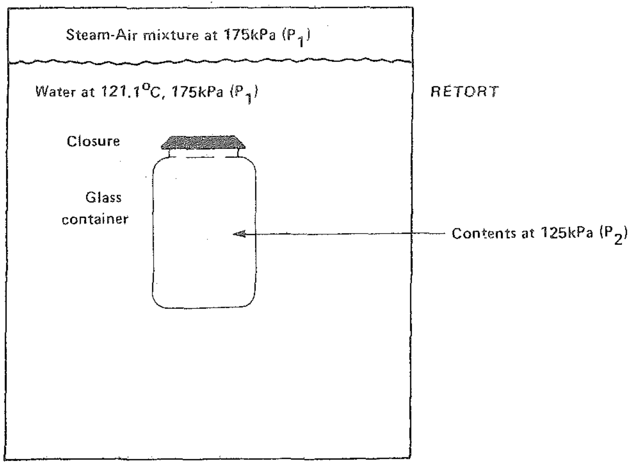


Figure 22 Counter balanced retorting system for processing glass containers in water; with air overpressure retort pressure (P_1) exceeds pressure in container (P_2) and closure remains in place

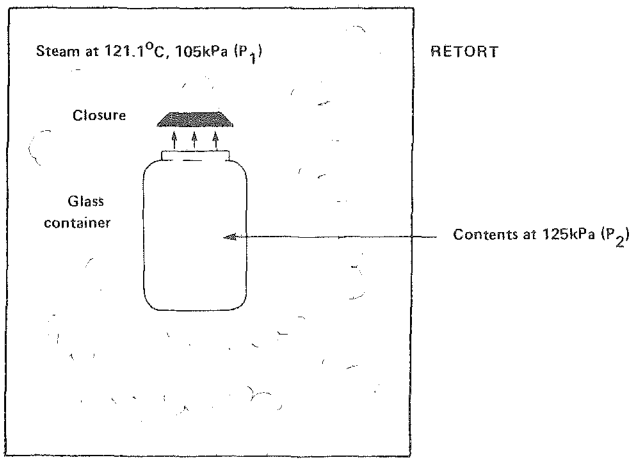


Figure 23 Standard retorting system; when pressure in the retort (P_1) due to steam alone is less than pressure in the glass container (P_2) the closure is displaced

After closing the retort, air and steam are introduced through the steam spreaders. During the come-up time the air supply should be at a higher level than it is during processing. Once processing temperature is reached the air supply is cut back, however, at all times it must be sufficient to maintain water circulation and a uniform temperature distribution, as well as the desired overpressure. In horizontal retorts it is necessary to include a recirculating pump to achieve adequate heat distribution throughout the entire heating phase, and to provide uniform cooling. Failure to reduce the air supply during the processing stage will cause unnecessary vibration.

Once process time has elapsed the steam is turned off and chlorinated cooling water is introduced. Air pressure is maintained until the product has cooled sufficiently for a vacuum to be drawn in the container, after which it is gradually reduced as cooling proceeds.

3.7 Post-process Handling

Delivery of the thermal process schedule must be strictly controlled to avoid under-processing spoilage; however, no matter how severe the process, product safety will be compromised if there is post-process leaker spoilage. There are several contributary factors leading to post-process leaker spoilage; these include the following:

- poor quality cooling water,
- poor post-process hygiene and sanitation, and
- container damage during handling and storage.

It is considered that even when can seam attributes comply with GMP guidelines for double seam formation, there is a small number of cans which "breathe" or leak after seaming. Some estimates put this figure as high as 1% of all cans sealed. The generally sound record of the fish canning industry suggests that, if this estimate is correct, only a fraction of those cans which leak ever spoil; this implies that either "micro-leakage" does not (necessarily) result in contamination, or not all contaminants are able to grow in the environment in the can. While this may be reassuring, there are no grounds for complacency. In 1978 and 1982 post-process leaker contamination by C. botulinum type E was held responsible for the death of three people who contracted botulism after eating commercially canned salmon.

3.7.1 Chlorination and cooling water quality

As product temperatures fall during cooling, there is a corresponding fall in the internal pressures in cans; and when the product temperature falls below the fill temperature a vacuum forms. This means that the pressure differential across the ends of cans undergoing the final stages of pressure cooling, will favour the entry of cooling water into those cans in which there are seal imperfections. It is prudent, therefore, to accept the possibility of there being micro-leakage through the double seams of some cans (or glass closure seals, or the seals on laminated pouches) and that when this occurs cooling water will mix with sterile product. On the few occasions that post-process leaker contamination does occur, it is important that the cooling water be of sound microbiological quality, for otherwise there is an unacceptably high probability of spoilage. It is because of the risks of post-process leaker spoilage that fish canners use sanitizing agents to control contamination levels in retort cooling water. Of those available, the most widely used are elemental chlorine and chlorine based compounds, however, other sanitizing agents include elemental iodine, iodine compounds and iodophors (a combination of iodine and a solubilizing compound which aids the controlled release of free iodine into the cooling water).

It cannot be assumed that sanitizers will be totally effective in eliminating contamination by viable vegetative bacteria and their spores; rather it is better to regard their action as being one which reduces the probability of survival to acceptable levels. Chlorine, for example is most effective against vegetative bacteria, less so against Clostridium spores and least of all against Bacillus spores. This is why the most likely contaminants in chlorinated cooling water are expected to be spores belonging to the genus Bacillus .

Chlorine may be added as gaseous chlorine (Cl_2) which hydrolyses to form hydrochloric acid (HCl) and hypochlorous acid (HOCl, the agent which is responsible for the destruction of vegetative bacteria and spores). Hypochlorites may also be used for chlorination of cooling water, the most usual forms being as liquid sodium hypochlorite (NaOCl) or solid calcium hypochlorite ($Ca[OCl]_2$). Irrespective of which form of chlorine is used, it is important to allow for the reactions that take place with inorganic and organic impurities in the water. When chlorine is added to commercial quality water, it first combines with these impurities (e.g., minerals and nitrogen containing organic compounds) to form chloro-derivatives which lack the germicidal properties of free chlorine. As the dose is increased these are oxidized, at which point the chlorine demand of the water is said to be satisfied and the "break-point" reached. The chlorine residual remaining after break-point chlorination is called the "total residual chlorine". Total residual chlorine comprises the chloramines and chloro-nitrogen compounds (i.e., the "combined residual chlorine" which exists below the break point) plus "free available chlorine" (i.e., the free chlorine or loosely combined chloro-nitrogen compounds which exist above the break-point). Once the break-point has been reached the addition of more chlorine will lead to a proportional increase in the free available chlorine.

At the normal pH of cooling water free available chlorine is a more effective bactericide than combined residual chlorine. It is usual to dose cooling water so that free available chlorine remains detectable after a contact time of 20 min. Excessive chlorination of cannery cooling waters is wasteful and it also should be avoided because chlorine is corrosive to some metals. The lethal effect of chlorination increases at low pH (at levels where undissociated hypochlorous acid predominates), at high temperature and with high levels of free available chlorine. There are practical contraints as to how low the pH can be, given that normal cannery cooling water is in the pH range of 6.5-8.5. Another constraint is that at high temperatures chlorine loses solubility and is driven off; elevated temperatures also make rapid cooling of cans difficult. High levels of organic matter increase chlorine demand, and, like inorganic impurities, they also protect bacterial contaminants.

Under GMP conditions it is sufficient to maintain residual free available chlorine levels of 2-4 mg/L after a 20 min contact time in order to be confident of holding total aerobic counts at less than 100 organisms/mL of cooling water. Free available chlorine should be still detectable in the cooling water at the completion of the cooling cycle. At all times records of free available chlorine levels should be maintained to provide confirmation that cooling water chlorination procedures were adequate.

3.7.2 Post-process hygiene and sanitation

It is known that when conveyors and can handling equipment down the line from the retort are unclean, they harbour high numbers of contaminants which can contribute to the incidence of post-process leaker spoilage. These basic hygiene problems can often be compounded because when cans pass from the retorts they are still warm, and this means that the plastisol lining compound in their ends will not have had sufficient time to "set up" and form a seal that is resilient to impact and deformation. Also at this stage the vacuum in the can will have partially developed, so that contaminants on and around the double seam are liable to be drawn into the container should the seal leak, even momentarily. Because of this, it is important to clean and regularly sanitize all those surfaces which come into contact with containers.

Conveyor guide rails, twist conveyors, transfer plates, elevators, push bars and accumulation tables should all be made of impervious materials which can be cleaned easily, thoroughly and regularly. In order that the containers are dry during post-process handling, it is good practice to include in the line, close to where the cans are unloaded from the retort, air blow-driers (or similar equipment). These systems are preferable to the inappropriate plastic curtains which are all too frequently installed to drag over the surface of cans as they are conveyed underneath. The longer the cans remain wet, the greater the opportunity for post-process leaker contamination. For this reason containers should be dried as quickly as possible, so that exposure to wet post-retorting conveying and handling equipment is at a minimum. In line with GMP guidelines conveyors or equipment surfaces should be effectively cleaned every 24 h, as well as being disinfected during production, if they are wet while in use. Container drying may be accelerated by dipping the retort crates containing the cans into hot water containing a wetting agent. It is sufficient to submerge the crates for approximately 15 sec, and after they are removed from the bath they should be tilted to allow any adhering fluid to drain from the surface of the cans. If this procedure is adopted it is important that the dip tank be held at $\geq$ 80°C and that the water be changed regularly to avoid microbial build-up. Use of porous labeller pads and drive belts is discouraged, as these materials can provide an excellent environment for the accumulation and multiplication of microbial contaminants, particularly when they are wet, dirty and irregularly cleaned and sanitized.

When adhering to GMP guidelines and while implementing adequate post-process hygiene and sanitation procedures, manufacturers should comply with the following guidelines for bacterial counts on container contact surfaces and in the water entrapped in can double seams:

- Post-process conveying surfaces; pre-production, post-production and after sanitation procedures during production. Not greater than 500 org/mL.

- Water in double seams after cooling and handling. Not greater than 10^4 org/mL.

3.8 Final Operations

3.8.1 Container damage during handling and storage

Poor quality cooling water and/or inadequate hygiene and sanitation will increase the risks of post-process spoilage if containers are subjected to rough handling, particularly when this results in damage to the seal area. While unloading retort baskets extreme care should be taken to avoid mechanical damage to hermetic seals, and, because of the risk of contamination from operators, wet containers should never be unloaded manually. Conveyor systems in which line-pressure prevents easy removal of cans by hand need readjustment or re-design to improve flow. Severe can to can impact leading to damage at the end of twist conveyors is indicative of poor line design which provides an opportunity for contamination, because at the moment of collision the can compound is frequently still warm and soft, and the seams wet.

Not all manufacturers find it appropriate to install semi-automatic or fully automatic equipment and so rely instead on manual handling to complete final operations. While this is often an attractive proposition, as it can be the cheapest and most versatile mode of operation, it carries with it the heightened risk of post-process cross-contamination from operators and/or their protective clothing when metal cans, glass jars or laminated pouches are mis-handled. Therefore, wherever manual procedures are adopted, manufacturers must be sure that containers are dry and that operators handle them carefully.

Operators must be discouraged from using processed cans, whether packed in cartons or loose in "bright stacks", for other purposes; such as for bench supports, or for seats, or for racks on which to dry wet protective aprons and gloves. The reason for this concern is that in the fish canning plant there are assumed to be food poisoning spoilage organisms which could grow and render the product a threat to public health, if they are able to gain entry into the processed container and contaminate the contents. The potential danger of post-process contamination can be comprehended when it is recalled that the last three botulism outbreaks involving canned fishery products manufactured in the United States (i.e., tuna in 1963 and salmon in 1978 and 1982) are all alleged to have occurred because sterilized containers were contaminated with C. botulinum type E. The 1963 case was believed to be the result of faulty double seam formation in the canner's end; the 1978 outbreak was attributed to seam damage followed by corrosion leading to a small hole in the seaming panel; and the 1982 outbreak was attributed to an indexing fault caused by a malfunction of a can reforming machine. In each incident spoilage through post-process leakage and contamination (by C. botulinum type E, or its spores) was implicated, rather than under-processing spoilage because the microorganism responsible was:

- relatively heat sensitive and therefore unable to survive even a marginal process;

- known to be widely distributed in the marine environment and therefore a possible contaminant of fish processing plants;

- non-proteolytic and therefore not a producer of the putrid odours which would normally deter consumers from eating the spoiled product.

The circumstances surrounding these outbreaks highlight the difficulties faced by all fish canners who, because of the origin of their major raw material, cannot avoid operating under conditions in which contamination by C. botulinum type E must be assumed to be the norm. Although a worst-case scenario such as this is extremely cautious, it confirms the need for extreme care when handling processed containers.

Frequent jamming of conveyors and container handling equipment indicates a need to re-appraise the machinery, the line design or the speed of operation because the potential risks arising from damage to the hermetic seal are untenable. Problems arising from poor handling are not confined to metal cans - they do not fracture like glass, or puncture like retort pouches. However, because they are robust and because it is easy to overlook apparently superficial damage, cans are not always handled with appropriate care. Considering that in some countries post-process leaker contamination has been estimated to account for between 40 and 60% of canned food spoilage it is clear that the problems of post-process container damage ought not be underestimated.

3.8.2 Rate of cooling

Cans should be rapidly cooled to 40°C in retorts, otherwise they may remain at thermophilic incubation temperatures during labelling, packing into cartons, palletizing and storage. When rapid cooling in water is not possible, some manufacturers choose instead to air cool their product; should this option be favoured, care must be taken to ensure that there is unrestricted air circulation around the cans. A further problem associated with inadequate cooling is stackburn which results from the over-cooking that occurs when product is stored while still hot.

3.8.3 Temperature of storage

Selection of storage temperatures for canned produce may be critical for those products containing thermophilic spore-forming survivors. Target F_o values are generally more than sufficient to kill mesophilic spore-forming contaminants provided that raw materials are of reasonable microbiological quality. However, because ambient temperatures in warm climatic zones often encourage the growth and multiplication of thermophiles, processes must be either sufficient to reduce, even these extremely heat resistant bacteria, to a satisfactorily low level (e.g., ≤ 1 in 10^2), or storage must be at temperatures unfavourable for their growth.

In addition to the concerns about storage temperatures, it is recommended that canned fishery products be stored under conditions which avoid sweating caused by extreme temperature fluctuations, as this phenomenon will encourage external rusting of the containers, particularly in areas of high humidity. These conditions are to be avoided also where containers are packed in retail cartons or outer shipper cartons as these will absorb moisture and may even collapse in the warehouse.

4. CANNING PROCESSES

In this Chapter are summarized the stages in the production for each of the main commercially produced canned fishery items. Where typical retorting schedules are given, they are intended for guidance and should not be adopted without first having their adequacy confirmed through heat penetration trials conducted under commercial operating conditions, or in laboratories equipped to conduct these determinations.

In addition to the requirement for product safety and shelf stability, canned fish are expected to have sensory properties which are characteristic of the species, and the product must be free of objectionable odours, taints or visual defects. Major product compositional and quality requirements are specified in the set of Codex Standards for Fish and Fishery Products (CAC/VOL. V - Ed. 1.1981[1/]), which include specifications for the following canned products:

Salmon, Canned Pacific.	Codex Standard 3 - 1981.
Shrimps or Prawns, Canned	Codex Standard 37 - 1981.
Tuna and Bonito, Canned in Water or Oil	Codex Standard 70 - 1981.
Crab meat, Canned	Codex Standard 90 - 1981.
Sardines and Sardine type Products Canned	Codex Standard 94 - 1981.
Mackerel and Jack mackerel Canned	Codex Standard 119 - 1981.

4.1 Sardine and Sardine-like Fish

Sardines are usually canned by one of two methods; the first is referred to as the traditional Mediterranean method (so named because of its origin, although nowadays similar technology has been adopted elsewhere and is generally described as the "raw pack method") and the second is a method incorporating a hot smoking step, rather than in can pre-cooking. The latter method is commonly practised in Western European countries.

4.1.1 Traditional Mediterranean method

Either fresh or frozen sardines can be used to produce a good quality canned product provided that the preliminary handling conditions have protected the fish from excessive deterioration during transport and storage. The sequence in which preliminary operations are carried out varies from processor to processor, and may reflect such things as the complexities of the line, the speed of production, the degree of automation, the availability of labour and the source and type of raw materials. One sequence for a Mediterranean style canning line is as follows: the sardines are weighed and washed and then, brined (by immersion in a saturated solution for up to 15 minutes, depending on size and fat content), graded, nobbed and packed. In an alternative sequence nobbing precedes brining so that the order of the pre-treatment operations becomes; weighing, washing, nobbing, brining (in batches, or continuously in screw conveyors, to a final salt content of between 1 and 2%) packing and washing - although a recent modification of this procedure includes direct addition of salt to filled cans, which means the brining step can be eliminated.

1/ FAO/WHO, 1981. Codex Alimentarius Commission, Codex standards for fish and fishery products. Codex alimentarius volume 5. Rome , FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/VOL. V - Ed. 1:135 p. Issued also in French and Spanish

Sardines are fed automatically or manually to the nobbing machines in which the heads, viscera and tails are removed. The machines are set to cut the fish to standard lengths, or into cross-out pieces, so that pack uniformity is achieved. Machines are available which complete the traditional nobbing operations and then pack the fish into cans automatically, however in many cases packing remains a manual operation.

Pre-cooking of the sardines in filled cans is carried out in automatic steam cookers. The first stage is a steamer, operating at around 95°C, through which the cans pass while held inverted on perforated conveyors to allow simultaneous entry of the steam and drainage of condensate and oil exuded from the flesh. In some pre-cookers the cans are steamed in the upright position but inverted and drained before passing to the second stage. The final phase of pre-cooking is a drying process taking place at around 130°C. As an alternative pre-cooking method, some canners fry their sardines, but this is generally more expensive.

Cans containing pre-cooked fish pass to a liquid filling station where one of either brine, water, edible oil, sauce or marinade is added manually or automatically. For those products which have not been brined, the salt is added in solid form prior to the addition of the liquid medium, or it can be blended with the liquid. The cans are then transferred to can sealing machines for double seaming with pre-coded can ends. While adding the liquid, there is usually some overfill which can be recovered. When the outside of the cans are contaminated with oil and/or fish remnants they should be washed in water and detergent before they pass to the retort for sterilization. It is preferable that can washing be completed prior to, rather than after, sterilization so that the risks of post-process contamination are reduced. If post-process washing cannot be avoided, it is essential that it be carried out in hot water of sound microbiological quality and preferably in which there has been included a surface active agent to assist can drying - at all times extreme care should be taken to ensure that processed cans are not manually handled while still wet.

Sterilization is usually in batch retorts in which the heating medium is either pure saturated steam, hot water or recirculated hot water which is pumped over the cans. Because of the large surface area, and therefore flexibility, of the traditional club, dingley and hansa style sardine cans the ends are prone to distort as a result of the internal pressure generated during processing. This can be compensated for by processing the cans under an over-pressure; but more importantly cans should be pressure-cooled, at least until the internal can temperatures have fallen. Retorting temperatures and times are selected to suit the desired textural properties and the target F_o value of the process. As a general guide 1/4 club and dingley cans are processed for between 45 and 60 min at around 115.6°C; although some processors choose to process at 112°C, because they find the bone softening at these temperatures to be preferable to that achieved by a shorter process at a higher temperature.

After cooling the cans are dried in air, packed in individual cartons and then into master cartons. Before release the finished product is held to ripen in order to develop the characteristic flavour and textural properties.

4.1.2 Norwegian method

The major difference between the Norwegian and Mediterranean methods of canned sardine manufacture is that with the former the fish are not eviscerated and are usually hot smoked, whereas the Mediterranean method includes evisceration and pre-cooking. With the Norwegian method evisceration is unnecessary because the catch is held alive for at least 48 hours in nets prior to landing (the holding process is known as thronging) during which time the fish digest their feed and thereby minimize the enzymic activity which if left unchecked would lead to belly-burst, while the smoking process replaces flash pre-cooking. After thronging the fish are transported fresh to the factory for immmediate use or for frozen storage. The following description is typical for the traditional Norwegian method of canned sardine manufacture.

If frozen raw material is used the blocks are thawed under running fresh water or sea water. When thawed with sea water, it is often not necessary to brine the fish; however when using fresh water, or when fresh fish are used, the sardines are flumed in a brine solution which washes them, removes scales and enables the fish to absorb from 1 to 2% salt.

The fish are automatically size graded and passed into threading machines where they are fed through a series of parallel plastic pipes out of which they emerge, one fish at a time, in rows. Metal rods (spits) are threaded through the eyes of the sardines, a row at a time. The spits are hung on frames and the frames are then stacked on trollies and transported to smoking ovens.

The drying and smoking process takes place in the smoking oven, the temperature of which is set to suit the size and fat content of the fish; typical inlet temperature is between 40° and 60°C, while normal outlet temperature is between 120° and 140°C. The total drying and smoking process takes approximately one hour. The hot air for drying is derived from steam heated heat exchangers, while the smoke is generated by burning oak or other hardwood chips. The removal of moisture in the smoking oven prevents the release of excess water during retorting, and the addition of smoke gives the sardines their characteristic flavour. In some instances canners use artificially flavoured oil to impart the "smoked" taste, however, when this technique is used there must be an accompanying declaration on the label; in these circumstances the other stages of the process are similar to those described in the Mediterranean style production line.

In the Norwegian hot smoking process the fish are smoked, while hanging on the spits, and then passed to rotating knives where their heads are removed with a cut directly under the gillbone. The bodies fall into trays below and are transferred to the filling floor for hand packing into cans. Filled cans are automatically conveyed to an in-line oil filler from which they then pass to a can double seamer where coded ends are applied. Sealed cans are transferred, via a fluming channel, to retort baskets sitting immersed in a tank containing hot water and detergent in which contaminating oil is washed from the outside surface of the containers.

The cans are processed in counterbalanced retorts in which an overpressure is necessary to prevent deformation (caused by the high internal pressure generated in the cans during the thermal process) of the relatively large and flexible ends. Typically for 1/4 dingley cans the total pressure in the system is approximately 122 kPa (18 psig). This means that when processing at 112°C, the pressure due to the steam vapour pressure will be around 52 kPa (7.5 psig), while that due to the air overpressure will be approximately 73 kPa (10.5 psig). Retorting temperatures and times vary, but generally for 1/4 dingley cans, the process is for 60 min at 112°C which is sufficient to deliver a target F_o of ≥ 6 min. The retorts use conventional steam heating or, alternatively, the heating medium can be water which is pre-heated in overhead vessels and then dropped into the retorts below, where it is brought to operating temperature with steam under pressure.

After sterilization, cans are dried in hot air and passed to automatic or manual case-packing for packing into cartons. As with Mediterranean style sardines, it is necessary to hold the finished product to allow it to "ripen" and develop fully its characteristic sensory properties.

4.2 Tuna and Tuna-like Fish

There are several styles of canned tuna described in Codex Standard No. 70 (referred to at the beginning of this Chapter); however, apart from minor handling differences arising from variation in the size of the species and the pieces, the relative proportions of light and dark meats, and the styles of liquid fillings, the stages in the canning processes are substantially the same.

The pre-treatment stages include thawing in running water, heading and evisceration of the smaller species (which are usually frozen whole). Larger fishes are headed and gutted on board prior to freezing. Once thawing is complete, or when fresh chilled fish are used, the fish are cut into vertical pieces, or horizontally into loins, and washed and placed on metal trays which are transferred on racks into the atmospheric steam pre-cookers. Pre-cooking is carried out in steam at between 100° and 105°C for as little as one hour for small species, or over eight hours for large specimens. The temperature and time combinations of pre-cooking are often regarded by canners as being critical to their overall yields; generally, the common aim is to raise backbone temperatures to between 60° and 85°C, after which the portions are removed from the cooker and allowed to air cool, often overnight. In climates where ambient temperatures are around 30°C, or more, it may be necessary to assist cooling by placing the fish into chilled storage, so that the flesh will not be held for too long in conditions favourable to contamination or microbial activity. Cooling can also be achieved by water spray in order to hasten the process. After cooling the flesh firms, which makes the subsequent cleaning and picking operations easier for the operators.

If not already done so, the head, tail and fins are removed; the skin is scraped from the flesh surface and the white and dark meat portions picked from the frames and segregated. The edible portions are selected for solid, chunk, flake or grated (shredded) style packs and then transferred to filling areas. In many of those countries where labour costs are relatively low, packing is a manual operation; however, there are machines which perform these tasks fully automatically for all styles of packs.

The filled cans are transferred to brine or oil fillers, or in some cases they first have dry salt added, after which the water, oil or sauce is added. Cans then pass to the can seaming machine where they are closed under vacuum by coded can ends attached in a double seamer. The hermetically sealed cans are manually or automatically loaded into the retort baskets of manually operated batch retorts, or they may be directly conveyed into crateless retorts or hydrostatic retorts for sterilization.

The temperatures and times selected for retorting depend on the container size, the pack weight, filling temperature and the pack style. Generally, while operating under GMP conditions it is sufficient to process to F_o values of around 10 to 15min; however this there is evidence that some canners select unnecessarily severe conditions which deliver Fo values in excess of 30 min. Apart from being wasteful of time and energy, such severe processes adversely affect the sensory characteristics of the product. As a guide to selecting temperatures and times for processing, a summary of the conditions used commercially for a variety of can sizes is shown in Table 7.

Table 7

Typical retorting conditions for tuna processed at 115.6 and 121.1°C in a variety of can sizes

Can dimensions		Retorting time	
Diam. (mm)	Height (mm)	115.6°C (min)	121.1°C (min)
66	40	65	40
84	46.5	75	55
99	68.5	100	85
154	118.5	230	190

After thermal processing cans are cooled (preferably under pressure, although some manufacturers pressure cool only their larger cans because they are the ones most likely to peak), dried in air or with the assistance of air blowers, and held in "bright-stacks" prior to labelling and packing, or labelled and packed directly off the line.

4.3 Salmon and Salmon-like Fish

Fresh or frozen salmon are transported from storage and graded before passing to the iron chink machine for dressing, an operation which automatically removes the head and tail, splits the belly, and removes the viscera and fins. After butchering, the fish are transferred to the sliming table for the final removal of flesh and blood remnants and for washing. The fish are cut to size for automatic or manual filling into pre-washed cans. Filled cans have salt added and then pass, via a check weighing machine, to a can seamer for vacuum sealing (using coded can ends). Between filling and seaming, cans pass to a "patching" station where operators check for traces of skin, bones or meat lying across the flange of the can; while making adjustments to pack fill weights if required.

Sealed cans are washed, packed into baskets and then loaded into retorts for processing. There should be no more than one hour's delay between container filling and the commencement of the thermal process as longer delays may lead to pre-process (incipient) spoilage. Cooled dry cans are either bright-stacked or labelled directly and then transferred to warehouses for storage.

Retorting conditions will vary depending on can dimensions and pack weights, however, the processing conditions summarized in Table 8 can be used as a guide.

Table 8

Typical retorting conditions for salmon processed at 115.6 and 121.1°C in a variety of can sizes

Can dimensions		Retorting time	
Diam. (mm)	Height (mm)	115.6°C (min)	121.1°C (min)
74	35	50	35
84	46.5	70	55
74	118.5	100	85
154	109.5	230	200

4.4 Crustacea

4.4.1 Crab

The preliminary stages of cooking and picking of crab meat are simple operations, often suited to small scale operators working in relatively unsophisticated conditions, but who are close to the supply of the raw material. It is important that the crabs should be handled under conditions which limit the opportunity for degradative enzymic action leading to the deterioration of their fresh flavour. This means that, ideally, the crustacea should be held wet and cool as soon as they are caught; and that preferably they should be cooked alive, or as soon as possible after death. Cooking can be either in boiling water, or in retorts using steam under presssure. If the cooked meat is not to be butchered and picked immmediately, it should be refrigerated or iced.

After cooking, the crabs are washed to remove sand and the scum that adheres to the shell after cooking. The claws and legs are removed from the body which is then eviscerated. It is important that the butchering operation be carried out separately from picking, and that at all times the opportunities for cross contamination are avoided by implementation of hygienic handling practices. Shell particles are removed and then the legs, claws and washed bodies are held ready for picking.

During the picking operation fragments of meat are drawn from the claws, legs and body either by hand or in some cases using automatic equipment. In the latter cases, the shell is crushed and the flesh separated by brine flotation which allows the shells to sink and the meat to float. A disadvantage of mechanical picking is that the flesh tends to become shredded and the structure of lumps is damaged. Pickers separate the flesh from the shell, and segregate it into grades with the best prices being paid for flesh in which the structure of the piece is retained. If there is a delay prior to canning, the picked flesh is stored under refrigeration so as to avoid contamination, because even though the meat has been cooked, it is nevertheless vulnerable to microbial deterioration, particularly in warm climates.

On receipt at the cannery (if the picked flesh has come from elsewhere), or prior to further treatment (if the crabs have been picked on site), the meat should be inspected for uniformity of grade, acceptable odour (off-odours indicating deterioration), satisfactory colour and the absence of shell and other contaminants. Once passed by inspectors, the flesh may be blanched in boiling water - this operation is optional, and is more usual when pre-cooking operations have not totally cooked the flesh. Blanching firms the flesh and protects yields, which otherwise are found to be depressed if pre-cooking is incomplete. Some manufacturers include metabisulphite in the blanching brine, and/or soak the crab prior to precooking - both treatments are used to prevent discoloration. After blanching, the hot meat is cooled in potable water, or in air.

As detailed in the Codex Standard, various pack styles are available. The flesh is packed in lacquered cans to prevent sulphur staining and in some cases parchment is also used. The filled cans are topped up with brine containing 2-3% Na Cl, and in some circumstances a 0.1 - 0.5% citric acid solution to prevent discoloration. Cans are then vacuum sealed and retorted. Typical processing conditions are shown in Table 9.

Table 9

Typical retorting conditions for crab processed at 115.6 and 121.1°C in a variety of can sizes

Can dimensions		Retorting time	
Diam. (mm)	Height (mm)	115.6°C (min)	121.1°C (min)
84	46.5	50	35
84	63.5	60	45

After processing and cooling in chlorinated water, cans are either bright stacked, or labelled and then transferred to the warehouse for storage.

Some canned crab tends to discolour and form a blue/black or grey/black pigmnent. This reaction has been discussed by Howgate (1984), who pointed out that the mechanism is not clearly understood, partially because the phenomenum appears to be species related. Howgate summarizes three current explanations for this discoloration, which have given rise to three different solutions to the problem:

(a) the blueing is due to the presence in the flesh of copper; the solution is to include in the brine a metal chelating agent such as citric acid, or ethylene diamine tetraacetic acid (EDTA).

(b) The grey discoloration results from a variation of the well known Maillard browning reaction which occurs between sugars and amino acids at high temperatures; a partial solution is to lower retort temperatures and increase processing time (e.g., process at 115.6°C rather than at 121.1°C), and/or to include sulphur dioxide in the brine.

(c) The discoloration is the result of melanin formation, derived from an enzymically related oxidation of tryosine; the solution is to expose the flesh to a sodium metabisulphite treatment as a dip, or include it as an additive in the blanch water.

While processors may find any or all of these solutions acceptable as a means of controlling or eliminating discoloration, they must first assure themselves that regulators in importing countries permit the inclusion of the additives which overcome the problem.

4.4.2 Shrimp

Raw shrimp should be received refrigerated, or well iced, to limit enzymic and microbial action which, if unchecked, leads to loss of quality. Some canneries receive their shrimp peeled and cooked, however, even under these conditions the need for adequate cool storage cannot be neglected. The shrimp are inspected on receipt at the cannery, and then washed to remove adhering dirt and ice. Peeling can be either manual or by machine. In an example of the latter, the shrimp are size graded, and the head and shell removed by a combination of gentle pressure and a controlled rolling action. The final pre-treatment is to devein the shrimp after which they are washed and reinspected.

Cleaned and shelled shrimp are precooked in hot brine, or steam. The choice of salt concentration and cooking time varies from processor to processor. Generally, salt concentration will range from 3 to 13% NaCl, and precooking time will range from 2 to 10 min; the conditions chosen will be affected by shrimp size, the temperature of the solution and whether the shrimp are to be for a wet pack (i.e., packed with brine) or for a dry pack. Steam precooking is usually carried out at around 95° to 100°C for 8 to 10 min, depending on shrimp size. The shrimp are then cooled, dried, inspected and size graded, prior to hand packing in cans which have been lacquered to resist the formation of unsightly black sulphide stains. Filled cans are topped up with hot brine (to which some processors add citric acid to reduce discoloration) and then sealed. Vacuum in dry pack cans is achieved by either exhausting the cans prior to sealing, or, alternatively, by sealing the cans in a mechanical vacuum closing machine.

Retorting temperatures and times vary according to pack dimensions and style (i.e., dry or wet pack), however, shown in Table 10 are guidelines for a variety of packs.

The difference in the processing times required for wet and dry packs in the same sized containers, arises because of the convection currents in the brine pack increasing the rate of heat transfer to the SHP of these containers.

At the completion of the thermal process, the cans are cooled with chlorinated water and removed from the retorts for either bright stacking or direct labelling and packing after which they are transferred to the warehouse for storage.

Table 10

Typical retorting conditions for dry pack and wet pack shrimp processed at 115.6 and 121.1°C in a variety of can sizes

Can dimensions		Retorting time			
		Wet pack		Dry pack	
Diam. (mm)	Height (mm)	115.6°C (min)	121.1°C (min)	115.6°C (min)	121.1°C (min)
66	101.5	26	14	80	60
84	63.5	27	15	75	50
84	101.5	27	15	75	55

4.5 Molluscs

4.5.1 Abalone

The best quality canned abalone is manufactured from the fresh product, although some canners may use frozen stocks, however, when they do, their yields are decreased and the texture of the finished product tends to be too soft. Fresh abalone is received chilled and is then shucked by hand before the meat is transferred to washing tanks for the removal of the pigment from around the lip. The cleaning is achieved by immersing the abalone in warm (35°-40°C) water for approximately 30 min, during which time the flesh is gently abraded by rotating the tank holding the brine or by stirring the brine with paddles. Some canners use proteolytic enzymes to assist removal of the pigment, in which case it is necessary to arrest enzymic activity by dipping the molluscs in a solution of hydrogen peroxide. Cleaning is completed by gently scrubbing the flesh with nail brushes or abrasive pads.

Good quality canned abalone has a creamy/yellow colour, however under some circumstances, not always clearly understood, there is a blue surface discoloration. It believed that the mechanism for this action is related to the formation of a metallic complex, which explains why it can be controlled by the addition of chelating agents such as citric acid and/or EDTA; it can also be controlled by the addition of metabisulphite. These additives may be included at a number of stages in the pretreatment; such as in the cleaning brine, in the blanch water, or in a dip. They may be added to the canning liquor, provided that the country in which the product is to be sold does not prohibit their inclusion.

After cleaning, the abalone are trimmed (to remove the viscera and gonads) and then blanched for 5 min at 70°C, before packing into lacquered 74 x 118.5 mm cans. Most manufacturers pack three to four whole abalone per can (individual abalone weights can range from approximately 90 to 180 g), and make up to minimum pack weight (i.e., usually 50% of net weight) with portions. The cans are topped up with brine containing approximately 2% NaCl and vacuum sealed with coded can ends. If hot brine is used, it may not be necessary to vacuum close the cans, however, under these circumstances it is important that the cans be pressure cooled in the retort.

During thermal processing there is a textural inversion associated with the softening of the pedal sole and the toughening of the myofibrillar proteins at the base of the adductor muscle. There is also a weight loss, which can account for reductions in yield of between 12 and 30% of fill-in weight under extreme conditions (e.g., with a severe thermal process combined with the use of stale or frozen stock). Given the high selling price of this commodity, manufacturers are therefore keen to avoid overprocessing, without compromising the safety of the product. This means that despite the unavoidable weight losses caused by retorting, canners must still be sure that their minimum target F_o values are ≥ 2.8 min.

Choice of thermal processing conditions depend upon total pack weight and the size and weight of the individual abalone, however, in Table 11 are shown typical process conditions suitable for abalone packed in 74 x 118.5 mm cans.

Table 11

Typical process conditions for abalone packed in 74 x 118.5 mm cans

No. of abalone per can	Maximum individual abalone weight (g)	Process time at retort temperature				
		110°C (min)	113°C (min)	115.6°C (min)	118°C (min)	121.1°C (min)
2	180	93	73	62	55	49
3	20	88	68	59	52	46
4	90	76	57	47	41	35

At the completion of the thermal process the cans are cooled in chlorinated water, removed from the retort and either bright stacked, or labelled directly, then transferred to the warehouse for storage.

4.6 Fish Pastes and Spreads

Fish pastes and spreads are manufactured from by-products or from under-utilized species, for instance those fish which are generally too small for other purposes. They usually require mincing and/or blending with other ingredients such as salt, sauces, spices, fat, emulsifying agents and thickening agents. Often they are sufficiently viscous to be filled as liquids or pastes in automatic filling machines as well as in manually operated devices. In some cases a blended mixture is formed into fish balls or fish cakes which are hand filled and topped up with brine or sauce. The scope for development of these items is large, and they have particular appeal as a relatively cheap, yet nutritious fishery product.

Generally, the products are packed into lacquered cans or glass jars, and sealed with coded ends and caps, respectively. Processing of cans is in conventional retorts, whereas glass jars, retort trays and cylindrical shaped flexible laminate packs require thermal processing in counterbalanced retorts. Some canners produce fish paste and seafood spreads in retortable aluminium trays and pouches. Because of the flat profile of these packages, heat penetration to the SHP of the container is rapid (relatively), which means that heat sensitive products (e.g., scallop and lobster pastes) can be processd without excessive loss of flavour and colour.

Processing temperatures and times depend upon the dimensions of the container and the nature of heat transfer to the SHP of the pack - for pastes this is largely by conduction, while for fish balls in brine it is by a mixture of convection and conduction. Post-process handling procedures are similar to those for other heat sterilized fishery products.

5. EQUIPMENT FOR FISH CANNING

For detailed descriptions of machinery used in production of the major commercially canned fishery products, and for accompanying flowsheets, reference should be made to the FAO Fisheries Circular No. 784. Planning and Engineering Data. 2. Fish Canning (1985), in which can be found also, examples of plant layouts for the major species canned. This Chapter contains a description of the processing equipment specifically used for the production of canned sardines and tuna (following the procedures outlined in Chapter 4), together with a description of the thermal processing equipment which is basic to most fish canning operations.

5.1 Machines for Canning Sardine

5.1.1 Grading machines

Grading machines are used to sort sardine and sardine-like fish into regular sizes. Machines are available which, in a single pass, segregate the fish into four different grades, with thicknesses ranging from between 5 mm and 33 mm. The fish pass, tail first, down inclined oscillating tracks which are separated by gradually widening gaps. When the gap between the tracks becomes greater than thethickness of the body, the fish fall through to belts below, from where they are segregated into storage bins or passed onto conveyors for further processing. The machines are fitted with water sprays which simultaneously wash the fish as they pass down the tracks.

Shown in Figure 24 is an example of a grading machine supplied by the Baader Company of West Germany. In the figure can be seen the feeding mechanism which deposits the fish onto the tracks down which the fish move while being graded for size. The Baader machine shown is designed to grade herring, mackerel, sprat and capelin.

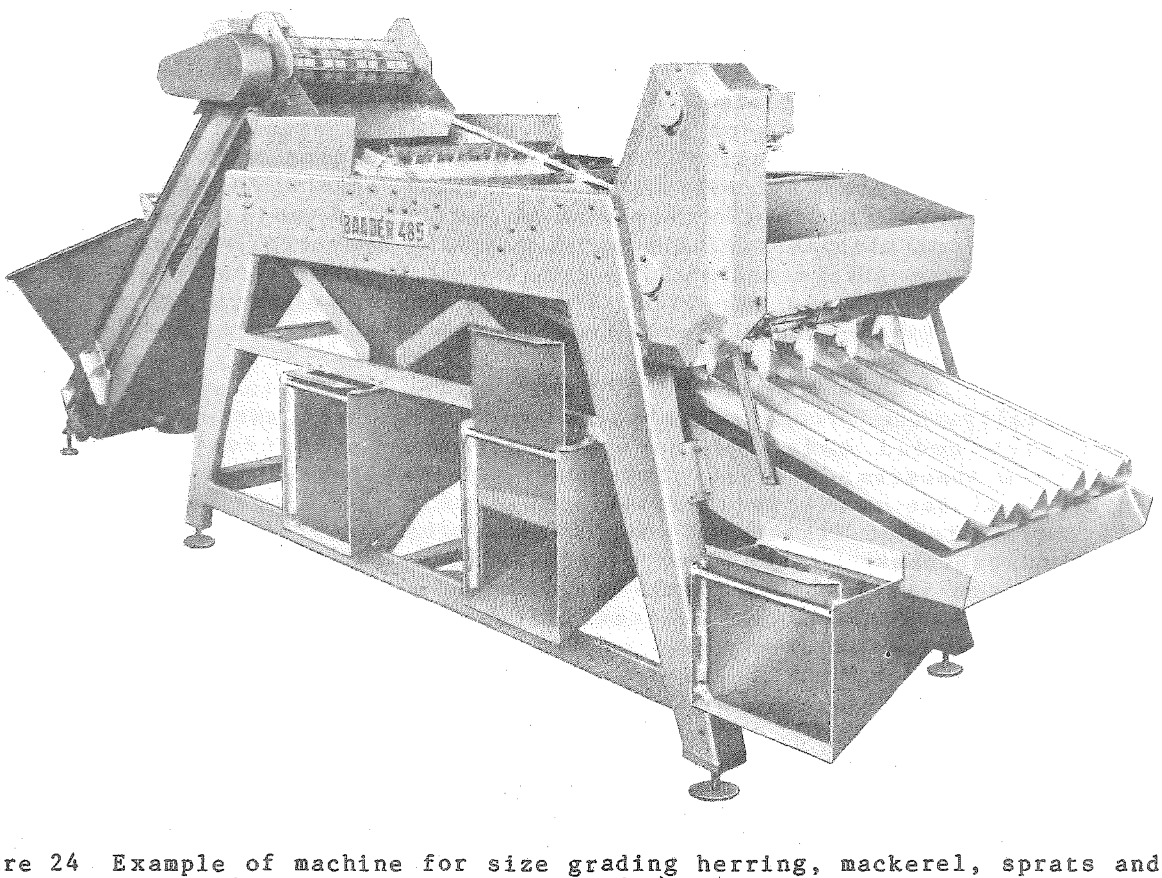


Figure 24 Example of machine for size grading herring, mackerel, sprats and capelin (photograph courtesy of Baader)

5.1.2 Nobbing machines

There is a range of nobbing machines available for the removal of heads, tails and viscera of sardines and sardine-like fish; and there are also machines which automatically pack the nobbed fish into cans. Fish may be fed to the nobbing machines manually, by between three and five operators; however, there are also machines in which one supervisor can manage an automatic feeding operation. Shown in Figure 25 is an example of a Baader feeding machine designed to handle herrings, sardines, sprats and similar fish. The fish are raised on an elevator and passed to five feed channels for delivery to the nobbing machine (or other piece of processing equipment).

Once placed in the nobbing machine the fish are fed to cutting knives which shear the head from the body without cutting the throat. The head is then pulled away from the body, after which the rotating action of tapered fluted rollers remove the viscera. Shown in Figure 26 is a simplified sequential sketch of the fish as they pass through a Baader nobbing machine. The machines can be set to leave the tails on the fish, or alternatively, the tails can be removed and the

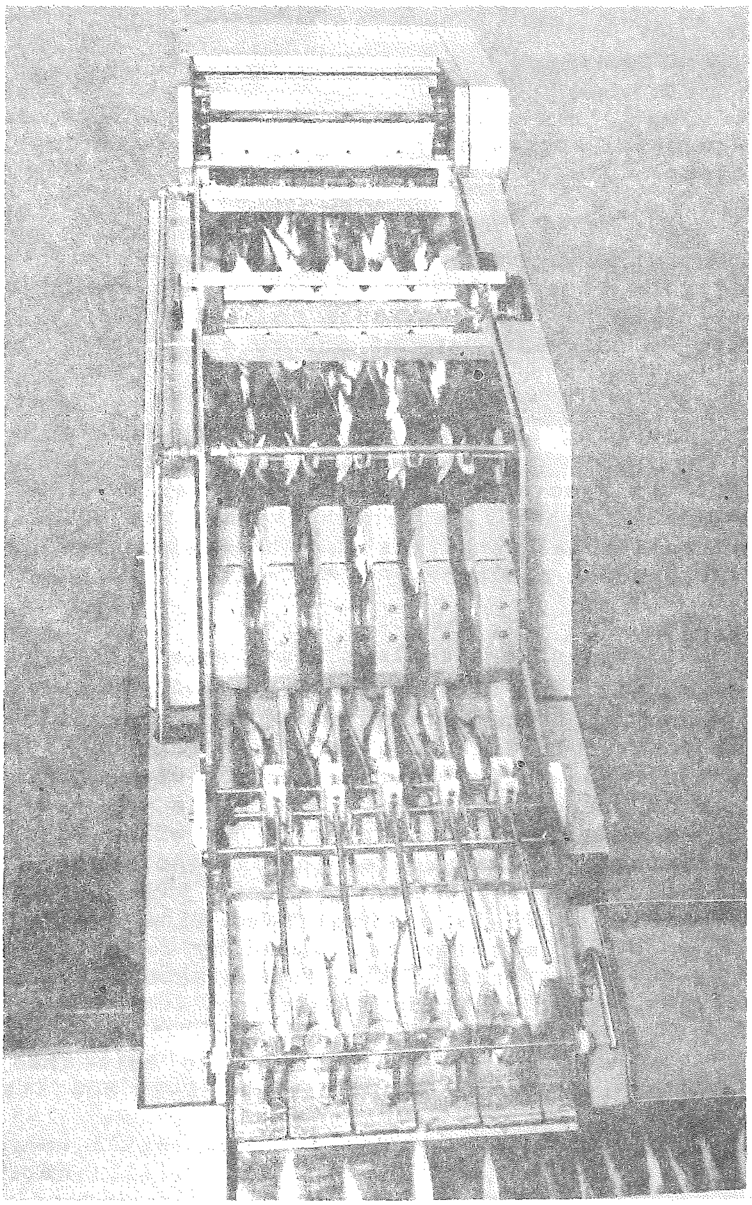


Figure 25 Example of automatic feeding machine designed to handle herrings, sardines, sprats and similar fish (photograph courtesy of Baader)

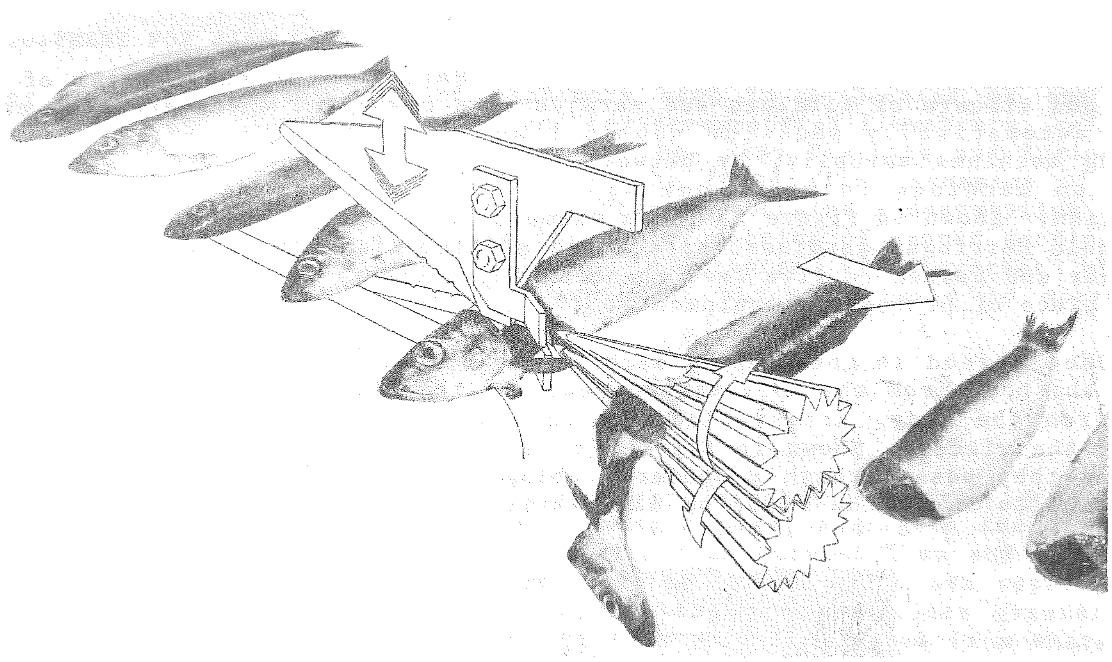


Figure 26 Sequential stages of nobbing operation (photograph courtesy of Baader)

body can be cut to standard lengths (in one or several pieces) to suit the size of the cans. In Figure 27 are shown two pack styles available for sardines and other similar fish. Machines are available to handle fish ranging in length from approximately 10 to 45 cm, at a rate of 150 to 450 fish per minute (depending on fish size).

In automatic nobbing and packing machines, fish are placed in moulded pockets (to suit the pack style) in which they are conveyed, in can lots, under rotating blades for the removal of the heads and tails. The fish bodies are then eviscerated by a suction process, after which they are automatically transferred to cans. In many traditional canneries the nobbing process is automatic but cans are still packed by hand on conveyors.

5.1.3 Flash cookers

Sardines are cooked and dried in flash cookers in open cans which are automatically transported through continuous machines. There are at least two systems available, however in each, the mode of operation is similar. Filled cans are automatically fed into a steam heating section where the sardines are cooked. For machines in which precooking takes place while the cans are in the upright position, the filled containers are inverted to allow draining; however, when cans are inverted during precooking, draining is continuous. At the completion of draining the sardines are dried, and the cans then proceed to the automatic discharge unit. In Figure 28 is a simplified line drawing showing the side elevation of a precooking machine (supplied by Trio) in which the fish are precooked and then the cans drained for approximately three minutes, prior to being returned to the upright position for drying.

The speed of the machines may be altered to suit the load and container size, typically the machines process in excess of 10 000 filled cans per hour.

5.1.4 Smoking ovens

In the manufacture of Norwegian style sardines, the fish are smoked either in a batch or a continuous system. The units consist of the drying chamber into which hot air (at around 40°C) is drawn, and a smoking section. Smoking ovens may be either simple batch operations into which are placed trolleys containing the smoking frames loaded with fish; or they may be automatic systems which continuously draw the fish on their frames through the drying and smoking chamber.

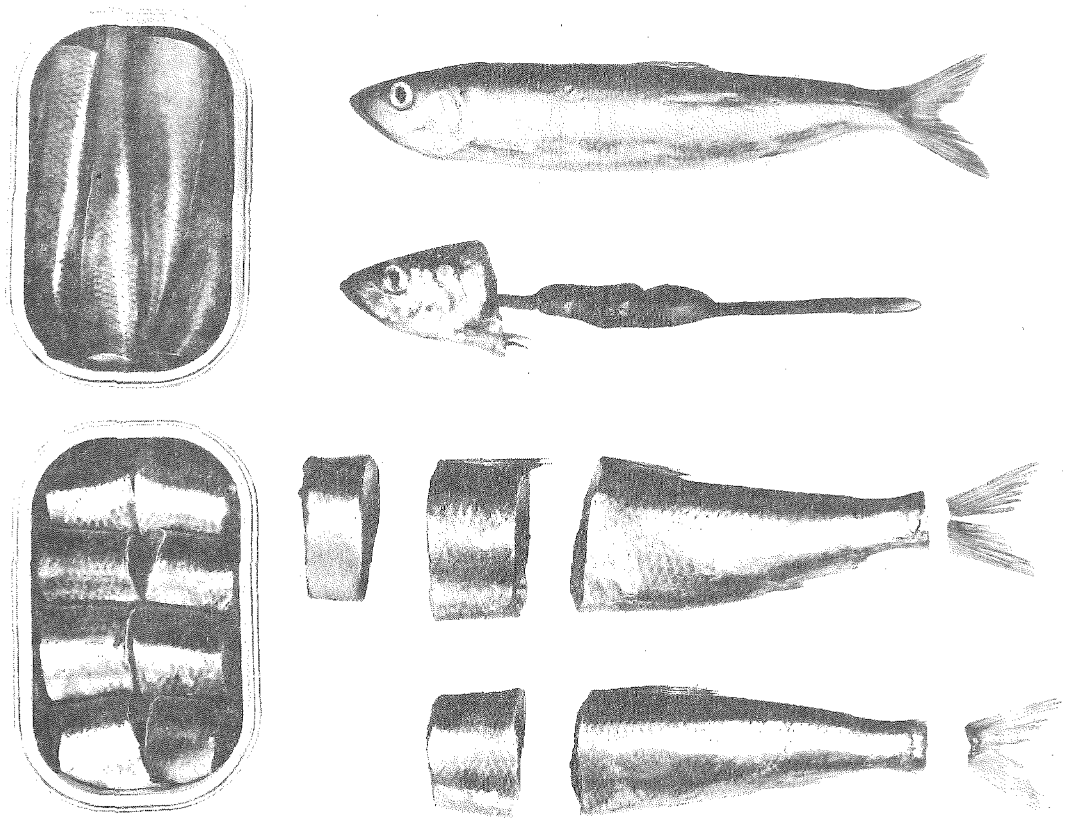


Figure 27 Examples of pack style available with automatic nobbing machine (*Photograph courtesy of Baader*)

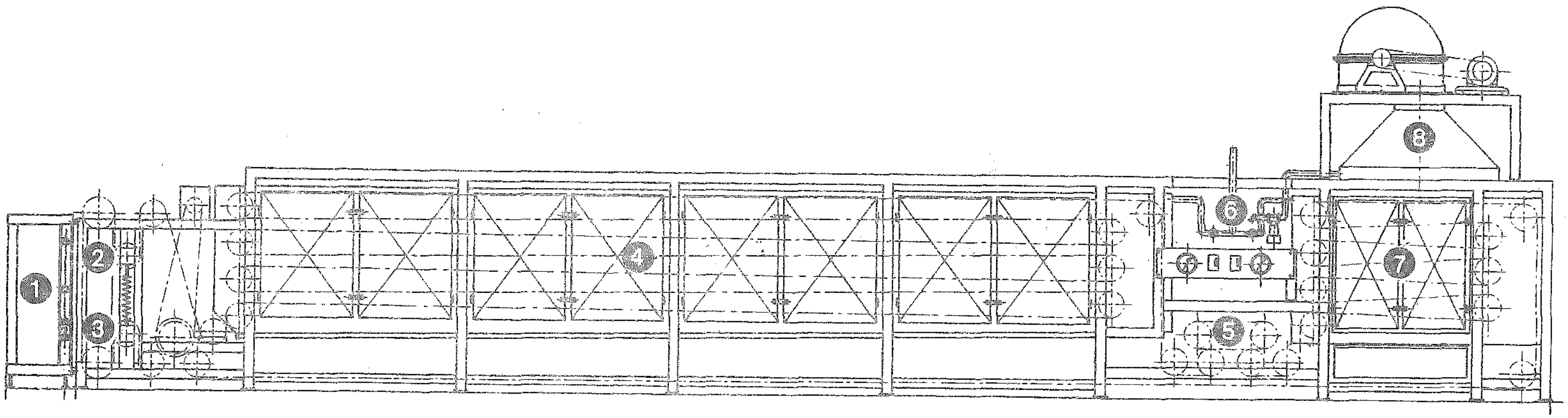
Equipment used for the remainder of the sardine canning process is similar to that described under the heading "General fish processing machinery" (see section 5.3).

5.2 Machines for Canning Tuna

5.2.1 Pre-cookers

The most common pre-cookers are live-steam cookers, fitted with condensate drains, vents and safety valves. The pre-cookers operate on a batch system, with doors at each end (so that fish may be rolled in and out on a flow-through basis). *The fish are loaded into galvanized iron baskets, and* the baskets are placed on racks which are rolled into the cookers for steaming.

Other preparatory stages taking place before filling are completed manually, and in many canneries, filling is also a manual operation. There are, however, fully automatic filling machines suitable for packing tuna in all pack styles in round and oval cans.



1. Automatic charge and discharge section
2. Feeding conveyor
3. Discharge conveyor
4. Steam chamber
5. Draining section
6. Steam regulation
7. Drying section
8. Ventilators

Figure 28 Side elevation of continuous flash cooker for precooking sardines; (diagram Courtesy of Trio Mask in Industry A/S)

5.2.2 Filling machines

Machines are available for filling chunk and grated (shredded) tuna which operate at speeds of between 80 and 350 cpm with cans ranging from 112 to 445 g (approx.). There are a number of manufacturers with various operating procedures, but one manufacturer (Carruthers Equipment Co., USA) has several machines for automatic tuna filling. In one machine (the Pack-Former) fish is discharged into filler bowls from where it is transferred into a series of piston pockets positioned around the circumference of the machine. As the filling heads complete a revolution, the fish is compressed into a cylindrically shaped slug in the pocket, in which form it is pushed out the bottom of the piston and is trimmed to the correct length, so that the weight of the pack in each can is controlled. The fish is then fed into the can which has been located below. A machine (a Carruthers Nu-Pak) operates on a similar principle, at speeds ranging from 200 to 600 cpm, with 225 g cans (and smaller).

Solid style tuna loins are packed fully automatically by a machine (a Carruthers Pak-Shaper) which handles cans ranging in size from 112 g to 1.8 kg (approx.) at speeds from 30 to 130 cpm. The machines are fed with solid loins which are transferred to a forming hoop in which the flesh is molded into the desired shape and then cut off cleanly to produce segments of the required length (and therefore weight).

Equipment used for the remainder of the tuna canning process is described in the following section.

5.3 General Fish Processing Machinery

5.3.1 Brining machines

Brining machines are sometimes coupled with washing machines, so that the two operations occur simultaneously. In continuous applications, the machine is usually a rotating perforated drum partially immersed in a brine bath and through which the fish pass at a predetermined rate. In less sophisticated operations, brining can be a batch process in which the fish are loaded into perforated drums which rotate and, because of the tumbling action, gently transport the fish through the salt solution. Whether using automatic, semi-automatic or batch equipment, it is important that the salt concentration be maintained at the desired level - this means that periodically the effects of gradual dilution must be monitored and salt added. The material used for construction of the equipment must resist the corrosive effects of the salt.

5.3.2 *Exhaust boxes*

The exhaust box is used to heat the contents of cans, so that they may be sealed hot, thus ensuring that, after cooling, a vacuum has formed in the container. Exhausting also drives entrapped air from the pack. Exhaust boxes may take many shapes and forms, depending on the requirements of the cannery; basically they consist of a tunnel through which the open and filled cans pass while being exposed to atmospheric steam. They require a feed and a discharge mechanism, and a conveying system for transporting the cans from one end to the other. Recent models are frequently constructed with stainless steel, however many canneries still find painted mild steel systems adequate.

5.3.3 Sealing machines

When selecting can sealing machines, fish canners must consider the following factors:

- the size and shape of the container,

- the anticipated speed and volume of production,

- the level of skill required to maintain the machine in good working order,

- the cost and availability of spare parts, and

- the ease of "changeover" when the machine settings have to be converted to accommodate cans of more than one shape and/or size.

In order to cater for the diverse requirements of fish canners, there is a wide range of machines from which manufacturers can choose a model to suit their operations. Since many sealing machines have features in common, the following is confined to a general description of the major categories which are readily available.

The simplest of machines are required by those packers who run their lines at speeds of from 8 to 25 cpm using hand operated or semi-automatic single-head equipment with motorized drives. For those with a low output (i.e., < 20 cpm), hand operated models are ideal - as with seasonal production or in those plants which are required to prepare test packs.

Single head seaming machines may be fitted with steam-flow closing or mechanical evacuation apparatus as a replacement for, or as an adjunct to, hot filling or exhausting. When mechanical vacuum closing is required the operator places the container (with the can end sitting in place on top of the can) in a chamber, which is then closed and evacuated by opening a line leading to a vacuum pump. When the desired vacuum is obtained in the chamber, the sealing operation is initiated by depressing a foot pedal which lifts the can up to the chuck on the sealing head and into position for double seam rolling. The first and second action rollers are sequentially brought into action while the can is rotated by the spinning seaming head. At the completion of the seaming operation the sealing chamber is opened to the atmosphere and the hermetically sealed container is removed. Machines of the type described can frequently have the facility for steam flow closing, in which case steam is injected across the headspace of the container (while it is positioned in the sealing chamber) immediately prior to double seaming.

Fully automatic in-line single-head steam flow closing machines which operate in the range of 70-90 cpm are available; while for canneries operating at higher speeds there is a variety of multiple-head machines from which to choose. Of the latter, three, four and six spindle machines are common and can be selected to cover seaming speeds of from 200 to 600 cpm, depending on can sizes and production capacity.

Machines for sealing glass containers generally do not operate at the speeds of can closing equipment, however, they can be fitted for steam-flow closing or mechanical evacuation. Fully automatic steam flow closing machines are available to apply caps at around 400 to 500 cpm (depending on container size), while semi-automatic machines can be operated at around 15 cpm. As with cans, vacuums in glass jars may be also obtained by hot filling, or by addition of hot brine, or by exhausting.

Laminated packaging materials are sealed by the fusion of the two facing layers of the innermost ply. The material is heated while clamped between jaws of the sealing machine for sufficient time for the two layers (usually polyethylene or polypropylene) to fuse and form an hermetic seal. One of the greatest difficulties faced by users of laminated packaging materials is that of ensuring effective seal formation. Under all circumstances the sealing surface must be clean and free of particulate matter, which can present difficulties when packing fish products, as it is not always possible to prevent flakes of flesh from contaminating the sealing surfaces. The solution to the problem is to clean the seal area before passing the package to the sealing machine, however, this further retards what is in many cases an already slow sealing operation.

5.3.4 Retorting systems

For a detailed description of recommended retorts and retort fittings reference should be made to the following publications:

FAO/WHO, 1977. Codex Alimentarius Commission, Recommended international code of practice for canned fish. Rome, FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/RCP 10-1976:42 p. Issued also in French and Arabic

FAO/WHO, 1983. Codex Alimentarius Commission, Recommended international code of practice for low-acid and acidified low-acid canned foods. Rome, FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/RCP 23-1979:50 p.

The main types of retorts used in the manufacture of low-acid canned foods include the following :

(a) Batch retorts heated with saturated steam. These may be either vertical or horizontal and are by far the most common retorts used by fish canners. Simplified drawings of these types of retorts are shown in Figures 29 and 30; in Figure 31 is shown a less frequently used batch system for processing cans in saturated steam. The latter system is referred to as a crates. Brief descriptions of these systems are found in sections 3.6.1, 5.3.5 and 5.3.6.

(b) Batch retorts heated with water under pressure. These retorts are vertical or horizontal and are most frequently used for processing glass containers which cannot be processed in pure steam because of the risks of thermal shock breakage. They are also widely used for sterilization of products packed in aluminium cans with score-line easy open ends. Simplified drawings of these types of retorts are shown in Figures 32 and 33; operational guidelines are given in section 3.6.2 and features of the system are described in section 5.3.7.

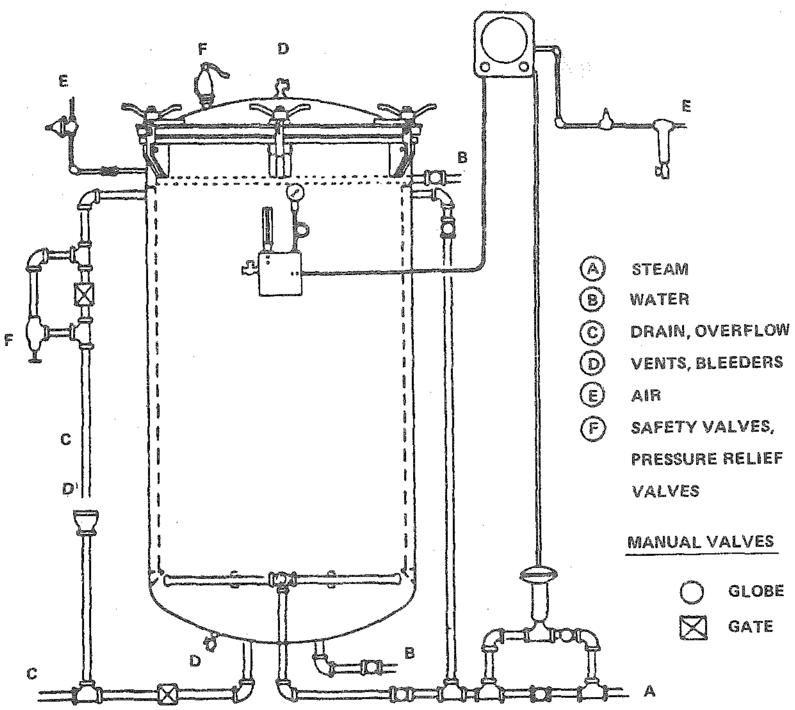


Figure 29 Controls and fittings for a vertical batch retort for processing in saturated steam and pressure cooling

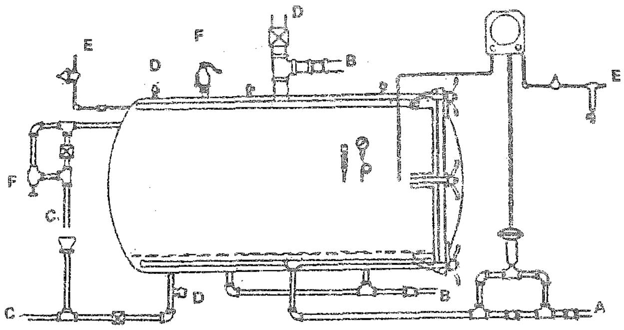


Figure 30 Controls and fittings for a horizontal batch retort for processing in saturated steam and pressure cooling (For code to symbols see Figure 29)

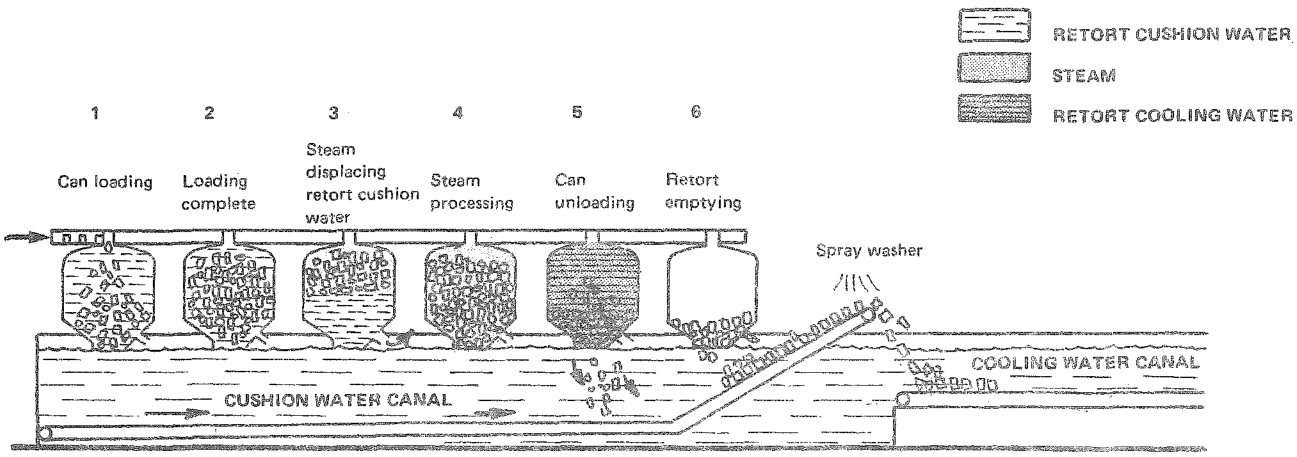
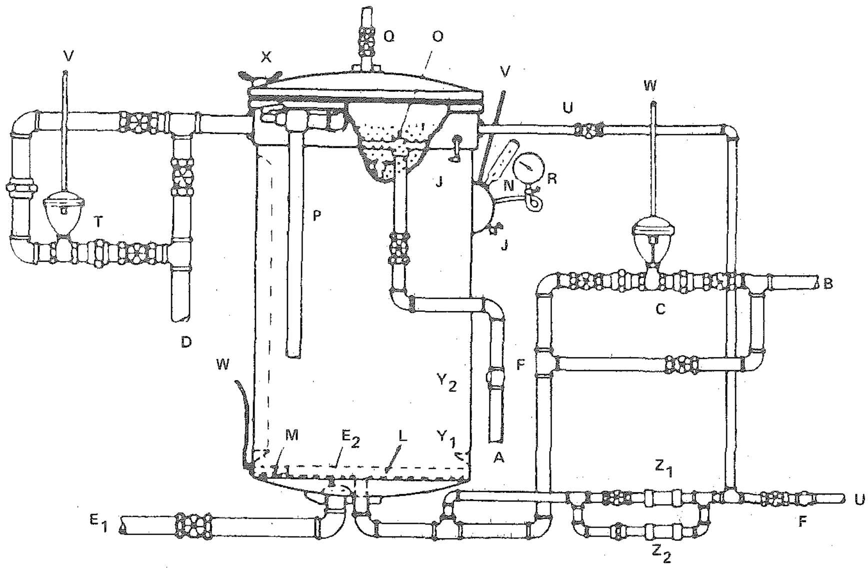


Figure 31 Crateless retort - operating sequence (Courtesy of FMC Corporation)

(c) Continuous retorts (other than hydrostatic retorts). Containers are passed through a mechanical inlet port into a pressurized chamber containing steam where they are processed before passing through an outlet port and, depending on the make of the retort, into either another pressurized shell, or an open water reservoir, for cooling. The motion of the cans through the retort causes some forced agitation which aids the rate of heat transfer to the SHP of the container.

(d) Hydrostatic retorts. A simplified drawing of this type of retort is shown in Figure 34 and the system is described in section 5.3.8.

(e) Retorts heated by a mixture of steam and air. The containers are processed under pressure in a system which relies on forced circulation (by a fan or a blower) for the continuous mixing of the steam with the air. Inadequate mixing can result in the formation of cold spots which could lead to under-processing spoilage. As with water filled retorts, this system is suitable for retortable pouches which require a counterbalancing overpressure to prevent their rupture.



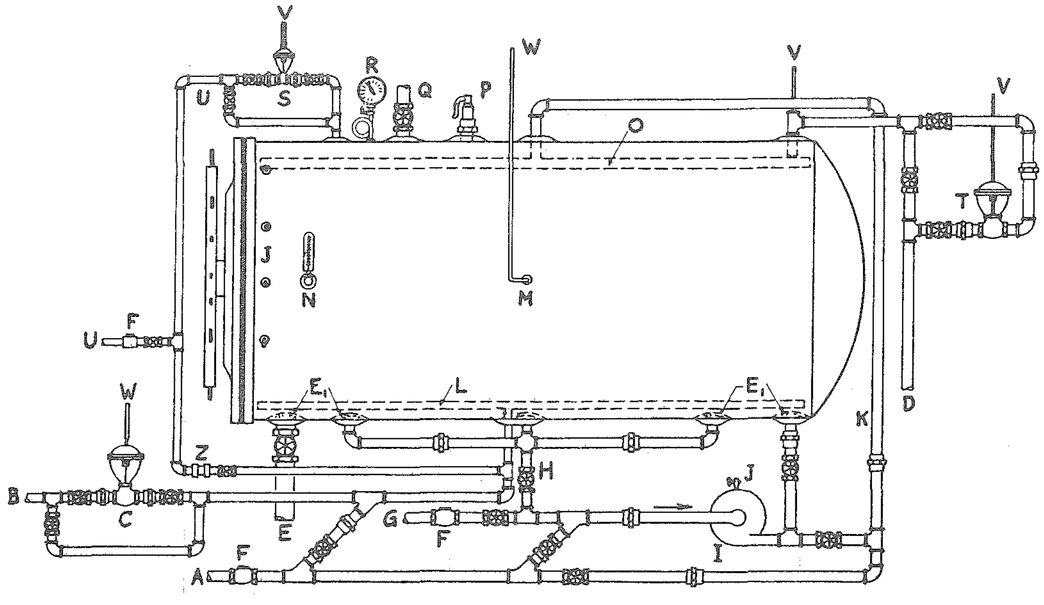
Code to symbols:

A	Water line	R	Pressure gauge
B	Steam line	T	Pressure control
C	Temperature control	U	Air line
D	Overflow line	V	To pressure control instrument
E_1	Drain line		
E_2	Screens	W	To temperature control instrument
F	Check valves		
J	Petcocks	X	Wing nuts
L	Steam spreader	Y_1	Crate support
M	Temperature control probe	Y_2	Crate guides
N	Reference thermometer	Z_1	Constant flow orifice used during come-up
O	Water spreader		
P	Safety valve	Z_2	Constant flow orifice valve used during cook
Q	Vent		

Figure 32 Vertical retort for processing glass containers

There is a comparatively rarely used retorting system whereby sterilization is achieved by directly heating cans with flames from gas burners positioned underneath containers which spin past on guide rails. This system is suitable for packs which contain a high proportion of liquid, thus permitting rapid transfer of heat by convection, but it is not used commercially in fish canning operations.

The most frequently used style of retort found in commercial fish canneries today, is the static batch system for processing cans in saturated steam. A description of the fittings for these retorts is given in the following section; however, many of the other retorting systems referred to above are similar with respect to fittings and methods of operation. The most significant difference between static retorts and continuous systems, is that the latter must have container transfer mechanisms to regulate the movement of cans at a predetermined rate through the heating and cooling sections.



Code to symbols:

A Water line
B Steam line
C Temperature control
D Overflow line
E Drain line
E_1 Screens
F Check valves
G Line from hot water storage
H Suction line and manifold
I Circulating pump
J Petcocks
K Recirculating line
L Steam spreader
M Teemperature control probe
N Reference thermometer
O Water spreader
P Safety valve
Q Vent
R Pressure gauge
S Inlet air control
T Presure control
U Air lines
V To pressure control instrument
W To temperature control instrument
Z Constant flow orifice valve

Figure 33 Horizontal retort for processing glass containers

5.3.5 Standard batch retorts for processing cans in steam

Irrespective of whether retorts for processing cans in steam are vertical, horizontal or crateless, they have a number of features in common. The major fittings are as follows:

- Steam inlet. The steam enters through a perforated steam spreader pipe which provides even distribution of the heating medium throughout the retort. The steam inlet is positioned opposite the main vent: in standard vertical retorts the steam spreader is usually located at the base of the vessel, while in crateless retorts it is circular and at the top; in horizontal retorts it extends the full length of the retort. In general the total cross-sectional area of the perforations in the spreader should be 1.5 to 2 times the smallest cross-sectional area of the steam inlet line.

The steam supply should be capable of bringing a fully loaded retort to operating temperature within 15 min from "steam on" and to regulate temperature to within 1°C during the process.

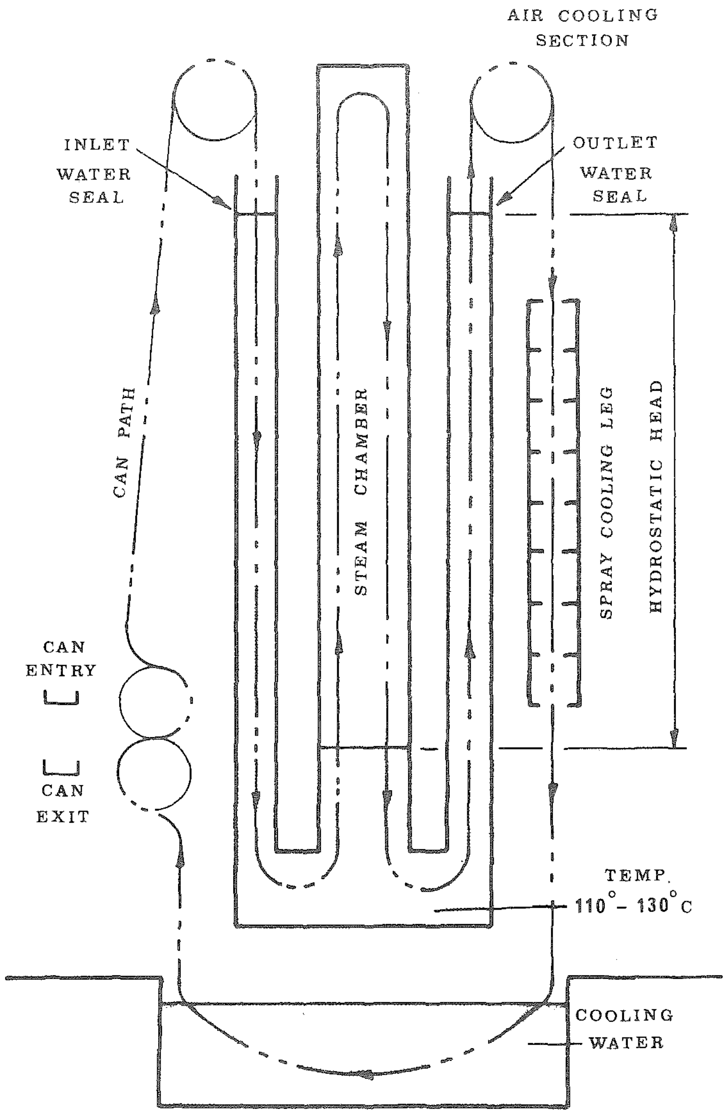


Figure 34 Hydrostatic retort (Courtesy of Churchill Livingstone)

- Vents. The vent is included to allow the operator to purge all air from the vessel prior to bringing the retort up to operating temperature. It is important that the outlet to the vent is visible so that the operator can see when venting is taking place.

- Cooling water inlet. In many retorts the cooling water is supplied via a separate spreader which is positioned at the top of the retort; however, in some installations the cooling water is introduced through the steam spreader at the bottom of the retort but this has the disadvantage that cans at the bottom are cooled first, which causes uneven cooling, particularly in plants where the water pressure is low. It is important that the water supply valve can be completely shut off during processing otherwise cold water may leak into the retort and possibly cause under-processing of some cans.

The water supply should be sufficient to fill a fully loaded retort, against the pressure of the steam, within 10 min.

- Bleeders. Small bleeders of at least 3 mm diameter are fitted to the body of the retort and left open (cracked) during the process so that any air and non-condensable gases that are introduced with the steam can be removed.

- Steam condensate trap. A steam trap or a bleeder must be fitted to remove condensate which would otherwise accumulate at the base of the retort during heat processing. This is particularly important with crateless retorts, as the random stacking of the cans means that some cans will lie directly on the base of the retort - unless they are fitted with false bottoms so that the bottom cans are clear of the condensate The condensate discharge should be positioned so that it can be seen to be functioning correctly by the operator.

- Pressure safety valves. All retorts must be fitted with safety valves so that internal pressure does not exceed the recommended working limits.

- Compressed air line. Compressed air is used to operate the automatic control valves and for pressure cooling. The supply should be sufficient to enable the retort to be cooled with water (within 10 min) without there being any drop in the pressure below that of the steam during the process.

- Retort baskets and divider sheets. So that the steam distribution to and around each container is uniform, the retort baskets and the divider sheets must be perforated.

- Instrumentation. Retorts require an indicating thermometer (a mercury in glass, or an alternative of comparable accuracy), a recording thermometer (to provide a permanent record and confirmation that the temperature and the time of the process were as scheduled), and a pressure gauge.

5.3.6 Crateless batch retorts for processing cans in steam

Crateless retorting systems are available in which loading, processing, cooling and unloading are all carried out fully automatically, often with the aid of computer control systems which enable one operator to supervise eight to ten retorts simultaneously.

Cans are automatically loaded through the top of the retort and fall into the cushion water below (step 1). When the prescribed number of containers have been loaded, the oncoming stream of cans is automatically diverted into the next retort, and the top of the retort is closed (step 2). Steam is forced into the retort and as it enters it displaces the cushion water through the bottom drain valve (step 3). Once all the air and water have been vented from the system and the retort reaches operating temperature, the process commences (step 4). At the completion of the scheduled retorting time, the steam is turned off, and water and compressed air are pumped into the vessel and initial cooling commences (step 5). After partial cooling, cans are released into the cushion water canal (step 6), which runs underneath the bank of retorts, and from there they are automatically transferred, on conveyors, into the cooling water canal.

Although offering considerable labour savings and flexibility, it is important that care be taken while loading and unloading the cans. In the former case there is a danger that, if the retorts are overloaded, or the cushion water level in the retort is too low, or if there are "floaters" (caused by insufficient removal of air prior to sealing the cans), incoming cans will damage the double seams of the uppermost layer of cans. Similarly, during unloading, seam damage can occur if the cans are permitted to drop out of the retorts in an uncontrolled manner. The risks to the seam are heightened at this stage if the cans are still hot, because the compound will be soft and the cans under positive internal pressure, so that damage to the double seam area may cause momentary venting of the seal. Because of the potential danger to the hermetic seals during unloading, it is strongly recommended that the water level in the cushion water canal be maintained above the level of the exit door (as shown in stages 5 and 6 of Figure 31). If this procedure is adopted, the cans gently float down and out of the retort, which means that their double seams are not exposed to as much physical abuse as when they are dropped directly into the cushion water lying below the level of the exit.

5.3.7 Batch retorts for processing glass containers in water

The operating principles for processing glass under water in counterbalanced retorts have been discussed in section 3.6.2. The similarities in retort fittings for processing glass in water and cans in steam are evident when comparing Figures 29 and 30, with Figures 32 and 33, respectively. The main functional characteristics peculiar to systems for processing glass are that:

- water is introduced and mixed with the steam as it enters through spreaders, at the base of the retort (thereby preventing thermal shock breakage); and

- counterbalancing air is required to transmit sufficient pressure through the water to ensure that there is always a greater pressure in the retort than in the container. (It will be recalled that this modification is to prevent the closures from being forced from the finish of the glass during the thermal process).

5.3.8 Hydrostatic retorts for processing cans in steam

In the diagram of the cross section of the hydrostatic retort shown in Figure 34 can be seen the columns of water in the inlet and outlet legs which balance the pressure in the steam dome and give this style of retorts their name. As the height of the column controls the steam pressure, it also controls the temperature in the steam dome. Cans are automatically loaded onto the chain which carries them through a preheating zone at the top of the inlet leg and down into the column where they are heated by water which becomes progressively hotter the further into the leg they move. At the bottom of the inlet leg the cans emerge from the water seal and then travel up into the steam dome (or steam chamber). In some hydrostatic retorts the cans have two passes through the dome (one up and the other down), while in others the cans have multiple passes. In Figure 34 a two-pass system is illustrated. The severity of the process depends upon the residence time that the cans are in the dome (which is controlled by chain speed and chain length), and the temperature of the steam (which is controlled by the height of the water column). At the completion of the process the cans move back through the water seal, on the cooling side of the retort, and up into the cooling leg where they are exposed to progressively colder water. At the top of the cooling leg the cans pass through an air cooling section and then pass down a final cooling section where they are sprayed with cool water. The cooling water canal shown in the illustration is omitted in some hydrostatic retorts.

Because of the high capital investment, the time taken to adjust the conveyor systems to handle different can sizes, and the time required to bring the retorts to operating temperature, hydrostatic cookers are best suited to long production runs. When dual chain systems are used, it is possible to process cans of different sizes simultaneously, for different times but at the same temperature. While savings of floor space, gentle can handling, and gradual changes in temperature and pressure, are attractive features of these retorts, the systems are expensive to install and maintain, and the costs of breakdowns can be high.

6. PROCESS CONTROL IN FISH CANNING OPERATIONS

Fatal errors in low-acid canned food manufacture are rare, which, given the volume of production, suggests that traditional process control measures (achieved through staff education and training, inspection of facilities and operations and testing or examinations) are effective. This comes as no surprise; for ultimately it is in the canners' interests to assure that their products are not only safe to eat, but also that they are of the expected quality. At the worst, failure to regulate end product quality will lead to outbreaks of food poisoning and expensive recalls; at best, it will gradually undermine the image of the product, and it will limit the ability of the manufacturer to supply to an agreed specification.

6.1 The Need for In-process Control

The collective experience of the international fish canning industry is generally sound; nevertheless, manufacturers can ill afford to overlook the outbreaks of botulism which in 1978 and 1982 led to the death of three consumers of commercially canned Alaskan salmon. In both these cases spoilage was the result of post-process contamination by C. botulinum (type E). The first outbreak involved only one can from a production lot of 14 600 units, yet the manufacturer inspected (visually and with a dud detector) some 14 million units. Reportedly, 3 515 cans were screened for botulinal toxin and all were negative. The second outbreak was attributed to a single can from a production lot of some 24 000 cans, and led to the recall of 60 million containers from nine canneries. During this investigation approximately 1 000 cans were tested for the presence of botulinus toxin and none was found. In addition to the logistical difficulties of implementing extensive recalls, these incidences demonstrate the impracticability of relying on large scale product recalls and quality audits as a means of detecting unsafe finished product.

In 1978 the International Commission on Microbiological Specifications for Foods (ICMSF), stated that microbiological sampling methods are inappropriate for assessing the safety of low-acid canned foods; they said "...experience demonstrates that, if present, C. botulinum would be expected to occur at such low frequency that no conceivable sampling plan would be adequate as a direct measure of its presence." Theoretically, the probability of a single C. botulinum spore surviving a "botulinum cook" (F_o = 2.8 min) is estimated at 10^{-12} (see section 1.3). The probability of botulism arising through C. botulinum entering containers, via post-process contamination, has been estimated to be from 10^{-7} to 10^{-10}; while that due to botulism being caused by the container failing to receive a thermal process has been estimated at between 10^{-6} and 10^{-8}. Notwithstanding that these figures are estimates and difficult to validate, it is clear that when the probabilities of C. botulinum (or its toxin) being present in a can of low-acid canned food are so low, the chances of detecting it by terminal analyses are remote - even with a 100% inspection procedure. Should the method of testing be reliable, which is not necessarily the case (e.g., when the presence of vacuum is taken to be the indicator of safety from non-proteolytic type E C. botulinum), many of the test procedures that are available are destructive and therefore not feasible. Questions as to the value of terminal analyses were revealed at the twelfth session of the Codex Committee on Processed Meats and Poultry Products when it was reported that "...there was general agreement within ICMSF that indirect inplant control and hygienic post-processing handling were better measures...(for protecting public health)...than extensive end product examination." (Codex Alimentarius 1982). It is recognized that traditional end product sampling procedures can indicate a gradual deterioration in performance, but they ought not be relied upon to detect manufacturing defects which may compromise the safety of the product.

The two botulism outbreaks cited, and the prevailing attitudes toward traditional terminal analyses (microbiological and/or physical), underscore the desirability of alternate methods to assure the safety of canned fishery products. Hence the attraction of a process control system that minimizes the chances of manufacturing defects, while providing permanent records which demonstrate that the canned product was prepared according to generally recognized standards of good manufacturing practice. It is against this background that application of the Hazard Analysis Critical Control Point (HACCP) concept for in-process control in the manufacture of canned fishery products warrants the attention of canners and regulatory agencies.

6.2 The Hazard Analysis Critical Control Point (HACCP) Concept

There are three elements to the HACCP approach for in-process control:

(a) Assessment of the hazards associated with the manufacture of the product. In the case of canned fish preserved by heat alone, the hazards are due to the possible survival of, or recontamination by, *C. botulinum* or its spores. The risk of botulism arises because:

- the environment within the can is suitable for toxin formation, and

- it is conceivable that under some circumstances the finished product is not likey to be treated (e.g, heated prior to consumption) in a manner which can be relied upon to render harmless any toxin that may be present.

(b) Identification of the process critical control points (CCPs) to control the hazards. Critical control points are defined as those stages in production where lack of control could lead to the manufacture of an unsafe product due to the presence of organisms of public health significance. This definition places the emphasis on protection of public health; however, some manufacturers broaden their interpretations to include factors which, if not controlled, could affect the marketability of the product. In line with the more stringent approach to CCPs, application of the HACCP concept in canned fish manufacture has the prevention of botulism as its primary objective whereas the wider interpretation encompasses control of safety factors and quality factors.

(c) Implementation of standard procedures to monitor the manufacturing process at CCPs. In order to monitor production effectively, the manufacturer must establish performance guidelines against which production at each of the CCPs can be evaluated. Embodied in these guidelines are the quality criteria which determine the specifications for the process. Also, there must be formal procedures to record the results of all the in-process tests which are used to monitor performance, and there must be provision for in line "corrective-action" and "follow -up" control mechanisms. In-process control records should be retained for a period of not less than three years. This is essential to help management regularly review production, but also permanent records are necessary should questions of product suitability arise and a product recall be initiated. In summary this means that at each CCP there must be a specification, a testing procedure, a permanent recording system and a facility for remedial action.

The distinction between traditional control mechanisms and the HACCP approach to in-process control is clear. The former relies on terminal analyses to assess the adequacy of each operation, while the latter relies on in-process testing to demonstrate that all factors critical to the safety (and marketability) of the product have been adequately controlled. Given that improperly manufactured canned fishery products present a potential health risk, and since the safety of high volume canned food production cannot be assessed solely by terminal analyses, the error prevention techniques of the HACCP concept are both rational and potentially more cost effective.

6.3 Identification of Critical Control Points

Central to the implementation of the HACCP concept for in-process control is the identification of the critical control points. Since manufacturing techniques for canned fishery products vary greatly between plants, it follows that there will be different CCPs for different production lines. The CCPs for a canning process can be identified with the aid of a process flow diagram which should be constructed for the entire operation from the receipt of the raw and packaging materials through to transport and storage of the finished product. The standard symbols used in process flow diagrams are shown in Table 12.

Process flow diagrams provide a visual means of summarizing the entire sequence of production, and from this it is a simple step to identify CCPs. A typical list of CCPs for manufacture of canned fishery products (preserved by heat alone) is shown in Table 13. This list identifies those points in production where the manufacturer must establish specifications, a monitoring system complete with records, and a follow up system to confirm that any adjustments made achieve the desired effects. The frequency of monitoring and the test procedures to be used must also be specified. As the list may not be appropriate for all canning operations, it is important that manufacturers construct their own process flow diagram so that they can be sure no CCPs have been omitted - or included unnecessarily.

6.4 Critical Control Point Specifications

In commercial practice there are only a few specifications which are constant for all fish canners. Instead, manufacturers must select specifications which are relevant to each of their particular operations, while taking care that they fulfill the absolute requirement of product safety. Specifications should be set to reflect the desired sensory qualities of the product, they should be realistic and they should be geared to the ability of the plant to match them while remaining profitable. Although it may be difficult to define standards which are applicable to, and accepted by, an entire industry, it is possible to speak in terms of compliance with generally recognized standards of good manufacturing practice (the GMP guidelines referred to throughout this text, and in particular in sections 1.5, 2.1.4, and 3.2).

For further information regarding GMP guidelines for cannery operations, readers should consult the following publications:

FAO/WHO, 1977. Codex Alimentarius Commission, Recommended international code of practice for canned fish. Rome, FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/RCP 10-1976:42 p. Issued also in French and Arabic

FAO/WHO, 1983. Codex Alimentarius Commission, Recommended international code of practice for low-acid and acidified low-acid canned foods. Rome, FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/RCP 23-1979:50 p.

Canned Foods. Principles of Thermal Process Control, Acidification and Container Closure Evaluation. 4th Edition. Washington: The Food Processors Institute; 1982.

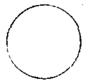
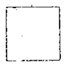
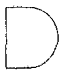
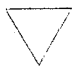
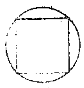
The major objective in seeking compliance with GMP guidelines is protection of public health; and because of this many of the articles referred to above tend to neglect those factors affecting the sensory and the physical properties of the product. Where this information is sought, in the first instance, reference should be made to the Codex Standards for Fish and Fishery Products (CAC/VOL. V - Ed. 1. 1981).

6.5 Checking for Compliance with End Product Specifications

It has been argued that it is unrealistic to suppose that terminal analyses of finished product can assure the safety of the canned product, and that a more rational method of achieving this aim is to implement a system of in-process control at process CCPs. However, this is not to imply that there is no need for terminal analyses of any description, for without doubt, the manufacturer must be confident that the finished product has the desired sensory characteristics. This means that some assessment (subjective and/or objective) of end product quality is necessary.

Table 12

Symbols for use in process flow diagrams

Symbol	Function
	Operation
	Inspection
	Transportaticn
	Delay or temporary storage
	Permanent or controlled storage
	Combined operation and inspection

The functions listed in Table 12 are described as follows:

Operation	Any change to the chemical, physical or microbiological characteristics of the food material is defined as an operation. Pre-cooking tuna, or steam flow closing filled cans are examples of operations. Operations require energy, through manual or automatic means, and take the material one step closer to the finished product.
Inspection	Inspection, usually requiring labour and/or equipment is required to maintain in-process control but it does not take the product any nearer to being finished. Inspection in fish canning operations includes checking for the removal of bones and viscera prior to filling, measuring product fill weight and temperature, and checking that the retort is at scheduled operating temperature.
Transportation	Transportation requires labour and/or equipment to move the product. An example is moving filled un-processed cans packed in retort baskets at the end of the filling line to the retort.
Delay	A delay or temporary storage occurs when there is an unscheduled interruption to the process which is the result of a constraint other tha that imposed by the method of production. Examples include delays while retort baskets are held awaiting entry to the next available retort.
Storage	Storage occurs when the material is held under controlled or permanent storage, as when bright stacked cans are held for labelling.

Table 13

Checklist of critical control points (CCPs)
for manufacture of canned fishery products

Raw and packaging material quality
Product temperature and delay during preparation
Container washing
Filling temperature
Filling weight (liquid to solid ratio if applicable)
Container size and adequacy of the hermetic seal
Retorting (venting; process time, temperature and F_o value; cooling technique)
Plant sanitation and cooling water chlorination
Line damage
Transport and storage conditions

In addition to the assessment of colour, flavour and texture, manufacturers should monitor (and record the results of their evaluations), for several other factors which contribute directly and indirectly to end product quality. These include the following:

- pH;
- drained weight, and correct rations of mixed portion packs (e.g., fish with vegetables);
- salt content;
- external and internal condition of the container (checking for stains, corrosion, rust and pin holes, etc.);
- vacuum (if applicable); and
- headspace.

6.6 Incubation Tests

Although they should not be used as the sole criterion of product safety, incubation tests can provide valuable information as to the adequacy of the thermal process and also a means of monitoring (indirectly) the microbiological quality of in-coming raw materials.

Should a process be of marginal severity, so that a measurable proportion of the population of spore-forming thermophilic bacteria survive, it may be possible to detect changes in the incidence of spoilage after thermophilic incubation tests on the production samples which have been collected as part of routine quality control. It is difficult to predict the level of spoilage in the trade which correlates with a known incidence of spoilage arising from incubation of test samples; however, it was reported by Stumbo (1973) that a thermophilic spoilage level of 1% after thermophilic incubation was found in commercial practice to give rise to a spoilage rate of 0.001% (i.e., 1 in 100 000 units) in the trade. Should a fish canner be able to collect sufficient data to draw their own conclusions concerning the relation between spoilage induced by thermophilic incubation and trade spoilage, the value of these incubation tests becomes clear; particularly for those manufacturers whose products are expected to be marketed in warm climates.

Under normal circumstances there would be little point in routinely monitoring spoilage arising from mesophilic incubation as all the spores which might lead to growth under these conditions should have been eliminated by thermal processes in which target F_o values are 10 to 15 min. However, if there are incidences of mesophilic spoilage detected by these test measures, it is reasonable to conclude that there has been either a significant lapse in the microbiological quality of the raw materials, or a gross failure in the delivery of the scheduled thermal process (see Table 3 for a summary of factors that could lead to this phenomenon). In such circumstances corrective remedial action should follow immediately and suspect stock should be isolated pending a detailed examination.

Incubation test may be carried out in the laboratory or with bulk samples. With the former, the validity of the results must be verified before any conclusions as to the suitability of the test sample (and by implication, the suitability of the population from which the samples were drawn). Factors to be considered when selecting testing procedures for laboratory incubation include:

- the purpose of the test and its statistical basis;
- the validity of the selection of incubation temperatures;
- the method of examination of incubated containers (e.g., not all spoilage will cause blown cans);
- the sample size required to draw statistically significant conclusions; and
- the tolerable levels for accepting lots with given levels of defectives.

With bulk incubation the factors to be considered include:

- the method can only provide the incidence of blown cans in the lot under examination;
- the method can highlight changes in spoilage levels, and prompt management to find the causes of any trends; and
- because of the heating lags in bringing cooled cans to incubation temperatures, it is advantageous to commence incubation as soon as possible after the cans leave the retort, when they will still retain some of the heat from the process.

APPENDIX 1

Additional References

In addition to the publications which are cited in full in the text, the following publications provide useful background information:

FAO/WHO, 1982. Codex Alimentarius Commission, Report of the twelfth session of the Codex Committee on processed meat and poultry products (draft food standards). Copenhagen, 4-8 October 1982. Rome, FAO, Joint FAO/WHO Food Standards Programme, FAO-ESN-ALINORM/83/16:62 p.

FAO/WHO, 1983. Codex Alimentarius Commission, Recommended international code of practice for low-acid and acidified low-acid canned foods. Rome, FAO/WHO, Joint FAO/WHO Food Standards Programme, CAC/RCP 23-1979: 50 p.

Great Britain, Department of Health and Social Security, 1981. The canning of low-acid foods: a guide to good manufacturing practice. London, Her Majesty's Stationery Office

Howgate, P., 1984. The processing of crab meat for canning. Part 2. INFOFISH Market.Dig., 5:39-41

International Commission of Microbiological Specifications for Foods, 1978. Microorganisms in foods. 2. Sampling for microbiological analysis: principles and specific applications. Toronto, University of Toronto Press

Standards Association of Australia, 1984. Double seams for tinplate cans for steel - based cans for foods. North Sydney Standards Association of Australia, (A52730)

Stumbo, C.R., 1973. Thermobacteriology in food processing. New York, Academic Press, 2nd ed.

APPENDIX 2

Conversion Factors

Length:	1 cm	= 0.3937 in
	1 m	= 39.37 in
	1 in	= 2.54 cm
	1 ft	= 0.305 in
Area:	1 square centimetre (cm^2)	= 0.155 square inch (in^2)
	1 square metre (m^2)	= 1550 in^2
		= 10.76 square feet (ft^2)
	1 in^2	= 6.452 cm^2
	1 ft^2	= 929 cm^2
Volume:	1 litre (L)	= 100 millilitre (mL)
	1 mL	= 0.061 in^3
	1,000 L	= 1m^3
Temperature:	°F = (°C x 1.8) + 32	
	°C = (°F - 32)/1.8	
Pressure:	1 pound/in^2 (psi)	= 6.897 kN/m^2 (or kPa)
	1 atmosphere	= 14.696 psi
	1 kg/cm2	= 101.38 kN/m^2 (or kPa)
		= 1.0138 bar
Weight:	1 kilogramme (kg)	= 1.000 grammes (g)
		= 2.205 pound (lb)
	1 metric tonne (t)	= 1.000 kg
	1 ton	= 2.240 lb
	1 ounce (oz)	= 28.35 g
	1 lb	= 16 oz
	1 lb	= 454 g

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