SEAFOOD PASTEURIZATION AND MINIMAL PROCESSING MANUAL

Virginia Tech

Virginia Cooperative Extension

Virginia Sea Grant

National Fisheries Institute

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Thomas E. Rippen
Virginia Seafood Research and Extension Center
Hampton, Virginia

and

Cameron R. Hackney
George J. Flick
Geoffrey M. Knobl

Department of Food Science and Technology
Virginia Polytechnic Institute and State University

and

Donn R. Ward
Department of Food Science and Technology
North Carolina State University

In cooperation with
Roy E. Martin
National Fisheries Institute

and

Robert Croonenberghs
Division of Shellfish Sanitation
Virginia Department of Health

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Virginia Polytechnic Institute and State University

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Introduction

Moderate temperature thermal processing is used to extend the refrigerated shelf-life of certain pre-packaged seafoods. The relatively mild heating conditions result in color, texture, and flavor characteristics that are similar to "fresh" products, but with greatly extended shelf-life. While almost any seafood can be moderately heat processed, only smoked fish, crawfish tail meat, seafood analogs (surimi), and crabmeat have received significant attention. These products are cooked prior to packaging for pasteurization.

Significant quantities of other seafoods are minimally processed by *sous vide* technology. Although similar to pasteurization, *sous vide* items are often not cooked prior to packaging and are produced primarily for flavor development and suitability for central distribution (Hackney et al., 1991). They generally do not possess the greatly extended shelf-life associated with pasteurized seafoods. The blue crab industry has found the greater thermal process of pasteurization to be a valuable tool for inventory management and marketing.

The current trend is to apply pasteurization as an integral step in comprehensive quality assurance plans. Potential pathogens are eliminated, and microbial quality and shelf-life standards can be predicted and defined in contracts between processors and buyers. Advances in packaging and processing procedures are opening new opportunities for marketers and consumers. The U.S. experience in moderate-temperature thermal processing of seafoods is based largely on meat from the blue crab (*Callinectes sapidus*). As a consequence, this manual focuses primarily on principles associated with pasteurization of crabmeat.

Markets for blue crabs were developed as early as the 1800s. Blue crab meat is highly perishable, and was virtually unavailable outside the coastal regions. The pasteurization of crabmeat in sealed containers has come a long way. First used by a few innovative processors who realized its potential for penetrating distant markets and for improved inventory management, pasteurization is now thought by many to have been the industry's salvation.

Anzulovic and Reedy (1942) described a waterbath method of pasteurizing crabmeat in sealed metal containers, achieving a six-week shelf-life. Byrd (1951) patented a procedure to select several processing temperatures (170-210°F) to target shelf-lives of 1-12 months. The current standard practice of heating 401x301 tinplate cans of crabmeat in a 190°F waterbath until cold-point temperatures attain 185°F for one minute was published by Tatro (1970). Shelf-life is extended from 6-10 days for fresh crabmeat to 6-18 months for properly pasteurized crabmeat.

As would be expected of any process which offers marketing flexibility, pasteurization is used with increasing frequency in the crabmeat processing industry. But many processors have adopted the procedure without fully understanding the total pasteurization process. Furthermore, some processors have modified the process to fit their particular needs, contributing to the confusion as to what constitutes an adequate pasteurization process. Lack of understanding and inconsistent processing procedures have brought the pasteurization industry to the attention of regulatory agencies.

This manual is intended to introduce to the crabmeat pasteurization industry the good manufacturing and thermal processing methods that are currently practiced by other segments of the food industry. It behooves the industry to use this manual to increase understanding of the pasteurization process and improve procedures to comply with stricter controls that may be required in the future.

This manual discusses pasteurization as a total process of both heating and cooling. All too often processors do not give full consideration to the second half of the process: cooling. The importance of container seam evaluation; an area that is receiving increased attention by both processors and regulatory agencies, also is discussed. Finally, the importance of adequate documentation of the various processing parameters is addressed.

SECTION 1.

Thermal Processing: Principles and Definitions

Definition of Terms

Thermal Processing: Thermal processing is the application of heat to a food or container of food so that a targeted total heat exposure is achieved at the cold point of the product. The terms D-value, z-value, and F-value are used to define a thermal process, including pasteurization.

Commercial Sterilization: A process that destroys all microbial pathogens, and all other organisms that could lead to spoilage under normal distribution and storage conditions. However, certain non-pathogenic thermophilic sporeformers may survive. Since virtually all psychrotrophic and mesophilic microorganisms have been destroyed, the product need not be refrigerated in order to achieve the anticipated shelf-life.

D-Value: Decimal reduction time; the time needed to reduce a population of microorganisms by 90% (one log cycle). D-values can be determined from survivor curves where the log population is plotted against time (Fig. 1), or by the formula:

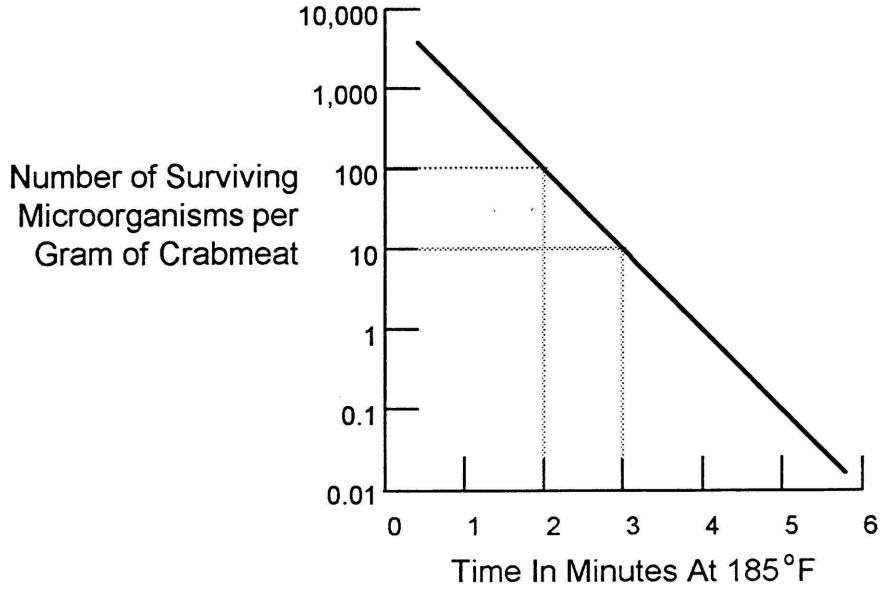


Figure 1. Logarithmic survivor curve (D-value curve). Illustration defines an organism or population of organisms having a $D_{185} = 1.0$ minute.

$D_{\text{reference Temperature}} = \text{Time}/(\log_a - \log_b)$

where a = the initial population, and
b = the survivors after a time interval.

The heat resistances of bacteria, vegetative cells, or spores vary with the species of bacteria, conditions under which the cells are grown (temperature of incubation, phase of growth, age of the spores), and the inoculum level. The heating menstruum, or medium in which the spores are tested, also influences the heat resistance. Factors affecting bacterial heat resistance include water content, pH, and the chemical composition (fats, salts, proteins, carbohydrates, and minerals) of the heating menstruum. Therefore, the D-values of microorganisms will vary depending on the conditions mentioned above.

Sometimes it is desirable to determine D-values at other process temperatures. Equivalent D-values are calculated by the formula:

$\text{Log } D_2 = \log D_1 - (T_2 - T_1/z)$ where

D_1 = the known reference D-value (at the reference temperature)
D_2 = the desired D-value (at the desired temperature)
T_1 = the reference temperature
T_2 = the desired temperature
z = the z-value as described below

It is important that equivalent D-values not be calculated for temperatures far greater or less than the reference temperature, since the real D-values may be considerably different than the calculated values. Survival curves are not always linear; they often have shoulders and tailings.

z-value: The number of degrees Fahrenheit or Centigrade required for a thermal death time curve to traverse one log cycle. The z-value gives an indication of the relative impact of different temperatures on an organism, with smaller values indicating greater sensitivity to increasing heat. This point should not be misinterpreted: z-value does not indicate overall heat resistance of an organism, only the relative impact of changing temperature. The z-value is obtained by plotting the logarithms of at least two D-values versus temperature (several D-values are required for greatest accuracy) (Fig. 2). Conversely z-values can be used to calculate D-values at various temperatures and are essential in process calculations.

These conversions are reasonably accurate within the range of normal processing temperatures. The formula for calculating z-values is:

$$z = (T_2 - T_1)/(\log D_1 - \log D_2)$$

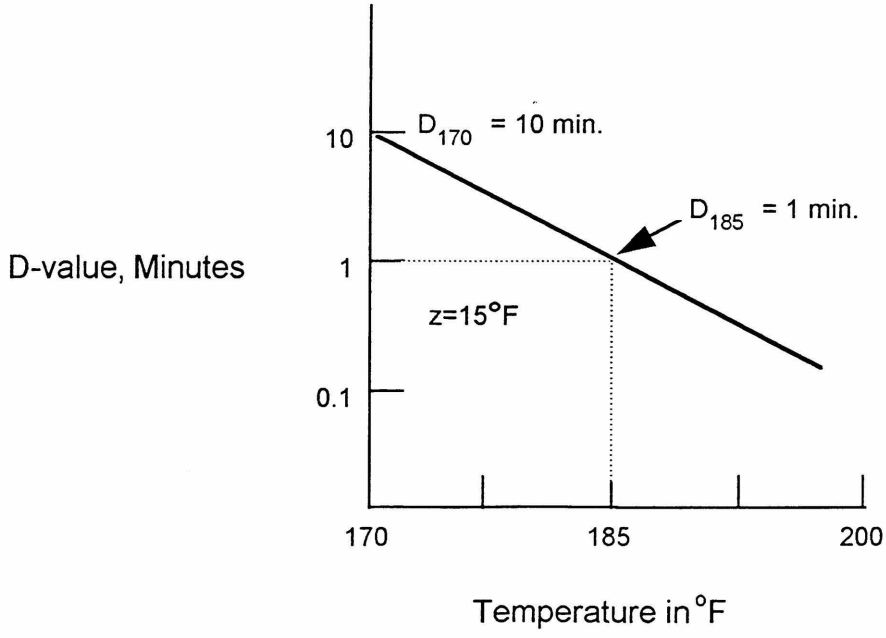


Figure 2. Example of a thermal resistance curve (z-value curve), illustrating an organism possessing a z-value of 15°F.

F-value: A mathematically calculated number that describes the total heating value of the process. It is the equivalent, in minutes at a given temperature, of all heat considered, with respect to its capacity to destroy spores or vegetative cells of a particular organism. The F-value defines a process that is equivalent to that which would result from instantaneously heating a product to a given temperature, holding it for a specified time, and instantaneously cooling it (Fig. 3). Of course, instantaneous heating is impossible in real processing. Therefore, an F-value is calculated to account for heating and cooling rates. Heating/cooling curves tend to be shaped like a wave beginning its approach to a beach (Fig. 4). The shape of the curve is affected by product type, container size, container shape, method of loading the pasteurizer, pasteurizer style, amount of agitation, temperature of the waterbath (Delta T), etc. The destruction of microorganisms begins at relatively low temperatures and accelerates with increasing temperature. As the internal temperature of the product

approaches or exceeds the reference temperature, the destructive impact is maximized. Even as the product cools, microorganisms continue to die because the heat that remains in the can contributes (in decreasing proportions) to the lethality of the process. Total or accumulated heat exposure and process lethality are phrases often used nearly synonymously with F-value. An F-value for a process usually represents multiple D-values.

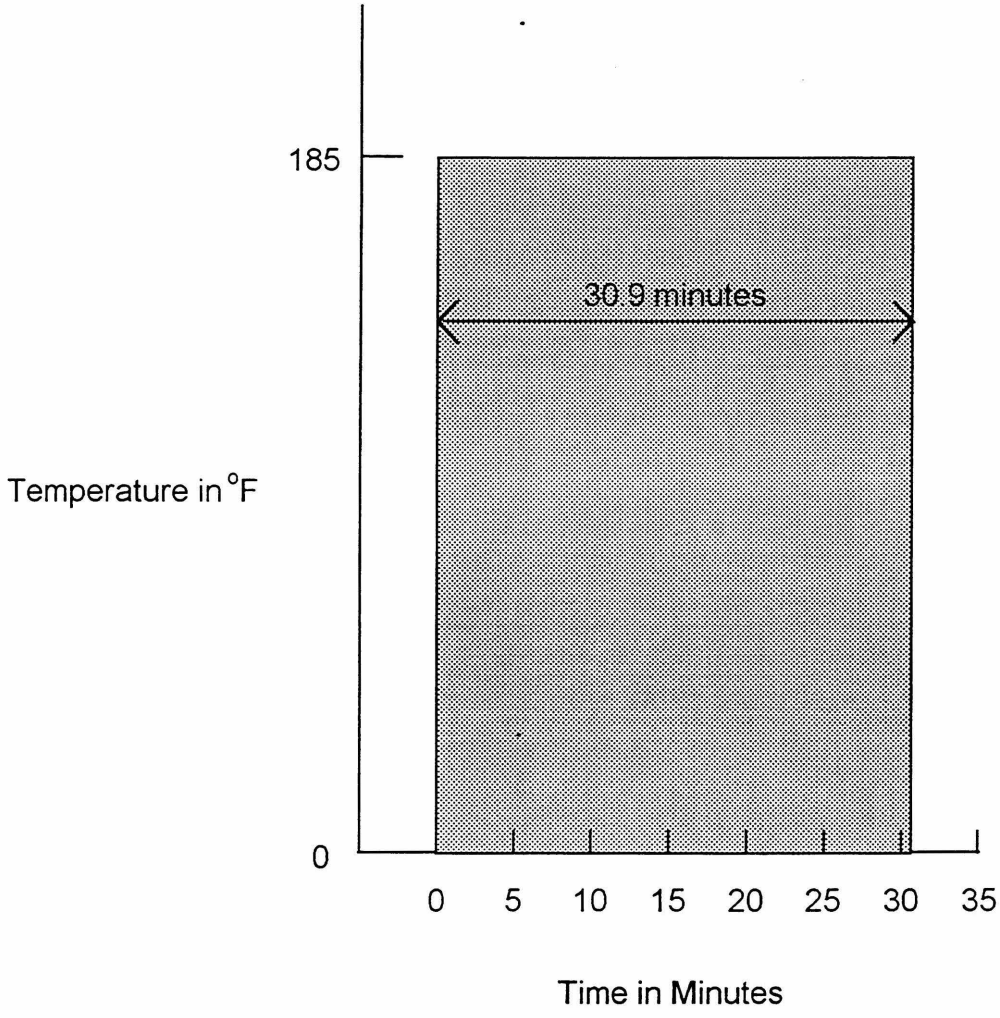


Figure 3. Hypothetical heat penetration curve assuming instantaneous heating and cooling. In this example, F_{185} = 30.9 minutes.

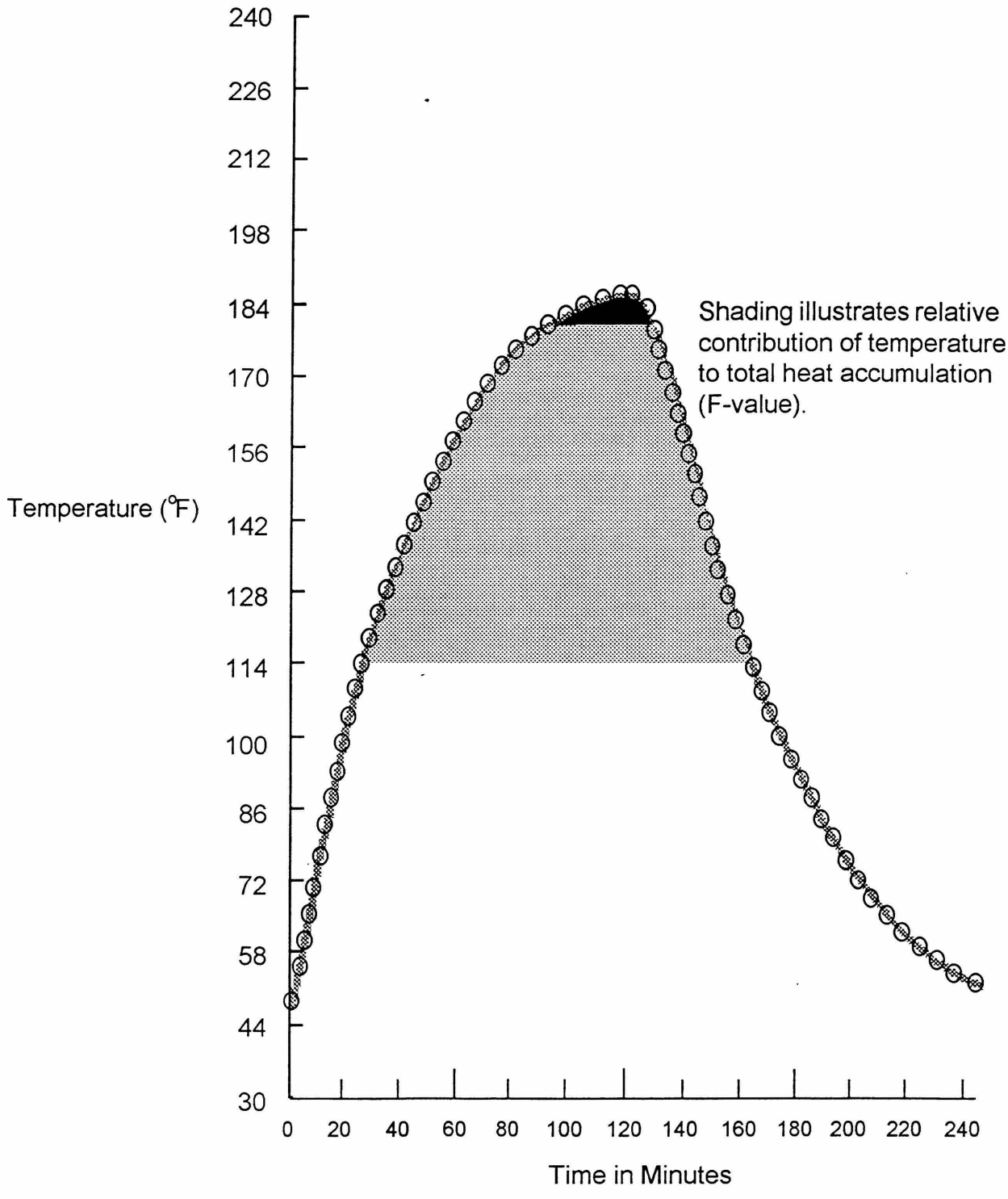


Figure 4. Heat penetration curve for 16 oz. of crabmeat in a 401 x 301 can, where F_{185}^{16} = 31 minutes.

To determine the F-value, the area under the curve must be integrated. This can be approximated by dividing the curve into small sections; the F-value is then calculated for each section and the individual F-values are added together. The formula for each section (time interval) is:

$$F = \log^{-1}((T_2 - T_{reference})/z) \text{ X (the time interval)}$$

where

T2 is the mid-point (median) temperature for the time interval.

Both the heating and cooling sections of the curve are considered in the calculations. When the time interval is large, the defined area has a staircase appearance; however, when the time interval is small, such as when the data are recorded and calculated by computer, the staircase appearance is nearly eliminated. In either case, error is minimized by the use of mid-point temperatures rather than actual measured temperatures in the calculations. For most applications, sufficient accuracy is achieved when calculations are based on time intervals of five minutes or less.

Sometimes it is desirable to calculate a process lethality at a different temperature than the reference. A reference F-value can be converted to an equivalent F-value at another temperature using the formula:

$$F_{temp.\ desired} = (F_{reference\ temp.}) \text{ X } (\log^{-1}((T_{desired} - T_{reference})/z))$$

Cold Point: The slowest heating point (location) in a container (Fig. 5).

Pasteurization

Definition and Basis

Pasteurization is a term that is used to refer to a mild heating process, usually at less than 212°F. By definition the term indicates that the product is not sterile, and therefore may continue to harbor microorganisms. Consequently, pasteurized products must be continuously refrigerated so that the surviving microorganisms will multiply slowly, if at all, and thus achieve an acceptable shelf-life. The term *pasteurization* as applied to seafood implies the use of hermetic packaging and anaerobic conditions in the containers during storage.

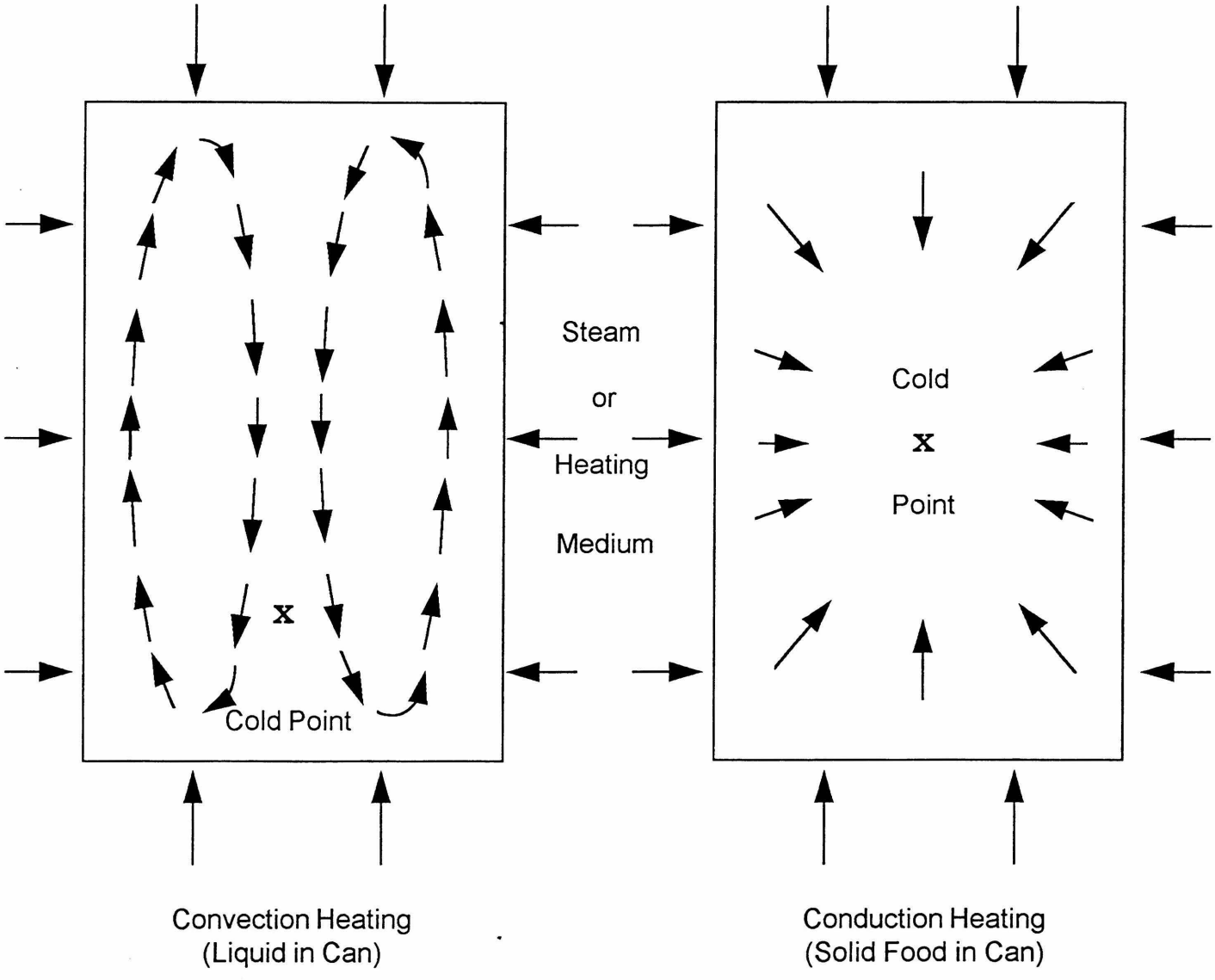


Figure 5. Product type affects heating rate and the location of the cold point (area of slowest heating).

Pasteurization of foods other than crabmeat is often defined in terms of a target organism. When the D- and z-values of the microorganism are known, it is easy to determine a pasteurization process at a selected temperature using the formula:

$F_{Tx}z = D_{Tx} (\log 10^n)$

where T_x = reference temperature, and
n = the number of decimal reductions desired.

For example, in milk the target organism is Coxiella burnetti, which has a heat resistance of $D_{150} = 0.60$ minutes and z-value of 9°F. The above formula can be used to determine a pasteurization process for milk at a desired temperature. If a desired pasteurization temperature is 150°F, the pasteurization process will be F_{150} (z=9) = $D_{150} \log 10^{15}$ or 0.6 x 15 = 9 minutes. Of course other D-values can be calculated using the formula for equivalent D-values given above. In this example a 15-D process was selected. This might seem high to those who are used to thinking in terms of a 12-D process for canned foods. The larger value is in response to the expected number of microorganisms that might be present in the raw product. Clostridium botulinum is the organism of concern in most canned products. The number of C. botulinum spores encountered in most foods is usually very low (an average of less than one per container is assumed); therefore a 12-D process provides a very large safety factor. Other target organisms may be used in other preservation systems and, if high numbers are expected, a greater process is warranted.

There is no target organism for the pasteurization of crabmeat. The process evolved based on shelf-life extension. The traditional pasteurization process, which was recommended by the Tri-State Seafood Committee soon after the procedure was released from earlier patent rights, was based on heating one pound cans (401x301) of crabmeat to a cold point (slowest heating point) temperature of 185°F and holding for one minute. Recommendations then called for cooling the product to a cold point temperature of 100°F in 50 minutes. The heating curve from this process gives an average F_{185} (z=16) of 31 minutes; however, many processors are achieving processes of F_{185} (z=16) of 60 to 120 minutes. In view of this process-based perspective on the dynamics of pasteurization, the Tri-State recommendations were revised in 1984 by the National Blue Crab Industries Association, and a National Industry Pasteurization Standard was recommended (appendix IV).

The z-value of 16 was picked arbitrarily, because there is no specific target organism. There is debate whether this value is truly appropriate, but from a historical standpoint it has worked and its use will probably continue. Within the range of normal crabmeat pasteurization temperatures, F-value calculations based on z=16 produce a reasonable and conservative process. However, caution should be exercised when calculating equivalent F-values at minimal processing temperatures (below about 170°F) for which inoculated pack studies are recommended.

Shelf-life

To our knowledge, controlled studies have not been published to equate various crabmeat pasteurization schedules with shelf-life. However, considerable empirical data have been accumulated in mid-Atlantic commercial blue crab processing facilities that support the observations listed in Table 1. Obviously, the actual shelf-life will also depend on such factors as the initial microbial load, composition of the microbial population, storage temperature, and container integrity.

Table 1. Observed relationship of blue crab pasteurization process to refrigerated shelf-life

F_{185} (z=16), minutes	Shelf-life, months
10-15	1.5
15-20	2-4
20-25	4-6
25-30	6-9
30-40	9-18
>40	12-36

Pasteurization of Products other than Crabmeat

Imitation crabmeat and other seafood analogs (surimi) are commonly pasteurized. Pasteurization has also been proposed for other products including shrimp (Lerke and Farber 1971), crawfish, and smoked fish (Eklund et al. 1988). The latter group examined the feasibility of pasteurizing vacuum packaged, hot processed smoked fish. Since the U.S. Food and Drug Administration dropped the Good Manufacturing Practice (GMP) regulations on the processing of hot smoked fish (new GMPs are expected soon), there has been increasing concern regarding the potential of a botulism outbreak associated with these products. The pasteurization process described by Eklund et al. (1988) has the potential to minimize the concerns associated with this product.

In their study, hot smoked fish were vacuum packaged and pasteurized in hot water at various temperatures. Both type E and nonproteolytic B were used as test organisms. Samples were processed in 85, 89.9, and 92.2°C water baths and required 29, 28.5 and 27.7 minutes, respectively, for the internal temperatures to equilibrate. Type E was the most heat sensitive of the test organisms, but none of the samples processed for 175 minutes at 85°C,

or 55 minutes at 92.2°C, developed toxin after 6 months of refrigerated storage. Unfortunately, F-values for the processes were not published. The sensory qualities of the pasteurized fish were unchanged with respect to taste and texture. The color did darken; however a lighter smoke before pasteurization eliminated the problem. The researchers reported that pasteurization was more effective for smoked fillets and steaks than for dressed fish. A small quantity of smoked fish is pasteurized commercially in the United States.

Effect of Container Type

As discussed earlier, crabmeat traditionally has been pasteurized to a cold point temperature of 185°F for one minute and then cooled to 100°F within 50 minutes (now 55°F within three hours). This process has been based on the pasteurization of 16 oz. of crabmeat in 401x301 cans. The obvious question is: What would be the effect of using this same processing parameter on smaller cans? (Fig. 6) The answer is, quite simply, under processing. This, of course, assumes that the traditional process in 16 oz. (401x301) cans is the reference process. Since the containers are smaller, they require less time to reach 185°F at the cold point. Consequently, the total time the product is exposed to the lethal effects of heat is significantly reduced. Hence, the F_{185} values are smaller than the 31 minutes achieved in the traditional 401x301 cans. Furthermore, pasteurization of 16 ounces of crabmeat in containers of dimensions other than 401x301 will impact the process (Figs. 7-9). Conversely, overprocessing may result if a time/temperature process established for a large container is used to pasteurize a small container (Table 2).

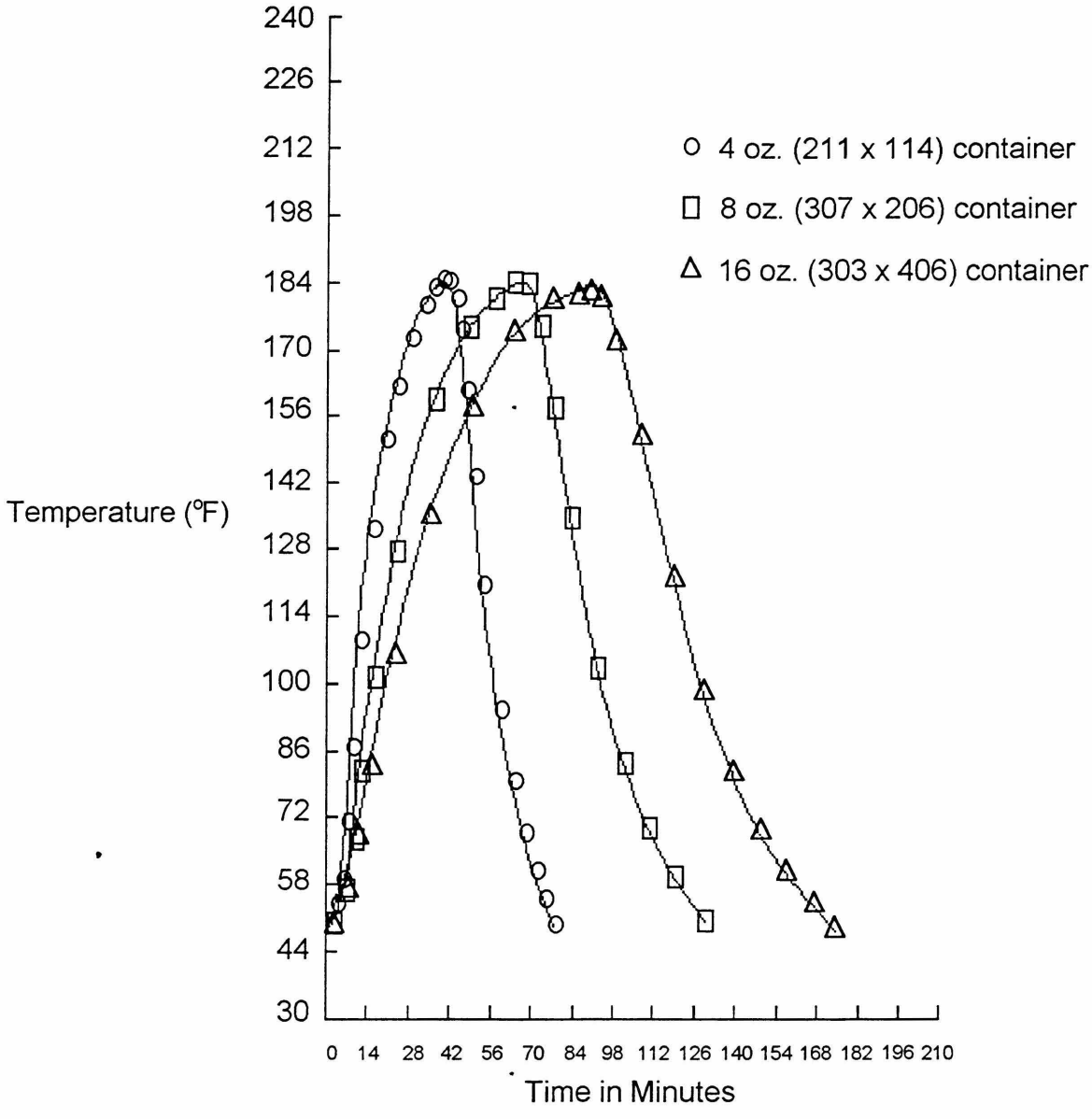


Figure 6. Heat penetration curves for crabmeat in 4, 8, and 16 oz. cans heated to 185°F, then cooled in ice slush.

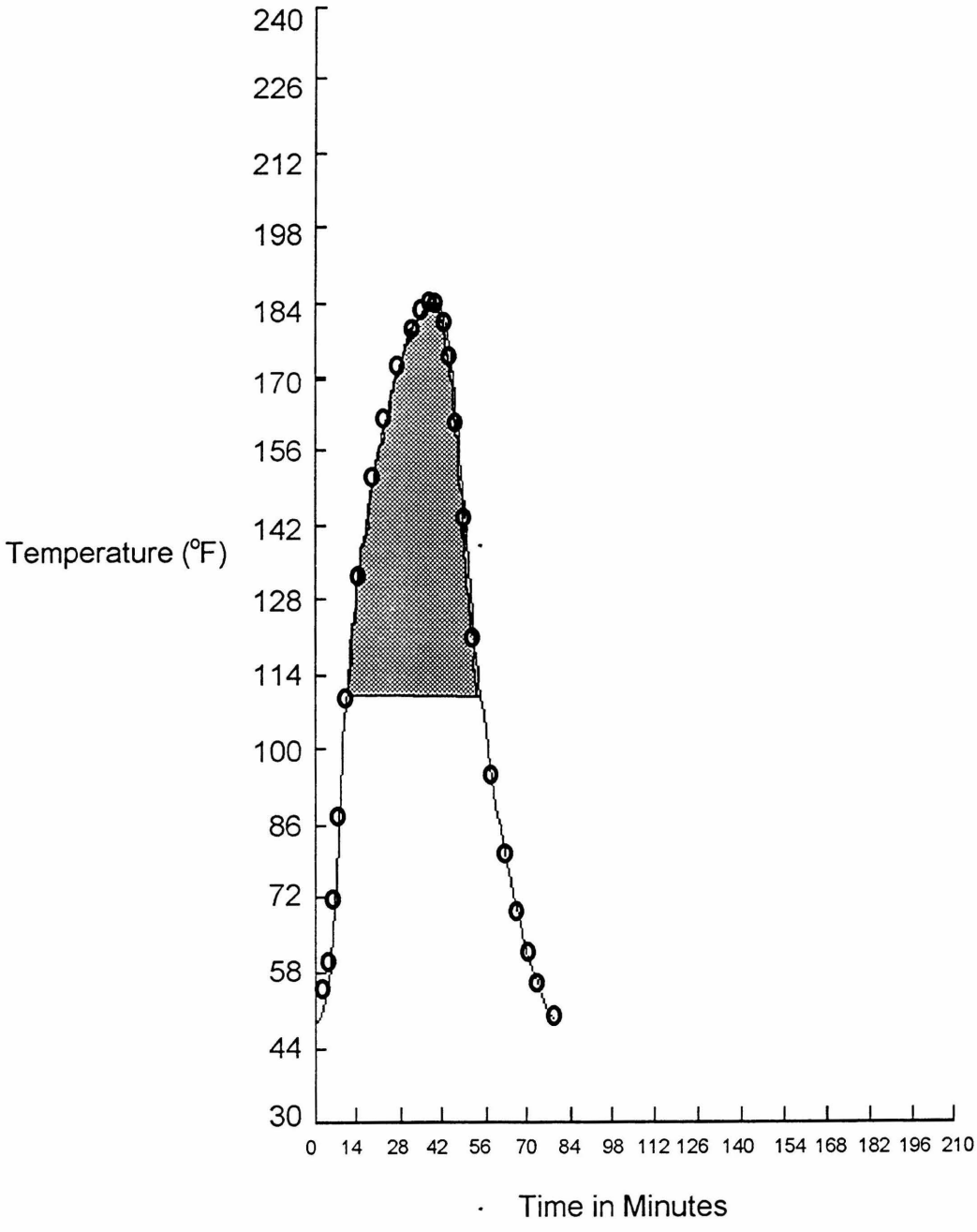


Figure 7. Heat penetration curve for crabmeat in a 4 oz. can.

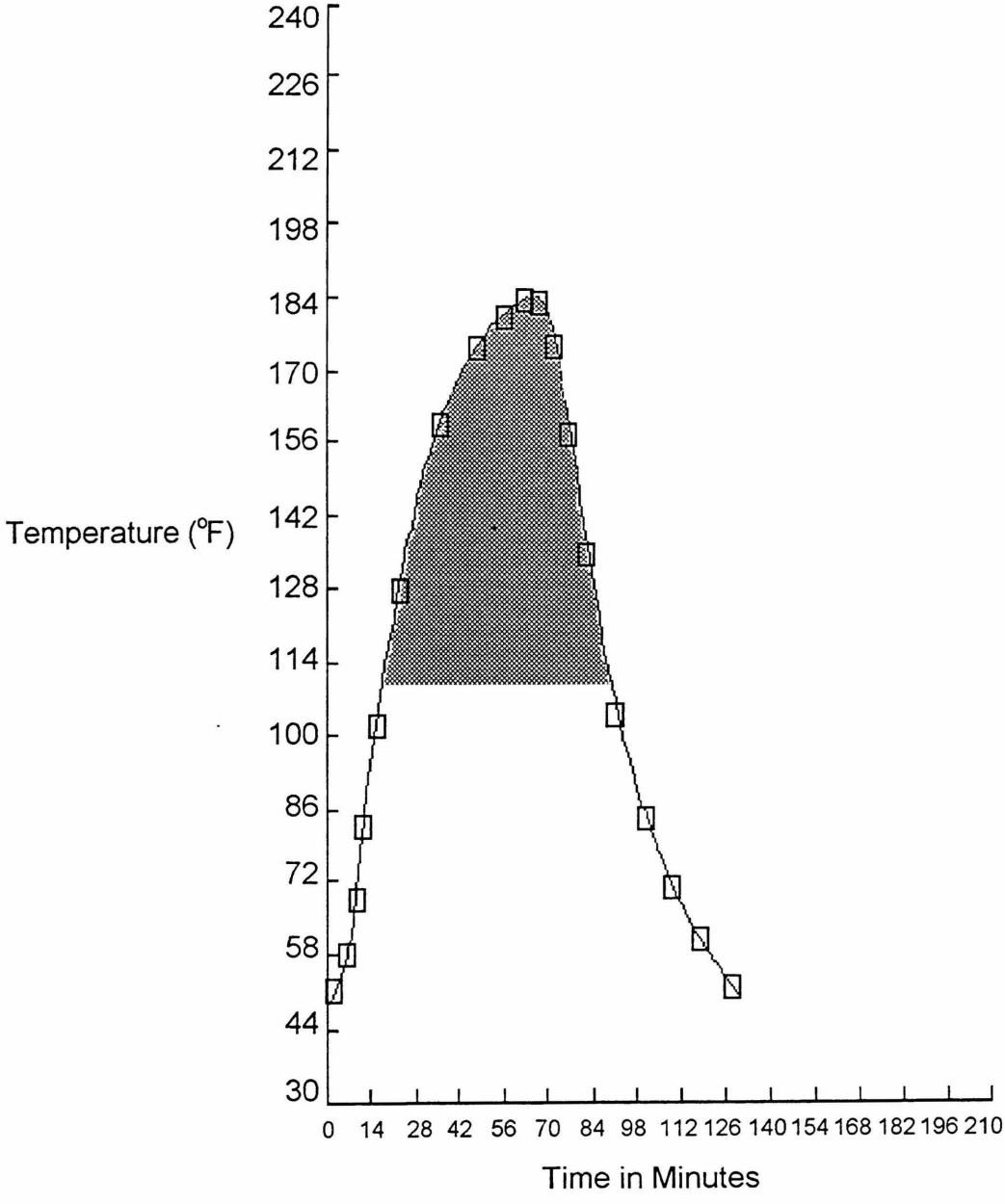


Figure 8. Heat penetration curve for crabmeat in an 8 oz. can.

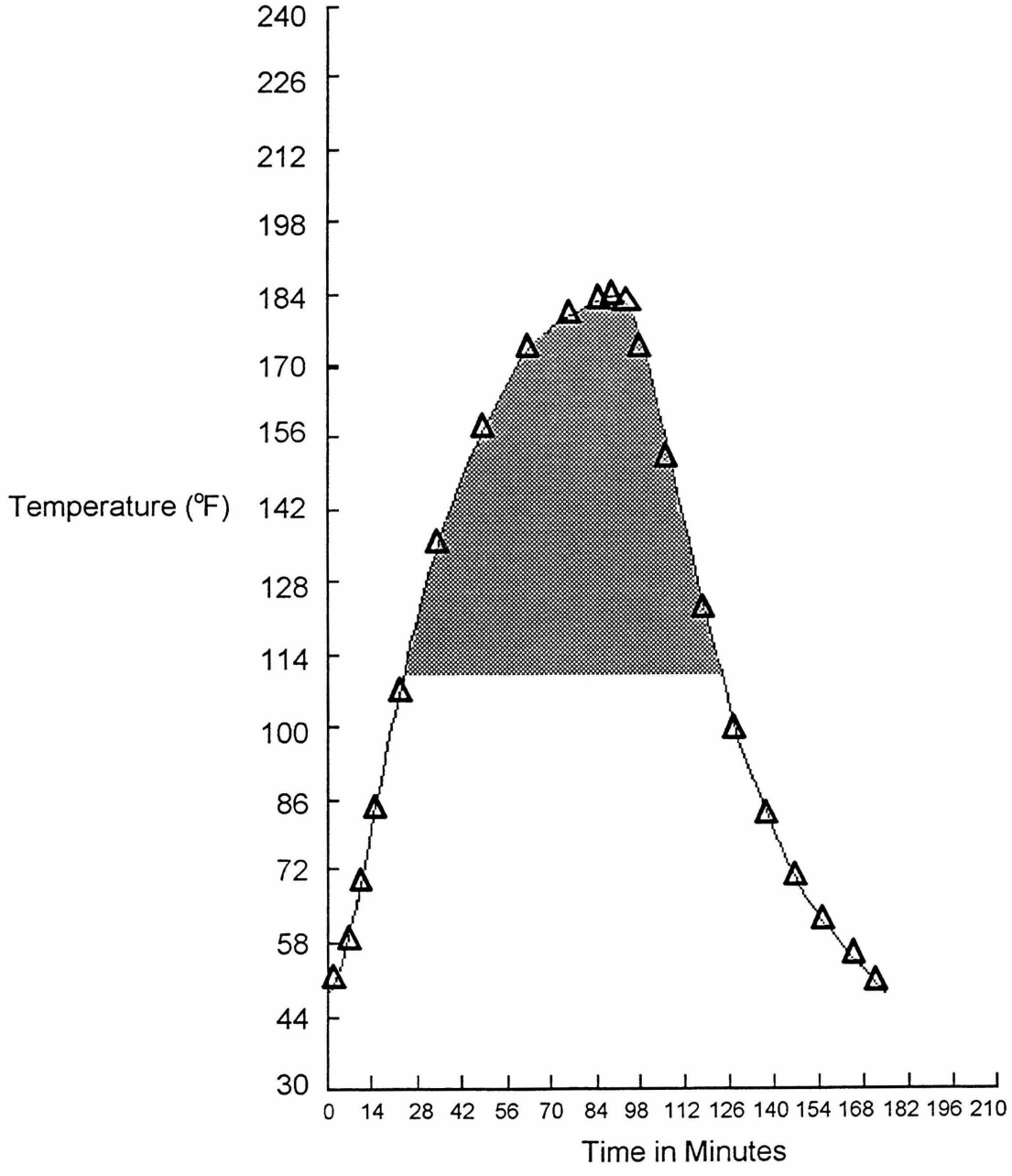


Figure 9. Heat penetration curve for 16 oz. of crabmeat in a 303 x 406 can.

Table 2. Effect of container size on accumulated F-value when processed in the same batch.

	8 OZ.		12 OZ.	16 OZ.
TIME	**F(185)**		**F(185)**	**F(185)**
3.0	.0		.0	.0
6.0	.0		.0	.0
9.0	.0		.0	.0
12.0	.0		.0	.0
15.0	.0		.0	.0
18.0	.0		.0	.0
21.0	.0		.0	.0
24.0	.0		.0	.0
27.0	.0		.0	.0
30.0	.2		.0	.0
33.0	.6		.1	.0
36.0	1.6		.4	.0
39.0	3.3	(185°F)	.9	.0
42.0	6.2		1.9	.1
45.0	10.2		3.5	.2
48.0	15.6		6.0 (185°F)	.6
51.0	22.8		9.5	1.1
54.0	31.7		14.1	1.9
57.0	41.1		19.9	3.2
60.0	51.4		26.5	5.0
63.0	62.3		34.2	7.4
66.0	74.1		42.4	10.5 (185°F)
69.0	86.8		51.3	14.5
72.0	99.4		60.5	18.8
75.0	109.3		66.5	23.5
----------	----------	----------	----------	----------Cooling
78.0	114.9		71.1	28.5
81.0	117.2		74.3	32.8
84.0	117.6		75.3	35.5
90.0	117.7		75.5	36.5
93.0	117.7		75.6	36.8
96.0	117.7		75.6	36.9
99.0	117.7		75.6	36.9
102.0	117.6		75.6	36.9
105.0	117.6		75.6	36.9
108.0	117.6		75.6	36.9
111.0	117.6		75.6	36.9
114.0	117.6		75.6	36.9
117.0	117.6		75.6	36.9
120.0	117.6		75.6	36.9
123.0	117.6		75.6	36.9
126.0	117.6		75.6	36.9
129.0	117.6		75.6	36.9
132.0	117.6		75.6	36.9
135.0	117.6		75.6	36.9
138.0	117.6		75.6	36.9

Industry interest in new generation packaging and packaging materials has increased in recent years. Specifically, there is growing interest in thin-profile containers such as pouches, boil-in-bags, and molded or drawn trays and cups, all of which can significantly increase the heating and cooling rates. This type of packaging is often perceived as resulting in products closer to fresh, and does not have the "canned" product connotation of tinplate and aluminum containers. Some designs also accommodate numerous convenience features. They may be microwavable or dual ovenable, easy opening, reusable and resealable. Actually, product quality is not substantially different than when crab is processed in conventional containers.

Special care should be taken with any innovative packaging, especially regarding seal integrity. Any new package must be able to withstand the rigorous conditions encountered during commercial filling and processing operations, as well as in distribution. Refer to appendix III for suggestions about integrity evaluation of plastic containers.

Process Considerations

Many factors contribute to the heating and cooling rates of crabmeat during pasteurization and the product's ultimate shelf-life. It cannot be assumed that a typical process of heating containers in 185°F water for two hours followed by two hours of cooling will assure a shelf-life of 12 months or longer. Heating and cooling rates and F-values (accumulated heat exposure) are determined by several parameters, including:

1. duration of the process
2. waterbath temperature
3. waterbath circulation
4. crabmeat temperature (I.T.)
5. container size, shape, and material

Subtleties may exist as well. For example, waterbath circulation and temperature layering patterns may be affected by method of agitation, batch size, container distribution, and the use of tank covers and insulation.

Although the effectiveness of a process is usually determined by its F-value, other factors may be just as important and yet not be accounted for in the routine calculations. In addition to F-value and heat transfer rates, shelf-life will depend on such factors as:

1. initial microbial load
2. composition of the microbial population
3. composition of the product (e.g. fat content)
4. storage temperature, and
5. container integrity.

To be meaningful, F-values must relate back to the first three factors, but these relationships are often under-appreciated. More specifically, evaluations of pasteurization procedures in plants experiencing problems have shown shelf-life to be significantly improved by:

1. use of agitated waterbaths
2. selecting process schedules that account for variations in initial product temperature
3. diligent can seam inspection and seamer maintenance programs
4. identifying seasonal or processing factors that contribute to crabmeat that is of reduced microbial quality prior to pasteurization (Hackney et al. 1991; Rippen et al. 1989).

Temperature abuse during distribution or storage is a serious hazard but, fortunately, is now less common, due to the industry's awareness of the risk. However, processors should never take lightly the importance of proper temperature control. And they should advise their customers about proper handling practices.

SECTION 2.

Cooling and Other Shelf-Life Factors

Cooling

All too frequently, the pasteurization process is regarded merely as the heating of the product to the desired temperature for the appropriate length of time. This, however, is a misconception that has proved costly to many processors. The process consists not only of heating the product, but also of cooling it to temperatures at which the growth rate of surviving microorganisms is greatly reduced. Even during the cooling phase, heat remaining in the cans contributes to the process lethality. However, this does not imply that cooling should be prolonged in order to take advantage of the lethal impact of residual heat. On the contrary, **cooling should be as rapid as possible.**

Many different types of microorganisms grow in a wide range of temperatures. Fortunately, those microorganisms that would ordinarily spoil fresh crabmeat are very susceptible to destruction by the heat encountered in the normal pasteurization process. Conversely, those organisms that do survive are typically those which grow well at elevated temperatures but not at refrigerated temperatures; hence the importance of refrigeration after pasteurization.

Even if the product has been adequately heated but then is allowed to cool at a slow rate, microorganisms that have survived pasteurization could start to multiply and thus shorten the anticipated shelf-life of the product. Also, slow cooling rates may allow injured bacteria, which would otherwise die, to recover; or encourage spores to germinate into a vegetative form that is more likely to spoil crabmeat at refrigeration temperatures. Therefore, it is imperative that processors reduce the internal temperature of the product as quickly as possible.

Tri-State and the more recent National Blue Crab Industry Association (NBCIA) standards recommend immersion of heated containers in an **ice-water bath**. Work conducted by Virginia Tech's Seafood Extension and Research Unit supports this recommendation (Fig. 10). An ice-water bath, vigorously agitated, is the most efficient method of cooling the product (Fig. 11-12). The Tri-State Seafood Committee previously recommended that the heated cans be cooled to 100°F in an ice-water bath within 50 minutes of processing, then removed to refrigerated storage. The rationale for these recommendations was that some residual heat was needed to evaporate the moisture from the cans to prevent rusting. Rusting is not a major problem with the majority of the cans being used today. The problem of microbial growth is of much greater consequence.

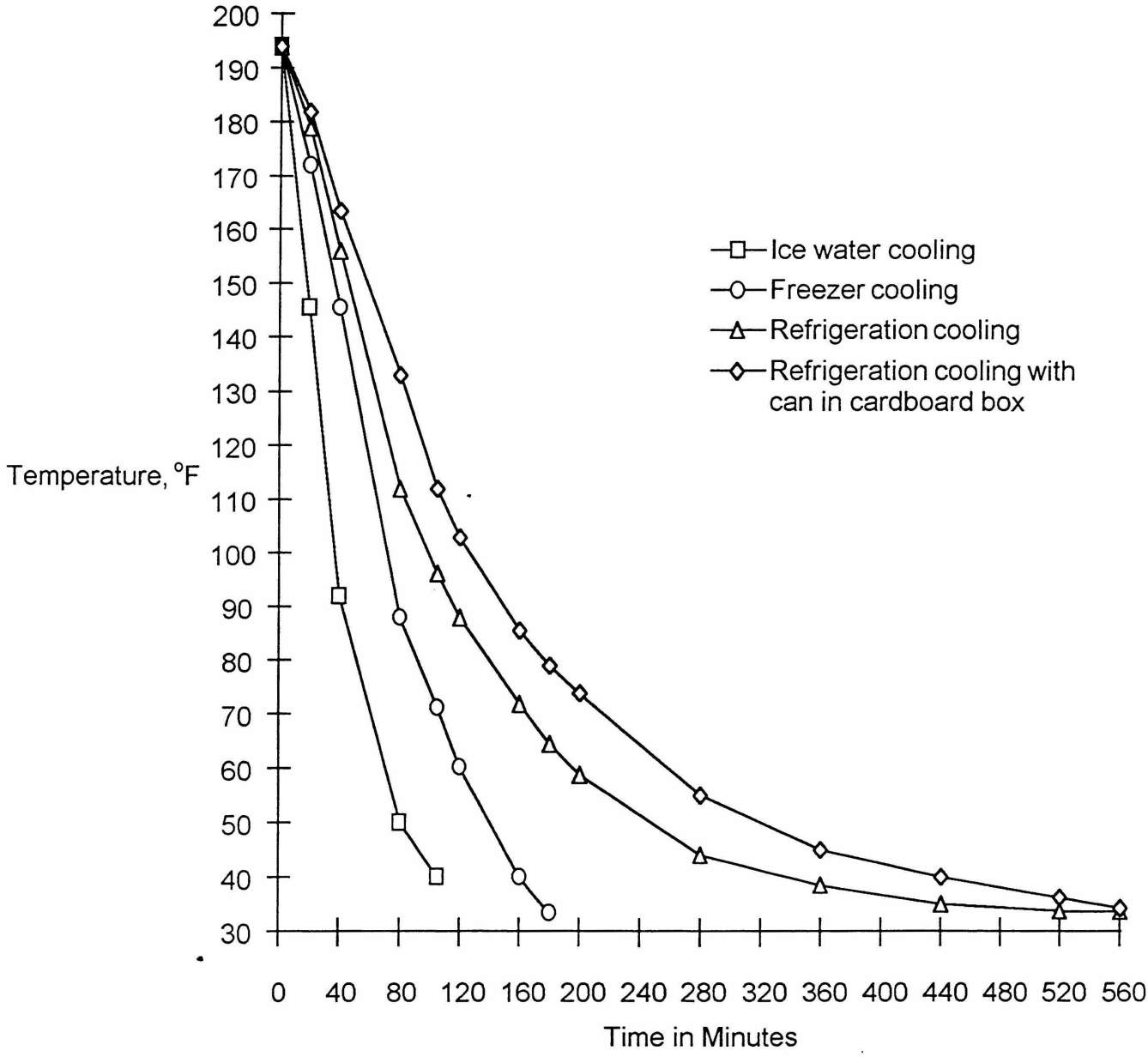


Figure 10. Cooling rates of pasteurized crabmeat, in 16 oz. cans, under four cooling conditions.

The more recent standards (NBCIA) call for the heated cans to remain in the ice-water bath until the cold point temperature reaches 55°F within three hours before being removed to refrigerated storage at 35°F. This standard is intended to improve both the quality of the product and its safety.

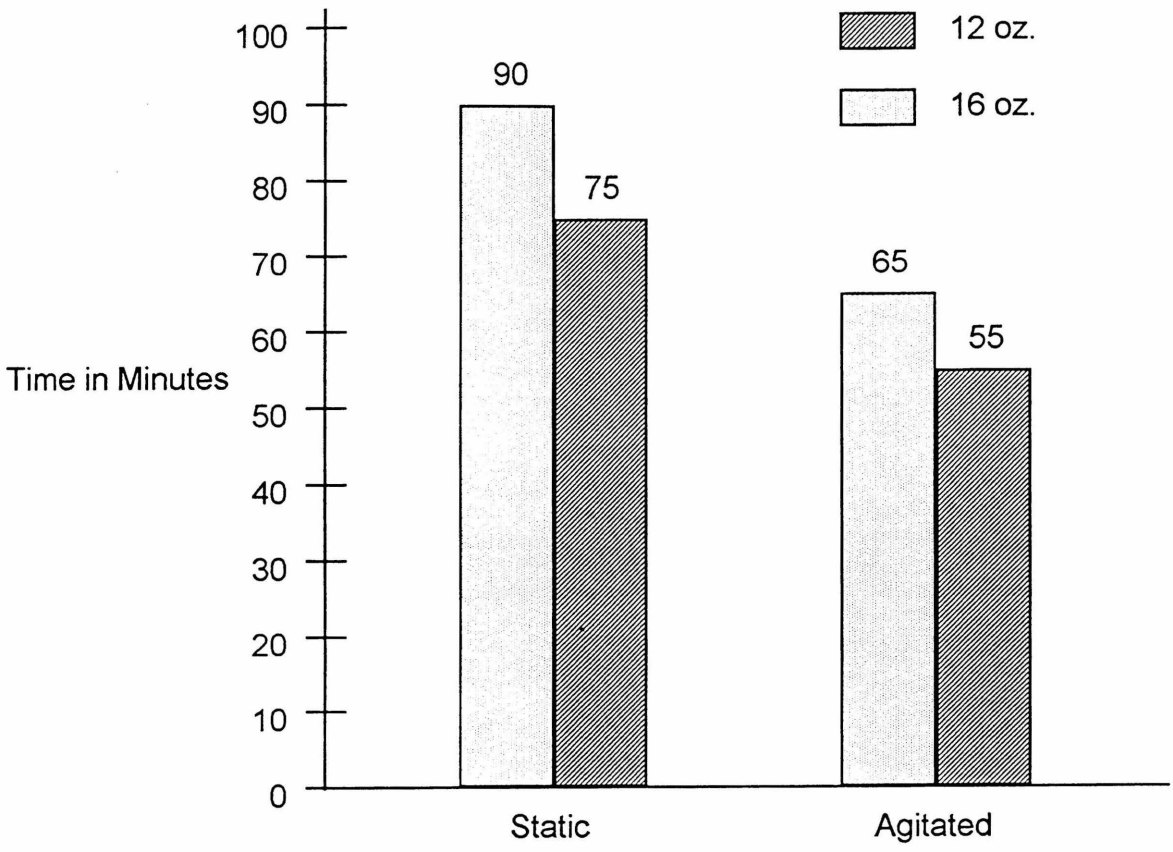


Figure 11. Time needed to cool crabmeat from 180°F to 55°F with and without air agitation.

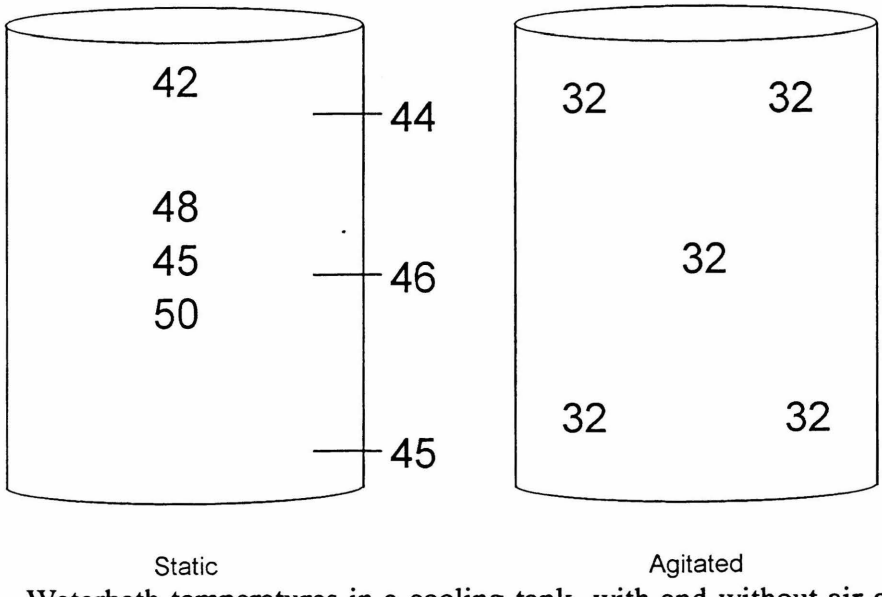


Figure 12. Waterbath temperatures in a cooling tank, with and without air agitation.

It is very important that the cooling water be **chlorinated.** There is a certain seam failure rate in any canned product. When the cans are hot the seals are more easily breached by microorganisms in the cooling water. As the sealant hardens the cans become impermeable to microorganisms. Chlorination of the cooling water kills organisms that might otherwise cause spoilage or safety problems if they were to get into the food; however, chlorination cannot be expected to compensate for defective seam integrity. Only breakpoint chlorination is recommended. That is, add sufficient chlorine sanitizer to assure that a slight residual of available chlorine (perhaps 5 ppm.) is present throughout the cooling period. Chlorine test strips are available for confirming these low levels.

Storage temperatures of **36°F** or below are necessary for both shelf-life and safety considerations. In the event of undetected container leakage, cooling waters may be drawn in, carrying *C. botulinum* or other pathogens with it. Documentation of storage cooler room temperatures is a critical component of a pasteurization HACCP plan. **Continuous or, at least, daily temperature records** will help mitigate regulatory concerns associated with *C. botulinum* in inventoried products. Care must be taken to prevent accidental freezing as sometimes occurs during storage or shipment. Severe product toughening, drip, and flavor loss result when pasteurized crabmeat is allowed to freeze under marginal freezing conditions.

Most often the processor is but one facet in a multi-faceted marketing channel. Unfortunately, the more complicated that distribution system becomes, the greater the opportunity for error. Moreover, if a problem occurs with the product due to mishandling or neglect somewhere along the distribution chain, the processor usually must take the ultimate responsibility, unless it can be unequivocally documented that another party is at fault. Therefore, it is imperative for the processor to periodically remind all members of his distribution system of the importance of proper refrigeration and handling of pasteurized crabmeat.

Can Seams

Defective can seams pose a threat to the health of consumers. Bacterial pathogens drawn into the can during cooling could possibly establish themselves, especially in the absence of the competitive microflora normally found in fresh crabmeat. Therefore, it is **critical that seams be routinely checked** to assure that they meet the manufacturer's specifications. Also, can seaming equipment should be inspected frequently by a qualified technician, with adjustments made as needed and any corrective actions recorded. Container seam inspection and closing machine maintenance is discussed in detail in Section 5.

Under-processing

Inadequate heating occasionally leads to early spoilage. **Temperature and time are often critical** for producing a predictable shelf-life. A difference of a few degrees in the waterbath, say 185°F versus 189°F, or a few minutes in the heating time, may significantly affect shelf-life. It is at the end of the heating step, when crabmeat is hottest, that the bacterial destruction rate is exponentially greatest. Employees responsible for pasteurization should be carefully instructed in this relationship since they may not fully appreciate the impact of apparently minor changes to the established schedule. Pasteurization systems should be loaded and operated so as to promote **uniform circulation** of the heating water.

Table 3 contains typical calculated F-values for crabmeat in a commercial pasteurization run. It lists a company's expected total F-values for various heating times when waterbath temperatures and other processing parameters are kept the same. Times represent minutes in the hot waterbath prior to transferring the cans to ice slush. Notice, in this case, that two hours (120 minutes) of heating produced lethalities slightly below the NBCIA minimum of F=31 minutes. Although residual heat during initial cooling will raise final F-values, this company may wish to heat for a minimum of 125 minutes when processing warm meat, and 135 minutes when processing chilled meat (less than 60°F).

Product Temperature

An often-overlooked factor is the initial temperature (I.T.) of the crabmeat immediately before it is pasteurized. Meat that is held in ice overnight before processing may require an additional 15 minutes or more of heating compared to meat packed and processed right off the picking tables. A process' F-value and therefore its bacteria-killing potential **can vary by 30 percent when initial product temperatures are not accounted for** in the pasteurization schedule. This critical effect is well known to individuals trained in low-acid canned food procedures but is rarely emphasized by pasteurizers of seafood. When the product temperature is unknown or when both cold and warm crabmeat are processed in the same batch, managers should select a longer process established for refrigerated crabmeat.

Table 3. F-values achieved in 187-190°F waterbath, 401 x 301 cans, crabmeat initial temperature (I.T.)=60-65°F (For illustrative purposes only--each pasteurization system must be evaluated independently!)

Heating Time, Minutes	F-value (F^{16}_{185}, Minutes)
90	5.0
95	6.8
100	9.7
105	13.4
110	17.3
112.5	21.0
115	23.4
117.5	26.8
120	30.2
122.5	32.7
125	35.6
127.5	40.7
130	43.6
132.5	46.5
135	49.4
137.5	52.0
140	55.1
142.5	58.0
145	60.9

Initial Microbial Population

Remember that pasteurization works by killing bacteria, and a certain number are killed by a given process. If the meat has low initial counts, then essentially all may be killed, while on another occasion high counts may lead to a shorter than normal shelf-life. This concept is described in detail in the following discussion. Pasteurization cannot be successfully used as a salvage technique for marginal quality crabmeat.

Concept of Microbial Survivors in a Batch

Occasionally seafood processors and regulators are confused by the premature spoilage of a few containers from a batch of thermally-processed products. Because of the spotty

occurrence, it might be assumed to be a problem of defective container seams. This is not the only possible explanation, however. In fact, **random survival patterns should be expected.**

If for a given initial microbial load the absurd were possible, and all of a very large batch of crabmeat were packed into one giant can and processed to an accepted F-value, it would spoil due to growth of survivors (Fig. 13). The more cans we fill (i.e, the smaller the can), the more cans are likely to spoil but also the smaller the percentage of spoiled to unspoiled cans. The effect is simply the result of partitioning and probability of survival (Fig. 14). If the initial load is smaller or the F-value higher, fewer survivors and spoiled cans will result. This simplistic model may not appear to describe pasteurization since significant numbers of organisms may survive in nearly every can. However, the thermal-tolerant bacteria present after pasteurization grow very slowly at refrigerated temperatures. Only those that grow out to a level of spoilage prior to the expected shelf-life of the product are of concern.

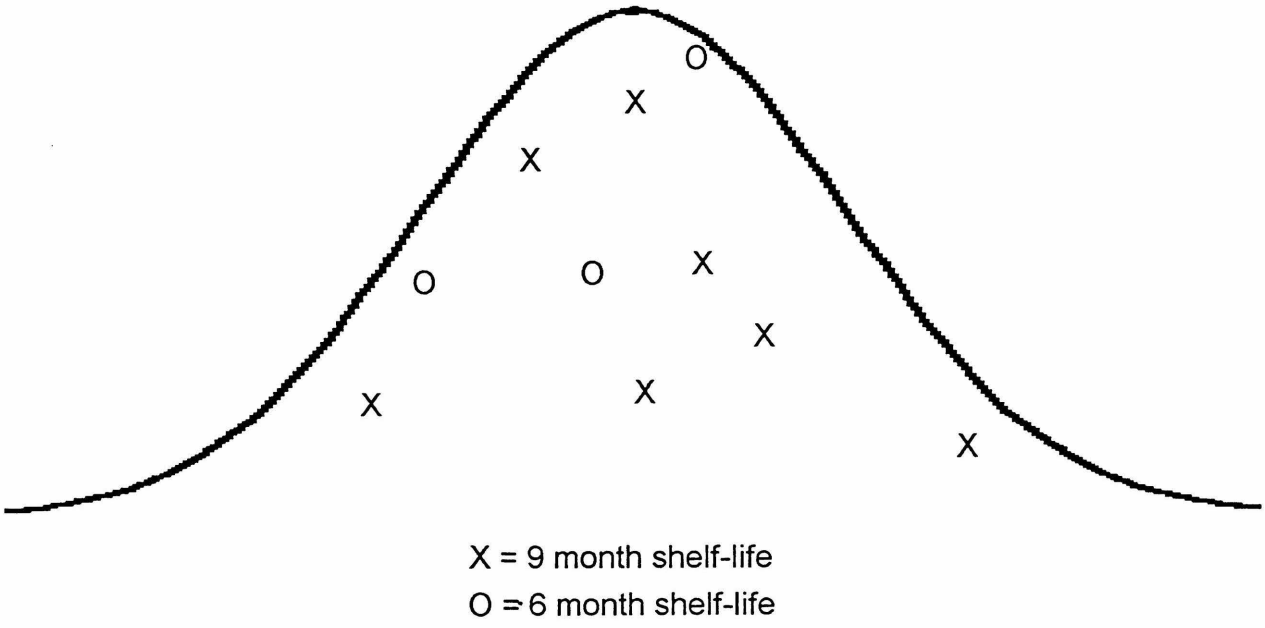


Figure 13. Hypothetical representation of a pasteurized pile of crabmeat; X's and O's indicate surviving bacteria capable of premature spoilage.

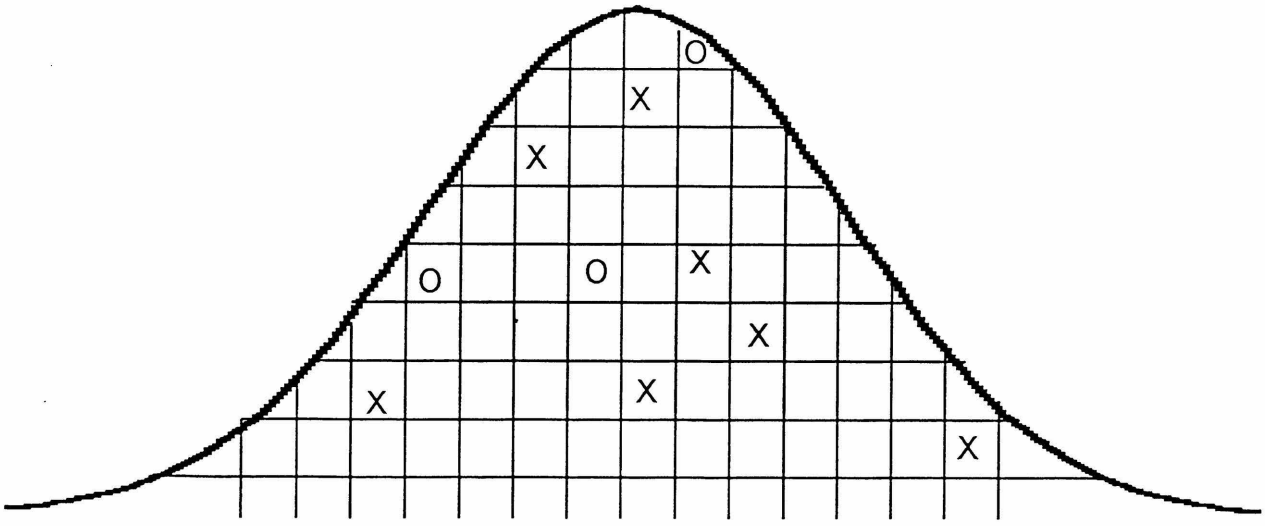


Figure 14. Representation of a pasteurized pile of crabmeat partitioned in containers; X's and O's indicate surviving bacteria capable of random premature spoilage in the pack.

Initial microbial load is important, but its significance may be poorly understood by managers who view the thermal process as a highly forgiving clean-up step. An F-value defines the number of targeted bacteria that are killed. Using a hypothetical situation, if a one-pound container of crabmeat contains 10,000 thermoduric bacteria that are capable of prematurely spoiling the final pasteurized product, then an F-value resulting in their destruction (a 5-D or five log-cycle reduction) will produce the expected shelf-life. Every time that this pasteurization process is applied to a container of crabmeat starting with no more than 10,000 of these thermodurics, satisfactory results are achieved. And anytime that more than 10,000 are present, the can will spoil prematurely.

In commercial production; however, we must kill far more organisms than those found in one container. If 50,000 of the one-pound containers of crabmeat are pasteurized during a season, then 500,000,000 of the offending organisms must be destroyed. In this scenario of volume processing, a 5-D process is inadequate to destroy all of the targeted organisms. Even a 6-D process would result in 500 survivors or a premature spoilage rate of up to one percent (500 cans) of the year's pack.

In practice, heat is never uniformly applied throughout the container. The F-value achieved near the sidewalls is likely to be many times that at the center. The concept still holds, however, since a process is established based on a desired F-value at the container center, and any survivors there would ultimately spoil the entire contents.

A "New" Spoilage Organism

A complicating factor in the recent episodes of shortened shelf-life has been the increased significance of **microflora type**. The recent isolation of a thermoduric psychrotrophic anaerobe (a non-pathogenic *Clostridium*) from prematurely spoiled pasteurized crabmeat has created uncertainty as to the adequacy of a F=31 minute process. The organism has not been previously described. Industry confidence in pasteurization has been clearly shaken over the past few seasons. Spoilage during storage has appeared throughout the industry at an unusually high level (Chai, Ward and Moody, 1990). Most of this loss resulted from can seam failures but another, potentially more serious, problem from a long term economic perspective was the appearance of the psychrotrophic *Clostridium*. This bacterium, and possibly similar isolates, have disrupted expectations such as those listed in Table 1. Preliminary investigation indicates an unusually high degree of heat resistance for a psychrotrophic spoilage bacterium; D_{185}=9 minutes in peptone-yeast-glucose broth (Webster et al. 1990). It may be even more heat resistant in crabmeat, requiring F-values of more than 90 minutes to achieve acceptable shelf-life.

Despite the safety factor associated with a F_{185}=31 minute process, regulatory concern is heightened when pasteurized products spoil prematurely, resulting in several recent recalls involving approximately $400,000 worth of crabmeat. At the workshop that produced a model HACCP (Hazard Analysis Critical Control Point) plan for the blue crab processing industry, it was recommended that "there be uniform pasteurization regulations among the states which are 'process' based. These regulations could be based upon previous NBCIA recommendations, or upon appropriate research" (anon., 1988). The latest research findings could be applied to establishing a new pasteurization standard. However, the problem now appears to be more isolated than initially believed; only machine-picked claw meat in one plant is clearly implicated. Consequently, significant modifications to process schedules appear to be unwarranted at this time.

Crabmeat Spoilage and Proper Retorting

The isolation of a spoilage organism that can survive pasteurization highlights the importance of proper cooking of the crabs. Preliminary information indicates that the organism could not survive normal retort temperature. Therefore, its presence in pasteurized

crabmeat indicates either contamination of the picked meat or inadequate cooking. It is important that the retort be checked for cold spots. Examine the steam spreader to make certain the holes are of the proper number and size and are unplugged. Our studies have clearly shown large differences in extent of cooking according to location in the retort. These differences can be eliminated or lessened by having the **retort in good working order and properly vented.**

Contamination can be lessened by developing a HACCP-based quality assurance program. Crabs that fall on the floor should not be used. In addition, it may be necessary to clean and sanitize basket carts to avoid cross contamination. These carts are exposed to live crabs, left in the open, and seldom sanitized. Spore-forming spoilage bacteria will survive on the carts and may later contaminate the crabs and the picking equipment. Other practices to avoid **cross-contamination** are described in a separate section beginning on page 34.

HACCP as a Quality Assurance Approach

HACCP as it relates to pasteurized crabmeat and other seafood processes is outlined in appendices I and II and reviewed by Garrett and Hudak-Roos (1990, 1991). U.S. low-acid canned food (LACF) regulations pertain to shelf-stable products (CFR, 1979). Critical operations, monitoring and control are identified based on the Hazard Analysis and Critical Control Point (HACCP) principles of quality assurance. Pasteurized and other refrigerated items are excluded. These products are covered principally under the general Good Manufacturing Practices requiring food processors engaged in interstate commerce to assure the wholesomeness and safety of their products (CFR, 1977).

Although seafood pasteurization is excluded from the specific process controls and record-keeping requirements of LACF production, processors must show evidence, satisfactory to the federal Food and Drug Administration, that they produce safe products processed under sanitary conditions. As with LACF, the most efficient means of accomplishing this goal is through the implementation of HACCP plans. Appendices I and II include descriptions of HACCP as it applies to seafood.

Ward et al. (1982) recognized three critical control points in crabmeat pasteurization:

1. container integrity
2. pasteurization (assuring a targeted process)
3. storage temperature

A set of industry guidelines was endorsed by the National Blue Crab Industry Association (NBCIA, 1984) based, in part, on this approach. A draft blue crab HACCP model, including pasteurization, was developed jointly by the National Marine Fisheries Service (NMFS) and the seafood industry (National Fisheries Institute) as part of the NMFS Model

Seafood Surveillance Project mandated by Congress (NFI, 1988). It identified four CCPs specific to pasteurization inclusive of those recognized by Ward et al (1982).

Preventive measures, monitoring and records were outlined for:

1. sealer operation
2. pasteurizer control (can seam inspection, time/temperature process and operator training)
3. adequate product cooling rate
4. assurance of 32-36°F storage (Appendix I)

Mostly unspecified were reporting instruments (forms) and recommendations related to records review and NUOCAs (Notice of Unusual Occurrence and Corrective Actions taken). This report did, however, provide a much needed framework for conducting field tests in participating processing plants (a voluntary FDA/NOAA program), which is currently under review.

As HACCP plans are developed, **pasteurization should be integrated into overall quality assurance programs** encompassing raw product handling through processing, distribution, and consumption. Processors are not likely to have control over each step, but HACCP and associated record-keeping allows for improved liability management and may qualify the company to supply major buyers. Detailed HACCP training programs and materials are available from the National Fisheries Institute (Arlington, Virginia) and Virginia Polytechnic Institute and State University, Department of Food Science and Technology (Blacksburg, Virginia).

Case Studies of Pasteurization Procedures

Investigations were conducted at Virginia Tech's Seafood Extension and Research Station and at three crab processing companies to evaluate the effect of waterbath circulation and initial product temperature on heat transfer rates, F-values, and shelf-life.

Laboratory Study: Both 401x208 and 401x301 containers heated significantly faster at the bottom of the hot water tank (immediately above the steam spreader) than at the top, with or without air agitation. As expected, the small containers heated significantly faster than the large containers. Differences in heating rates were reflected in correspondingly significant differences in F-values. Waterbath temperatures during heating ranged from 190°F to 194°F without air agitation and remained uniformly at 191°F throughout the tank with agitation (Fig. 15). Starting the process with cold meat (37°F) resulted in 30 percent lower F-values compared with starting with crabmeat at 73°F in 401x301 cans (Fig. 16).

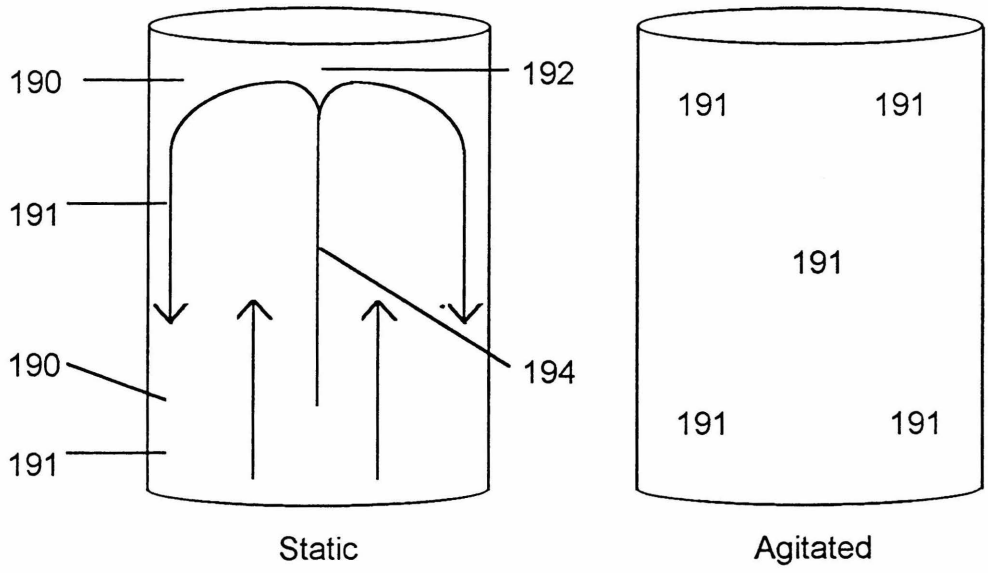


Figure 15. Waterbath temperatures in a heating tank, with and without air agitation.

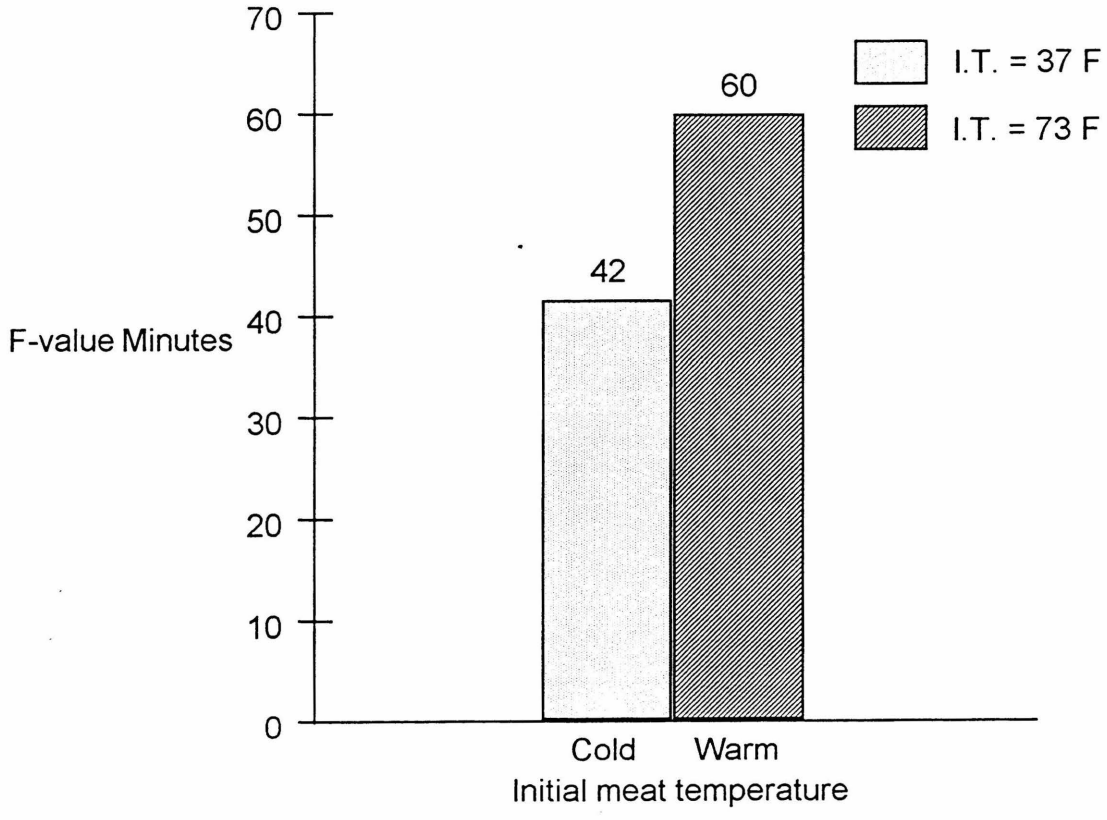


Figure 16. Effect of initial crabmeat temperature on F-values, 401 x 301 cans.

During ice slush cooling, the use of air agitation resulted in significantly faster cooling rates (Figs. 11-12). Crabmeat temperatures in 401x208 cans dropped from 180°F to 55°F (industry guideline temperature) in 55 minutes with agitation and in 65 minutes without agitation. The corresponding cooling times in 401x301 cans, with and without agitation, were 89 and 75 minutes, respectively. Ice bath temperatures surrounding the warm cans ranged from 42°F to 50°F without agitation and remained uniformly at 32°F with agitation (Fig. 11-12).

In-plant Studies: No significant differences were found relating heat transfer rates in containers to their location in the tanks.

Plant 1

Problem: Shelf-life was variable and very short (spoilage was observed within 6 weeks) despite heating 307x409 cans for 120 minutes at 187°F to 189°F. Thermal penetration studies conducted on two different dates revealed F_{185}-values of 14 and 23 minutes, well below the minimum recommended standard of $F_{185} = 31$ minutes. Heating and cooling rates were both significantly slower than industry averages.
Modifications: Vigorous air agitation was added to the heating process and a new cooling tank with air agitation was installed. Formerly, the crabmeat had been cooled only with crushed ice.
Results: Heating rates increased by 20 percent and cooling rates by 90 percent. Spoilage losses during 12 months of storage dropped from an estimated 7 percent of the pack to near 0 percent.

Plant 2

Problem: Shelf-life was variable and dependant on the day of processing. Study revealed that the crabmeat was under-processed on those days when it had been refrigerated overnight for pasteurizing on the following day. Warm, freshly-picked meat developed $F_{185} = 45$ minutes while cold meat received $F_{185} = 27$ minutes.
Modification: The process time was lengthened by 15 minutes for cold crabmeat.
Results: Spoilage losses have approached 0 percent.

Plant 3

Problem: Crabmeat pasteurized in institutional pouches heated and cooled at an extremely slow rate (more than 10 hours to heat and cool), which reduced production and caused the meat to discolor.
Modification: When spacers were loosened to encourage circulation around the containers, F-values doubled but heat transfer rates remained unacceptably slow. When improved spacers were installed and air agitation was added to the cooling tank, heating rates improved by 460 percent and cooling rates by 1500 percent.
Results: Process times were very much shortened while F-values achieved acceptable levels.

Waterbath circulation

In the laboratory and in-plant studies previously discussed, the effect of agitating the waterbaths was pronounced, especially in the cooling tanks. Bath temperatures were far more uniform and closer to the temperature desired. Another effect is also important here. Just as a blast freezer cools more quickly than does static air, moving water transfers heat more rapidly than does uncirculated water. Heat transfer rates are largely determined by the temperature difference between the crabmeat and the surrounding water, creating the necessary driving force (the engineer's delta T). Cold containers cool the heating water surrounding them and, when transferred to ice slush, hot containers heat the surrounding cooling water. Therefore the temperature gradient that forms on the outside surface of each container, like layers of an onion, must be stripped away for most efficient heating or cooling.

Although pumps have a demonstrated value in circulating water, our experience has shown them to be difficult to control for uniformity throughout the tanks. Injection of compressed air into a spreader pipe in the bottom of the tanks is effective, simple, and inexpensive since air lines are usually present in the pasteurization room for other purposes. If the existing steam spreader is used, connect compressed air to the steam line between the steam regulating valve and the tank. (Important: install check valves to prevent steam from entering the air or water lines.)

Circulation problems are most acute in ice slush, and vigorous agitation of the cooling water is very effective. The benefits are less dramatic in heating tanks, and very rapid water movement may be unnecessary. The heating tank should be bubbling uniformly across the tank but not appear to be a "rolling boil." Indeed, at temperatures marginally conducive to bluing, the problem may be aggravated by excessively vigorous circulation of the heating water.

Microbial Populations of Cooked Crabs and Fresh Crabmeat

The microbiological quality of fresh crabmeat may determine the effectiveness of a pasteurization process. It is influenced by the method by which whole crabs are cooked, the processing environment, and storage conditions. The cooking of crabs in commercial processing operations is performed by either boiling or retorting (pressure steaming), and usually varies by geographical location. Commercial processors in states bordering the Gulf of Mexico often boil crabs, whereas in some Mid and South Atlantic states it is mandated by state law that crabs be cooked by retorting.

When crabs are cooked by boiling, it is recommended that the water be allowed to return to a rolling boil and that cooking continue for at least an additional 10 minutes. Nonetheless, even following this recommendation, microorganisms may survive the boiling process. Cann (1977) observed that crabs in the middle of the basket did not reach a temperature of 60°C (140°F) during commercial processing, while Schultz et al. (1984) reported that crabs boiled for 10 minutes obtained a temperature of only 63.9°C (143°F).

On the other hand, Dickerson and Berry (1974) found that temperatures would often approach 190°F. The differences in observations may be partially explained by the time required to return to a rolling boil. In some instances, this time interval can be quite long, with the temperature of the crabs slowly increasing during the "come up" period. The final product temperature achieved during boiling, as well as the length of time at lethal temperatures, influences the microbial load of the crabs. The microflora of live crabs is comprised largely of Gram-negative, heat-sensitive bacteria, which are killed at temperatures achieved by proper boiling. Nonetheless, it is not unusual to observe aerobic plate counts of 1,000 per gram when freshly boiled crabs are tested.

Retorting crabs can result in a product that is essentially free of microorganisms, as sampled directly from the retort. The process obtained from retorting crabs for 10 minutes at 250°F is equivalent to F_{250} ($z=18$) of 0.7 to 1.8 minutes, depending on the size of the individual crabs and whether or not female crabs are bearing an egg mass often referred to as the "sponge" (sponge crabs heat much more slowly) (Dickerson and Berry, 1974). For reference, an F_{250} ($z=18$) of 2.3 to 3 minutes is considered adequate for commercial sterilization of canned foods.

Although cooking, especially retorting, can eliminate most of the crab's natural microflora, microorganisms are introduced during subsequent processing steps. Sources of microorganisms include workers, utensils, contact surfaces, and insects. Since picking of the crabmeat is so labor intensive, the workers are perhaps the greatest source of microbial contamination. In areas of the country where crabs are debacked, washed, and refrigerated before picking (removing the meat), microorganisms are introduced from the workers and the wash water during debacking. In other areas, the customary practice is to cool the crabs in

the retort baskets and allow the pickers to deback the crabs immediately prior to picking. This latter processing protocol is superior from a microbiological standpoint.

Microorganisms that can be introduced onto crabmeat from workers include spoilage organisms and pathogens. A partial list of pathogens that can be introduced from workers include: *Staphylococcus aureus, Salmonellae, Campylobacter, Listeria* (this is more likely to be an environmental contaminant), and Enteropathogenic *Escherichia coli*. Of the pathogens listed, *S. aureus* is the most common contaminant. The organism is naturally present on the skin, hair, and nasal passages of much of the population. Because of the extensive human handling of crabmeat, *S. aureus* is a major concern of regulatory agencies.

Listeria monocytogenes can be found in the processing plant environment, and as a consequence can potentially be introduced into the crabmeat through a variety of routes. Some of the more obvious include contamination of the cooked whole crabs prior to picking, through contact with the floor, contaminated gloves, or contaminated shovels used to load crabs onto the picking tables. Perhaps a less obvious route would be drip from ceiling condensate in cold rooms used to store cooked crabs. This can occur if cooked crabs are not sufficiently air cooled before being placed in refrigerated storage; steam rising from the warm crabs will condense on the ceiling of the cooler and contaminate the crabs with a variety of microorganisms, *Listeria* among them. Once on the surface of the cooked crabs, these organisms easily contaminate the meat as it is being removed by pickers.

Crabmeat's ready-to-eat status has made the control of *Listeria monocytogenes* in these products a high priority to FDA (Hooker et al. 1991). Although *L. monocytogenes* exhibits greater heat resistance in crabmeat than in fluid milk products, D-values reported by Harrison and Huang (1990) show it is eliminated by conventional pasteurization at any inoculation level (Table 2). Commercial buyers are increasingly qualifying suppliers based on their ability to deliver pathogen-free products. The uses of pasteurization for fresh cooked seafoods and of milder thermal processes for targeting vegetative pathogens in products destined for frozen distribution are applications likely to become more important in the 1990s as safety concerns predominate. Other pathogens from the environment might include *Vibrio* species and *Salmonellae*. Hackney et al. (1980) demonstrated that *Vibrio* can contaminate crabmeat from the environment. Reservoirs include waste containers, insects, and dust.

Most spoilage microorganisms and pathogens are heat sensitive and can be destroyed by low to moderate heat. The heat resistance of various non-spore forming microorganisms is summarized in Table 4. The D-values of pathogens and spoilage organisms were calculated from heat resistance data in the literature, with milk being the most common heating medium. Heat resistance of microorganisms is significantly influenced by the food medium being heated.

Table 4. D-value in seconds of nonspore-forming microorganisms at either 185°F or 150°F

Organism	D-value (185°F, sec)	D-value (150°F, sec)	z-value (°F)	Heating medium	Reference
Vibrio cholerae	0.16	11.7	18.9	buffer	Schultz et al. (1984)
	0.29	93.0	13.9	crabmeat	Schultz et al. (1984)
Listeria monocytogenes	0.16	39.8	15.1	crabmeat	Harrison and Huang (1990)
	0.02	11.2	13	milk	Bradshaw et al. (1985)
	0.09	28.2	14.4	milk	Bunning et al. (1986)
	0.007	19.8	10.4	skim milk	Bradshaw et al. (1987)
	0.02	17.2	12.2	cream	Bradshaw et al. (1987)
Staphylococcus aureus	0.002	15.0	9.2	various foods	Stumbo (1973)
	0.04	132.0	9.9	various foods	Stumbo (1973)
Salmonella typhimurium	0.002	2.3	11.2	milk	Bradshaw et al. (1987)
	0.001	4.2	9.9	?	Bradshaw et al (1987)
Salmonella senftenberg	0.017	53.6	9.9	?	Stumbo (1973)
Yersinia enterocolitica	0.0007	21.4	9.9	milk	Lovett et al. (1982)
Shigella dysenteria	0.0002	3.0	8.5	milk	Stumbo (1973)
Campylobacter jejuni	0.0007	1.03	10.4-12.1	skim milk	Doyle and Roman (1981)
Other Bacteria[1]	0.008-0.01	60-180	7.2-10.8	various foods	Stumbo (1973)

[1] *Pseudomonas, Achromobacter, Enterobacter, Micrococcus,* and *Lactobacillus,* as well as most spore-forming bacteria.

Discoloration in Pasteurized Crabmeat

The bluing that occurs in pasteurized crabmeat occurs during heat treatment and intensifies during storage. It has been observed that crab meat processed above 190°F develops the off-color more readily than that produced at lower temperatures. Some processors have adopted alternative processing schedules to the previously described 190°F process to reduce product rejection in the marketplace. These alternative processes were usually based on personal judgment rather than thermobacteriological principles or studies. While one problem may have been either eliminated or reduced in magnitude, another may have been created. As pasteurization temperatures are reduced, processing times must be substantially increased. Unfortunately, the magnitude of this increase must be obtained from both thermocouple temperature profiles and mathematical computations. Failure to determine an equivalent thermal process can result in product loss and may even present a health hazard.

Cause and Prevention of Blue Discoloration

Crabs possess a copper-based hemocyanin that tends to form gray to blue-black complexes when the picked meat is canned or pasteurized (Babbitt et al., 1973, Boon, 1975, Groninger and Dassow, 1964). Meat processed above approximately 190°F frequently discolors, hence the selection of 185°C-190°F waterbaths. The discoloration of pasteurized blue crabmeat involves more than elevated temperatures, however, since retorted whole crabs do not discolor. Waters (1971) confirmed that contamination of the picked meat with metals, especially iron, can greatly exacerbate bluing.

The addition of citric acid (Waters, 1971) and sulfates (Fellers and Harris, 1940) inhibits the formation of blue pigments. Certain food grade phosphates (e.g., addition of 0.3% by weight dry sodium acid pyro-phosphate) may also be beneficial in color control (Moody, 1991), as is EDTA (ethylenediaminetetraacetic acid). Additives and GRAS (Generally Recognized as Safe) substances should be used judiciously, if at all. Although no standard of identity currently exists that would specifically prohibit the use of appropriate additives, regulatory officials must be notified and labelling requirements followed. Also be aware that many consumers are looking for food products which are "natural" or "contain no additives." Also, the use of additives requires additional quality assurance programs, and the possibility exists that an additive may fall out of favor at some future time. Any undesirable publicity could cause consumer rejection of the product for an extended time.

Recommendations to Minimize Discoloration

1. All crabmeat should be processed at internal temperatures lower than 190°F.
2. Pasteurizer waterbath temperatures should not exceed a range of 189-192°F.
3. Pasteurized crabmeat should be stored for reasonable time periods and the "First-in First-out" rule should be followed.
4. Free liquid produced in the can during thermal processing facilitates the bluing process. When bluing occurs, processors should consider processing procedures that do not require boiling, washing, or fluming of the cooked crabs or cores.
5. Design heating tanks for uniform water circulation. Excessive turbulence in one portion of the tank may trigger bluing in meat from that area.
6. Minimize contact of crabmeat with any source of iron, including corroded steel and aluminum (often contains trace metal contaminants).
7. Experiment with more than one container style and manufacturer since enamel composition and quality varies.

Other Defects

A targeted F-value defines microbial kill at container center and can be accomplished with many optional time/temperature combinations in nearly any suitable container type. This flexibility permits the consideration of other quality parameters. A new process based on the destruction or inactivation of a target anaerobe, for example, must be evaluated with the following factors in mind. Their relative impact is likely to vary according to container type and heat/time/waterbath circulation parameters.

Heating temperatures below 190°F are used to reduce bluing, a visual defect. In addition to bluing, defects of non-microbial origin in pasteurized crabmeat include a dry appearance and coarse texture, excessive free liquid, cooked odor and flavor, and formation of small crystals that feel gritty when chewed. None of these problems has been sufficiently studied to permit a comprehensive understanding of causes and control measures. However, observations in commercial facilities and the existence of similar problems in other food products may offer some insights.

Product dryness, usually accompanied by darkening, occurs on the surface of the meat where it contacts air in the headspace. Whereas bluing appears to be particularly temperature sensitive, product dryness is mostly time dependant. That is, most heat-induced quality changes require some optimal combination of temperature and time for them to develop. Bluing can occur even at 180°F if the crab is held there for a very long time, but appears quickly at 200°F. A dry over-cooked appearance is likely to develop most often

when the heating time continues well beyond the two-hour process typically given one-pound cans. A short exposure to high temperatures affects appearance less.

A reasonable compromise process, then, for controlling both of these defects should include rapid heating to a temperature of between 185° and 189°F, holding for the time necessary to achieve target lethalities, and rapid cooling. Limiting the depth of the headspace and periodically inverting pasteurized meat during storage may also mitigate dryness. Crabmeat pasteurized in vacuum-sealed pouches does not exhibit this problem.

Not surprisingly, **excessive liquid** in pasteurized crabmeat usually arises from a wet pack. Crabmeat picked from boiled crabs tends to release more moisture when pasteurized than does meat from steamed crabs, especially when they have been debacked and washed prior to picking. Boiling and rinsing are customary practices along the Gulf coast and in many foreign countries. Although yields are improved and the meat is often whiter, a penalty is usually paid in higher microbial counts and wetter texture. Since bluing develops during storage preferentially on the meat in contact with this liquid, discoloration problems are also exacerbated. Under-cooked crabs also tend to have elevated moisture levels. This is quite common in meat picked from lightweight (recently shed) crabs which may be short-cooked to improve yields.

Grittiness is normally associated with silt and sand particles transferred from the shell and gills of winter-dredged crabs to the meat during picking. This condition affects all body meat produced from these crabs, not just pasteurized. A less-understood problem relates to very small crystalline grains that form during pasteurization. The composition of these particles has not been confirmed, but preliminary evaluation indicates struvite, magnesium ammonium phosphate (Moody, 1991). As in canned products, the problem arises from naturally occurring constituents and is prevented by the addition of sodium acid pyrophosphate. Other chelators (additives that bind certain ions) have not been evaluated for control of struvite in crabmeat.

Use of Steam Tunnel Processes to Reduce Microbial Levels

Consumers have typically demonstrated a preference for fresh crabmeat over meat that is either pasteurized or frozen. However, some potential fresh markets are beyond reach due to shelf-life limitations. Based on a preliminary study by North Carolina State University researchers (Gates 1977), an investigation was conducted at Virginia Polytechnic Institute and State University to determine the feasibility of using atmospheric steam to extend refrigerated shelf-life (Rippen et al. 1988).

Development of Atmospheric Steam Process for Flake Crabmeat

Flake crabmeat was spread in trays and passed through a steam tunnel so that the meat achieved a temperature of 167°F. It was hand packed, while still warm, into standard plastic containers used for fresh meat and stored on ice. Researchers felt that pre-chilling or packing with sterile implements would reduce its acceptance by the industry. Results indicated significant reductions in aerobic plate counts, and complete elimination of coliforms, fecal coliforms, and *S. aureus*. No changes were found in color, moisture content, or sensory quality. The crabmeat maintained significantly lower APC's than untreated controls during storage, and sensory shelf-life was extended by 85 to 100 percent.

A process such as this has merit where the intent is to extend the shelf-life of a fresh pre-cooked product or to reduce the probability of contamination with potential pathogens. Furthermore, the competitive microflora reduce the risk of botulism since subsequent contamination with a mixed spoilage microflora is expected, and containers are not hermetically sealed. Far more caution is warranted for refrigerated products that are mildly pasteurized after they are placed in hermetic containers.

Atmospheric Steam Process for Lump Crabmeat: A Study

Lump crab meat is very uneven in size. Because of this variability, slightly higher temperatures (175°F and 185°F) were selected.

In three separate trials, forty pounds (88 kg) of fresh lump crab meat, previously picked and packaged, was obtained from a Virginia crabmeat processing plant. Twenty pounds, packaged in eight-ounce tamper-evident containers, was stored in ice and used as control. The remaining twenty pounds was spread out on a perforated stainless steel tray and exposed to atmospheric steam. The crab meat was heated in a modified steam blancher until the internal temperature of monitored lumps reached the designated temperatures of 175°F or 185°F. (Please note the differences in temperatures from the 167°F for flake meat. It was earlier established that lower temperatures were not adequate, therefore a higher temperature was added). The processed meat was then packaged into eight-ounce containers and placed in ice.

At day 1, a sample container from each temperature and the control were analyzed for total coliforms (APHA procedure, 3-tube MPN in LST broth, incubated 48 hrs at 35°C) and for moisture content (AOAC vacuum oven dry procedure). At days 1, 3, and 5, each treatment was evaluated for aerobic plate count (pour plate with plate count agar incubated for four days at 20°C), *Staphylococcus aureus* counts (APHA, Baird-Parker spread plate, incubated at 37°C for 48 hrs), *Listeria* counts (recovery procedure using Oxford agar overlay, incubated at 30°C for 48 hrs), texture (Instron), and color (Minolta Chroma-meter,

Hunter L,a,b scale). These procedures were continued until sensory evaluation of the sample was borderline. Sensory properties were evaluated by a 10-12 member trained panel. Sensory scores were based on the 9-point scale (end of shelf-life was indicated by a mean score of 5, borderline, or below). The procedure was conducted in triplicate. Statistical analysis was performed using the SAS system.

Results: Aerobic plate counts were significantly decreased and *Listeria*, *S. aureus*, and coliforms were eliminated. Unheated control samples were positive for a non-pathogenic *Listeria* which was never isolated from the heat-treated samples. With the elimination of spoilage and potential pathogenic organisms, shelf-life was increased 10-14 days.

After a shelf-life of 11 days, sensory evaluation results indicated that the controls were no longer acceptable. Odor and flavor values were unacceptable and aerobic plate counts were 1.57×10^8 cfu/g. Aerobic plate counts of both the heat-treated samples were 5 logs less (99.999 percent fewer) than the control samples at day 11. Both test samples continued with acceptable sensory ratings for an additional 14 days.

The steam treatment enhanced flavor of the treated samples. The test samples consistently rated higher in sensory evaluation than the control even on day 1. Texture (Instron) of all samples was not significantly different ($p > 0.05$.) throughout sensory evaluation. Color was not significantly ($p > 0.05$) changed when heated to 175°F; however, when the samples were heated to 185°F, darkening of the meat occurred. Moisture contents were not significantly ($p > 0.05$) affected by the addition of steam to heat meat to 175°F. Reductions were observed at the higher temperature (185°F).

In summary, the process of heating the meat to 175°F produced the best product with the least changes in quality, and greatly extended shelf-life.

Minimally Processed Seafoods (*Sous Vide* Seafood Products)

Minimally processed foods, including seafood, are being introduced into the U.S. market. The process was developed in France where the products are portion controlled, vacuum packaged in plastic pouches or ridged containers, which are highly impermeable to oxygen and moisture, and then cooked in either a water bath or high humidity oven. Cooking temperatures are usually far less than those associated with pasteurization of crabmeat. The cooking procedures may involve using temperatures very close to that desired for the internal temperature maximum for the products, therefore requiring long cooking times; or products may be cooked quickly using temperatures considerably above the desired internal maximum. In either case, the principles that apply to pasteurization also apply with this processing technology. The products should be cooked to a desired F-value and cooled quickly. The

earlier discussions on container size, initial bacterial population, cooling, and survivors also apply to *sous vide* processing.

Advantages

Sous vide is an outgrowth of the French cooking method **en papillote** (cooking a product in oiled parchment to lock in flavor). While the idea of cooking in vacuum-sealed pouches has been around since the early part of this century (it was actually patented by W.R. Grace and Co.), it was not until the mid 1970s that the French chef George Pralus made it a popular cooking method in Europe. Pralus first used *sous vide* as a preferred cooking method for preparing *foie gras* (goose liver). He discovered that by cooking under vacuum the product has less shrinkage, better flavor, and improved color retention. The product also has an extended shelf-life when held under refrigeration. Furthermore, vacuum cooking allows the food to cook in its own juices and loss of flavor volatiles is minimized. The products are usually packaged raw and lightly spiced since flavors are retained in the packages. The products are usually produced at central facilities and used at upscale restaurants as a means of enhancing menu selection.

Safety Considerations

The safety of *sous vide* products has been questioned since these products are only minimally processed and do not contain preservatives to control microbial growth. Furthermore, the cooking process does not eliminate non-proteolytic types of *C. botulinum*, and there is some question as to whether it may allow other organisms such as *Listeria* to survive. Shelf-life and safety of these products is dependent solely on refrigeration, therefore it is critical that psychrotrophic pathogens not survive and grow.

In the United States, companies have produced these products as refrigerated, ready-to-eat, heat and serve products. They are processed under controlled conditions and caution is exercised during distribution. As of early 1992, the products are being sold only to food service establishments and are not being sold retail. This could change in the future as demand increases.

The U.S. Food and Drug Administration has limited the production of *sous vide* products to approved food processing operations and currently is not allowing production at retail establishments, such as grocery stores. It is important that these products be produced under an approved HACCP (hazard analysis critical control point) program, and that the principles that have been outlined for pasteurization be understood and applied to their production. Several major manufacturers have gone to freezing *sous vide* products, opted for full

pasteurization process schedules, or stopped production due to safety and regulatory concerns.

Clostridium botulinum Type E

As has been noted, seafood pasteurization processes are not based on destruction of Clostridium botulinum; instead it is shelf-life that is the important consideration. Fortunately the heat resistance of type E provides a large safety factor. *C. botulinum* type E has a D_{185} value of 0.2-0.32 minutes. Therefore, a process of F_{185} of 31 minutes provides at least a 96D process. However, other types of psychrotrophic non-proteolytic *C. botulinum* are more heat resistant. Non-proteolytic type B is reported to have D-values of 0.45-14.33 minutes. A 31-minute F-value may provide only a 2.2D process for this organism. Type F is reported to have a similar heat resistance.

Despite the safety factor, in any discussion of pasteurized crabmeat and public health, the principal consideration is the potential presence of *C. botulinum* Type E toxin. Although unlikely, the possibility exists for the toxin to be present and therefore it merits attention.

Human botulism is relatively rare; however, its control and prevention is one of the most important considerations in food processing. History has shown repeatedly that an outbreak of botulism can cause severe, often ruinous, economic problems for processors. Furthermore, when a problem does arise, a whole segment of the food industry is often affected, not just the processor involved (Eklund 1982, Eyles 1986).

C. botulinum, the etiological agent of botulism, is divided into eight types, based on seriological differentiation of the neurotoxin: A, B, C1, C2, D, E, F, and G (Sakaguchi 1979). The types have been divided into 4 groups according to proteolytic activity (Smith 1977). Group I and II are the most important with respect to human botulism. Group I includes type A and proteolytic strains of type B and F. This group is strongly proteolytic and produces putrid, unpleasant odors. This group also produces highly heat-resistant spores and has a minimum growth temperature of about 50°F. Group II includes all types E and non-proteolytic strains of B and F. Group II is neither proteolytic nor gelatinolytic and cultures do not produce putrid odors in food. This group can grow at temperatures as low as 38°F, and the spores are heat labile.

The symptoms of botulism usually develop in 12 to 36 hours after ingestion of the food; the range is 2 hours to 14 days. In general, the shorter the onset time, the more severe the symptoms. The amount of toxin in food does vary, and death has been reported after a mere taste of a small piece of bean pod or asparagus.

Food poisoning occurs more frequently in women because they prepare and taste the food more often than men do. Botulism is difficult to diagnose. Gastrointestinal problems are often the first sign (i.e., vomiting, nausea, and sometimes diarrhea). Other early symptoms

are weakness, lassitude (weariness), dizziness, and vertigo. These can be followed by eye problems such as blurred vision, diplopia (double vision), dilated and fixed pupils, and impaired reflection to light. Other symptoms are weakness of facial muscles pharyngolaryngeal paralysis (difficulty in speech and swallowing), impaired salivation (dryness of the mouth, tongue, and throat), complaint of thirst. Abdominal pain is severe and often accompanied by constipation. Muscle weakness occurs in the soft palate, tongue, diaphragm, neck and extremities, causing difficulty in walking and grip. Fever is absent and mental processes are normal. The major cause of death is respiratory failure and airway obstruction.

C. botulinum is widely distributed in soils and, because of run off, all types may be isolated from the aquatic environment (Dolman 1964). Type E is the toxin most frequently isolated from aquatic environments and is most often implicated in botulism associated with seafood products. The spores of type E are often isolated from fresh water and marine sediments in temperate zones (Dolman 1964). The numbers of all types of *C. botulinum* found in waters, seafood, and sediment are usually low; the highest counts are usually found in sediment (less than 100 per gram). The incidence in marine fish usually follows patterns associated with the bottom sediments. Presnell et al. (1967) examined the incidence in Mobile Bay, Alabama. *C. botulinum* was found in only 4.1% of the sediment samples and 2.7% of the oyster samples. Ward et al. (1967a) surveyed the U.S. Gulf Coast. They found 3% to 5% of fish, and 5% to 8% of the sediment, sampled to contain *C. botulinum*. In further work, Ward et al. (1967b) found a slightly lower incidence on the Atlantic Coast. Cockey et al. (1974) found *C. botulinum* in 21 of 24 crab samples from the Chesapeake Bay. In these surveys, type E was usually the predominant type.

Most outbreaks of botulism associated with fishery products have implicated semi-preserved products, i.e., smoked, salted, or fermented products that are eaten without further cooking (Eklund 1982, Lynt et al. 1982). Type E is inhibited by water activity less than 0.975 (5% NaCl) and pH less than 5.3 (Emodi and Lechowich, 1969). The spores are sensitive to heat. Decimal reduction times at 82.2°C (180°F) range from 0.49 minutes to 6.6 minutes, depending upon the heating medium and the strain (Lynt et al. 1982, Simunovic et al., 1985). The spores are most resistant in tuna packed in oil. For foods not packed in oil, a D-value of 4.3 minutes at 82.2°C is usually considered the maximum expected heat resistance. Z-values range from 4.8°C to 9.6°C (Simunovic et al., 1985). For comparison, other members of Group II produce slightly more heat-resistant spores with D-values for non-proteolytic type B ranging from 1.49 - 32.3 minutes at 82.2°C (Scott and Bernard 1982). The D-values for non-proteolytic F are similar to non-proteolytic B.

SECTION 3.

Temperature Measurements

Thermocouples

A thermocouple is a device for the measurement of temperature (Fig. 17). Its operation is based on the observation that a small electric current will flow in a closed circuit composed of two dissimilar metallic conductors. The pair of conductors, or thermocouple elements, which constitutes the thermoelectric circuit, is called a thermocouple. Simply stated, a thermocouple is a device that converts thermal energy to electric energy. The amount of electric energy produced can be used to measure temperature when connected to an appropriate recorder.

Of all the available temperature transducers, why use a thermocouple in a particular application? There are numerous advantages to consider:

1. Physically, the thermocouple is inherently simple, being only two wires joined together at the measuring end.
2. The thermocouple can be made large or small depending on life expectancy, drift, and response time requirements.
3. It may be flexible, rugged, and generally easy to handle and install.
4. It normally covers a wide range of temperatures and its output is reasonably linear over portions of that range.
5. Compared to many temperature transducers, the thermocouple is less subject to self-heating problems.
6. Usually, thermocouples of the same type are interchangeable within specified limits of error.
7. Also, the materials are readily available at reasonable cost. The expense in most cases is nominal.

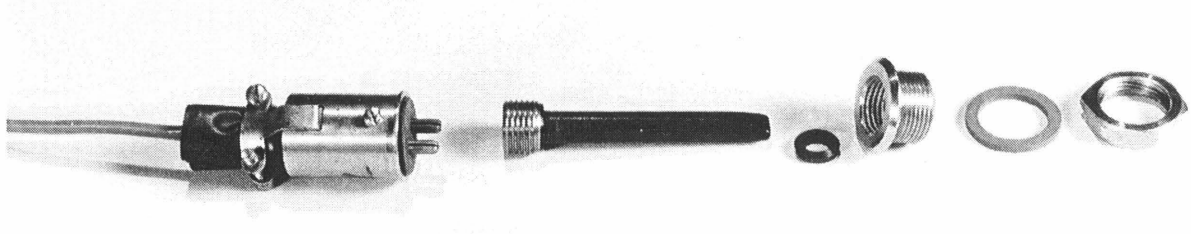


Figure 17.

The commonly used thermocouple types are identified by letter designations originally assigned by the Instrument Society of America (ISA) and adopted as an American Standard in ASA C96.1-1964. Some of these are:

1. Type T - Copper (+) Constantan (-)
2. Type J - Iron (+) Constantan (-)
3. Type K - Originally Chromel* (+) Alumel* (-)
4. Type E - Originally Chromel* (+) Constantan (-)
5. Type S - Platinum/10% Rhodium (+) versus Platinum (-)
6. Type B - Platinum/30% Rhodium (+) versus Platinum/6% Rhodium (-)

*Trademark - Hopkins Manufacturing Company

Table 5 gives recommended maximum temperature limits for various gauge sizes of wire.

General Application Data

Type T: These thermocouples are resistant to corrosion in moist atmospheres and are excellent for subzero temperature measurements. They have an upper temperature limit of 700°F and can be used in a vacuum and in oxidizing, reducing, or inert atmospheres. This is the only thermocouple type for which limits of error are guaranteed in the subzero temperature range, and it is probably the most commonly used thermocouple in the food industry (including those used in heat penetration studies for pasteurized seafoods). A wide variety of manufactured thermocouple hardware is available for this type.

Table 5. Upper Temperature Limits (°F) for Protected Thermocouples for Various Wire Sizes

Thermocouple	Wire Size				
	No. 8 (0.128 in)	No. 14 (0.064 in)	No. 20 (0.032 in)	No. 24 0.020 in)	No. 28 (0.013 in)
J	1400	1100	900	700	700
E	1600	1200	1000	800	800
T	-	700	500	400	400
K	2300	2000	1800	1600	1600
R and S	-	-	-	2700	-
B	-	-	-	3100	-

Type J: These thermocouples are suitable for use in vacuum in oxidizing, reducing, or inert atmospheres, at temperatures up to 1400°F. The rate of oxidation of the iron thermoelement is rapid above 1000°F, however, and the use of heavy-gauge wires is recommended when long life is required at the higher temperatures. Bare thermocouples should not be used in sulfurous atmospheres above 1000°F. This thermocouple is sometimes used for subzero temperatures, but the possible rusting and embrittlement of the iron wire under these conditions makes it less desirable than Type T for low temperature measurements. Limits of error have not been established for Type J thermocouples at subzero temperatures.

Type K: Type K thermocouples are recommended for continuous use in oxidizing or inert atmospheres at temperatures up to 2300°F. Because their oxidation resistance characteristics are better than those of other base metal thermocouples, they find widest use for measuring temperatures as low as -420°F, although limits of error have been established only for the temperature range 0 to 2300°F.

Type K thermocouples may be used in hydrogen or cracked ammonia atmospheres if the dewpoint is below -40°F. However, they should not be used in:

1. Atmospheres that are reducing or alternately oxidizing and reducing unless suitable protected with protection tubes.
2. Sulfurous atmospheres unless properly protected. Sulfur will attack both thermoelements and will cause rapid embrittlement and breakage of the negative thermoelement wire through interangular corrosion.
3. Vacuum except for short periods (preferential vaporization of chromium from the positive element will alter calibration).
4. Atmospheres that promote "green-rot" corrosion of the positive thermoelement. Such corrosion results from preferential oxidation of chromium when the oxygen content of the atmosphere surrounding the thermocouple is low and in a certain range. Corrosion can cause large negative errors in calibration and is most serious in the temperature range 1500°F to 1900°F.

Green-rot corrosion frequently occurs when thermocouples are used in long unventilated protecting tubes of small diameter. It can be minimized by increasing the oxygen supply through the use of large-diameter protecting tubes or ventilated protecting tubes. Another approach is to decrease the oxygen content below that which will promote preferential oxidation by inserting a "getter" to absorb the oxygen in a sealed protection tube.

Type E: Type E thermocouples are recommended for use over the temperature range of -420 to +1600°F in oxidizing or inert atmospheres. In reducing atmospheres, in alternately oxidizing and reducing atmospheres, in marginally oxidizing atmospheres, and in vacuum

they are subject to the same limitations as Type K thermocouples. These thermocouples are suitable for subzero temperature measurements since they are not subject to corrosion in atmospheres with high moisture content. However, limits of error for the subzero range have not been established.

Type E thermocouples develop the highest emf (electromotive force) per degree of all the commonly used types and are often used primarily because of this feature.

Types R and S: Type R and S thermocouples are recommended for continuous use in oxidizing or inert atmospheres at temperatures up to 2500°F, intermittently up to 2700°F.

They should not be used in reducing atmospheres, nor those containing metallic or nonmetallic vapors, unless suitably protected with nonmetallic protecting tubes. They never should be inserted directly into a metallic primary protecting tube.

Types R and S thermocouples may be used in a vacuum for short periods of time, but greater stability will be obtained by using Type B thermocouples for such applications.

Continued use of Types R and S thermocouples at high temperatures causes excessive grain growth that can result in mechanical failure of the platinum element. It also renders the platinum susceptible to contamination, which causes negative drifts in calibration, that is, a reduction in the emf output of the thermocouple.

Calibration changes also are caused by diffusion of rhodium from the alloy wire into the platinum, or by volatilization of rhodium from the alloy. All of these effects tend to produce negative calibration shifts.

Type B: Type B thermocouples are recommended for continuous use in oxidizing or inert atmospheres at temperatures up to 3100°F. They are also suitable for short term use in vacuum to this temperature.

They should not be used in reducing atmospheres, nor in those containing metallic or nonmetallic vapors, unless suitably protected with nonmetallic protecting tubes. They should never be inserted directly into a metallic primary protecting tube.

Under corresponding conditions of temperature and environment Type B thermocouples will show less grain growth and less drift in calibration than with Type R or S thermocouples.

The limits of error for the common letter designated thermocouple types, as listed in Table 6, are taken from ANSI Standard C96.1. Most manufacturers supply thermocouples and thermocouple wire to limits of error or better.

Table 6. Limits of Error for Standard and Special Grade Thermocouples

Type	Temperature Range (°F)	Limits of Error	
		Standard	Special
J	32 to 530	±4°F	±2°F
	530 to 1400	±3/4%	±3/8%
K	32 to 530	±4°F	±2°F
	530 to 2300	±3/4%	±3/8%
R or S	32 to 1000	±5°F	±2½°F
	1000 to 2700	±½%	±¼%
T	-300 to -75	-	±1%
	-150 to -75	±2%	±1%
	-75 to 200	±1½°F	±3/4°F
	200 to 700	±3/4%	±3/8%
E	32 to 600	±3°F	±2¼°F
	600 to 1600	±½%	±3/8%
B	1600 to 3100	±½%	-

Extension wires are inserted between the measuring junction and the reference junction and have approximately the same thermoelectric properties as the thermocouple wires with which they are used. The wires are normally available as single or duplex, solid or stranded, insulated wires in sizes ranging from 14 to 20 B&S gauge. A variety of insulations and protective coverings are available in several combinations to suit the many types of environments encountered in industrial service. Extension wires may be separated into two categories having the following characteristics:

Category 1: Alloys substantially the same as used in the thermocouple. This type of extension wire normally is used with base metal thermocouples.

Category 2: Alloys differing from those used in the thermocouples. This type of extension wire normally is used with noble metal thermocouples and with several of the nonstandardized thermocouples.

Several possible sources of error in temperature measurement accompany the use of extension wires in thermocouple circuits. Most of the errors can be avoided, however, by exercising proper precautions. One type of error arises from the disparity between thermocouple and extension wire components. This disparity results from the variations occurring among thermoelements lying within the standard limits of error for each type of thermocouple and extension wire.

For example, it is possible that an error as great as $\pm 8°F$ could occur in the Type K/KX and J/JX thermocouple extension wire combinations, where the standard limits of error are $\pm 4°F$ for the thermocouple and the extension wires treated as separate combinations. Such errors can be reduced substantially by selecting extension wires whose properties closely match those of the specific thermocouple, up to the maximum temperature of the thermocouple-extension wire junction.

A second source of error can arise if a temperature difference exists between the two thermoelement-extension wire junctions. Errors of this type are potentially greater in circuits employing category 2 extension wire.

A third source of error lies in the presence of reversed polarity at the thermocouple/extension wire junctions, or at the extension wire-instrument junctions.

A fourth source of error concerns the use of connectors in the thermocouple assembly that have conductive characteristics which differ appreciably from those of the thermocouple extension wires. The magnitude of errors of this type can vary over a wide range depending on the materials involved and the temperature difference spanned by the connector.

A complete thermocouple temperature sensing assembly usually consists of the following:

1. Sensing element assembly basically composed of two dissimilar wires, supported by an electrical insulator and joined at one end to form a measuring junction
2. Protection tube, either metal or ceramic, and commonly referred to as thermowells
3. Connector
4. Miscellaneous hardware; for example: adaptor to join the protection tube to the head or thermocouple glands.

Numerous variations in measuring junction are possible; the specific application dictates the most desirable method.

1. Exposed bare wire junction: in this type of a junction the sheath and insulating material are removed to expose the thermocouple wires. These wires are joined to form a measuring junction that may be twist or butt-weld type.
   a. fast response
   b. exposed magnesia will not pick up moisture
   c. not pressure tight

d. wires subject to mechanical damage
f. useful life shortened as a result of rapid calibration drift

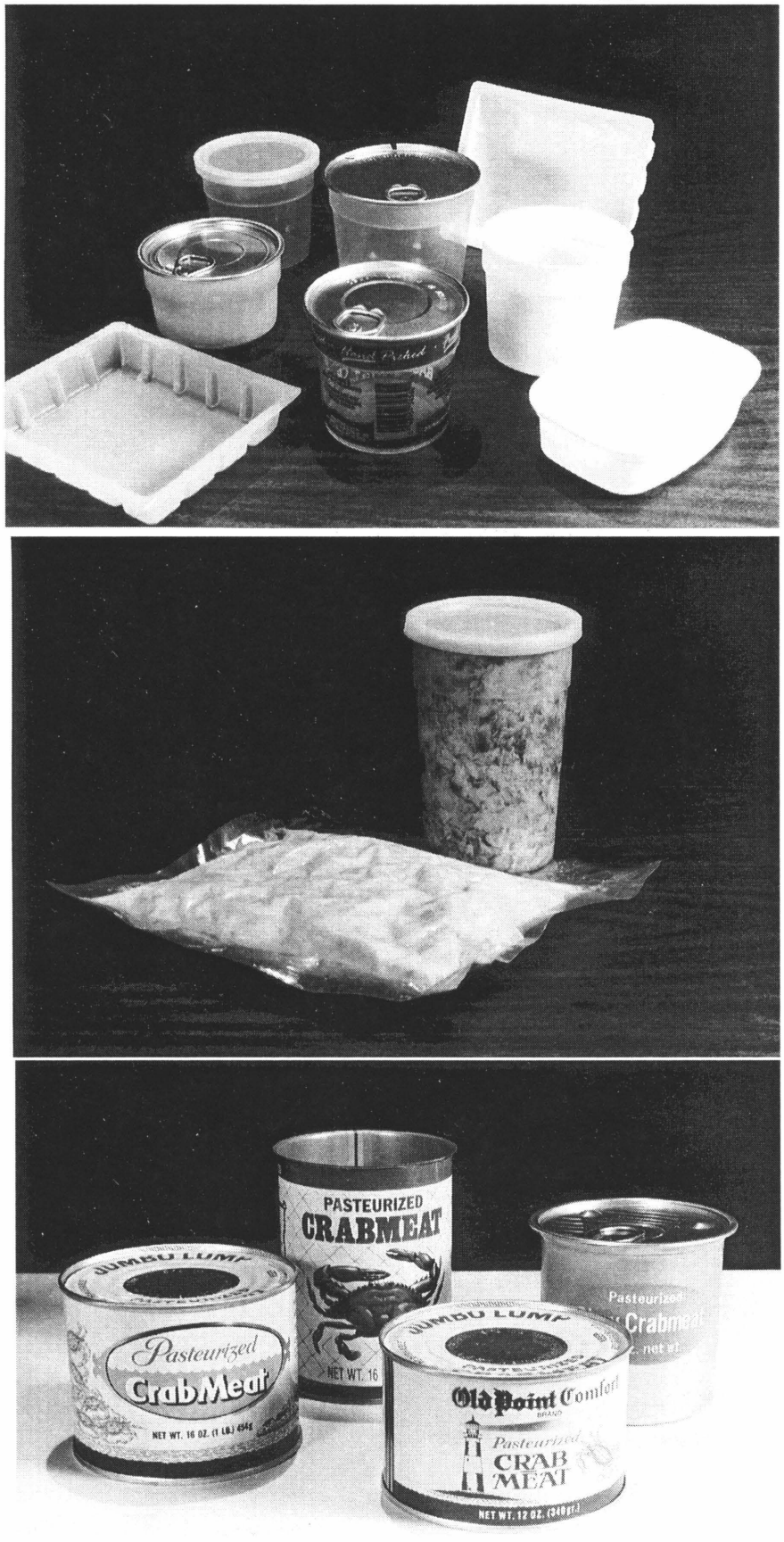
2. Grounded junction: a closure is made by welding in an atmosphere so that the two thermocouple wires become an integral part of the sheath weld closure.
   a. slower response than exposed wire
   b. pressure tight to above 100,000 psi
   c. wires protected from mechanical damage
   d. wires not exposed to environment and will have a longer life
3. Ungrounded or isolated junction: this type is similar to the grounded junction except that the thermocouple wires are first made into a junction which is then insulated from the sheath and its closure.
   a. slower response than grounded hot junction
   b. pressure tight to above 100,000 psi
   c. wires protected from mechanical damage
   d. wires not exposed to environment and will have a longer life
   e. most expensive

Thermocouple Installation

Containers suitable for pasteurizing crabmeat are available in a variety of shapes and sizes (Fig. 18). It is important that all pasteurization temperature measurements be individually determined. The container types most commonly used for crab meat are of metal or polymer construction. In order to record internal temperatures, thermocouples of various types and sizes are required (Fig. 19). The use of an incorrect thermocouple will result in the development of erroneous processing times and temperatures, which can cause substantial product loss and perhaps illness. If a processor is uncertain as to either the proper procedure or the proper equipment for monitoring and developing adequate thermal processes, professional advice should be obtained or, perhaps more advisable, the responsibility should be delegated to a qualified individual.

Thermocouples and their installation tools are available from a variety of firms that serve the food processing industry. The equipment is simple (Fig. 20) and relatively inexpensive.

Figure 18. Containers suitable for pasteurized and minimally processed seafoods.



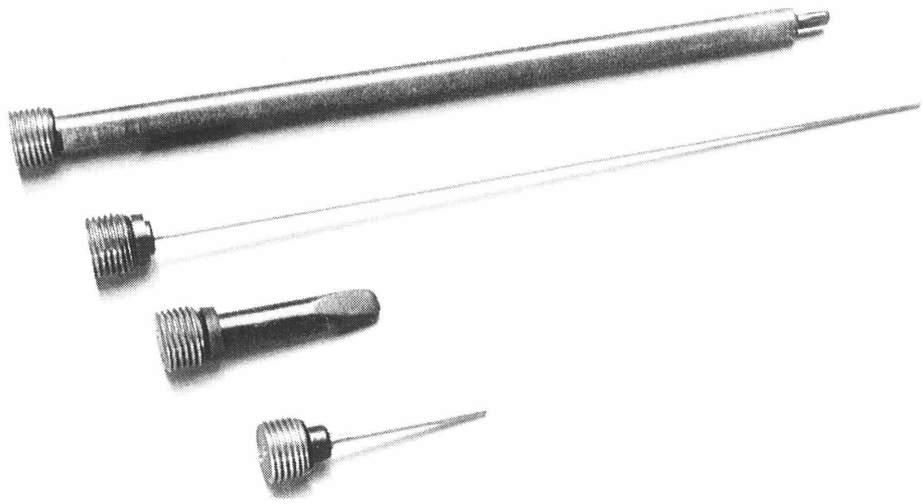


Figure 19. Common thermocouples.

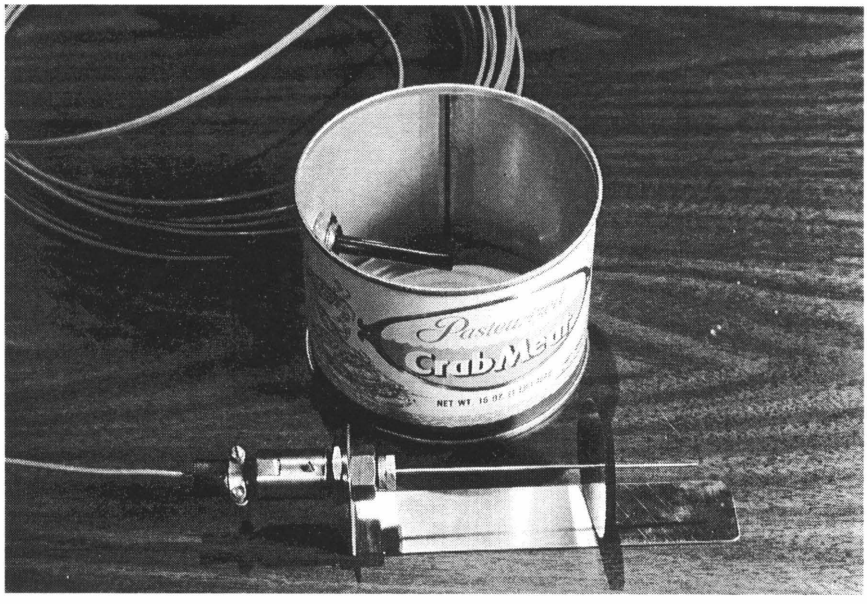


Figure 20. Thermocouple assemblies for cans and pouches.

Procedures

Thermocouples can be easily installed, using the following steps:

Step 1: Thermocouples should be installed in the geometric center of the container because this is the location that is slowest to heat. This location is easily determined in containers where the width or diameter is uniform (such as a can). However, it becomes more difficult when a variable width container (such as a nestable polymer type) is used. The diameter of

the can will determine the length of the thermocouple while the height determines the location of the thermocouple insertion (Fig. 21). Both measurements are usually very important. Obviously, for a flattened container, such as a pouch, thickness is the most critical measurement.

Step 2: Once the proper measurements have been taken, a pilot hole is made in the container with an awl or punch (Fig. 22). The awl is used on both metal and semi-rigid polymer type containers. Care should be exercised in making the hole since excessive pressure will bend or damage the container. For pouches, a paper punch is often used to produce a small hole near a side or end seam for fitting specialized hardware.

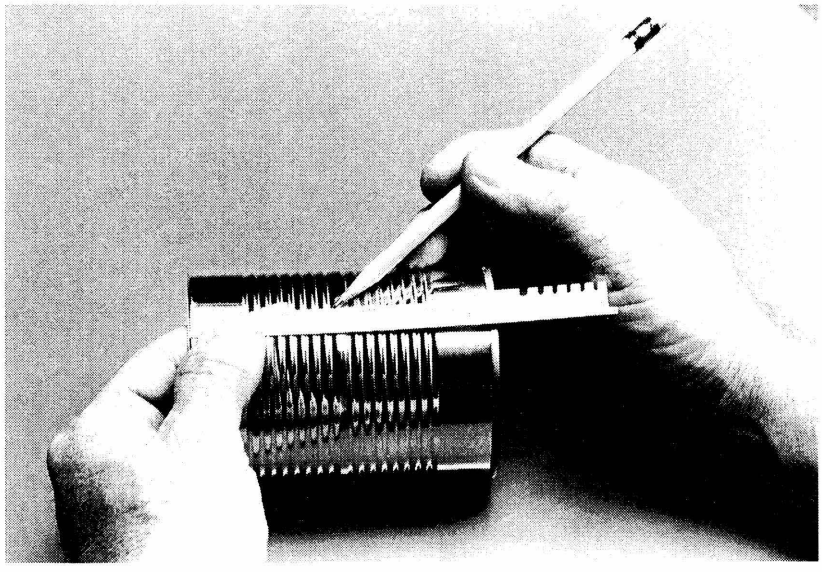


Figure 21. Locating the thermocouple insertion point.

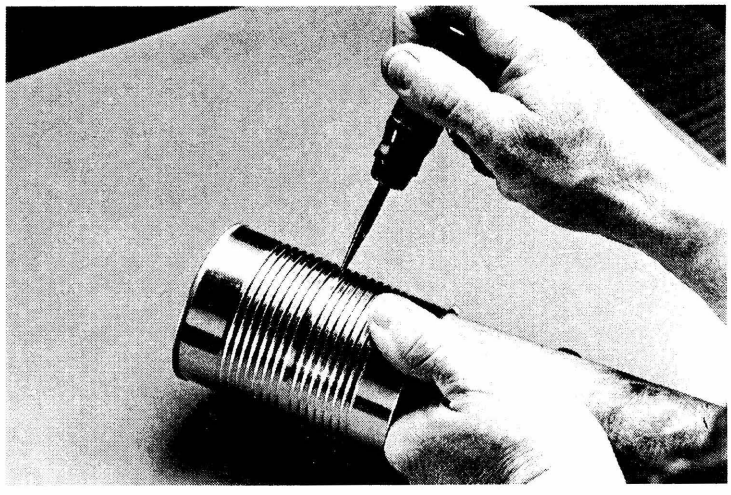


Figure 22. Forming the pilot hole at the thermocouple insertion point.

Step 3: After the pilot hole is made, a hole puller or cutter is installed and, depending on the style, either slowly tightened with a wrench or cut directly (Fig. 23). A round hole will be produced after the cutter penetrates the container. During this process, metal containers may develop a slight deformation near the hole but this is expected and often necessary to assure a properly shaped gasket seat for the thermocouple receptacle. The hole cutter should be replaced when cutting becomes difficult or the seat is indistinctly formed.

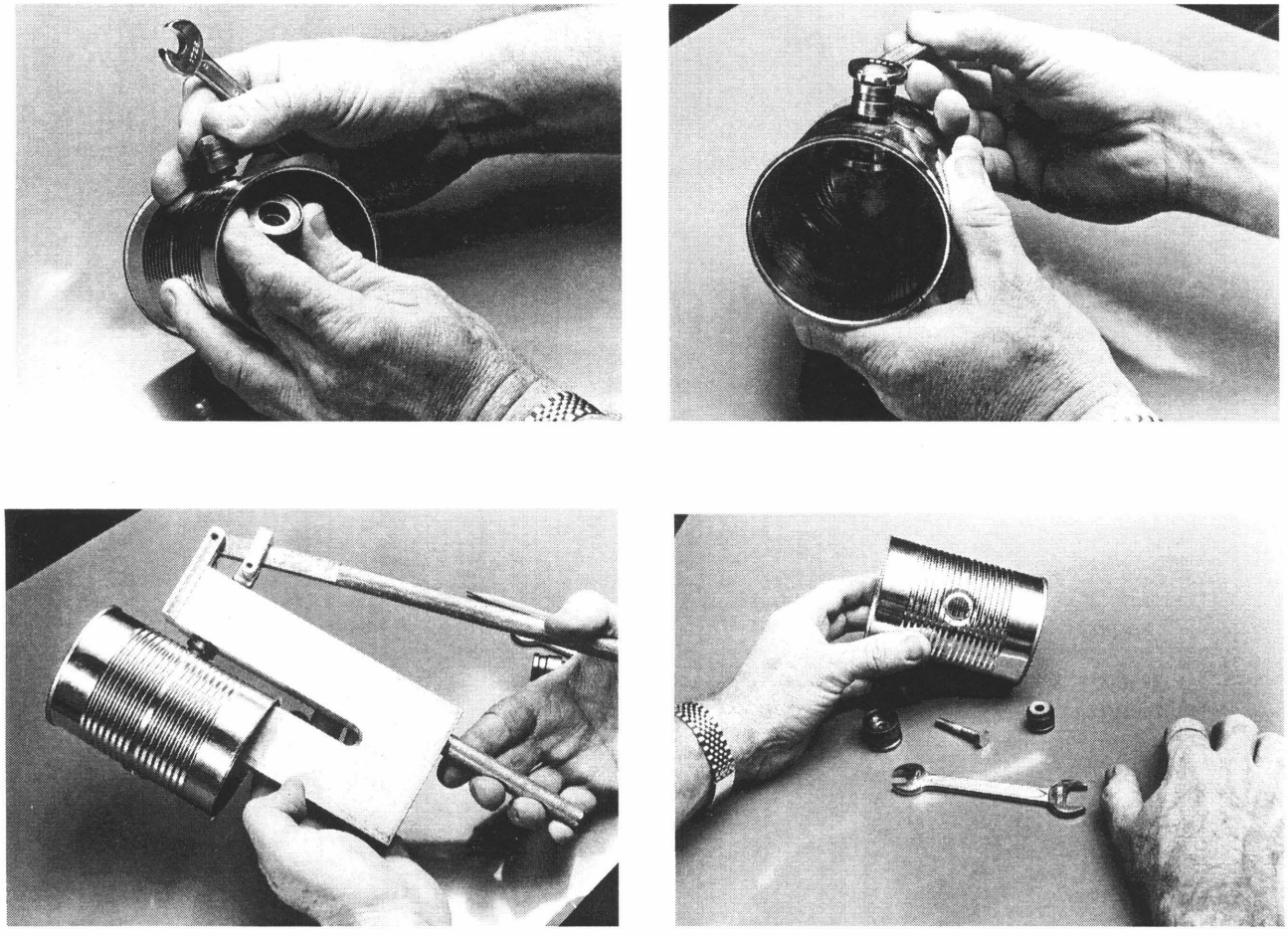


Figure 23. Completing the receptacle hole at the thermocouple insertion point.

Step 4: Slip a gasket over the threaded end of the receptacle and insert the receptacle from outside the container (Fig. 24). On the inside, install a receptacle nut. Tighten the nut with a wrench (Fig. 25). The receptacle should fit snugly but over-tightening should be avoided. Check the container since an improper installation may cause a leak, resulting in misleading temperature measurements.

Step 5: Containers should be filled with product to normal net weight capacity, then seamed in the usual manner. Some seamers require the use of flush mount style receptacles to prevent jamming.

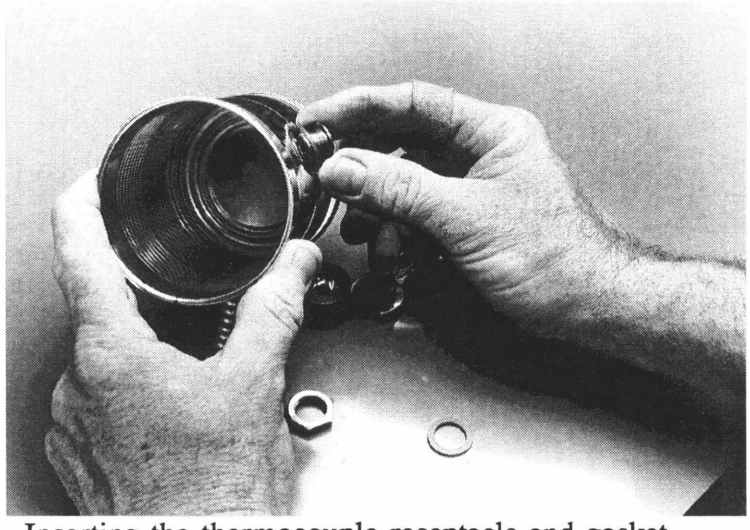


Figure 24. Inserting the thermocouple receptacle and gasket.

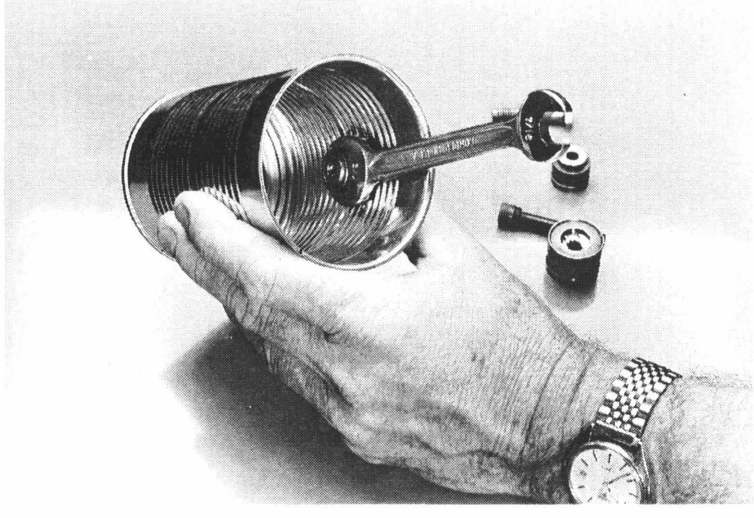


Figure 25. Completing the thermocouple receptacle installation.

Step 6: The thermocouple rod is then installed with a special tool (Fig. 26). Frequently, needle type thermocouples are used for pouches. They may be positioned halfway between the pouch side panels with the aid of a spacer that slips over the end of the thermocouple in conjunction with an external bracket (Fig. 27). (In pouch applications, the thermocouple is installed prior to filling with product and sealing.) All gaskets should be replaced periodically to prevent leakage. Thermocouples should also be examined for physical defects as well as electric conductance (continuity). A Volt-ohm meter is useful for the latter procedure.

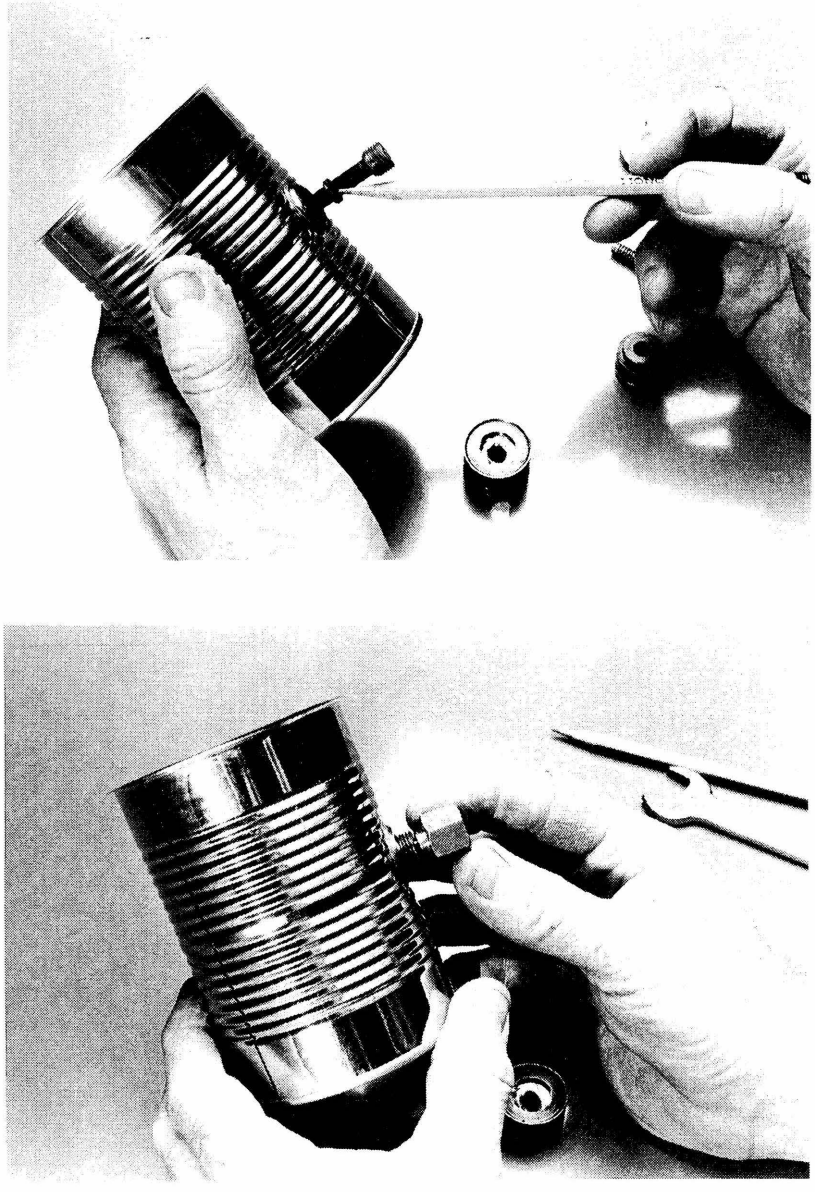


Figure 26. Installing the thermocouple and gasket into the receptacle.

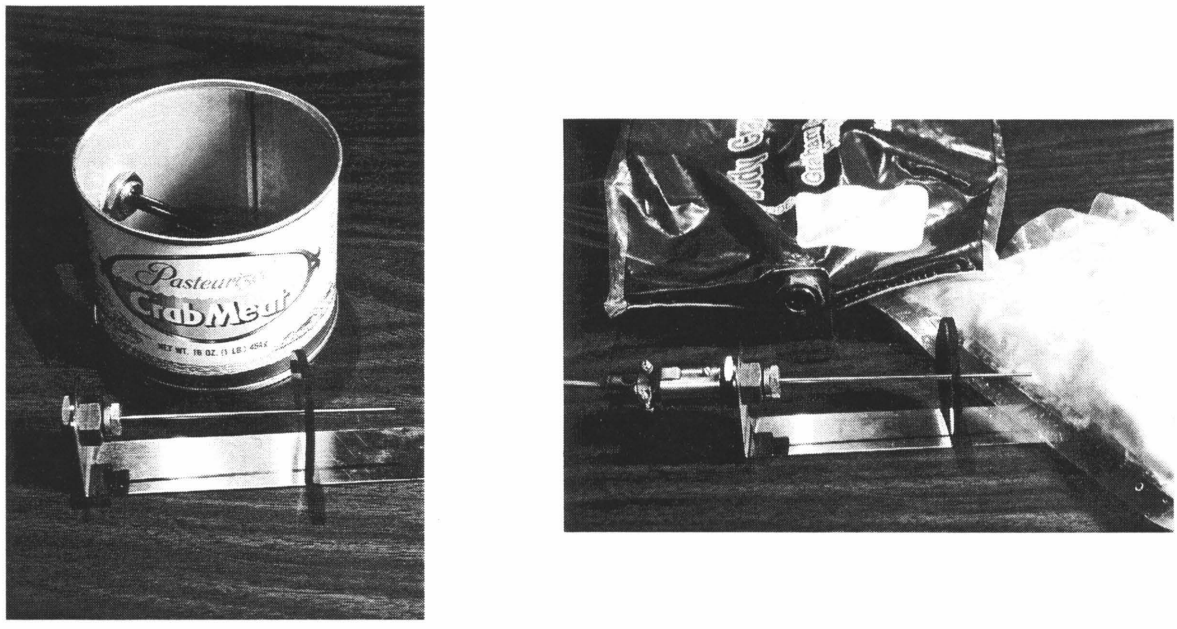


Figure 27. Completed thermocouple assemblies for a can (top left) and for pouches or bags.

Step 7: A properly installed thermocouple may cause minor deformation in metal containers and stress marks in polymer containers. This is perfectly acceptable and does not interfere with the measurements.

Step 8: The cross-section in Figure 28 depicts an acceptable non-projecting plug-in thermocouple installation. Figure 29 provides a view of a thermocouple assembly. After the thermocouple has been installed, temperature measurements can be made using any of several datalogger recorders and supporting equipment. As previously mentioned, special mounting hardware is available for placing temperature sensors into flexible packages (Fig. 27).

Recorders

One of the most important functions in any food processing operation is data gathering. Temperature is usually the most important kind of data to be gathered in a food-processing facility but there are other parameters such as those measured in amps or watts that may also be important. These data can indicate the status of processing operations so that problems can be identified manually or automatically with alarms; or they can be filed for future reference as required by regulatory agencies. Data gathering can be achieved either manually or automatically using recorders or dataloggers. The high cost and variable reliability of human labor contrasted with the low cost and generally high reliability of recorders has rendered some manual data recording obsolete.

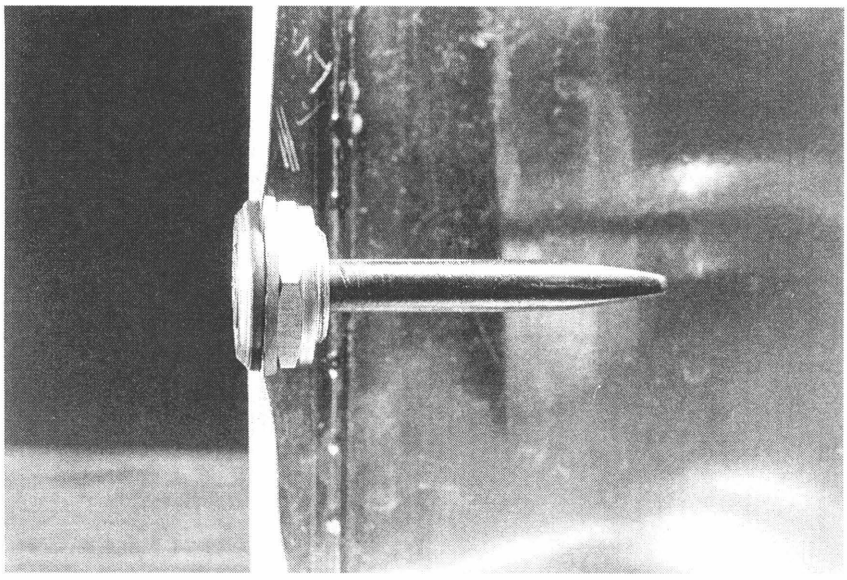


Figure 28. Cross-section of thermocouple installed in sidewall of can.

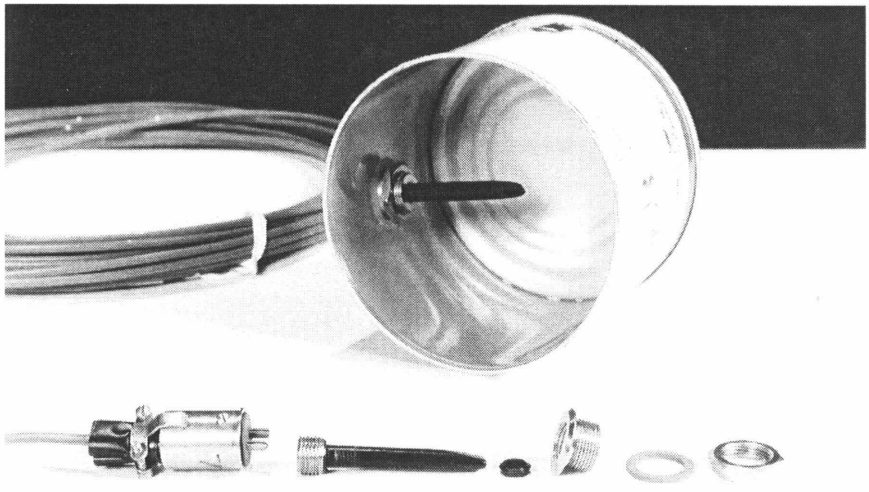


Figure 29. Thermocouple hardware including thermocouple wire and compatible plug.

In one form or another recorders are found in almost every food processing plant. They are the efficient method for data gathering. These devices vary as to size and price, recording speed, type of data storage media, and ability to record different types of inputs such as voltage, amperage, or power. While these variations may present a confusing array of choice, relatively few are appropriate, because recorders are often designed for one specific application. For example, if permanent records are required, a recorder with some

type of inked chart may be needed. Recorders of this type are sometimes called analog devices because the data received are continuously recorded.

The advantage of devices with chart recorders is that they provide an instant historical record of a process. However, chart recorders are subject to pen malfunctions such as blotting or interruptions of ink flow from the pen. The more versatile the recorder, the more knowledgeable the user usually must be with its installation and operation. The cost may also be higher than necessary for a specific application.

Analog recorders are steadily being replaced by digital devices that record data as discrete values at prescribed time intervals (Fig. 30). The concept of digital recording is graphically contrasted to analog recording. Digital recorders can output data to paper tape, cassette tape, strip charts, internal memory chips for later retrieval with a computer, or directly to a computer. Computers can also function as recorders if coupled with a data acquisition system and can record data as fast as several thousand times per second. Because digital recorders are usually programmable, they are very versatile. Stand-alone units normally sample no faster than once per second but a rate this high is usually unnecessary. Most processing parameter-measurement devices such as temperature transducers usually have a slow response so that a high sampling rate is unnecessary. In addition to recording, both analog and digital devices can be interfaced to alarms to warn operators when problems occur. They may also serve as process controllers.

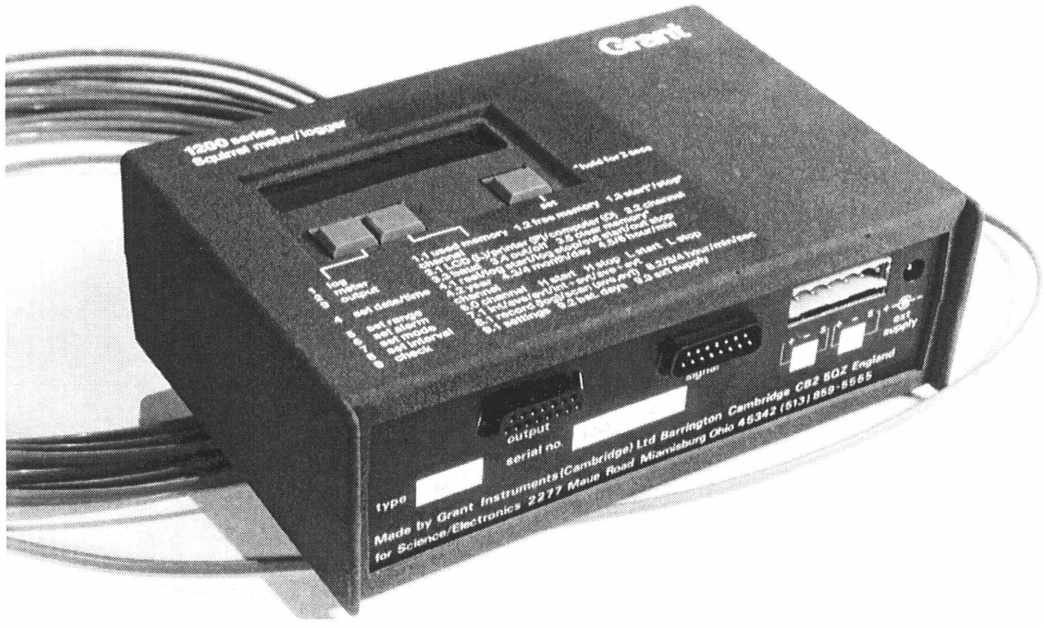


Figure 30. Digital recorder (datalogger).

While the forgoing discussion may provide the processor with an introduction to data recorders, it is usually unnecessary to be concerned with the working principle of a data recorder. The important point is to find a reliable recorder that meets the needs of the application and user. In addition, consideration should be given to price, ease and rapidity of repair, and how comfortable one feels with the operation of a particular unit.

Appropriate regulatory agencies should be contacted prior to selecting thermal recording equipment to assure compliance with current interpretation of good manufacturing practices.

SECTION 4.

Pasteurization Processing Equipment and Controls

The equipment used to pasteurize crabmeat is fairly simple in both design and construction. Within the industry, however, the actual operations and operation controls vary in degree of sophistication. For example, most processors employ a simple batch-type process using one tank to heat the product and another tank to cool. A few processors have installed continuous pasteurizers that employ variable speed timing chains to move baskets of crabmeat through long tanks of heated water. As new packaging is introduced in the future, pressurized systems may also be adopted.

Irrespective of processing techniques, whether it be batch or continuous, the fundamentals of process control are the same. Several states have adopted either the Tri-State, or National Blue Crab Industry Association, recommendations regarding minimum pasteurization and control equipment requirements. Although the Food and Drug Administration does not have a specific GMP (Good Manufacturing Practices) guideline for the pasteurized blue crab industry, indications are that the FDA considers these requirements to be basic to the processing of wholesome products.

Recording and Indicating Thermometers

Indicating thermometers monitor the time-temperature relationship discussed earlier in this manual and are standard equipment in the canning industry. The indicating thermometer assesses the accuracy of the recording thermometer. Although the recording thermometer, once calibrated, is fairly accurate, it is important to use a properly calibrated indicating thermometer. The standard in food industries is a permanently mounted Mercury-in-glass (MIG) thermometer (required under LACF) or glass thermometer containing alcohol or other medium, which in turn is calibrated against MIG. These may not be reliable when installed in wells on pasteurization tanks, however, due to locational cooling and restriction of circulation currents.

Small thermocouple thermometers are available that are quite reliable (Fig. 31). These can be positioned in different areas of the tanks to give a truer measure of waterbath temperatures. It is important to calibrate these periodically to confirm their accuracy. Calibration can be done against a standard reference MIG thermometer or, at the least, by immersing them in rapidly boiling water (212°F at sea level) and rapidly agitated ice slush (32°F). The low-acid can-food industry is required to periodically assess the accuracy of the MIG thermometer with a reference thermometer. Although no such requirement is made of

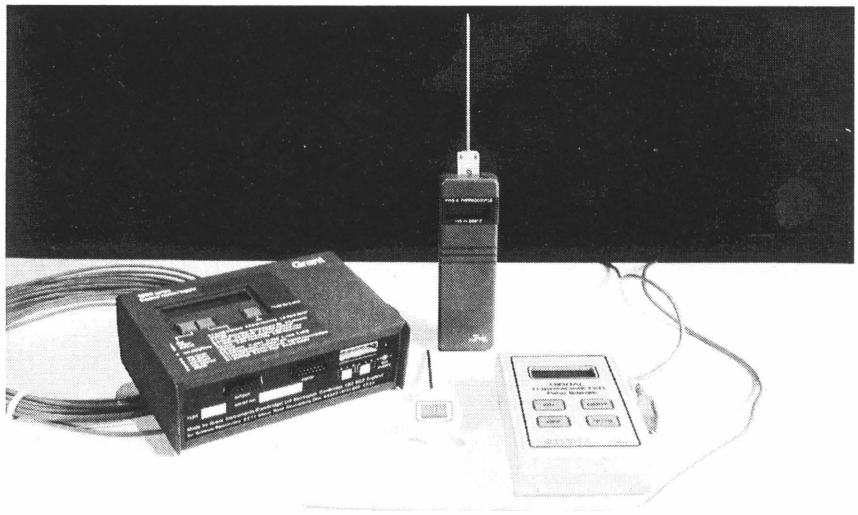


Figure 31. Digital thermocouple thermometers.

the pasteurized crab industry, it is wise to standardize equipment and to use indicating thermometers. **Important: keep a current record of calibration for all temperature instruments.**

The recording thermometers are used to document the processing profile of each batch of crabmeat pasteurized. They record water-bath temperature and time of processing. This record is important in providing information about each process and must be kept on file for future reference. Chart recorders may have an advantage here over digital printouts. Their tracings provide a continuous history of the waterbath temperature so that even the shortest process deviation will be recorded. For this reason, some regulatory agencies may request their use. Short-interval digital records are sufficient in most instances, however, and provide other features described previously. The importance of record keeping will be discussed in a separate section.

Some seafood processors now monitor internal crabmeat temperatures in two or more containers of every batch as well as waterbath temperatures. This extra monitoring provides detailed process information and permits interfacing with a computer for database development and routine thermal process calculations. This record becomes a powerful tool for managers by confirming the adequacy of every batch processed, and by permitting data sorting and retrieval for preparing reports to customers or regulatory agencies. Thermocouple wires can be run from a connection box in the pasteurization room to a computer in the company's office. For assistance with hardware and software selection, contact your Land Grant or Sea Grant university's food science department.

The range of accuracy of both the recording thermometer and the clock are important and should be standardized throughout the industry. This is part of the Tri-State recommendations as revised by the National Blue Crab Industry Association Standards Committee and included in Section 6.

Proportional Flow Steam-Control Valve

Most crabmeat pasteurization operations use steam as the source of heat to raise the temperature of the water bath. A proportional flow steam-control valve is usually required in the operation for maintaining the desired waterbath temperature. These valves are most frequently air-actuated and meter the steam as required, "anticipating" the volume needed, as opposed to a solenoid valve which is either open or closed. Without the proper valve, temperature fluctuations may be too extreme for a time/temperature-based process.

Agitation of Waterbath to Maintain Uniform Temperature

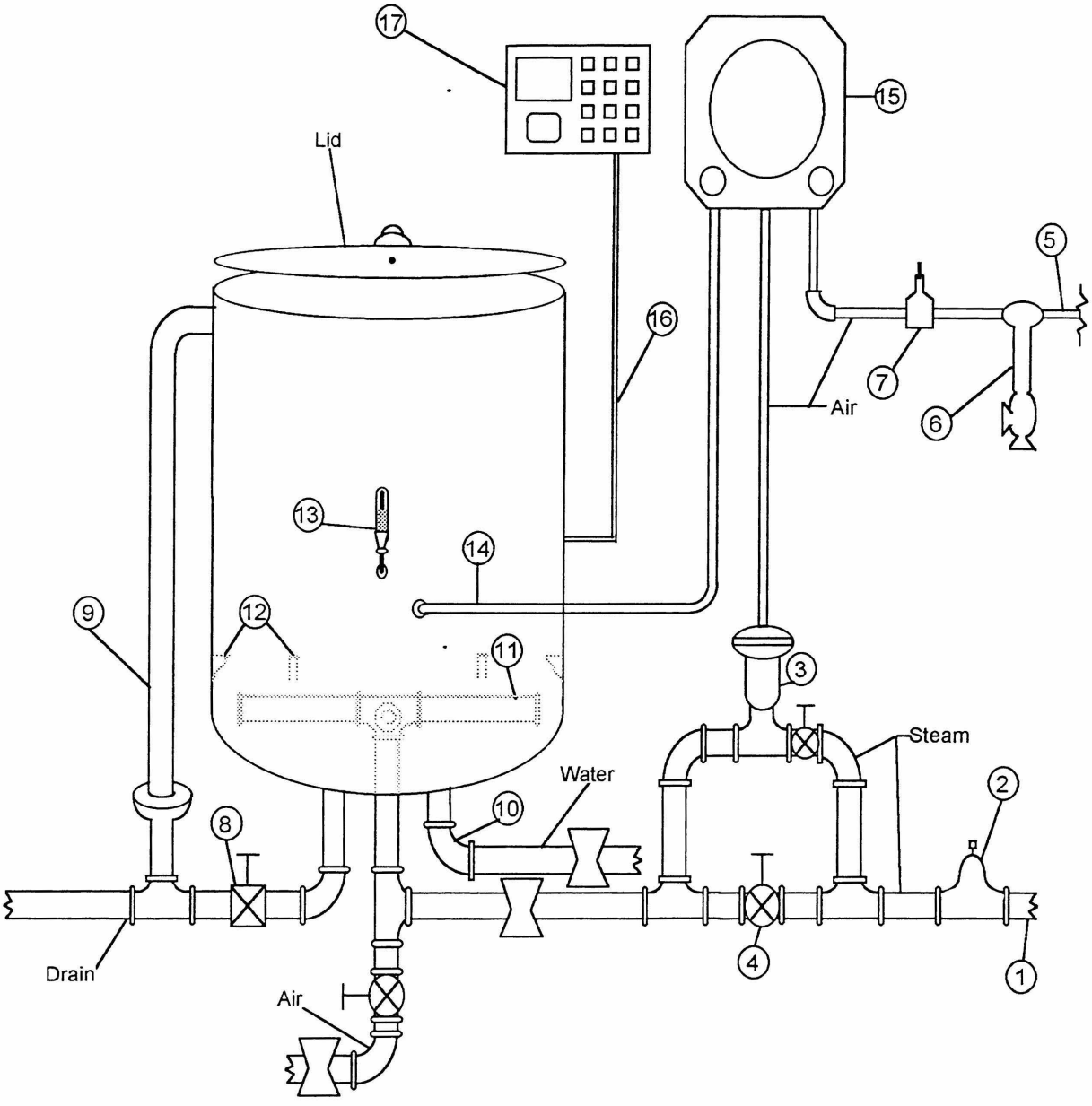
Uniform temperature throughout the heating and cooling baths is crucial; without some means of agitating the water, cold spots and hot spots may develop. Water can be successfully agitated with air injected through a spreader in the bottom of the tank. Make certain that hole sizes and their placement in the spreader are such that air is released uniformly across the tanks. Otherwise, most of the agitation may originate near the air inlet point. Virginia Tech staff have measured as much as a 6°F difference between locations in a heating tank depending on the uniformity of agitation. The spreader also must be level to assure even air bubble distribution across the tank. Check this carefully during installation.

Baskets

Pasteurization basket bottoms, sides, tops, and dividers must be designed to permit free circulation of waterbath water. They should be well maintained and free of burrs or sharp edges, especially when used for flexible packaging.

Pasteurization Tank Hook-Up

A typical pasteurization tank hook-up is demonstrated in Figure 32. Minor variations may exist, depending on the requirements of individual plants; nonetheless, the fundamental elements of all operating plants should be the same. Some plants have the minimum required equipment but do not use it. For example, the recording thermometer and clock is of little value as a process documentation record if a chart is not installed or never changed.



1 Steam inlet
2 Steam pressure reducer
3 Steam control valve
4 By-pass
5 Air, instrument
6 Filter
7 Pressure regulator
8 Drain
9 Overflow
10 Water inlet
11 Steam & air spreader
12 Basket supports
13 Indicating Thermometer
14 Control element (bath temp. sensor)
15 Process controller/recorder
16 Product temperature
17 Datalogger (F value)

Manual Valves:

globe
back flow prevention
gate

Figure 32. Pasteurization tank hook-up and recording/monitoring equipment.

The crabmeat temperature (F-value) datalogger system depicted in Figure 32 is not necessary, but its use is encouraged. It permits frequent process verification and records for HACCP plan compliance and may prevent a recall by identifying lots achieving acceptable F-values even if process deviations occur.

Servicing of Equipment

The old axiom, "If it ain't broke, don't fix it," has a great deal of merit. There is, however, another axiom which may not be quite as widely accepted: "If it's working, is it really working?" As with most equipment, periodic maintenance and calibration is necessary for the equipment used in the pasteurization process. Manufacturers of process recorders and clocks suggest routine servicing. Maintenance requirements of individual processors depend on the frequency of use and the environmental conditions in the area of operation. Periodic servicing is necessary to ensure that the equipment is performing properly.

When conducting heat penetration studies with thermocouples as previously described, and at regular intervals (approximately monthly), several operational measurements should be determined for the use and accuracy of pasteurization controllers/recorders. The following questions should be answered and documented:

1. At what time on the chart tracing are the cans submerged? Be certain that the tracing includes the entire time that the cans are in the tank (the timed portion of the process schedule). Make certain that the same routine is followed during normal operations as they are on the day that the schedule is established.
2. Is the chart speed correct? That is, do the time intervals eclipsed by the chart tracing agree with your thermocouple datalogger or watch?
3. Is the chart temperature tracing close to the recorder set-point temperature?
4. Does the tracing agree with the indicating thermometer?
5. Do the indicating thermometer and chart tracing agree with your datalogger waterbath leads? For precise determination of temperature agreements, wrap leads around the controller's temperature sensor, indicating thermometer, and another thermometer known to be accurate.

Virginia Tech researchers have found that problems with pasteurization systems that are difficult to regulate (wide temperature fluctuations or over-shooting of the set-point temperature) are often due to improper placement of the controller's waterbath temperature sensor used to determine the need for steam. It should be located near the steam spreader in the bottom of the tank; usually under the basket support flanges. If located at a higher position or in a well, the controller may lag—responding too slowly to rapidly changing temperatures. Also, control valves should be properly sized and be of the air-actuated, proportional flow type.

Thermometers in Refrigerated Storage Areas

While refrigerated storage is not part of the actual pasteurization process, the ultimate success of the process is contingent on proper refrigeration of the pasteurized product. In fact, if cans of pasteurized crabmeat spoil during storage, documentation verifying continuous safe storage temperatures may prove to be the processor's best defense with regulatory authorities. Temperatures of 36°F and below will not support the growth and toxin production of *Clostridium botulinum* even if the bacteria should enter containers through defective seams. Therefore, the authors strongly advise that storage refrigeration control and monitoring be given critical consideration. As is the case with the indicating thermometer in the pasteurization process, all recording thermometers used to monitor refrigerated areas should be periodically checked using a certified standard reference thermometer. Again, the industry must monitor these storage areas because the storage temperature of pasteurized crabmeat is a critical factor in the production of a safe, high quality product.

SECTION 5.

Can Seam Evaluation and Can Coding

In previous sections, problems associated with swollen and/or decomposed cans of pasteurized crabmeat were attributed to inadequate heating, cooling, or storage. A fourth potential problem area is defective can seams. During the past few years, there have been several incidences of swollen cans and decomposed crabmeat due to defective can seams. Although only recently recognized as a potentially significant problem, defective can seams are not new to the crabmeat industry.

Some state regulatory agencies that have responsibility for the crabmeat industry have neither inspected can seams nor required processors to inspect them. There are several reasons: first, the significance of the problem was not widely recognized until recent years; second, some agencies did not have staff members trained in can seam evaluation; and, third, the processing plants did not have employees trained in can seam evaluation. Both industry and the regulatory agencies are now aware of the problem, and many are training their personnel in can seam evaluation. Unfortunately, in some cases, the seafood industry was too slow in accepting the importance of the seaming operation until the cost of negligence became prohibitive despite the availability of training schools and reminders mailed by can companies.

Unlike low-acid canned foods, pasteurized crabmeat must be refrigerated; therefore, the crabmeat industry has been exempt from the strict inspection, process control, and record keeping requirements imposed on the low-acid can food (LACF) industry. One requirement of the LACF industry, which may become applicable to the pasteurized crabmeat industry in the future, is the periodic inspection and teardown of can seams.

What happens when a can seam is defective? Nothing may happen, in some cases, or "leaks" may develop. Even when leaks do not develop at first, this is probably a temporary situation, unless the problem causing the defect is corrected. When leaks occur, bacteria in the environment can be drawn into the container through the leaks; thus spoilage of the product is hastened. The leaks may be extremely small "micro-leaks," but the bacterial load introduced into the container by just one small drop of water can be enough to cause major contamination. The presence of micro-leaks can be detected using a specifically designed detector (Fig. 33).

Figure 33. A can leak detector which uses vacuum to draw air out of the suspect can. Leaks are identified by bubbles viewed through the transparent plate as they rise through water previously poured into the can.

Usually, air or water droplets gain entry through micro-leaks in the can seams during the cooling phase of the pasteurization process. A leaking seam allows air to escape when the container is heated and the internal pressure increases. When the container is cooled, the pressure is relieved, and a vacuum occurs because of this loss of air. Outside air or water then enters through the leak to relieve the vacuum.

Defective can seams can create serious problems for the industry. What is in question, however, is the extent of the problem. Some processors in the pasteurized crabmeat industry do not know how to evaluate can seams. Although some of the major suppliers of pasteurization cans provide a can seam evaluation service, discussions with company officials indicate that only a portion of those buying cans make routine use of the service. The NBCIA Standards Committee has recommended that all companies pasteurizing crabmeat have at least one employee who has been trained in can seam evaluation. That employee is responsible for can teardown examinations every four hours of operation. The NBCIA also recommends that a record of these evaluations be kept and filed for future reference.

Can Coding

The proper coding of cans is a significant protection device not only for the consumer but also for the processor. The more refined the coding system, the easier it is for the processor to locate and recall the product. According to the Handbook of Product Recalls and Package Coding and Equipment, a product code at a minimum should include:

1. Product should be coded for easy identification and at frequent enough intervals to keep the lots small.

2. Codes should be related to processing records so that lots that may need to be recalled because of a process deviation or other problem may be identified quickly and completely.
3. Keeping of raw product and quality-control records should be kept in such a way that the product in any batch can be identified.*

It is to the processor's advantage to keep each lot small. If lots are kept small, only the lots in question can be recalled instead of an entire day's production. Several coding systems and methods can be used, according to the requirements of the plant, and the choice should be left to the individual processor. Special attention should be given to the clarity of the code mark. In the case of recalls, illegible codes could create serious problems.

Double Seam Evaluation: Determining Proper Formation

Double Seam Defined

The double seam consists of five thicknesses of plate interlocked or folded and pressed firmly together. It is formed in two operations. A first operation roll tucks the curled edge of the cover underneath the flange on the can body, as illustrated in Figure 34. The seam is then completed by the second operation roll, which presses the folds of metal tightly together, squeezing the compound lining into the spaces between the metal to effect a hermetic seal (Fig. 35).

The names of the various parts of the double seam are shown in the cross section views of first and second operation seams. The juncture of the double seam and the side seam of the can is referred to as the crossover or lap.

Visual Inspection of External Seam Formation

Cans leaving from the closing machine should be examined visually. Carefully inspect the entire periphery to detect any seam malformation or defects such as pronounced cut overs, cut seams, droop, lips, false seams, spinners (skids), cracked plate, or any evidence of seam looseness. Rotating the seam between the thumb and forefinger is very helpful in detecting certain types of seam defects.

The frequency of these examinations will depend on the speed at which the closing machine operates. At a minimum, visual external seam inspection of cans from each seaming head must be made every thirty minutes of machine operation and recorded.

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*This requirement may have less application to the pasteurized crab industry than do items 1 and 2.

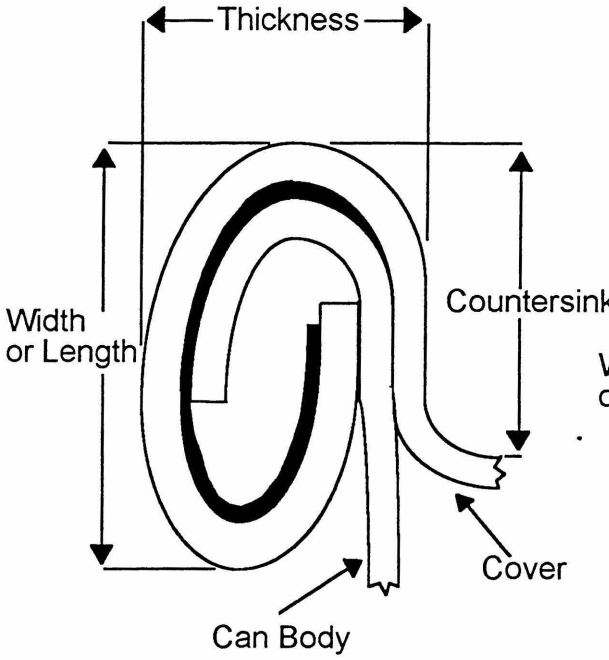


Figure 34. Cross sectional view of seam following first operation.

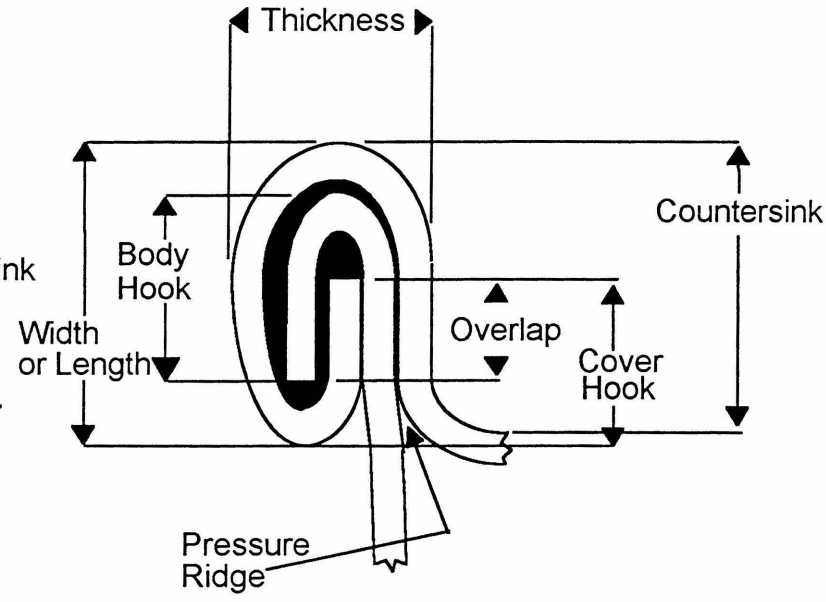


Figure 35. Fully formed seam following second operation

Cut Over: A cut over is a sharp fin of the cover formed over the top of the seaming chuck flange during the seaming operation (Fig. 36). This condition usually occurs at the body lap of soldered cans, but may occur all the way around the end. A slight sharpness, best noted by running a finger around the inside of the seam, is not indicative of a defective seam, but when pronounced could result in a more serious cut over. A severe cut-over condition is dangerous, leading to a possible fracture known as a cut-through cut over. Correction is mandatory when severe cut overs are encountered.

Possible Causes of Cut Overs:

1. Incorrect vertical alignment of the first operation seaming roll groove relative to the seaming chuck. The seaming chuck and first operation seaming roll groove should be set to maintain .001 inch to .002 inch vertical running clearance between the top of the chuck flange and the lead-in angle of the seaming roll groove (Fig. 37).

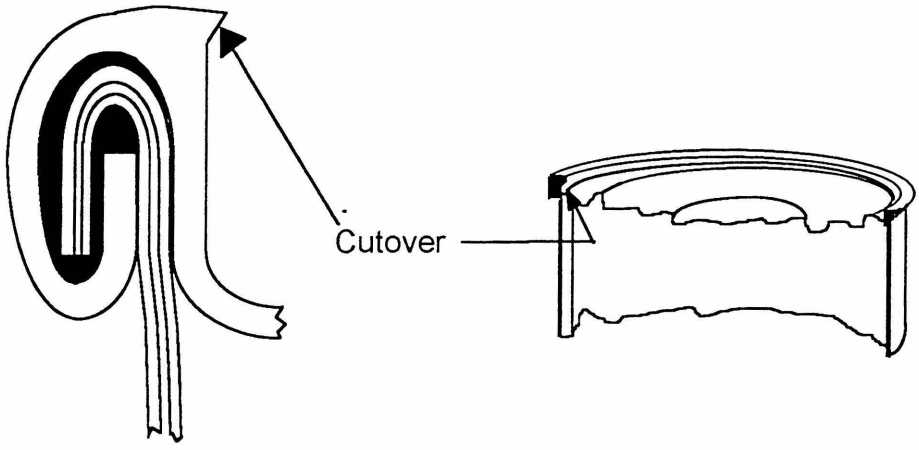


Figure 36. Seam cross-section at the crossover (lap), soldered cans.

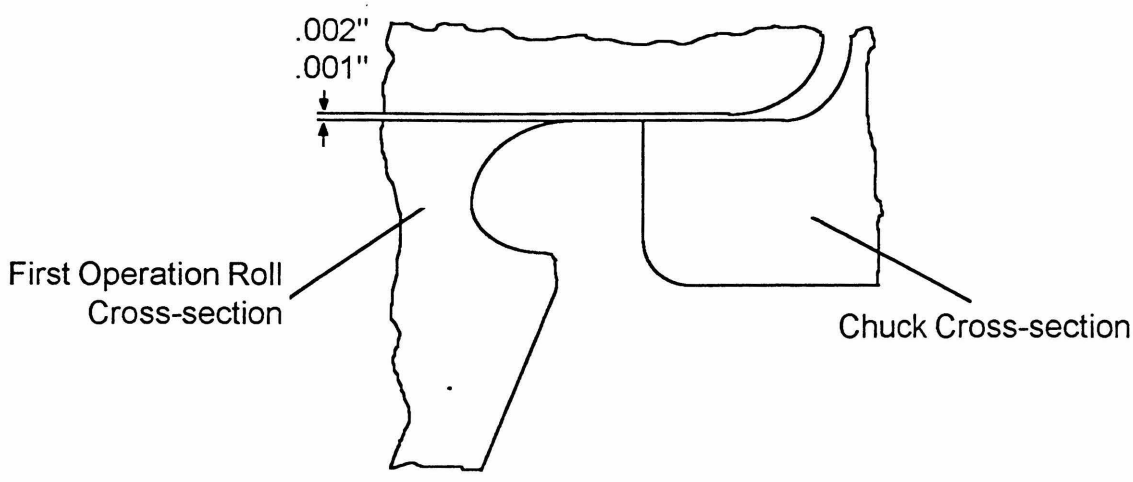


Figure 37. Roll & chuck alignment on seamer (closing machine).

2. Vertical play of first operation roll. Roll should revolve freely but vertical play in excess of .002 inch should be avoided.
3. Vertical play in seaming head assembly.

4. Worn seaming chuck flange. Usually caused when the lead-in angle of the first operation seaming roll groove rides the chuck flange. Not sufficient vertical running clearance.
5. First or second operation seaming rolls set too tight. When either operation roll is set too tight, the seam formation can be forced beyond the ideal limits of the seaming roll groove profile to produce a cut over.
6. Worn seaming roll grooves. All first and second operation roll groove profiles were developed to produce good seam formations and maximize the life of the groove. Incorrect setting of seaming rolls, even though the seam formation produced is acceptable, should be avoided as the life of the roll grooves will be reduced and the development of seam defects hastened. Any seaming roll, when suspected of creating cut overs because of possible worn groove conditions, should be replaced only after determining that the roll is set correctly.
7. Solid or semi-solid product trapped in seam.
8. When excessively long body hooks force too much metal into the seam, sharpness all around the seam as well as at the crossover often results.

Cut Seam: A double seam, wherein the outer layer of the seam is fractured (Fig. 38), is known as a cut seam. Immediate correction must be made when this condition exists.

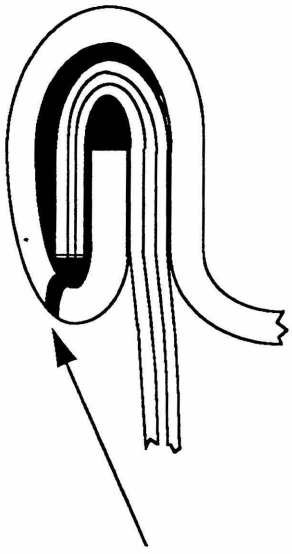
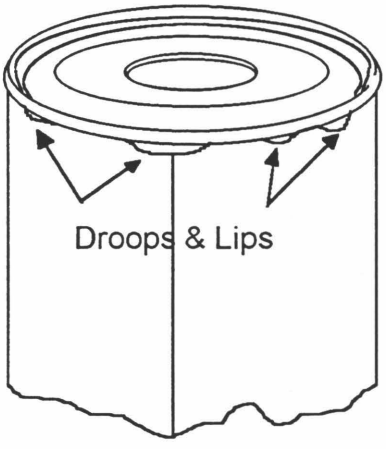


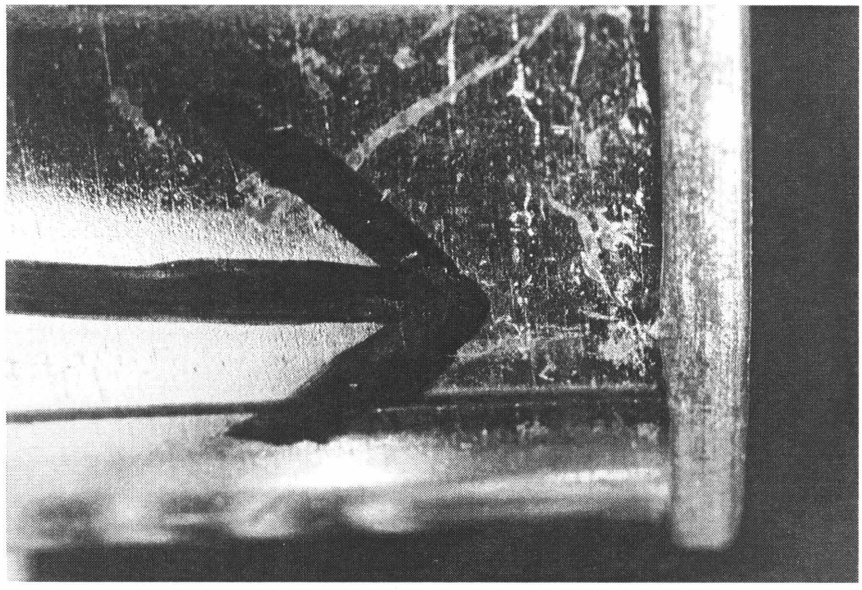
Figure 38. Cut or fractured seam.

Possible Causes of Cut Seam:

1. Seam too tight.
2. Defective end plate.
3. Excess sealing compound.
4. Long body hook.

Droop: A smooth projection of double seam below the bottom of a normal seam is identified as a droop. While droops may occur at any point of the seam, they usually are evident at the side seam lap (Fig. 39). A slight droop at the side seam lap or crossover may be considered normal because of additional plate thicknesses incorporated in the seam structure of soldered cans.





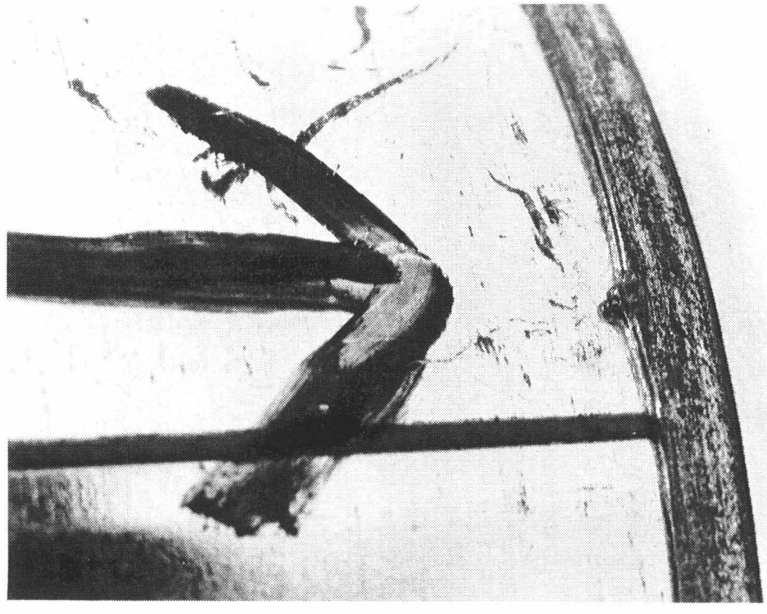


Figure 39. Seam Defects.

A droop at the crossover exceeding ½ the cover hook length should not be tolerated, immediate correction is mandatory. Similarly, slight droops in the seam at points away from the lap are undesirable, and corrections should be made to eliminate them.

Lip: An irregularity in a double seam showing as a sharp "V" projection below the normal seam (Fig. 39) is called a lip, or a "V" droop. If lips are observed during the inspection of double seams, the cause should be determined and corrections made.

Possible Causes of Droops and Lips:

1. First operation seam too loose.
2. Worn first operation roll groove.
3. Body hook too long.
4. Product trapped in seam.
5. Formation of can body out of shape.
6. Excessive amount or unequal distribution of end lining compound.

False Seam: A false seam is a seam or portion of a seam that is entirely unhooked and in which the folded cover hook is compressed against the folded body hook (Fig. 40). This is a serious defect that will cause leakage, and if it is repetitive must be corrected immediately. Sometimes the folded body hook does not project below the seam, and the false seam can then be detected only by very close inspection.

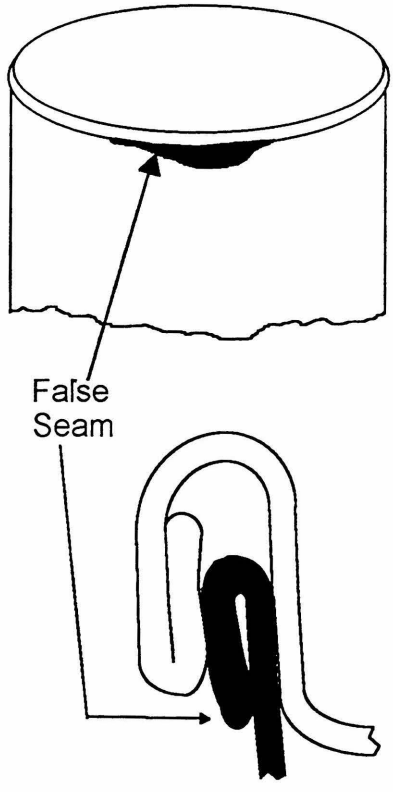


Figure 40. Seam Defects.

Possible Causes of False Seam:

1. Mushroomed can flange.
2. Bent can flange.
3. Damaged or bent cover curl.
4. Misassembly of can and cover.
5. Can not properly aligned at assembly.
6. Improperly filled can. Product extending over can flange.

Spinner (Slip, Skid, Dead Head): An incompletely rolled finished seam (Fig. 41) is known as a spinner, slip, skid, or dead head. Correction must be made immediately.

Possible Causes of Spinners:

1. Insufficient lifter pressure.
2. Improper end fit with chuck.
3. Worn seaming chuck.
4. Incorrect pin height setting. Chuck set too high in relation to lifter plate.
5. Seaming rolls binding.

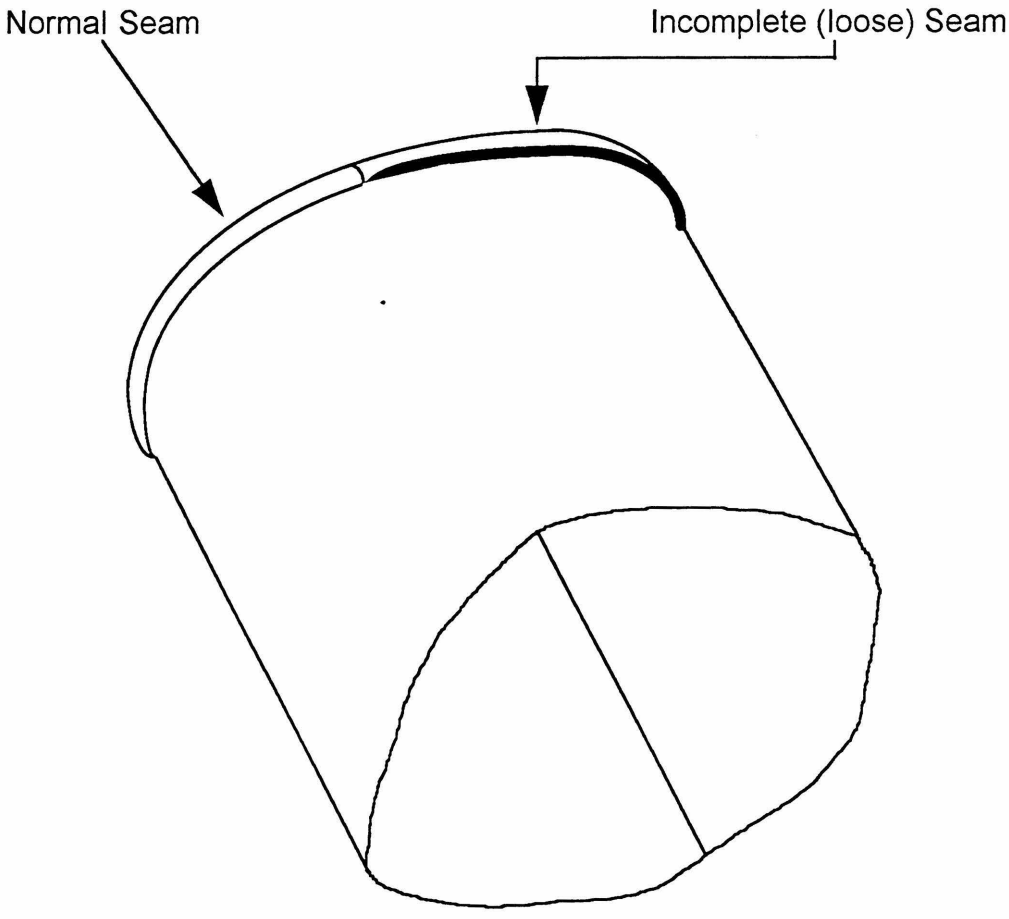


Figure 41. Seam Defects.

6. Oil or grease on seaming chuck or lifter.
7. Excessive vertical play of seaming chuck spindle.

Checklist: Recommended Daily Seamer Operating Procedures

Start-up:

1. Inspect seamer for extraneous debris or loose items in or around seamer.
2. Inspect cans and lids for damage.
3. Run seamer fully engaged for ten minutes prior to beginning production.
4. Run two sample cans for teardown, for vacuum or pressure micro-leak test, and to remove excess grease from header.

Production:

1. Fully evaluate the seam of one can every four operating hours.
2. Routinely monitor visual parameters, including external seam measurements and potential defects.
3. Seamer operator should continuously confirm that product does not lay over the top of body flanges.
4. Seamer operator should continually confirm that no damaged cans (especially dented flanges) are seamed.

End of day:

1. With machine running, hose down the interior and exterior of seamer.
2. Shut off seaming machine including main switch and grease with appropriate food grade lubricant.

External Seam Measurements

Following visual inspection of the external seam formation, the seam width, thickness, and countersink depth should be measured. These measurements and complete internal seam inspection should be made at least once every four operating hours. Complete inspection of the double seam should also be made on start-up, after a prolonged shut down, after a severe closing machine jam, and after a change in can size or body or end material. It is recommended that the width and thickness of the first operation seam be checked at least every forty operating hours or whenever an adjustment of the seaming rolls is required.

Seam measurements should be made at three points around the periphery of the can, at least ½ inch away from the crossover. The highest and lowest readings should be recorded. Average dimensions derived from two or more individual measurements should **not** be used.

A micrometer especially made for measuring double seams is shown in Figure 42. Care should be exercised that the micrometer is in proper adjustment. When the micrometer is set at zero position, the zero graduation on the moveable barrel should match exactly with the Index Line on the stationary member. If, for any reason, the zero adjustment is more than half a space from the Index Line at this setting, an adjustment should be made.

Seam Width (Height, Length)

To measure the seam width, hold the flat surface of the micrometer against the can body as shown in Figure 43 and turn the barrel until the entire seam is lightly trapped between the calipers.

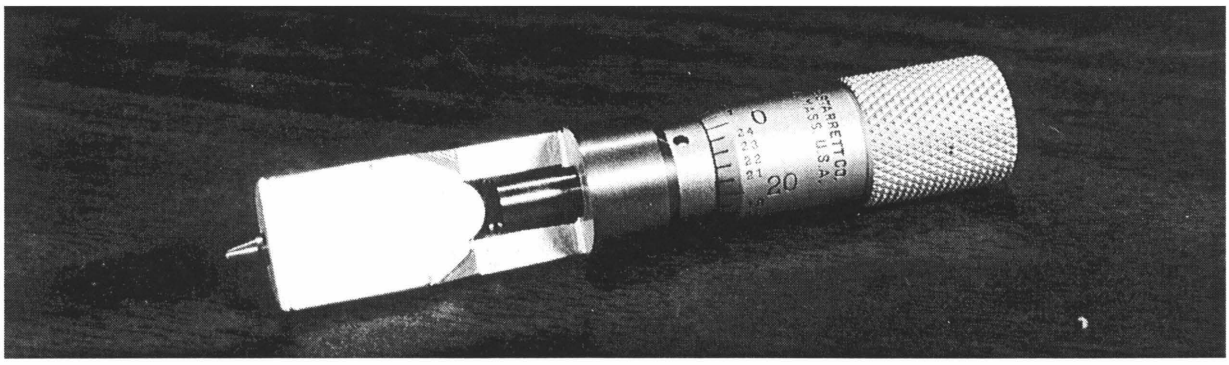


Figure 42.

Figure 43.

Seam Thickness

The thickness of the seam should be measured as illustrated in Figure 44. When taking the measurement, balance the micrometer with a finger immediately above the seam and turn the barrel until the anvil assumes the same angle as the taper of the countersink, when the calipers grip the seam.

Figure 44.

Countersink

The countersink or drop from top of the seam to the lid surface is an optional measurement but is useful and easily performed (Fig. 45).

Figure 45.

Inspection of Internal Seam

Judging the quality of the double seam formation involves both visual inspection of the torn-down seam as well as consideration of the dimensions of the various parts of the seam.

Allowances must be made for the variations due to normal differences in plate thickness and temper as well as in sealing compound weight and placement.

Internal seam evaluation and recording of seam measurements should be done at a minimum of once every four operating hours. As indicated in the preceding section, complete inspection of the double seam should always be made after prolonged shut downs, after severe closing machine jams, and after changes in can size or body or end materials.

First Operation Seam Formation

Figure 46 shows the appearance of a correct first operation seam in cross section away from the lap. Notice that the cover hook curves around against the inside of the body hook and the body hook is in contact with the flange of the end. The seam should be rounded at the bottom and in contact with the body of the can. Due to extra material in the seam at the lap of soldered cans, however, the first operation seam will be somewhat tighter at this point only and will show a slight flat at the bottom, as indicated in Figure 47.

If the first operation is too tight, the bottom of the seam will be slightly flattened through its length, as shown in Figure 48. If the seam is too loose, the cover hook will not be in contact with the can body, as shown in Figure 49.

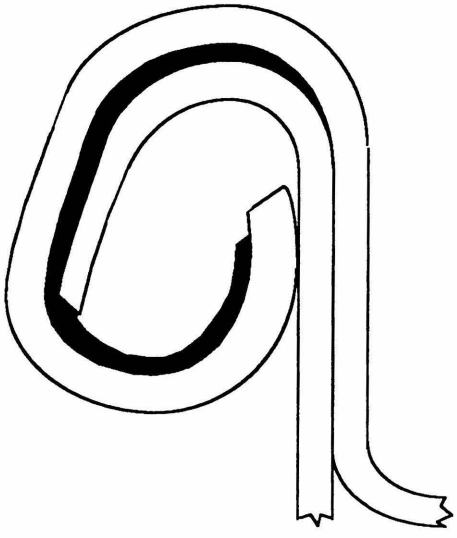


Figure 46. Correct First Operation.

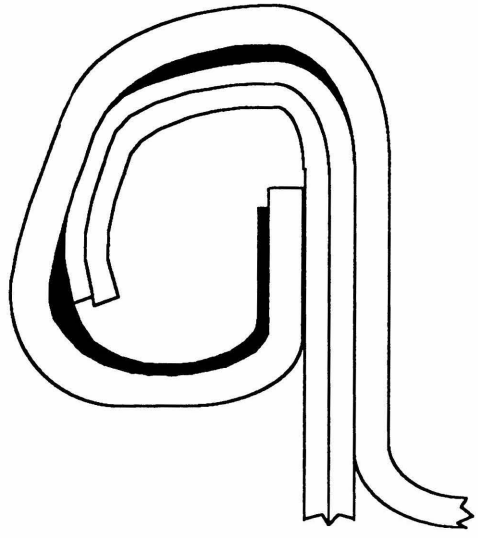


Figure 47. Correct First Operation at Crossover.

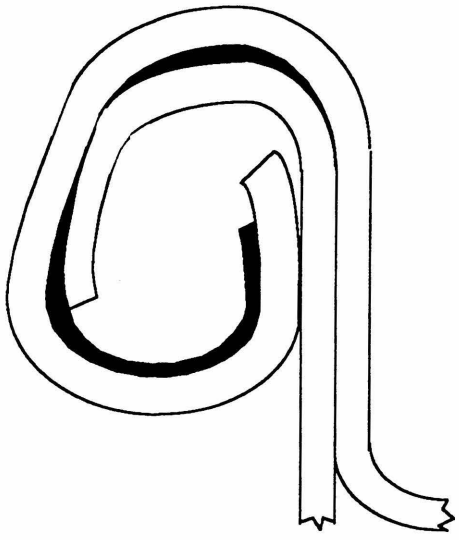


Figure 48. Tight First Operation.

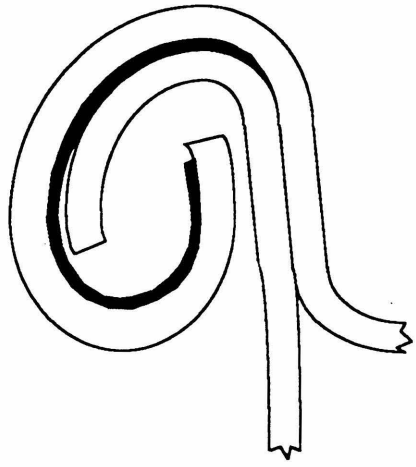


Figure 49. Loose First Operation.

Due to possible variations in end curl configurations, first operation thickness may vary. The ideal first operation thickness should be determined by sectioning the seam so the portion of the cover hook relative to the body hook may be noted (Figs. 46 and 47). The seam may be sectioned either by filing radially across the seam or by use of a seam saw.

Second Operation Seam Formation

The second operation roll groove flattens the seam and presses the folds together tightly enough to compress the sealing compound and cause it to fill the parts of the seam not occupied by metal. This compressed sealing compound is illustrated by the solid black area around the body and cover hooks in the well-formed seams shown in Figures 35 and 50.

Excessive pressure does not produce a good seam and may even produce a defective seam. Extreme tightness of the second operation roll will stretch the metal and cause an increase in the width and outside diameter of the seam. This tightness is also likely to produce slippage between the hooks, commonly called "unhooking," especially if the first operation rolls are set too loose or if they are excessively worn. Therefore, a seam which is rolled too tight is more likely to leak than is one made with proper pressure. Figure 51 illustrates an incorrect second operation seam, which could be partially unhooked at some points.

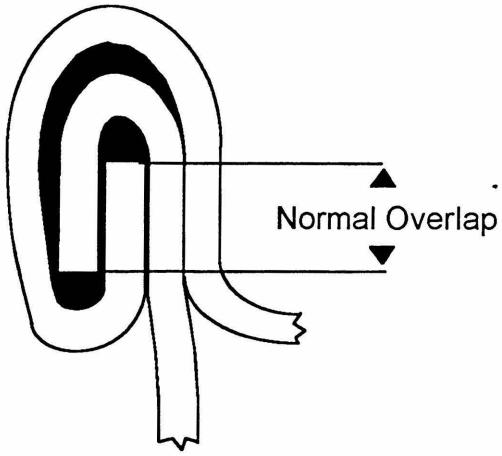


Figure 50. Normal double seam and overlap.

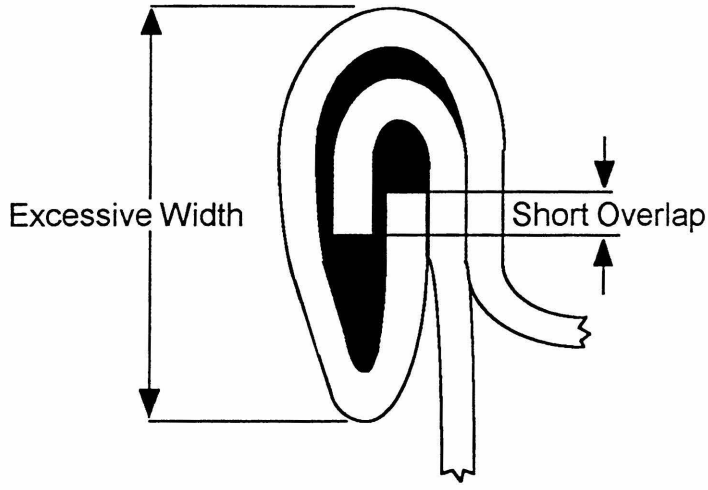


Figure 51. Wide or long double seam, short overlap.

The degree of interlock of the cover hook and the body hook is known as overlap (Fig. 50). The integrity of the double seam is dependent in large measure on the length of this overlap. Insufficient overlap may result in leakage, particularly at the crossover of a malformed seam, if the cover is then distorted due to internal pressure during filled can processing or when the double seam is disturbed due to rough handling.

Tearing Down the Double Seam for Inspection:

The method preferred by most evaluators is to separate the body and cover hook of the finished seam in the following manner:

1. Use can opener to cut out center section of cover approximately 3/8" from double seam (Fig. 52).
2. Use a nipper to remove remainder of the center cover (Fig. 53).
3. Cut through double seam about 1" from lap, as shown in Figure 54.
4. Remove stripped part of cover by gently tapping with nippers, taking care not to distort can body hook (Fig. 55).

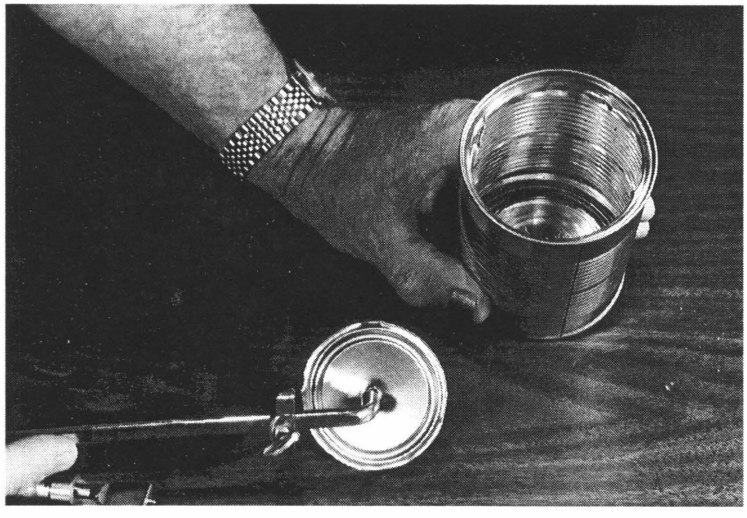


Figure 52. Use special seam evaluation opener to remove end of can.

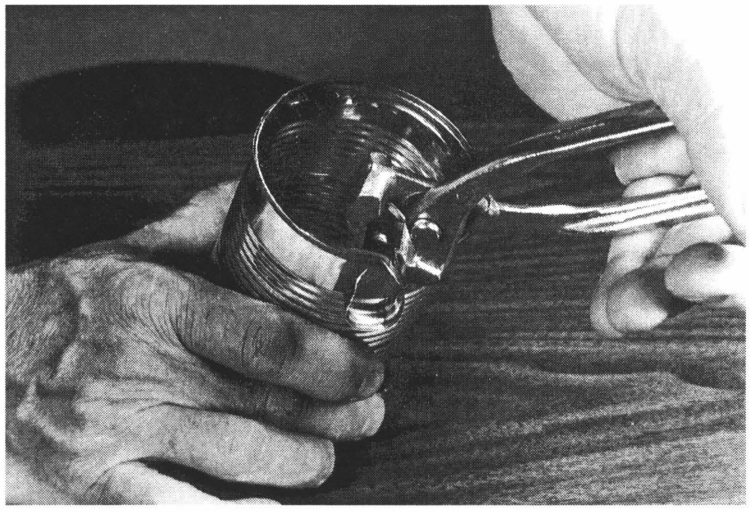


Figure 53. Tear remaining center cover with nippers without distorting seam.

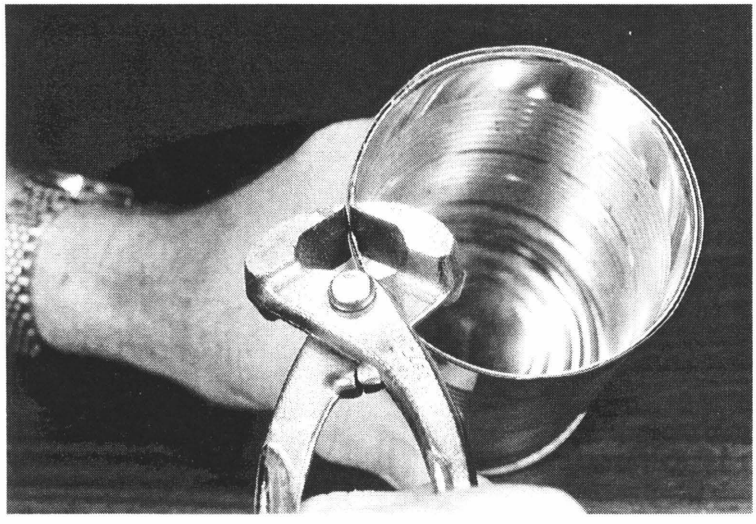


Figure 54. Cut through seam and can body.

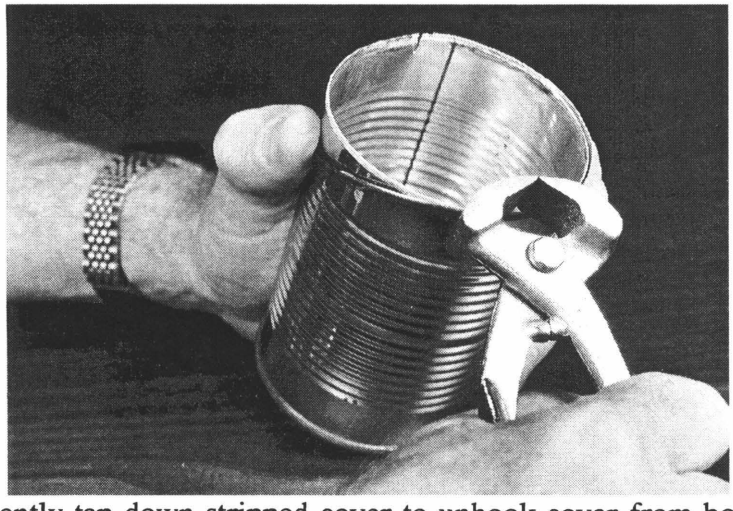


Figure 55. Gently tap down stripped cover to unhook cover from body.

Visual Inspection of Internal Seam

Visual inspection of internal seam formation should include examination for such seam defects as insufficient cover hook tightness, lack of evidence of a pressure ridge, jumped seam, excessive droop of the cover hook at the crossover, and body or end fractures. See Table 9 for causes of seam defects and likely solutions.

Cover Hook Tightness (Wrinkle) Rating

Seam tightness is judged primarily by seam thickness and the smoothness of the cover hook. Percent tightness is expressed in terms of how far the waves or wrinkles extend from the top edge of the cover hook toward the base of the cover hook. The percent tightness is determined by the largest wrinkles present.

Wrinkles or waves have three basic dimensions. **Height**, the distance the wrinkle extends from the top edge of the cover hook to where it fades out towards the base; **depth**, the amount the wrinkle projects out from the face of the cover hook; and **length**, the width or distance the wrinkle extends around the top edge of the cover hook. Since a wrinkle or wave is graded only by its height, it is important to note that a true looseness wrinkle has height, depth, and length. Often the profile of an ironed-out, first-operation wave with no depth will show on the face of the cover hook; this is incorrectly graded as a looseness wave.

When a wrinkle extends one-fourth of the length of the cover hook, the seam is rated 75% tight; when the wrinkle extends halfway, the seam is rated 50% tight; etc.

In hemming a straight edge of plate, no wrinkles are formed. On curved edges, wrinkling increases as the radius of curvature decreases. For this reason, different wrinkle ratings are specified for small diameter cans as compared to large diameter cans.

In small round cans, 300 diameter and under, it is important to note that ironed-out, first-operation folds should not be confused with true seam wrinkles. The ironed-out folds will be apparent only in tightly rolled seams.

Excessive sealing compound will sometimes cause impressions on the face of the cover hook, which cannot be ironed out. These should not be confused with looseness wrinkles. The presence of an unusual amount of compound on the face of the cover hook is usually evidence of heavy compound.

A heavy enamel coating on the cover hook may interfere with judging the tightness. If this occurs, the enamel may be removed to facilitate judgment.

Determining Tightness (Wrinkle) Rating

The tightness of a double seam is graded according to percentage figures. Figure 56 shows the cover hook with 0 to 100% tightness, with the formerly used "wrinkle number" shown below.

An experienced double seam inspector can tell a good deal about tightness by the flatness of the cover hook; that is, there should not be a rounded appearance to the cover hook. This observation can be made on a cover hook removed from a seam that has been sectioned with a seam saw (Fig. 57), or by observing cover hooks torndown by hand. Notice the heavily wrinkled and rounded cover hook at the top of Figure 58.

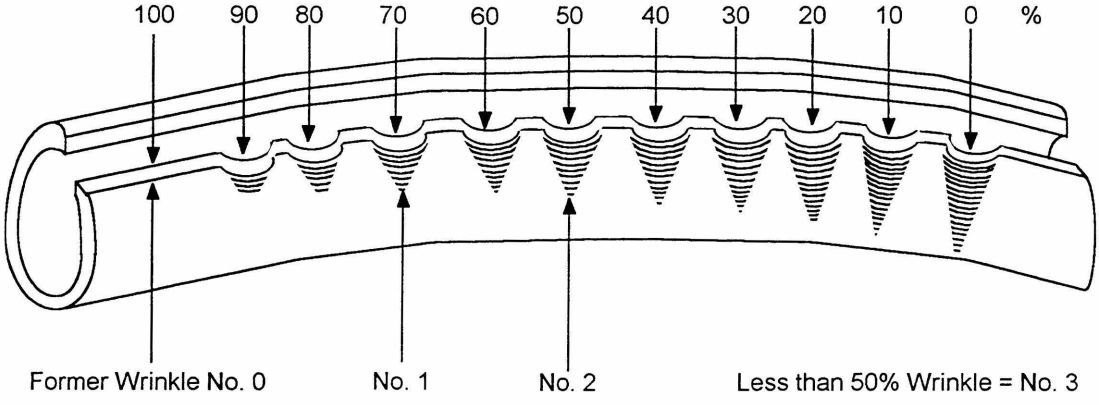


Figure 56. Tightness (wrinkle) rating in percent.

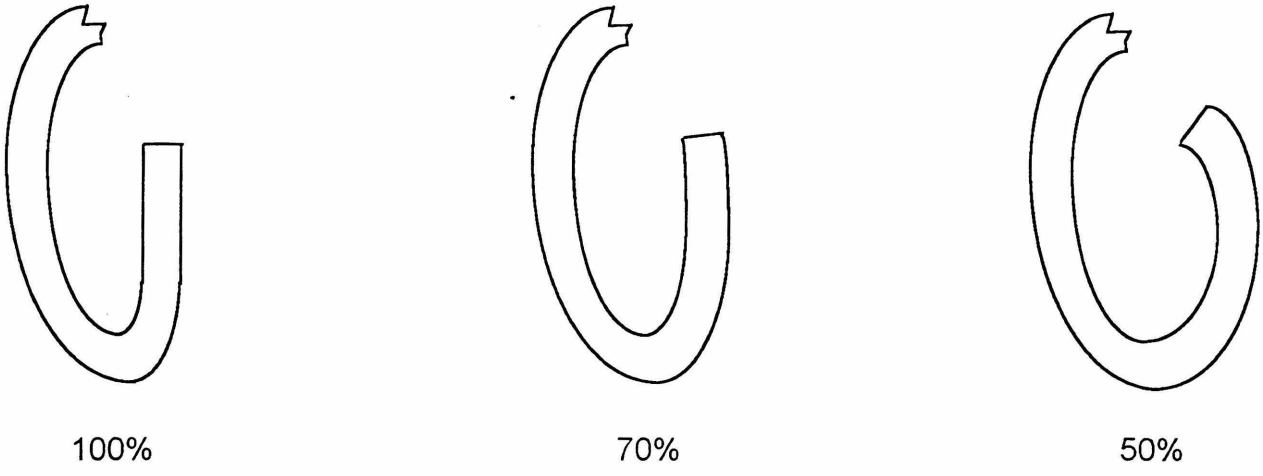


Figure 57. Cross-sectional appearance of cover hook corresponding to three wrinkle ratings.

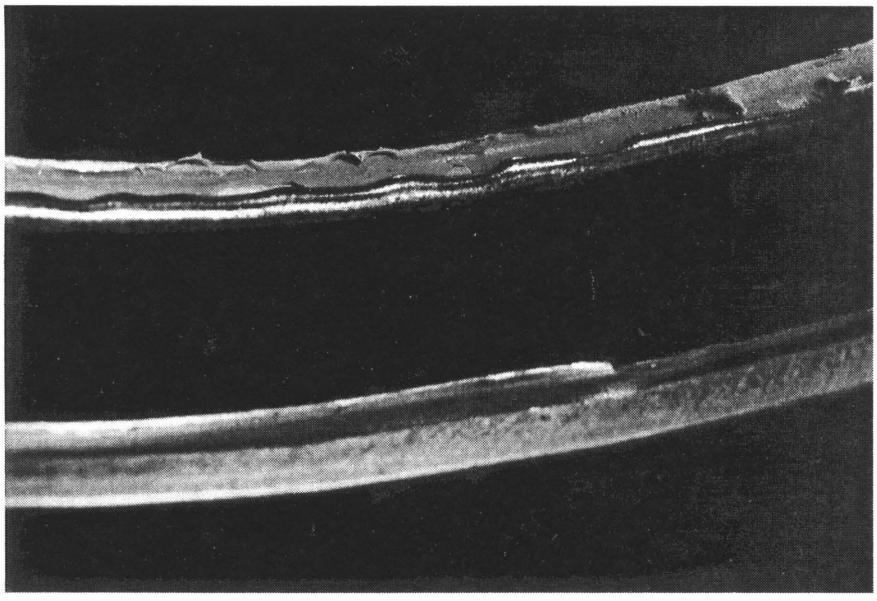


Figure 58. Stripped cover hooks from loose seam (top) and normal seam.

Pressure Ridge: The pressure ridge is formed on the inside of the can body in the double seam area as the result of the pressure applied by the seaming rolls during the seaming operation. The practice of visually inspecting this point in the torn-down can serves as an additional check on the tightness of the finished seam. The pressure ridge should appear as an impression around the complete inside periphery of the can body. An excessively deep pressure ridge should be avoided, particularly on inside enameled cans and cans with aluminum ends. It should, however, be present and visible.

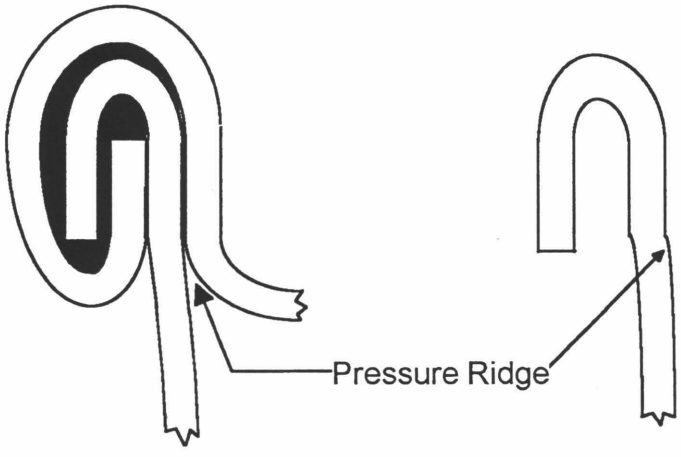


Figure 59. Location of pressure ridge.

Figure 59 shows a cross-section of the finished double seam and a cross-section of a stripped seam, illustrating the pressure ridge produced in making a good commercial seam.

Crossover Droops: The extra thickness at the lap of the side seam of a soldered can causes a normal slight deformation of the cover hook at this point.

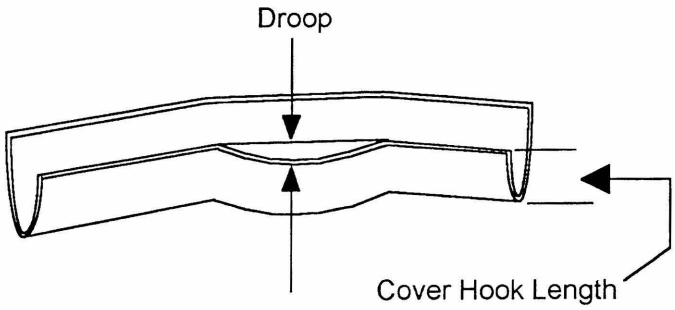


Figure 60. A droop on the cover hook.

Excessive droop at this point, exceeding ½ the cover hook length (Fig. 60), requires immediate correction.

Jumped Seam: For soldered cans, the most critical portion of the double seam is at the crossover, the juncture with the side seam. The cover hook immediately to either side of the crossover should be examined for looseness indicative of a jumped seam (Fig. 61). A jumped seam is a double seam that is not rolled tight enough adjacent to the crossover; it is caused by jumping of the seaming rolls after passing over the lap. Thus, the location of a jumped seam wrinkle in relation to the crossover will depend on the direction of rotation of the seaming rolls.

Possible Causes of Jumped Seam

1. Operation of closing machine at excessive speed.
2. Sluggish-acting, second-operation seaming-roll cushion spring.
3. Second operation seaming roll cushioning too weak.
4. Broken cushion spring.
5. Can lap too thick at double seam area.

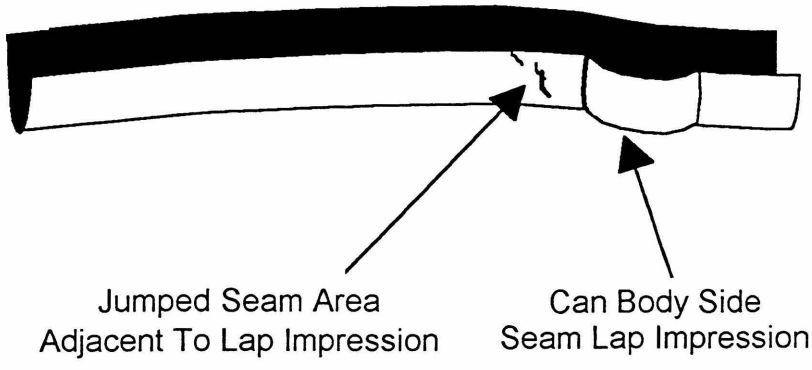


Figure 61. View of coverhook at the crossover (lap) of soldered can.

Internal Seam Measurements

The cans that have been previously measured for external seam dimensions, torn down, and visually inspected should be measured for body hook length and cover hook length. Optical projection and inspection of a cross-section of the seam at one point cannot be substituted for measurement of the body and cover hooks at several points around the seam. As indicated under "External Seam Measurements," measurements should be made at a minimum of three points around the periphery of the can, at least ½ inch away from the crossover. The highest and lowest readings should be recorded. Average dimensions, derived from two or more individual measurements, should not be used. This topic is discussed in more detail in the following section.

Double Seam Evaluation: Daily Testing and Records

Good double seams are essential in insuring against spoilage from leakage and the ingress of oxygen, which result in internal corrosion and product deterioration. The best safeguards against improperly constructed double seams are

1. regular inspections by a qualified person using approved methods, and
2. the operation of the closing machines without deviation from the instructions given by the can companies.

Examination of Cans Prior to Use

Metal-can seam evaluation involves more than tear-down inspection of final seams. It includes careful handling and inspection of cans and lids prior to closing. Make certain that lid and body flanges are undamaged, that no sharp burrs are present on body flange edges, and that lids delivered from the manufacturer contain uniform distribution of sealing compound in the seam area. Bent or burr-edged body flanges are particularly serious defects when a tinplate can body is fitted with an aluminum lid, since the body hook may crack the more brittle cover hook. Dented body flanges can sometimes be straightened with a special crimping tool designed for this purpose.

When lids are stored, the sealing compound tends to become hard over time and is less likely to compensate for slightly malformed double seams. This compound is the glue that keeps out bacteria. When cans are closed with lids containing good, fresh sealing compound, the compound will look and feel tacky (gummy) during manual seam tear-down inspection. Store lids in cool, dry storage.

Double Seam Evaluation

When significant seam defects are noted, closing machine adjustments should be made immediately, and all corrective actions recorded. The following is a recommended schedule for the examination of can seams:

1. **Visual Examination:** During regular production runs, a constant watch should be maintained for gross maladjustments such as deadheads, cut-overs, and other similar double seam defects. Maintaining this constant check may be accomplished in several ways, depending on the type of closing machine, line speeds, and general equipment layout. It may best be performed by training the closing machine operator to recognize irregularities by visual examination. However, an adequate check program can be maintained through use of other trained personnel. The operator, can closure supervisor, or other qualified person should visually examine, at intervals of not more than 30 minutes of operation, the top seam of a randomly selected can from each seaming station, and should record his/her observations. Additional visual seam inspections should be made immediately after a can-jam in a closing machine, or after startup of a machine following a prolonged shutdown. If irregularities are found, the action taken should be noted.

2. **Tear-Down Examination:** Tear-down examinations should be made at a frequency of at least 1 can per seaming station every 4 hours of operation or each major fraction thereof. Such examinations should be made as soon as possible after starting up following a shutdown, waiting only long enough for the machine to "warm-up." Cans for visual inspection should be taken during this warm-up period. The results of the tear-down examinations should be recorded.

3. **General Observations:** Following are some of the many factors that influence double seam quality:
   a. condition of the seaming equipment: whether or not the mechanical operation and adjustment of the closing machine give the proper seam contours.
   b. can materials: variations in tinplate thickness.
   c. can size: roll contours change with can size to accommodate variations in plate thickness.

   Other pertinent observations should be recorded, indicating the presence or absence of such defects as cut-overs, droops, etc.

Regardless of whether or not a seam scope or seam projector is used, the double seam should be torn down for examination. Tools required for seam examinations are available from the can suppliers as well as from other sources.

Two measurements should be made for each double seam characteristic if a seam scope or seam projector is used. If a micrometer is used, 3 measurements should be made at points approximately 120° apart, beginning 1/2 inch from the side seam. The high and low measurements must fall within limits considered to be normal for the conditions.

Table 7. Essential and Optional Seam Measurements

Measurement	Method
Essential	
Body Hook	Scope or Micrometer (preferred)
Cover Hook	Scope or Micrometer (preferred)
Overlap	Scope
Length (Width)	Scope or Micrometer
Thickness	Micrometer
Tightness / Wrinkle	Visual Observation
Optional	
Overlap (by calculation)	Micrometer
Countersink	Micrometer

With regard to measurements, the canner should follow the specifications recommended by the can supplier.

Overlap length (Fig. 62) can be calculated by the following formula when a scope is not available:

Theoretical Overlap length = CH + BH + T - W

Where CH = cover hook

BH = body hook

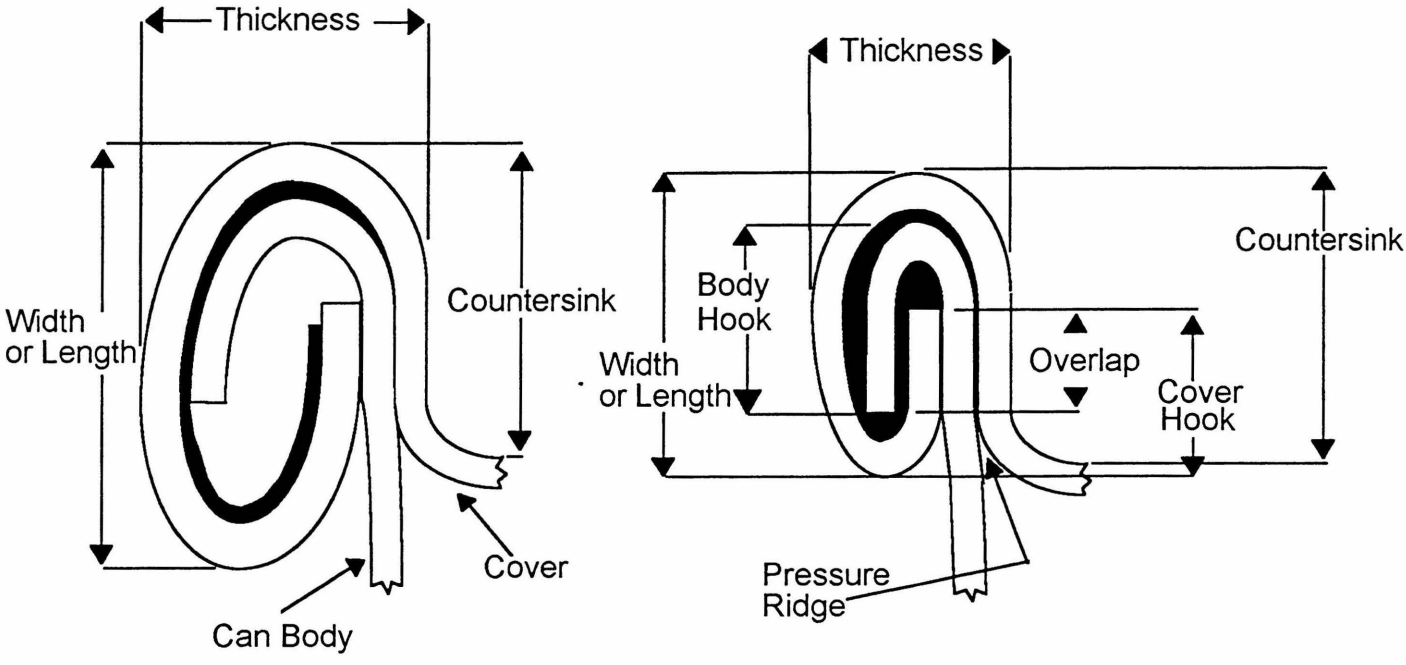
T** = cover thickness, and

W = seam width

(These are micrometer measurements, usually)

Figure 62 is a cutaway diagram of a double seam, showing the measurements to be made and the terminology for the measurements. The completed seam (second operation) diagram should be displayed in the plant area where seams are to be examined. The formula for calculating the overlap length is listed as well.

**In general practice .012 may be used for the aluminum thickness and .010 for tinplate.



First Operation

Second Operation

Minimum Measurements

Width* (not essential if overlap is measured optically)
Thickness (desirable but not essential)
Countersink (desirable but not essential)
Body hook*
Cover hook* (required if micrometer is used)
Overlap* (essential if optical system is used)
Tightness* or wrinkle

*Essential Requirements

Calculation of Overlap Length

Overlap length = CH + BH + T - W
Where CH = cover hook
BH = body hook
T** = cover thickness, and
W = seam width

** In general practice 0.010 may be used for tin plate thickness and 0.012 when aluminum lids are used.

Figure 62. Seam features commonly measured.

An example of a recommended form is shown in Figure 63. It should meet recognized recordkeeping requirements. Such forms should be modified as necessary to meet the needs of individual companies and must be appropriate for each container used.

Stripping Seams for Inspection and Measurement

Some examiners strip the entire seam, while others find it preferable to leave about one inch of the double seam opposite the side seam undisturbed. In the latter case, the cover is left hinged to the unstripped portion of the double seam. This method of stripping has the following advantages:

1. The coded top and cover hook portion of the seam stay fixed to the can, assuring accurate identification of the entire container in case it is to be inspected by the can company servicemen or interested cannery personnel.
2. It permits measurement of both hooks four points apart (90°), or at three points (120°) apart, either of which is usually considered satisfactory.
3. It permits good visual inspection of the cover hook.
4. It permits inspection and measurement of the undisturbed outside portion of the double seam.
5. It permits filing a notch through the undisturbed portion of the double seam to see if can and cover hook are properly abutted.

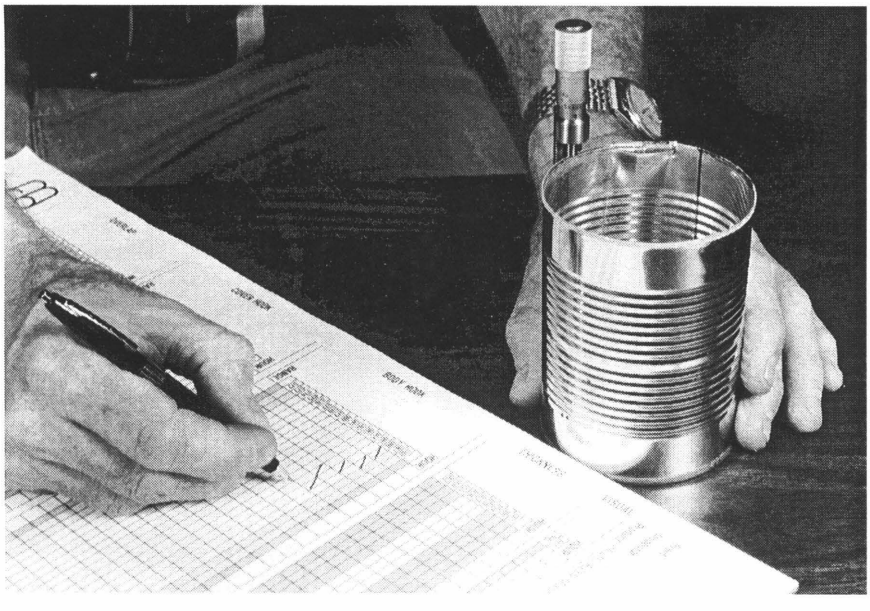


Figure 63. Recording seam measurements on a form.

The most convenient tools for stripping seams are:

1. a can opener (Fig. 64) with a point on the end to pierce the center of the cover and act as a fulcrum, equipped with an adjustable slide cutter to make a circular cut in the cover leaving 3/8 to 1/2 inch strip attached to the seam; or a set of "Airplane" left-hand snips (for example, the Wiss 8 in.) which are easily handled when cutting the top out of the can
2. a pair of 6-inch end nippers for tearing the seam apart (Fig. 64)
3. a hook gauge (or can seam micrometer) for measuring the can hooks (Fig. 65)
4. a pocket size magnifying glass or seam scope (projector) for close inspection of seams (Fig. 66)
5. a seam saw for use with seam projectors (Fig. 67)

Seam specifications differ depending on the can size and the manufacturer. It is not possible, therefore, to list measurements that would apply in all cases and for all sizes of cans. For this reason it is recommended that double seam specifications be obtained from the can supplier. There are, however, the following fundamental characteristics of a double seam:

1. There should be little or no "cut-over," which may cause cans to leak (caused by tinplate being rolled over the chuck).
2. Double seams should not be rolled so tightly that they become distorted and stretched. An otherwise good double seam can be destroyed by rolling it too tightly.
3. Body and cover hooks should be about the same height and kept within a specified tolerance range.
4. A good seam is one in which the first operation has been rolled just tightly enough to produce the desired length of body and cover hooks, and the second operation tightly enough to iron out the wrinkles in the cover hook without stretching the metal. A wrinkle is the degree of waviness occurring in a cover hook. Wrinkles are classified either by percent tightness or by number as follows (Fig. 56):
    0. Smooth, no wrinkles.
    1. Slight wrinkle. Wrinkles up to 1/3 distance from edge.
    2. Somewhat heavier wrinkle. Wrinkles up to 1/2 distance from edge.
    3. Large wrinkle. Wrinkles more than 1/2 distance from edge.

Figure 64. Tools commonly used to tear-down and measure double seams.

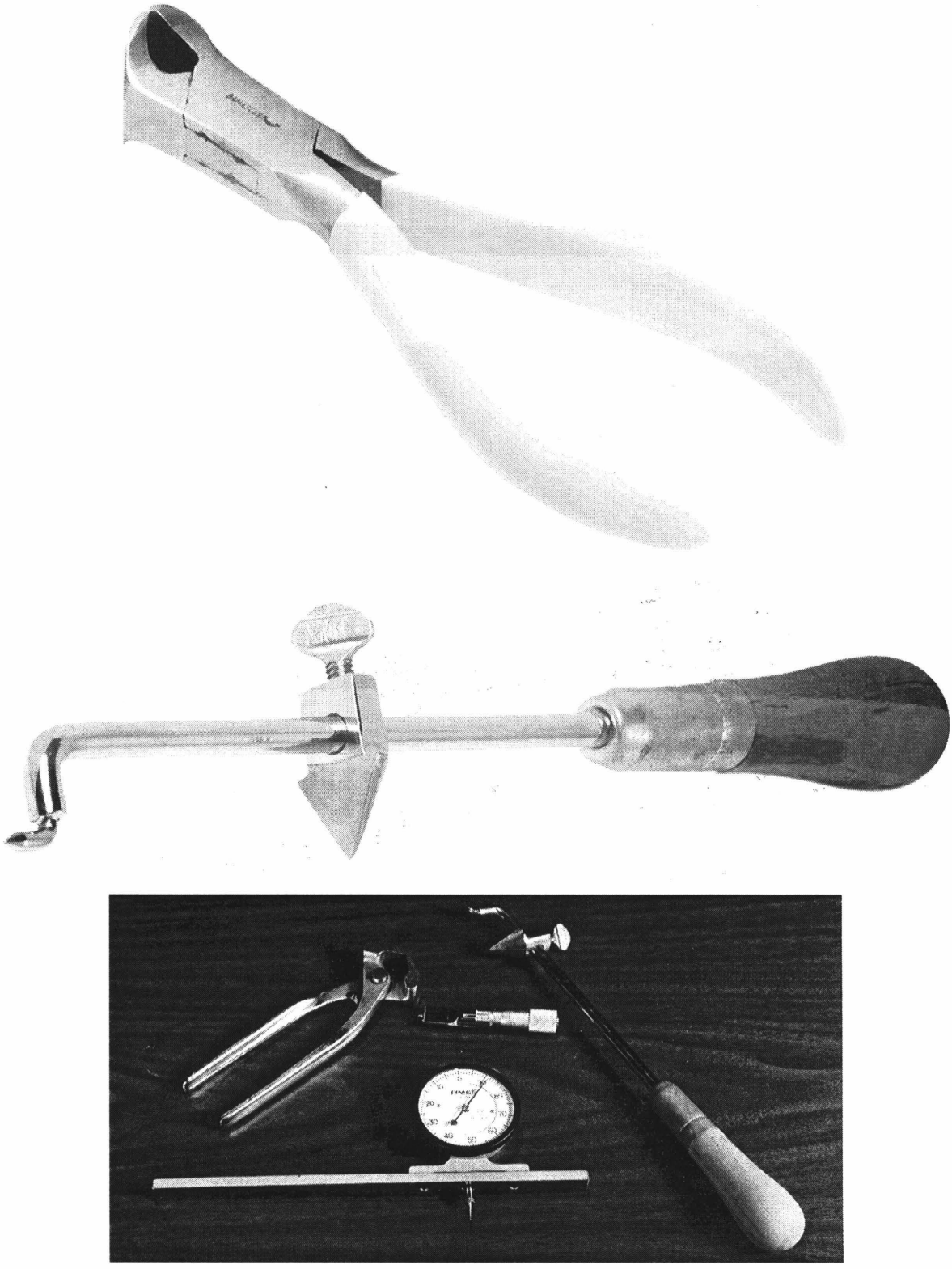
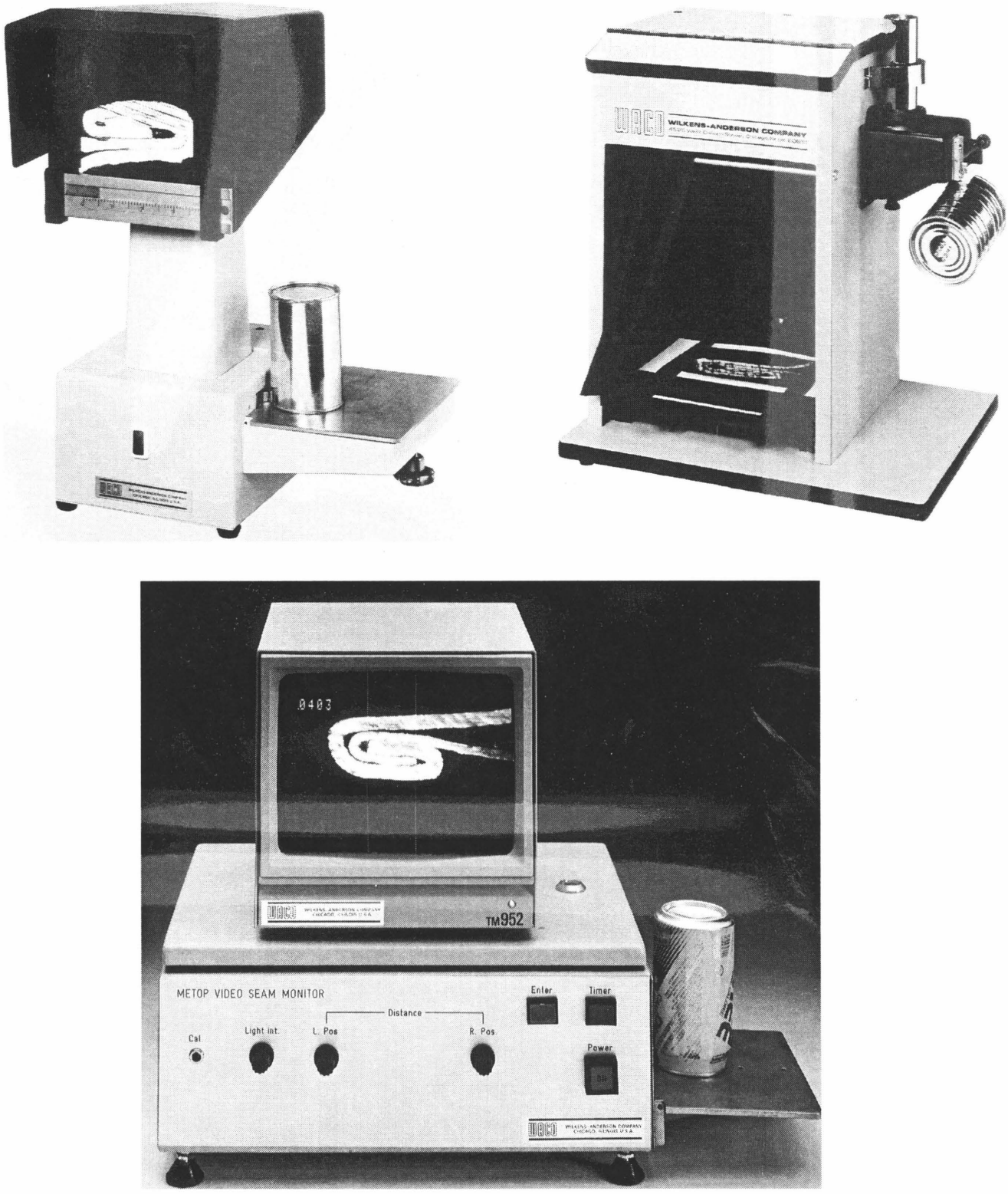


Figure 65. Use of a can seam micrometer to measure hooks.

Figure 66. Seam Scopes.



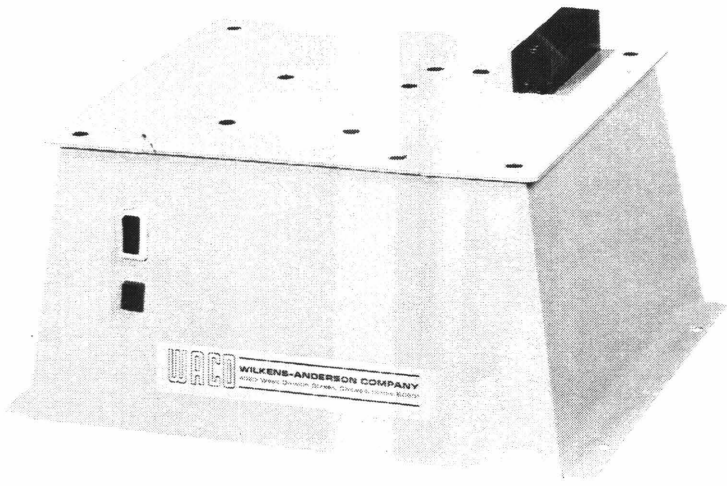


Figure 67. Seam saw used for sectioning double seams.

In 307 diameter cans having wet seams, consistent No. 0 wrinkles indicate that the seams are on the tight side and should be adjusted to produce wrinkles not greater than No. 1. No. 2 wrinkle is the borderline between a satisfactory and unsatisfactory seam, and when the wrinkles in the double seam approach this point the seam should be tightened. No. 3 wrinkles indicate a loose seam likely to give trouble.

It is important to note that, in small cans under 307 diameter, ironed-out first-operation folds should not be confused with the normal wrinkle. Typical seam specifications for 401 x 301 cans are given in Table 8.

Table 8. Example Seam Dimensions for Steel 401 x 301 Can

(Dimensions in Inches)

	Aluminum End	**Tinplate End 85 lb.**
Thickness	.060 +- .002	.056 - .058
Width / Length	.125 max.	.115 - .125
Body Hook	.080 +- .008	.080 +- .008
Cover Hook	.080 +- .008	.080 +- .008
Overlap	.045 MIN	.045 MIN
Tightness	80 - 100%	75 - 100%

Testing Cans for Leakage

Detection of can leaks is an important, but often difficult, task in the study of spoilage. The pressure test is the method most generally used, although others have been suggested. Pressure is applied by various means.

One apparatus consists of two metal plates faced with rubber and held together by screw clamps. One plate has a pipe connection to the center for the admission of air. With this equipment the opened can should be against the gasket to which the air line is connected. This assembly is then immersed in water and the air turned on. Leaks are detected by air bubbles. Care should be taken to obtain a good seal against the rubber, especially if the double seam is at all irregular, because air leaks between the rubber and the double seam make it difficult to see seam leaks.

Another method for pressure testing cans is to cut a small hole in the end of the can just large enough to remove the contents using an adjustable slide opener. Remove the can contents, wash out the can, and dry in an incubator or warm oven. Solder a piece of metal over the hole. Puncture the can and make a hole just large enough to insert a piece of metal tubing. Solder the metal tube into the can and connect to an air pressure line. (An alternative is to solder over the hole a solderhemmed cap, and, through the center of this, attach a special apparatus having a hollow triangular spur, a sealing clamp, and attached pressure gauge.) Immerse the can in water and turn on the air pressure. A maximum pressure of 20 psi is recommended. The pressure should be increased from zero in stages and the can observed for leaks at each stage. A leak will be indicated by the formation of air bubbles. This procedure cannot be used when the entire can end has been removed.

One objection to these methods is that can leakage normally occurs from the outside in, and the use of internal pressure may produce or indicate leaks that would not occur in a normal can under slight vacuum. On the other hand, leaks that would occur under vacuum may be obscured. To obtain results more comparable to those that may occur naturally, a leak detector employing vacuum has been developed by Bee and Denny, similar to that shown in Figure 33.

Alternative Packaging: Special Considerations

Flexible Pouches and Bags

Some seafood processors pasteurize in pouches, bags, or tubes (casing) designed to withstand the temperatures and stresses encountered in a heat processed, refrigerated, or frozen product. By definition, a pouch possesses seals on all four sides when closed: three side seals formed by the pouch manufacturer and a head seal formed by the processor after

filling. Bags usually possess only one distinct seal: the head seal. Tube casing materials and certain bags are closed with a clip.

Pouches may consist of a foil and plastic film laminate (these are opaque) or contain two or more types of plastic film, e.g. polyethylene and polypropylene formulations. Bags may be composed of several plastic materials coextruded into a single film layer. These materials provide numerous properties, including durability, puncture and stretch resistance, shrink control, seal strength, and the barrier levels desired for transmission of water vapor, oxygen, and other gases.

Heating and cooling rates (and corresponding process lethalities) of product in flexible packaging is very sensitive to package thickness and vacuum level. See Appendix III for a brief example operations protocol for moderate thermal processing in pouches.

Testing Methods for Plastic Packaging

The National Food Processors Association established a national committee of industry leaders to develop standards for the evaluation of flexible packaging. The Flexible Package Integrity Committee sets guidelines for the production and testing of:

1. paperboard packages
2. flexible pouch packages
3. plastic cans with heat sealed lids
4. plastic cans with double seamed metal ends.

For a copy of their complete set of guidelines or for an informative color poster (prepared jointly with FDA) contact:

National Food Processors Association
1401 New York Avenue, N.W.
Washington, D.C. 20005
202-639-5900

(Request publication 41-L, Flexible Package Integrity Bulletin)

Refer to Appendix III for examples of in-plant test procedures for pouch integrity. Inexpensive hand pump-up devices are also available for strength testing of plastics. The manufacturers of flexible and semi-rigid containers establish seamer/sealer set-up specifications for their packaging. These procedures should be incorporated into each plant's quality assurance and record-keeping programs.

Table 9. Causes and Solutions to Common Double Seam Defects

Possible Causes	Possible Solutions
DROOPS	
1. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed for can size.
2. First seam roll operation too loose.	Tighten first seam roll operation.
3. Food trapped in seam.	Clean can edge carefully before seaming.
4. Defective cans (bent or dented).	Inspect cans for damage before using.
5. First seam roll worn.	Replace seam roll.
VEE	
1. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed
2. First Seam roll operation too loose.	Tighten first seam roll operation.
3. Food trapped in seam.	Clean can edge carefully before seaming.
4. First seam roll operation too tight.	Loosen first seam roll operation.
5. First seam roll worn.	Replace seam roll.
SHARP SEAM AND CUTOVER	
1. First or second seam roll operation too tight.	Loosen first and/or second seam roll operations.
2. Food trapped in seam.	Clean can edge carefully before seaming.
3. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed for can size.
4. Worn seam rolls and/or chuck.	Replace seam rolls and/or chuck.
CUT SEAM	
1. First and second seam roll operations too tight.	Loosen first and second seam roll operations.
INCOMPLETE SEAM	
1. Baseplate pressure too high or too low.	Check sealer instructions for number of spacers needed for can size.
2. Worn seaming chuck.	Replace chuck.
Seam rollers not rotating freely.	Clean, oil, or repair seam rollers so they rotate freely.

3. Oil or grease on seaming chuck turntable.	Clean seaming chuck and/or turntable.

FALSE SEAM

1. Bent or damaged lid or can edges.	Inspect cans and lids for damage before using.
2. Food trapped in seam and/or can overfilled.	Clean can edge carefully before seaming. Check fill of can.
3. First seam roll operation loose.	Tighten first seam roll operations.
4. Second seam roll operation too tight.	Loosen second seam roll operation.

LOOSE THICKNESS (seam too loose)

1. Second seam roll operation too loose.	Tighten second seam roll operation.

TIGHT THICKNESS (seam too tight)

1. Second seam roll operation too tight.	Loosen second seam roll operation.

LONG SEAM WIDTH

1. First seam roll operation too loose.	Tighten first seam roll operation.
2. Second seam roll operation too tight.	Loosen second seam roll operation.
3. Worn seam rolls.	Replace seam rolls.

SHORT SEAM WIDTH

1. Second seam roll operation too loose.	Tighten second seam operation.
2. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed for can size.

DEEP COUNTERSINK

1. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed for can size.
2. Incorrect chuck for can size being sealed.	Check sealer instructions for correct chuck size.

SHALLOW COUNTERSINK

1. Baseplate pressure too low.	Increase turntable pressure. Check number of spacers needed for can size.
2. Chuck worn.	Replace chuck.

LONG BODY HOOK (Fig. 68)

1. Baseplate pressure too great.	Decrease baseplate pressure.
2. Incorrect pin height setting.	Check number of spacers or pin height needed for can size.
3. Seaming chuck too low in relation to baseplate.	
4. Mushroomed can flange (misshapen curl).	Check can flanges for uniform shape prior to filling.

SHORT BODY HOOK (Fig. 69)

1. Baseplate pressure too low.	Increase baseplate pressure. Check number of spacers or pin height needed for can size.
2. Incorrect pin height setting.	
3. Seaming chuck too high in relation to baseplate.	
4. First seam roll operation too tight.	Loosen first seam roll operation.
5. Second seam roll operation too loose.	Tighten second seam roll operation.
6. Improperly formed can flange.	Check can flanges for uniform shape prior to filling.

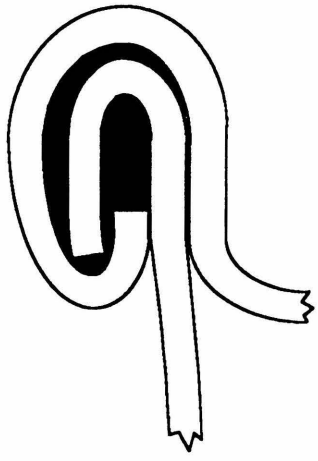


Figure 68. Long body hook.

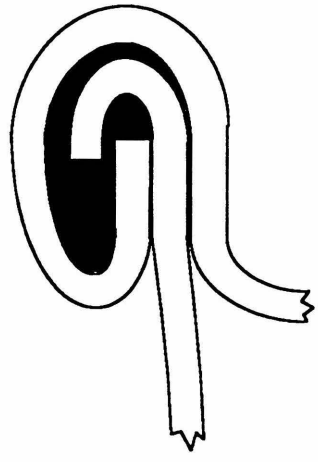


Figure 69. Short body hook.

LONG COVER HOOK (Fig. 70)

1. First seam roll operation too tight.	Loosen first operation seam roll.
2. Baseplate pressure too low.	Increase baseplate pressure. Check number of spacers needed for can size.

SHORT COVER HOOK (Fig. 71)

1. First seam roll operation too loose.	Tighten first operation seam roll.
2. Baseplate pressure too great.	Decrease baseplate pressure. Check number of spacers needed for can size.
3. First seam roll worn.	Replace seam rolls.

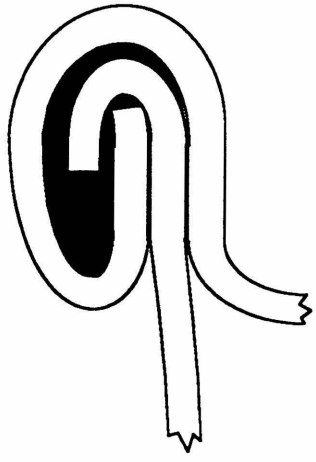


Figure 70. Long coverhook.

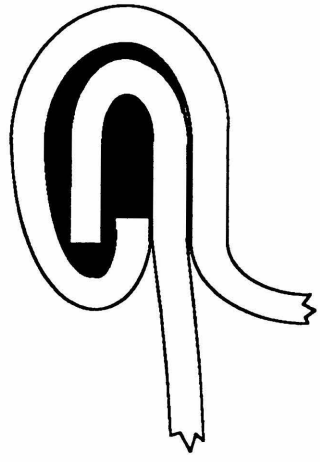


Figure 71. Short coverhook.

SHORT OVERLAP (Fig. 51)

1. Damaged can or lid edges.	Inspect cans and lids for damage before use.
2. First seam roll operation too tight.	Loosen first operation seam roll.
3. Baseplate pressure too low.	Increase baseplate pressure. Check number of spacers needed for can size.

LOOSE (pronounced) WRINKLE

1. Second seam roll too loose.	Tighten second operation seam roll.

TIGHT (no) WRINKLE

1. Second seam roll too tight.	Loosen second operation seam roll.

PRESSURE RIDGE NOT PRESENT	
1. Second seam roll operation too loose.	Tighten second seam roll operation.
2. Baseplate pressure too low.	Increase baseplate pressure. Check number of spacers needed for can size.
LOW VACUUM	
1. Cans not exhausted or food is cold before attaching lid.	Check canning instructions for exhausting and hot packing methods used with cans.
2. Incipient microbial growth.	Pasteurize soon after seaming.
3. Too little headspace in filled can (rare in crabmeat).	Check canning instructions for correct amount of headspace.
HIGH VACUUM	
1. Too much headspace in filled can.	Check canning instructions for correct amount of headspace.

Can Handling

The condition of a metal can or glass food container is of concern both when it is empty and when it is filled and sealed. In the case of the empty container, the principal concerns are the prevention of contamination with extraneous material and physical damage that may interfere with container integrity.

Empty Can Handling

Tin and glass containers are usually purchased, although a few of the larger canners manufacture their own cans. Glass containers are delivered to the cannery in boxes or, less frequently, palletized. Cans are received either loose, bagged, or palletized. Loose cans usually arrive at the cannery in freight cars or trucks. At every step of can off-loading, transfer, storage, washing, etc., employees should be instructed in the importance of careful handling procedures. Damaged containers, particularly dented body flanges, may not seal properly. Scratched can enamels may lead to crabmeat bluing problems or be unsightly.

Cans are transferred to the cannery on runways which lead directly to the fillers or to the storage loft. The runways outside the factory should be covered to prevent foreign objects from falling, being thrown, or kicked into the open cans. Inside the factory the can runways should be covered at any point where they pass under catwalks, dripping pipe lines, unprotected light fixtures, and so forth. Where the runways pass through floors, a protective metal collar should be placed around the runways at floor level to keep out floor dirt. When

empty cans are stored in lofts, the tiers of cans closest to the floor should be protected with paper or cardboard to prevent objects from being kicked or swept into the cans.

When cans are received bagged, care should be exercised to prevent breaking of the bags prior to use. Bags of cans should be opened only as needed, and partial bags should be covered until the next use. Some canners use plastic covers for this purpose. Where cans are bright palletized and fed automatically into the can liners, cardboard separators should be left over the top of the open cans until they are fed into the distributing unit. Some canners also use plastic covers for palletized cans awaiting use. At the end of the day's operation all cans beyond the can washer or invertor should be removed from the can track, to prevent can contamination during the clean-up and shut-down period.

Cans should be used for food and food only. This must be a hard and fast rule if product contamination is to be avoided. Occasionally, maintenance men use cans as containers for nails, bolts, electrical supplies, and cleaning compounds, and workers on canning lines have been known to make them repositories for watches, jewelry, and other personal belongings. In addition, cans have been used for measuring ingredients, oils, and other materials. The possibility exists that these dirty cans may find their way into the packing lines without being emptied or washed. In one case several dollars in cash allegedly were found in a can with the product.

Container Washing

Some, though not all, canners have units installed in the empty-can handling lines that are referred to as can washers. These are either commercial or homemade and of various designs. All of them have their faults, and canners do not regard them as completely satisfactory. Some state regulatory agents have recommended steam injection of the empty container as a cleaning procedure.

The National Food Processors Association employed an experimental procedure in an attempt to evaluate in the laboratory the efficiencies of can washing methods. In brief, the procedure consisted of dying a mixed microbial contaminant and adding a measured quantity of the dyed contamination to the cans to be tested. The intensity of the dye was measured before and after the can washer as an index of remaining contamination. The amount of dye reduction is a rough measure of the efficiency of the washing procedure. The results indicated that only one living spore remained for each 100 grams of food. The time to reduce the survivors by 90% (the decimal reduction time [D-value]) was $D_{240}=1$ minute.

Preliminary tests indicate that hot water cleans more efficiently than cold water, cold water more efficiently than steam, and steam more efficiently than air blast. However, steam has a tendency to paste larger particles of contamination to the can rather than remove them.

While water at 170-180°F under 60 to 70 pounds of nozzle pressure will do a good cleaning job under laboratory conditions, the commercial application of this procedure presents serious economic and engineering problems.

In the case of glass containers, suitable jar washers are available especially for baby food jars. Alternate air blasts and vacuum have been used successfully in cleaning glass containers. Glass containers also have the advantage that they can be observed as they pass an inspection point and defects or extraneous material can be detected.

Containers should be rinsed or dipped with an approved sanitizer (most often chlorine) and drained immediately prior to filling with product.

SECTION 6.

General Recordkeeping Requirements

In regard to most processors' attitudes on recordkeeping, it would be accurate to say that no one likes recordkeeping and no one really wants to be burdened with it. Many processors see no real need for or benefit of any additional recordkeeping. Regardless, it appears that some additional recordkeeping is essential and may be required in the not too distant future. This section discusses requirements which agencies such as the Food and Drug Administration impose on other food industries. Similar requirements may be forced on the pasteurized crabmeat industry in the future. Bear in mind that, while some or all of the suggestions discussed here may not be specifically required by state or federal authorities, the rationale behind them often justifies voluntary implementation by processors.

Process Documentation

The Tri-State recommendations and the revised recommendations of the National Blue Crab Industry Association Standards Committee suggest the use of recording and indicating thermometers. Information that should be included in the record are:

1. Date
2. Batch Code(s)
3. Can Size and Number of Cans (or weight)
4. Indicating Thermometer Temperature after Optimum Temperature has been reached
5. Time process begins, Time process ends
6. Indication of power failure or adjustment
7. Signature of operator

Item five refers to the heating portion of the process. Since cooling is also important, companies would be wise to record the time that the product is removed from ice slush. Some may find it difficult to include all of this information on the recorder chart and double seam inspection record, particularly if several lots of crabmeat are to be pasteurized in one day. If that is the case, it may be desirable to include this information on a separate log that can later be attached to the recording chart and filed for reference (see also p. 114-115 for recordkeeping recommendations).

Cooling Record

As indicated above, record the time containers are immersed in the ice-water bath (if not immediately following the heating step) and the time they are removed. This can be done on the inspection report and should be easily cross-referenced with process documentation.

Distribution Records

Records should be maintained to identify the initial distribution of the finished product to facilitate the segregation of specific codes when necessary.

Can Seam Evaluation

Written records of all container closure examinations should specify the product code, the date and the time of container closure inspection, the measurements obtained, and all corrective action. Records should be signed by the individual making the inspection.

Refrigerated Storage Temperature Documentation

Since the production of safe, wholesome pasteurized crabmeat is dependent on proper refrigerated storage, it is important to maintain a temperature log of the storage room. Daily readings, preferably in the mornings before the storage room is opened and subject to temperature increases, should be made and recorded to insure that the temperature is below 38°F.

Regulatory agencies suggest that thermometers be periodically cross checked with a standard reference thermometer to insure accuracy in daily use. (Annual check is considered adequate).

Record Retention

Since the anticipated shelf-life of pasteurized crabmeat ranges from 6 to 12 months, the NBCIA standards call for retaining records for a period longer than the reasonable expected shelf-life of the product before discarding (two years in most cases).

Keeping records of the various factors of the operation protects the processor. If records are not kept and a problem occurs, the processor has little recourse. Consequently, a tremendous loss of both money and creditability may be needlessly incurred. If adequate records are available this problem may be avoided. Even if the processor is liable, the extent of the problem may be minimized by accurately identifying the implicated product lot(s) and/or by providing evidence that may rule out the possibility of a health hazard, thereby avoiding a recall situation.

Recordkeeping to Comply with Federal Regulations in the Pasteurized Crabmeat Industry

The production of pasteurized crabmeat must be done in such a manner as to ensure not only product quality, but also the exclusion or outgrowth of microorganisms of public health significance, most notably *Clostridium botulinum* Type E. To ensure the achievement of such a goal, specific equipment and procedures have been developed to allow for the proper pasteurization of crabmeat. It is necessary, however, for plant management to continually monitor such equipment and procedures to determine if product quality and safety are being attained on a daily production basis. In the final analysis, such a determination can only be made if some form of recordkeeping system is instituted and properly maintained.

The Food and Drug Administration (FDA) currently inspects all manufacturers of pasteurized crabmeat under Title 21 Code of Federal Regulations (CFR) Part 110 - "Current Good Manufacturing Practice in Manufacturing, Processing, Packing or Holding Human Foods."

While Part 110 outlines requirements with respect to equipment, procedures, processes and controls, there is no reference in this regulation to the maintenance of records documenting that critical parameters involved in the pasteurization of crabmeat have been identified and are being controlled. In other words, there is no Federal requirement that *specific* control records be established and maintained. However, federal code places the burden on the processor to show evidence that he produces a safe, wholesome product. Documentation of procedures and daily records of processing, packing, storage, and distribution parameters are appropriate and generally expected of processors by regulators. Also, the occurrence of Class I and Class II recalls of imported and domestic pasteurized crabmeat clearly indicates the necessity of ensuring better quality and public health control over this product.

Hazard Analysis and Critical Control Points (HACCP)

Traditionally, food plant inspection by FDA personnel involved having a field investigator monitor manufacturing procedures during a very limited time frame; that is, conditions were recorded based upon what the inspector saw or heard during the time he or she was in the plant. Following two incidents involving contamination of commercially-produced low-acid canned food (LACF) with *C. botulinum* in 1971, it was realized that an inspection system had to be instituted whereby the adequacy of day-to-day line operations could be determined. This new system was in contrast to the aforementioned traditional approach that revealed only those conditions present during the investigator's in-plant time.

An idea for this different inspection approach was obtained from a large multi-dimensional food processing firm which had previously instituted a quality control system based upon pin-pointing potentially troublesome areas along the processing line and monitoring these areas on a daily basis via a strict recordkeeping system.

This new control technique was designed to be preventive in nature. Its main objective was and still is to bring potential dangers to the attention of management for "Before-the-Fact" corrective action; that is, before a potential health hazard became an actual health hazard. The new approach was dubbed the **Hazard Analysis and Critical Control Point (HACCP) method.**

When regulations were being proposed for the LACF industry, it was recognized that there are many significant elements in a manufacturing process which need to be controlled. These elements, moreover, could vary from manufacturer to manufacturer and product to product. After considerable study, it was determined that there were certain critical elements inherent in every LACF process, a lack of control over which could cause, allow, or contribute to a microbiological hazard in the final product. From this determination it was decided that it was plant management's responsibility to:

1. Identify such critical elements or points (CCP's) through Hazard Analysis;
2. Control them through the use of certain processes and procedures; and
3. Record the facts that such processes and procedures were performed.

Factor 3, above, is the only way management has of proving--to itself as well as any regulatory agency--that critical control points on its processing line are being controlled on a day-to-day basis. It should be emphasized that it is more important for management than the regulatory authority to receive such assurance, for management is in a much better position to effect immediate corrective action, should it become necessary. When one produces a product which is subject to a microbiological hazard, it is easy to see proper record maintenance can benefit a firm's over-all quality control program.

Federal regulations governing certain record-keeping requirements for the LACF industry became effective in 1973 and 1974. They were amended in 1979. Among others, the records required were those pertinent to container closure integrity; delivery of the scheduled thermal process; regular measurement of product, container or equipment variables that could adversely affect the safety of the finished products should they be outside certain specified limits; and handling of process deviations. These regulations, designated as 21 CFR Part 113, are not required of the pasteurized crabmeat industry, because pasteurized crabmeat is a refrigerated product. To meet the definition of a LACF, pasteurized crabmeat would have to be shelf-stable at room temperature, i.e. approximately 70°F.

The recordkeeping requirements in Part 113 would be of benefit as recommendations for the pasteurized crab industry. Accordingly, let us attempt to define what critical control

points might be inherent in a pasteurized crabmeat manufacturing process and see what types of records could benefit plant management with respect to controlling these factors on a continuing basis. The idea is to prevent a potential problem from ever developing.

Critical Control Points and a Pasteurized Crabmeat Process

If a critical control point is defined as a point in the process where lack of control may cause, allow, or contribute to a hazard in the final product, what would be the critical control points along a pasteurized crabmeat line and how can they be controlled? A survey of a typical pasteurized crabmeat line indicates the following areas:

Container Integrity

The first critical control point along the line is the proper sealing of the containers. 21 CFR Part 110.80(h) states:

> **Packaging processes and materials shall not transmit contaminants or objectionable substances to the product, shall conform to any applicable food regulation and should provide adequate protection from contamination.**

The pasteurized crabmeat industry most frequently uses a technologically-standard round, three-piece side-seam welded can or a two-piece seamless aluminum container. Many, if not most, packers use an aluminum end and a tin-plated, enameled steel body for their 12 and 16 oz. containers. The purpose of the aluminum end is to minimize the potential for rusting during the cooling phase of the process and during storage prior to ultimate use. Some packers employ an all-steel, three-piece, soldered side seam container. Those packing 8 ounce cans may use an all-aluminum "drawn" two-piece container with a pull-tab type top.

Regardless of the type of container employed, the technology involved is basically the same: the proper alignment of a filled container with a lid end, or cover, and the seaming of this lid onto the can body in two stages or operations; hence the term, **double seam.**

The components of a double seam, the proper alignment of the components, and some of the seam defects that can occur are discussed in detail in Section 5.

There are two basic types of examination that should be performed on a finished, filled container to determine general seam integrity:

1. A visual exam for gross closure defects (non-destructive) and
2. A tear-down of the completed double seam for visual exam and measurement of components (destructive).

Both of the above are requirements for the LACF industry. 21 CFR Part 113.60, pertinent to LACF products, recommends that a visual exam be performed on a container from each

seaming head at intervals not to exceed 30 minutes. It also requires that a visual exam be performed immediately following a jam in the closing machine, after closing machine adjustment, or following a prolonged shut down. This regulation also recommends that tear down examinations be made at intervals not exceeding four (4) hours.

Recommendations made specifically for the pasteurized crabmeat industry are:

1. Seam tear-down at start-up on each day, approximately every 1000 cans thereafter, and any time following a jam.
2. An "inspection of can seams... at the start of the process and at intervals of 250 cans."

All results of container closure examination should be recorded on appropriate forms. These records should contain the product code, the date and time of container closure inspections, the measurements or other results obtained, all corrective actions taken, and the closure examiner's signature or initials. They should also be reviewed by a qualified representative of plant management with sufficient frequency to ensure that container integrity is being maintained.

Additional information that could be recorded on the closure examination records is the empty container manufacturing lot number (both bodies and ends), if known. This would be of benefit, for example, in the event of a leakage problem along the side seam or end applied by the manufacturer.

Another sound inspection step involves the periodic examination of empty containers for evidence of bent or otherwise damaged flanges. Lids should also be examined periodically for appropriate amount of curl, damage to the curl, and sealing compound deposition or distribution. A record should be made of any abnormalities noted, particularly if it should appear to be a problem involving manufacture of the can body or end. Such comments could be included on the packer's seam inspection record or maintained on a separate form.

Finally a record should be made of any maintenance performed on the seamer (other than routine lubrication). This record could be in the form of a maintenance log book, a file folder containing detailed receipts for services rendered by a supplier's mechanic, or on the packer's seam examination records.

Pasteurization

The second critical control point on the line would appear to be the pasteurization process itself. 21 CFR Part 110.80 (f) states:

> **All food processing, including packaging and storage, should be conducted under such conditions and controls as are necessary to minimize the potential for undesirable bacterial or other**

microbiological growth, toxin formation, or deterioration or contamination of the processed product or ingredients.

Each batch must be pasteurized according to a minimum specified time/temperature schedule established by a recognized processing authority.

Pasteurizers in the crabmeat industry are equipped with some type of indicating thermometer, such as a mercury-in-glass. The LACF industry is required to have such an instrument and, as it is the reference instrument for determining whether or not proper sterilizer temperature has been attained, it is required to be calibrated against a known reference thermometer upon installation and at least once a year thereafter (21 CFR Part 113.40 (a) (1) ref.). Records of such calibration are a recommendation to the LACF industry.

The indicating thermometers for the pasteurizers in the crabmeat industry should also be calibrated against a known standard often enough to ensure proper operation. In the Blue Crab National Industry Pasteurization Standard (NIPS, Appendix IV), it is recommended that a representative of the state regulatory authority check both the indicating and recording thermometers upon installation and at least once each operating season (Section 8, paragraph A). Manufacturers of indicating thermometers, such as mercury-in-glass, usually have a service section that will visit a plant and calibrate these instruments.

The indicating thermometer should be the reference instrument, because it can be checked against a known standard thermometer. Readings should be taken from it during the cook and recorded on an appropriate form. Furthermore, a comparison of indicating and recording thermometer readings should be made to determine if the recorder is in need of adjustment.

Most, if not all, processors have recording thermometers which are, in some cases, combined with the steam controller to form what is referred to as a recorder-controller, on their pasteurization tanks. Such a device is a requirement in the LACF industry (21 CFR Part 113.40 (a) (2) ref.) and would appear to also be extremely important to the proper processing of pasteurized crabmeat. A recording thermometer, or recorder, properly instrumented, installed, operated, and maintained will give a complete and accurate written history of the processing of a particular batch. The chart should be identified with the pasteurizer's number, if applicable, the date, the operator's signature or initials, and other necessary data.

With respect to "other necessary data", Section 8, paragraph G of the Blue Crab NIPS recommends recording within the confines of the pen markings the following additional information after the pasteurization cycle is completed:

1. Quantity of each batch
2. Processor's code

3. If pasteurization is being done for someone else, the customer's name, address, and license of certification number
4. Any failure of the recorder to operate properly and the corrective action taken
5. Indicating thermometer readings and the time of the readings

In some cases, inclusion of all of the above information on the recording chart in the area so designated might prove somewhat difficult. Accordingly, it might be advisable to maintain a separate hand-written processing log on which would be recorded the pasteurizer number, if applicable, batch number, batch quantity, code, time batch was placed in tank, time pasteurizer reaches scheduled process temperature, time the process ends, time cooling cycle ends, comparative indicating and recording thermometer readings, and operator's signature or initials. Additionally, any instance of equipment malfunction or process deviation should be reported on the processing log, along with any corrective action taken. Any of this information that is obvious from, and consistently produced by, recording instruments need not be duplicated by hand entry.

The number of comparative thermometer readings to be made can be determined by qualified plant management but should probably be made at the beginning of the pasteurization cycle, that is, after the pasteurizer reaches proper temperature and stabilizes early in the process and once more prior to the end of the cycle. The purpose is to ensure that the recording thermometer is in agreement with the indicating thermometer. Also, the recording chart time should be aligned at the beginning of production to agree as closely as possible with the time-piece used to determine the process time recorded on the log. Generally, devices such as a wall clock with a sweep second hand or stopwatch would be considered acceptable time pieces. Mechanical wrist watches and pocket watches are less desirable because they tend to run fast or slow after a period of time.

Storage Temperature

The third critical control point in a pasteurized crabmeat process would appear to be storage of the processed product at proper refrigeration temperatures. As stated before, this particular storage condition is what exempts pasteurized crabmeat from compliance with the LACF regulations. 21 CFR Part 110.80 (j) states:

> **Storage and transportation of finished products should be under such conditions as will prevent contamination, including development of pathogenic and toxigenic microorganisms, and will protect against undesirable deterioration of the product and the container.**

Most recommendations for proper storage temperature appear to stipulate below 38°F. The reason for this temperature recommendation is that *C. botulinum* Type E has been shown

to grow slowly at 38°F. A safe storage temperature up to 36°F is therefore recommended (NBCIA). A processor should be able to show, through records, that the proper storage temperature has been maintained while the product was under his control. This can be accomplished in one of several ways. Ideally, a properly calibrated, installed, and read indicating thermometer, and a recording thermometer located on a storage unit would give the most complete record of storage temperatures on a daily basis. At the very least, a properly prepared hand-written temperature log should be positioned near the storage unit and the temperature read and recorded at intervals of sufficient frequency to ensure the proper temperature is being maintained, on a day-to-day basis.

Management Review of Critical Control Point Records

The LACF industry is required to have scheduled process records reviewed no later than one (1) working day after the actual process and before shipment or release for distribution, by a representative of plant management who is qualified by suitable training or experience. The records are to be reviewed for completeness as well as to ensure that the proper scheduled process was delivered to the product. The date of the review and the reviewer's signature or initials must be written on each record page (21 CFR Part 113.100 (b)). Container closure records are required to be reviewed with sufficient frequency to ensure that container integrity is being maintained (21 CFR Part 113.100 (c)). Many LACF processors review these records on a daily production basis. Management review of critical control point records on a routine basis appears to be an excellent method of ensuring that proper processes and procedures are being applied in the pasteurized crabmeat plant.

Coding Requirements and Records of Initial Distribution

Although not by itself a critical control point, proper coding of containers and inclusion of coding information on records of initial distribution, i.e. records covering shipment of product from manufacturer to a direct customer, are important to a plant's overall quality control program. 21 CFR Part 110.80 (j) states:

> **Meaningful coding of products sold or otherwise distributed from a manufacturing, processing, packing or repacking activity should be utilized to enable positive lot identification to facilitate, where necessary, the segregation of specific food lots that may have become contaminated or otherwise unfit for their intended use. Records should be retained for a period that exceeds that shelf-life of the product, except that they need not be retained more than 2 years.**

The LACF industry is required by 21 CFR Part 113.60 (c) to code its products to indicate the plant where packed, the product packed, the year of the pack, day of the year of the pack and time of the day of the pack. 21 CFR Part 113.100 (a) requires that records showing initial distribution be maintained, and 113.100 (e) requires that all critical processing records be retained at the plant or some other reasonably accessible facility for 3 years.

The purpose of the above regulations is simply to facilitate a recall of product for all concerned, should one become necessary. If a processor should have a code identifying, for example, only the year of the pack, and a problem of potential health significance, or other type of violation, is traced to that particular lot, the processor may be faced with the necessity of recalling an entire year's production. If the code identifies the month of the pack and the problem is shown to be confirmed to one particular month, then a recall of the entire month's production may be necessary. If, through the coding system, a problem is known to be confined to a particular day or batch only, then the firm may have to recall only that particular day's production or batch.

It is in the interest of the packer, consumer, and regulator to be able to trace, through some type of distribution record, which customers received the suspect code. Should distribution records not indicate which accounts received the suspect code, it may be necessary, in the interests of public health, to contact all of a processor's customers.

Seafood HACCP

Refer to Appendices I and II for current seafood processing HACCP concepts and recommendations. Specific requirements of the National Marine Fisheries Services' (NOAA) voluntary HACCP-based inspection program are available from that agency.

Summary

In brief, adequate control of critical processing points along a pasteurized crabmeat line entails first, identifying these points; second, establishing a recordkeeping procedure for monitoring the operation of the line at those points; and finally, ensuring that the records are properly filled out, accurately reflect what occurs at the processing point, and have been reviewed by qualified management with sufficient frequency, to ensure that the firm's quality control program is being met on a continuing basis. Although there are no current federal regulations requiring the maintenance of such records, the institution of such a program by the pasteurized crabmeat processor would seem to be in the interests of everyone. A more complete outline of the steps involved in developing an HACCP plan are described in Appendix II.

Finally, good, basic procedures are an important part of a pasteurized crabmeat operation. Allowing the microbial load of the crabmeat to significantly increase prior to pasteurization could adversely affect the pasteurization process. Allowing pasteurized product to come into contact with surfaces or media, such as cooling water, with high microbial loads could adversely affect the finished product. It is necessary for management, therefore, to continue to ensure sanitary facilities and controls within the plant.

APPENDIX I

Crabmeat Industry Pasteurization HACCP Recommendations

The following processing steps and CCP's were outlined at the Blue Crab HACCP Industry Workshop, June 7-9, 1988, Charleston, South Carolina, by the seafood industry (National Fisheries Institute), the National Marine Fisheries Service, and represented state institutions.

PROCESS AND CRITICAL CONTROL POINTS IN PROCESSING BLUE CRAB

Group B Report

The group reviewed the processes being used for blue crab products in the United States Participation was primarily from East Coast processors. Softshell crabs were included in the considerations of the group. The following definitions were used for critical control points and control points.

- Critical Control Points: Specific operational steps of a food manufacturing process, the failure of which may automatically result in an unacceptable consumer health or economic risk.
- Control Points: Specific operational steps of a food manufacturing process where biological, chemical, physical, and/or economic factors may be controlled.

This group followed the terms of reference or approach in the following order:

1. The operational steps were defined. A strawman flowchart for the processing of blue crab was provided as a basis for discussion. The working group used this as a basis for defining their sequence of processing steps.
2. The hazards that arise at each of the processing steps were discussed and a consensus list was developed. The hazards related to safety, hygiene/sanitation, and consumer fraud that might arise from each process step were considered.
3. Preventive measures were identified for each of the hazards noted, and a consensus list was prepared.
4. Monitoring procedures were defined for the preventive measures. The emphasis was on observations or physical measurements that could be readily carried out at minimal costs.
5. Relative importance of the hazards were then assigned based upon a review of the steps and a discussion among participants. Scoring from one (lowest importance) to five (highest importance) were recorded based upon a group consensus. Extensive discussions were required to resolve the relationships of application of critical control point scores and the record keeping and inspection procedure methodology.
6. Critical Control points were defined as those having scores of either four or five in importance. By agreement, those steps which were critical and would have available machine generated records useful for monitoring were given scores of five. Those which depend on human observations (and recordings) were given four ratings.
7. Records to be made available for review for each of the critical control points were discussed. Major concerns were expressed on the types of records to be made available to the regulatory agency at inspection.

A total of eight critical control points (Table 1A) were defined in the process to produce fresh blue crabmeat, pasteurized crabmeat, and to repack crabmeat. Three critical control points were identified in the steps to produce fresh blue crabmeat; four in the additional steps to pasteurized crabmeat; and one in the steps in repacking crabmeat.

From the review of softshell crab processing, no critical control points were identified for the receipt, storage, sorting, and shipping of live animals. The preparation and shipping of frozen softshell blue crabs was identified as having one critical control point (Table 1B).

The type of records to be kept and made available for inspection was the focus of extensive discussion. The need for evidence that the critical control points are actually under control during regular production was the basis for difficulty. The consequences of revealing unusual occurrences (under NUOCA - Notice of Unusual Occurrence and Corrective Actions) at inspection time seem to be multiple. While fulfilling the need for evidence of process control, these records expose the plant and recorder to capricious or punitive actions by the regulatory agency or personnel.

The working group was led by Jack L. Amason, Sea Garden Seafood, Inc., Valona, Georgia; and facilitated by Lloyd Regier (NMFS), Joe Slavin (NFI), and Donn Ward, North Carolina State University.

TABLE 1A HARD BLUE CRABS PROCESS STEPS AND CONTROL POINTS

STEP	HAZARD	CONTROL POINTS	IMP.	PREVENTIVE MEASURES	MONITORING	RECORDS
1. Receive	1. Decomposition	1. Receiving	2	1. Examine and reject decomposed crabs	1. Visual & odor	
2. Wash (optional)	1. Contamination not removed (water used not approved)	1. Washing area	1	1. Adequate washing 2. Use approved water supply	1. Visual inspection 2. Water supply check	
3. Raw storage	1. Decomposition	1. Cooler	3	1. Control time, temperature & humidity	1. Visual check 2. Thermometer 3. Animal Condition	
4. Cook a. Steam pressure	1. Microbial survival 2. Decomposition (short shelf life)	1. Cooker	4	1. Adequate time & temperature	1. Pressure monitoring 2. Temperature monitoring 1. Time in retort 2. Venting 3. Check of piping & construction	1. Annual cooker retort certification 2. NUCOA
b. Steam atmospheric (reserved for partially cooked)	1. Microbial survival	1. Cooker	4	1. Adequate steam distribution & venting		1. Annual cooker retort 2. NUCOA
c. Boiling	- Research recommended on evaluation of processes to establish equivalent lethalities with different processes and equipment.					

TABLE 1A HARD BLUE CRABS PROCESS STEPS AND CONTROL POINTS

STEP	HAZARD	CONTROL POINTS	IMP.	PREVENTIVE MEASURES	MONITORING	RECORDS
5. Cooling	1. Sour decomposed crabs 2. Cross contamination	1. Cooler	3	1. Air cool prior to refrigeration 2. Separate cooked from raw crabs	1. Visual checks 2. Touch check of temperature 3. Time in air	
6. Deback wash/cool (optional)	1. Bacterial contamination 2. Cross contamination	1. Cleaning room	3	1. Sanitary operation 2. Potable water	1. Visual check 2. Periodic checks	
7. Cool/refrig store	1. Decomposition 2. Cross contamination	1. Cooler	3	1. Adequate temperature 2. Control time	1. Temperature checks 2. First in - first out	
8. Picking (hand and machine)	1. Bacterial contamination 2. Foreign material 3. Excessive shell	1. Picking station 2. Machine	4	1. Good manufacturing practice 2. Personal hygiene 3. Clean & sanitize equipment 4. Pest control 5. Short hold time 6. Immediate icing	1. Supervisory checks 2. QA checks	1. NUCOA
9. Pack/weigh and seal fresh meat	1. Incorrect weight 2. Foreign material 3. Bacterial contamination	1. Packing weighing station	4	1. Scale check 2. Employee training 3. Sanitation 4. Time/temperature control	1. Supervisory checks 2. Scale calibration 3. Q.C. checks	1. Annual scale certification
10. Icing (fresh meat)	1. Bacterial contamination	1. Icing area	3	1. Pack to prevent water entry	1. Supervisory checks	

TABLE 1A HARD BLUE CRABS PROCESS STEPS AND CONTROL POINTS

STEP	HAZARD	CONTROL POINTS	IMP.	PREVENTIVE MEASURES	MONITORING	RECORDS
11. Chill storage (optional)	1. Decomposition	1. Cooler	3	1. Limit time/ temperature (rotation, FIIFO)	1. Supervisory checks 2. Temperature alarm	
12. Ship (fresh meat)	1. decomposition if transporting on own equipment	1. Truck	3	1. Maintain refrig systems on truck	1. Check at destination	
ADDITIONAL STEPS - PRODUCT FOR PASTEURIZATION						
13. Picking (hand machine)	1. Bacterial contamination 2. Improper seal 3. Incorrect lid labeling 4. Defective containers	1. Sealer	4	1. Equipment in proper operating condition	1. Equipment checks daily 2. Periodic can tear down of both factory & canners closures	1. Log of can seam evaluations
14. Hold (optional)	1. Decomposition	1. Cooler	3	1. Time/temperature control 2. Icing	1. Supervisory checks 2. Q.C. checks	1. Annual scale certification
15. Pasteurization	1. Bacterial contamination due to leakers 2. Inadequate process schedule	1. Pasteurizer	5	1. Can seam inspection 2. Adequate time/ temperature control (NBCIA: temp=185°F time=60 sec) 3. Operator training course	1. Supervisory checks 2. Temp. logs or records	1. Time/temp. recording chart 2. Annual pasteurization equipment certification

TABLE 1A HARD BLUE CRABS PROCESS STEPS AND CONTROL POINTS

STEP	HAZARD	CONTROL POINTS	IMP.	PREVENTIVE MEASURES	MONITORING	RECORDS
16. Cool	1. Bacterial growth (slow cool) 2. Bacterial contamination	1. Cooler	4	1. Adequate cooling capacity 2. Agitation (NBCIA regulation to be used for rates)	1. Supervisory checks 2. Time/temperature logs	1. Log of cooling time
17. Chill storage	1. Decomposition 2. Bacterial spoilage	1. Storage room	4	1. Store at 32-36	1. Time/temperature log	1. Daily temperature log
18. Ship (pasteurized meat)	1. Decomposition if transporting on own truck	1. Truck	3	1. Maintain refrig. systems on truck	1. Check at destination	
ADDITIONAL STEPS - CRABMEAT FOR REPACKING						
19. Repacking crab meat (pack/weigh and seal)	1. Incorrect weight 2. Product identity & history lost 3. Bacterial growth 4. Bacterial contamination	1. Packing station	4	1. Use material only from licensed plants 2. Check temperature on receipt 3. Check scales 4. Employee training	1. Maintain records on product traceability 2. Supervisory checks 3. Scale calibration	1. Log of product identification and code dates 2. Scale certification
20. Freezing (after pack/weighing and sealing)	1. Decomposition	1. Freezer	3	1. Control freezer loading to allow complete freezing	1. Time/temperature logs 2. Supervisory checks	

APPENDIX II

Developing a Hazard Analysis and Critical Control Plan

A. DEVELOPING A HACCP PLAN

1.1 What Does HACCP Do?

1.2 HACCP

B. HOW TO DEVELOP A HACCP PLAN

1 STEP 1 - Prepare Process Flow Charts

1.1 Develop the Flow Charts

1.2 Assess Potential Hazards at Each Step

2 STEP 2 - Identify Critical Control Points

3 STEP 3 - Set Critical Limits That Must Be Met At Each CCP

4 STEP 4 - Define Monitoring Procedures

5 STEP 5 - Define Corrective Actions

6 STEP 6 - Devise a Record Keeping System

7 STEP 7 - Establish Verification Procedures

C. REGISTRATION AND CERTIFICATION OF PLANTS

D. PRODUCT RECALL SYSTEM

The principles of HACCP as generally recognized for seafood processing operations by the National Fisheries Institute, the National Marine Fisheries Service, and the U.S. Food and Drug Administration are contained in the Seafood Industry Hazard Analysis Critical Control Point (HACCP) Training Manual (NFI, 1991). Although not officially adopted to date, this manual provides a valuable discussion of the concepts and implementation of HACCP. The excerpts which follow are provided as an aid to managers and employees who are contemplating the development of HACCP programs. Contact NFI, Sea Grant institutions, or an appropriate regulatory agency regarding more complete training programs and materials.

1.1 What Does HACCP Do?

HACCP provides a more focused approach to the control of hazards in food than is achievable by traditional inspection and quality control programs. It does **not** require continuous inspection. Rather, HACCP is a combination of industry self-inspection and government monitoring. HACCP can be boiled down to the following: The program is based on the identification and control of potential hazards versus the end use of the product. The ability to identify and to control potential hazards is absolutely fundamental to the successful implementation of HACCP. Once the potential hazards are identified, HACCP allows you to focus efforts to control the hazards at specific *critical* points in the process. Furthermore, since the hazards are identified with regard to the end use of the product, more control and monitoring will be necessary for products such as cooked crabmeat, which do not require additional cooking, than for fresh fish, which in all probability will be cooked.

Simply then, what do you do under HACCP as a seafood processor? You study and critique your plant's procedures from the receipt of raw materials through shipment of the final product. You determine which processing steps are critical elements in controlling hazards, and you assess overall sanitation. Then you write your own HACCP plan identifying the steps to be monitored and the records to be kept that will indicate compliance with your plan. This is not as difficult as it may sound; there are documents and aids already developed that will assist you. The remainder of this chapter, as well as the other chapters in this training manual, are designed to assist you in identifying the potential hazards in your specific processing plant and to assist in determining effective control and monitoring procedures.

1.2 HACCP

The HACCP procedure was developed by the National Advisory Committee for Microbiological Criteria for Foods, an independent panel of food safety experts convened by the National Academy of Sciences (NAS) at the request of federal food inspection agencies. To understand and implement an effective HACCP program, you as a seafood processor must follow the steps in Table A-1.

	Table A-1. Implementation of a HACCP Program
Step	Process
1.	Prepare a process flow chart. Assess the hazards associated with each operational step: growing, harvesting, using raw materials and ingredients, processing, manufacturing, distribution, marketing, preparation and consumption of the food.
2.	Identify the critical control points (CCPs) where the identified hazards can be controlled.
3.	Set the critical limits that must be met at each CCP.
4.	Define monitoring procedures to ensure critical limits are met.
5.	Define corrective actions to be taken when the monitoring procedures identify a deviation.
6.	Devise record-keeping systems that document the effectiveness of the HACCP plan.
7.	Establish verification procedures to ensure that the HACCP system is working correctly. Verification measures may include biological, physical, chemical, and sensory methods. Where they are needed, establish limiting criteria.

Initially, the process may seem unnecessary and perhaps difficult, but it is absolutely essential. The reason for this perceived difficulty is that you will be asked to evaluate closely your production processes. You are familiar with these processes. Consequently, it can be difficult to step back and view them with a critical eye. It may be helpful to imagine yourself as an outsider viewing the process for the first time and asking questions, especially "**why**' and "**what if**" questions.

HOW TO DEVELOP A HACCP PLAN

A. What Is a HACCP Plan?

In this section, we are going to describe how you, as a member of the fishing industry, can develop your own HACCP plan. This plan will not only be appropriate for your own seafood processing operation, but will also meet the requirements of the federal agency that will eventually be responsible for administering a seafood inspection program based on the HACCP system. You will see that the procedures for developing a HACCP plan are quite straightforward, involving only seven basic steps, all of which can ba accomplished by you and your staff. Before we get to these seven steps, however, let's first define some terms so that you have a clear understanding of what we are talking about.

As you know, "HACCP" stands for "Hazard Analysis Critical Control Point." What does this really mean?

Hazard

First, the term "hazard" as used here simply means a chance for, or the risk of, an unacceptable biological, chemical, physical, or economic property in a food product that could cause consumer distress or illness.

Hazard Analysis

Next, the term "hazard analysis" means the process of identifying biological, chemical, physical, or economic fraud chances or risks relative to a food product or manufacturing process, a process which takes into consideration the intended end use of the food product. They key word here is end-use; it means that the conditions or situations that should be considered hazardous are those that present a risk only with respect to the ultimate use of the product. For example, the presence of certain pathogens in raw materials would not necessarily be considered hazardous if the pathogens are destroyed during processing. Such is the case with fully cooked products and those intended to be fully cooked by the consumer before being eaten. On the other hand, the presence of glass in a product would obviously be considered a hazard whether it was eventually cooked or not.

Critical Control Points

A "critical control point" is an area or item of equipment in the processing facility where specific operational steps in a manufacturing process take place, and where the loss of control of such steps would automatically result in an unacceptable safety, hygiene, or economic fraud risk.

Food Safety

"Food safety" risks are those that could cause harm to a consumer's health or physical well-being. Safety issues are usually addressed through biological, chemical, or physical criteria, and are distinct from issues relating to food hygiene or economic fraud.

Food Hygiene

"Food hygiene" refers to those characteristics of a product or process relating to wholesomeness or facility sanitation.

Economic Fraud

"Economic fraud" refers to those illegal or misleading actions which defraud purchasers. Such actions include, among other things, species substitution, short weight, overglazing, and short fill. Also included is the excessive use of so-called approved chemicals in processing, such as the overuse of sulfites to slow down decomposition, as well as the misuse of chemicals, such as sodium tripolyphosphate, originally intended to minimize drip loss, for the express purpose of adding weight to the final product.

HACCP System

A "Hazard Analysis Critical Control Point" system is a non-traditional inspectional approach to controlling hazards in foods. It is a two-part process done on a commodity-by-commodity basis. The first part deals with defining the consumer hazards within a specific food commodity relative to the intended use of the product. The second part deals with: 1) flow charting each operational step of a food manufacturing process and defining the hazards associated with each step; 2) assessing the relative importance of the hazards and identifying the critical control points of the manufacturing process; 3) determining the appropriate preventive measures to be employed; 4) determining either by observation or by measurement the monitoring procedures that are needed to ensure that the hazard is being controlled; 5) establishing the critical limits that must be met at each Critical Control Point and the corrective actions to be taken to return deviations to acceptable limits; 6) developing the records necessary for monitoring that will ensure hazards are being controlled; and 7) establishing verification procedures to assure an effective HACCP plan.

HACCP Plan

A "HACCP Plan" is a planning document and its related records which, under a HACCP-based inspection system, would be required to be on file at each processing facility. The planning document and related records are established by the facility in conjunction with the regulatory agency prior to the facility's admission to a HACCP seafood surveillance program.

Such a plan includes: 1) documentation of critical control points, 2) action taken when critical deviations occur, 3) disposition of product subjected to "critical" deviations, 4) clear designation of the records to be made available for government inspections, and 5) provisions for their maintenance.

Now that you have a clearer understanding of what a HACCP plan is all about, you are ready to develop a HACCP plan to fit your own operation.

B. HOW A HACCP PLAN IS DEVELOPED

Since a fully developed plan would likely include much general information that you already possess, such as organizational charts and responsibilities, company directives concerning product manufacture, process specifications, etc.—the components that are essential to a HACCP plan can be developed by you and your staff following these seven basic steps:

1 - Prepare process flow charts and assess potential hazards
2 - Identify critical control points
3 - Set critical limits that must be met at each CCP
4 - Define monitoring procedures
5 - Define corrective actions
6 - Devise a record keeping system
7 - Establish verification procedures

STEP 1 - Prepare Process Flow Charts and Assess Potential Hazards.

The first step in starting a HACCP program is to prepare a detailed process flow chart for your major processing operation (or charts for each distinct processing operation) from which you will analyze your operations.

1.1 Develop the Flow Chart.

The chart should list in sequence the specific operational steps (control points) of the manufacturing process of your food product where microbiological, chemical, physical, and/or economic factors can be controlled (see sample). In addition to developing such flow charts, standard operating procedures (SOPs) should be written, if not already done, and should be followed by your firm. The SOPs relate to the operations that must be accomplished at each process step in terms of both product-processing methods and sanitation controls.

Each chart should begin with the "receiving" of fresh and/or frozen raw materials and end with the "shipping" of your product to the wholesale or retail trade.

The following example is a general process flow chart for raw processed crab meat. It identifies specific processing steps or control points where hazards can be monitored and

controlled. Of these control points, various steps are identified as "critical control points." How to determine such critical control points is discussed in "Step 2."

1.2 Assess Potential Hazards At Each Step.

Following development of your process flow chart(s), you are ready to begin to identify and assess hazards that could occur at each processing step (control point). Using your process flow chart as a guide, **at each step** in the processing operation, ask yourself the following question:

- What can go wrong at this step in terms of product safety, wholesomeness, and economic fraud?

The following are examples of hazards that could arise at individual processing steps for various seafood products. You may determine that one or more of these hazards could occur at any single step in the processing of your product.

Microbiological/Chemical	Physical	Economic
• Fuel oil	• Filth	• Excess moisture
• Pathogens	• Insect/rodent contamination	• Excess glaze
• Cross-contamination	• Metal fragments	• Short weights
• Contaminated dip	• Shell fragments	• Mislabeling
• Contaminated ice	• Other foreign materials	• Misgrading
• Decomposition	• Parasites	• Masking country of origin
• Time/temperature abuse	• Freezer burn	• Incorrect product in package
• Chemical contamination	• Dehydration	• Wrong proportions of additives, ingredients
• Additive abuse	• Damaged packaging	
	• Damaged product	
	• Improper sealing of package	

STEP 2 - Identify Critical Control Points

You must now determine the relative importance of the hazards involved in the processing of each of your products. It is here that the "Critical Control Point Analysis" phase of the HACCP system takes place. Each hazard in each processing step must be evaluated by

answering the question: "Does the critical control of this hazard occur here or at another step?" The is, if there should be a failure to control this hazard at this specific step in the manufacturing operation, would it automatically result in an unacceptable safety, hygienic, or economic risk in terms of the end use of the product? Every and all steps where the answer to this question is "yes" should be considered "critical control points."

A simple method of deciding whether a control point is critical is to follow the Critical Control Point Decision Tree contained in Figure A-1.

STEP 3 - Set Critical Limits That Must be Met At Each CCP.

The third step in setting up your HACCP plan is to establish the limits that must be met at each "critical control point." A critical limit is defined as one or more prescribed tolerances that must be met to ensure that the plan effectively controls a hazard or risk. There may be more than one limit for a critical control point. If any one of those limits is out of tolerance, the process will be out of control and a potential hazard or risk can exist.

Examples of criteria frequently used for limits are temperature, time, moisture level, amounts of preservatives, additives and ingredients, net weight, and fill of container. Many types of limit information may be needed for control of a critical control point.

STEP 4 - Define Monitoring Procedures.

Your next step is to determine the appropriate "monitoring procedures" to be used with the various preventive measures. Such procedures should be primarily observations or physical measurements that can be readily carried out in terms of realistic time delays and costs. Examples of such monitoring procedures include the following:

- Sampling and inspection of fresh and frozen raw materials
- Checks and documentation of temperatures of raw materials
- Checks and documentation of temperatures of product
- Checks and documentation of temperatures of coolers/freezers
- Checks of temperature and humidity in dry storage rooms
- Checks of inventory control
- Checks of amounts of additives used for each batch/lot
- Monitoring adequacy and potability of water supply
- Product sampling for bacterial analysis
- Periodic checks of net weights
- Checks of labels used
- Checks of production schedules

Example Blue Crab Processing Flow Chart

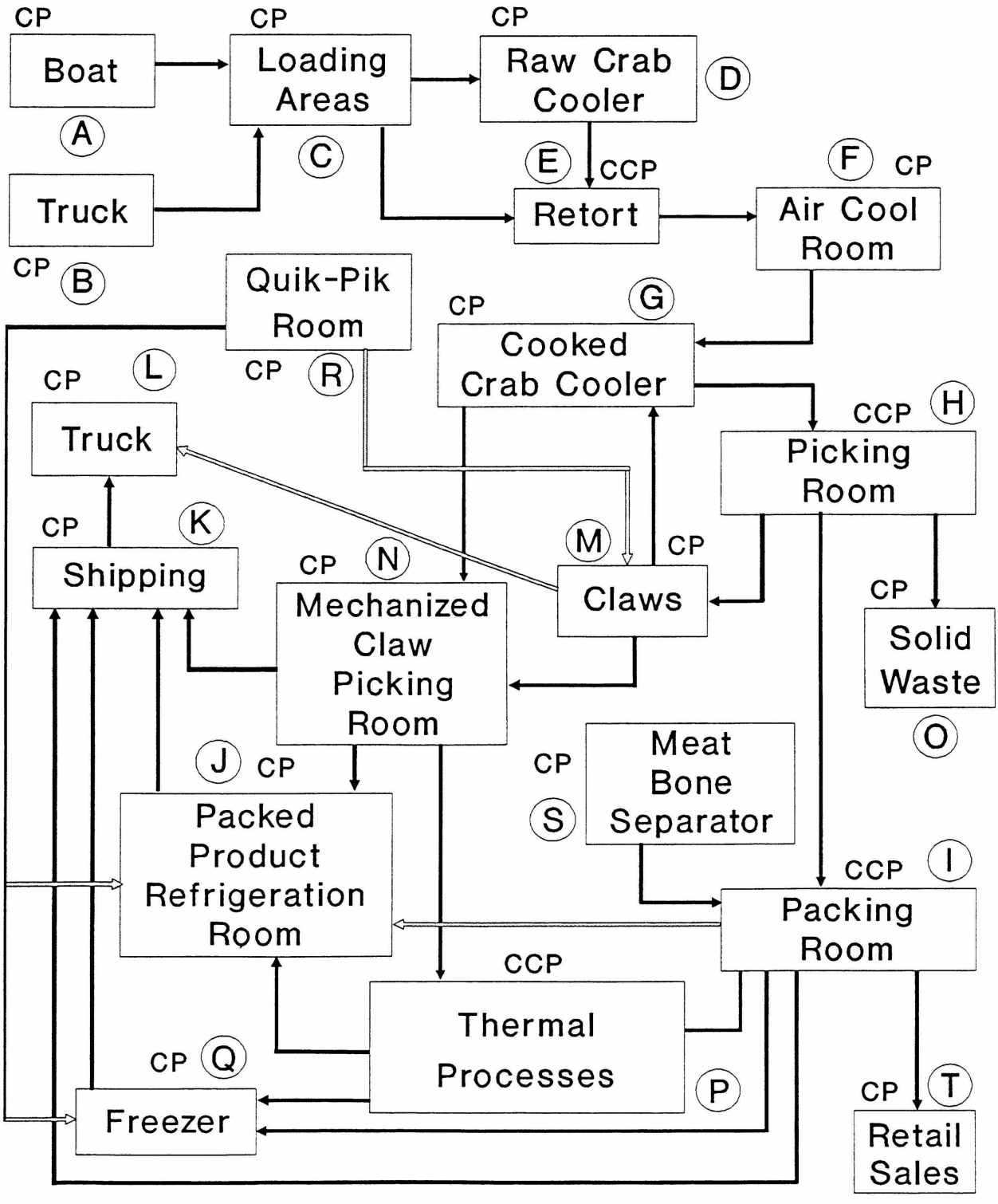


Figure A-1.

- Periodic checks of process control specification
- Visual inspections of product and equipment
- Checks of equipment maintenance
- Supervisory check points throughout the processing operation

STEP 5 - Define Corrective Actions and Preventive Measures to Control Hazards.

The fifth step in setting up your HACCP plan is to determine, for each processing step, the appropriate corrective actions to be taken when prescribed limits are exceeded, and the preventive measures to be employed that will be effective in controlling the potential hazards you identified earlier.

Listed below are examples of some common corrective actions and preventive measures that all seafood processors might consider:

- Rejection of unsatisfactory raw and finished product
- Physical separation of raw and finished product in storage
- Using approved, potable water supply
- Ensuring proper time/temperature control
- Using approved chemicals only
- Using adequate screens to keep out insects/pests
- Ensuring proper removal of extraneous materials
- Ensuring proper maintenance and sanitation of equipment
- Ensuring proper scale calibration
- Using visual and organoleptic inspection of product
- Ensuring proper packaging/labeling of product
- Ensuring proper rotation of product in storage (FIFO)
- Using standard operating procedures for plant
- Using training programs for employees
- Ensuring good personal hygiene of employees
- Employing good housekeeping practices
- Using trucks capable of maintaining proper temperatures
- Ensuring proper loading of trucks
- Developing a product recall system
- Requiring individual accountability from supervisors

STEP 6 - Devise a Record Keeping System.

In addition to the "monitoring procedures" and "corrective actions" that you have already identified for each processing step, the HACCP system requires that your plan include one

additional safeguard, particularly for those processing steps you determined to be "critical control points." That safeguard is the inclusion of a suitable record-keeping system in your HACCP plan.

The key to a successful application of the HACCP inspection system is the ability of plant management, quality control personnel, and regulatory authorities to perform routine and meaningful examinations of the process controls used, the level of plant sanitation, and the product itself throughout the entire processing operation. Most of these examinations are, in turn, dependent on the examination of the records maintained by your plant in these areas. Such records provide several vital functions: 1) they document that the limits set for a critical control point have been met by recording the results of monitoring activities; 2) if critical limits were exceeded, they document what action was taken to bring the critical control point back under control and the disposition of the affected product; and 3) they offer product traceability from start to finish.

It is recognized that a plant, in the course of doing business, must keep records of many types and kinds of information. However, HACCP regulatory authorities will need only those records that verify monitoring results, pinpoint problems, and provide product traceability. They will have no need for any information that is legitimately of a proprietary nature!

Records can be of different types. In most cases, they need not be complex. In fact, the simpler the better, as long as they provide the necessary information. Examples of some of the primary records of these types are:

- Invoices of receipt of raw products
- Raw product origin certification records (Molluscan ISSC)
- Incoming product inspection reports
- Product purchasing and processing specifications
- Quality control and assurance reports
- Scale calibration records
- Additives use logs
- Time/temperature records
- Unit and package weight records
- Shipping records, etc.
- Logs of NUOCAs (Notices of Unusual Occurrences and Corrective Actions taken)

The NUOCAs come into existence only when deficiencies are found during the established monitoring process, and provide valuable supplementary information to your other routinely-used processing records, particularly those required for critical control points. They serve to record what you found to be wrong, unusual, or unacceptable from a potential safety, quality, or

economic hazard standpoint during the course of a particular processing step...and what action(s) you or your plant personnel took to correct it. NUOCAs may be separate forms of your own design which record such basic information as the...

- Date and time of occurrence
- Processing step involved
- Problem identified
- Corrective action taken
- Other comments

...or they may simply be your inclusion of the above information onto another type of record you may be using, such as one of those indicated above. For example, the receipt of decomposed product by the Receiving Department and its consequent return to the shipper could be noted on your copy of the receiving invoice. That invoice would now serve as your NUOCA.

STEP 7 - Establish Verification Procedures.

The seventh and final step is to establish adequate verification procedures to assure that your HACCP plan is in fact being complied with and that it is effective. Both the producer and the regulatory agency have a role in verifying HACCP plan compliance. Verification confirms that all hazards were identified in the HACCP plan when it was developed. Verification activities include: establishment of appropriate verification inspection schedules; review of the HACCP plan; review of records kept for critical control points; review of process deviations and product dispositions; visual inspections of operations to observe if critical control points are under control; random sampling and analysis of products; and a written record of verification inspections that certifies compliance with the HACCP plan or deviations from the plan and the corrective actions taken.

There, we have the seven steps for the development of a HACCP plan. As we said, these steps are straight-forward, rational, and reasonably easy to accomplish. There are, however, two other important aspects of a mandatory HACCP system that you need to be aware of, and that need to be addressed in your plan. They are: Registration and Certification of Plants and a Product Recall System.

C. REGISTRATION AND CERTIFICATION OF PLANTS

A mandatory seafood surveillance program will likely require that all plants processing finished products for export or domestic trade first be registered (for identification purposes only) and then certified in terms of plant process and sanitation controls. Sanitation (plant

hygiene) will likely be assessed through use of an appropriate Plant Sanitation Compliance Checklist similar to the example following that was developed for the manufacturers of raw fish products.

Such plant sanitation compliance checklists are comprehensive forms intended for use on an intermittent basis to determine the general sanitation compliance of a plant. They are not intended for use on a daily basis and, in fact, cannot be used to determine if a plant will produce a safe and wholesome product during any day's run. Note that the sanitation compliance checklist incorporates minor, major, serious, and critical deficiency scores.

The definitions of each of these scores are:

Minor defect

One not in accordance with the requirements; however, is not major, serious, or critical in terms of deterioration of product quality.

Major defect

One which inhibits general sanitation; however, the deterioration of product quality is not serious or critical.

Serious defect

One which prevents proper plant sanitation; may result in tainted, decomposed, or unwholesome product, but not considered critical.

Critical defect

One which results in unwholesome product; presents health and safety threats; is not in accordance with Good Manufacturing Practices (GMP).

You should determine for your plant the maximum number of minor, major, or serious items acceptable at any one time. However, at no time should your plant operate with a critical deficiency.

Table 2. Sample Plant Sanitation Compliance Check List

For Seafood Processing Plants

Premises	Minor	Major	Serious	Critical	Check If OK
1. Litter, waste, or improperly stored equipment	X				
2. Excessively dusty roads, parking lots.	X				
3. Inadequate drainage	X				
4. Controls not in place to discourage pests such as flies and rodents		X			
BUILDING CONSTRUCTION 5. Design, materials, or construction inhibits sanitation		X			
6. Ceilings over exposed product not free of peeling paint			X		
7. Exterior openings, where practical, not equipped with screens, etc., to prevent entrance of pests, etc.		X			
8. Air curtains, strip doors, and screen doors, if installed, must be effective		X			
9. Processing area opens directly (without barriers) into living quarters, garage, or heavy maintenance shop		X			
LIGHTING 10. Lighting is inadequate	X				
11. Lights in product, packaging, or ingredient storage areas not safety type and unshielded			X		

Premises	Minor	Major	Serious	Critical	Check If OK
VENTILATION 12. Accumulation of condensates over exposed product, packaging material, or ingredients.	O	X			
13. Mold is present in processing or storage area	X				
WATER SUPPLY 14. a. Inadequate supply of cold or hot water b. Water not accessible		X X			
15. Water subject to contamination, e.g., siphoning, cross-connection.			X		
16. Freshwater not potable				X	
17. Water not approved by appropriate authorities for food processing			X		
18. Seawater not treated as specified in HACCP plan				X	
19. Seawater not approved by appropriate authorities for food processing			X		
ICE 20. Not made from potable water or appropriately treated seawater				X	
21. Not made from an approved water supply			X		
22. Not manufactured, handled, or used in a sanitary manner			X		
23. Transferred and re-used on other raw products	X				
DISPOSAL OF WASTES 24. Liquid waste not disposed of in a sanitary and timely manner		X			

Premises	Minor	Major	Serious	Critical	Check If OK
25. Dry waste not collected in suitable containers conveniently located throughout the plant or disposed of in a sanitary and timely manner	X				
26. Product waste not collected or disposed of in a sanitary manner		X			
27. Absence of functional washing facilities, tissues, soap, hot water, hand drying facilities, or signs directing employees to wash hands.			X		
28. Insufficient number of toilets as defined by USDA requirements	X				
CONSTRUCTION AND REPAIR OF EQUIPMENT, CONTAINERS AND UTENSILS 29. Product contact surfaces of all equipment, containers, and utensils not constructed from suitable, impervious, non-toxic corrosion resistant material, with the exclusion of the re-use of wooden boxes holding round or gutted fish until appropriate research is concluded			X		
30. Design, construction, or location of equipment, containers, and utensils is such that it demonstrably contributes to contamination and cannot be cleaned nor effectively sanitized, with the exclusion of the reuse of wooden boxes holding round or gutted fish until appropriate research is concluded				X	
31. Equipment, containers, or utensils not in good repair	X				

Premises	Minor	Major	Serious	Critical	Check If OK
32. No demonstrated monitoring program to remove used or abused containers, utensils, and equipment	X				
CLEANING AND SANITIZING 33. Equipment, utensils and containers not cleaned and sanitized before use			X		
34. Cleaning methods do not preclude product contamination			X		
35. Rooms and areas used for receiving, processing, and storing raw materials and finished product not maintained in a clean and sanitary manner		X			
36. Absence of effective in-plant sanitation program			X		
37. Sanitation control of finished product not sufficient to protect the product from contamination			X		
38. Absence of accessible washing and/or hand-dipping stations		X			
INSECTS, BIRDS, ANIMALS 39. Birds and animals not excluded from the plan		X			
40. Insect & rodent control measures not effective		X			
CHEMICALS 41. Insecticides or rodenticides not used as prescribed by EPA or USDA		X			
42. Chemicals not employed by approved methods or handled and stored in a safe manner		X			
43. Chemicals, toxins, sanitizer, food additives not properly labeled or stored		X			

Premises	Minor	Major	Serious	Critical	Check If OK
44. Unapproved chemicals and sanitizer used			X		
FROZEN, REFRIGERATED, DRY STORAGE FACILITIES 45. Shelves, cabinets, dunnage, and/or other methods not used where necessary to inhibit contamination	X				
46. Storing methods do not minimize deterioration	X				
47. Storage facilities not clean, not sanitary, not in good repair: a. Product packaging and ingredient storage b. Other storage		X X			
48. Plant management does not have in effect measures to restrict people with known disease (i.e., cuts, boils, influenza, etc.) from contaminating the product		X			
49. Personnel Cleanliness - Specified personnel not maintaining a high degree of personal cleanliness and conforming to hygienic practices while on duty (e.g., lack of clean outer garments or hairnets; presence of jewelry (other than unadorned wedding bands); chewing gum, drinking coffee, using tobacco, eating at the work station; storage of personal belongings at work station)	X				

Premises	Minor	Major	Serious	Critical	Check If OK
50. Personnel Practices - Personnel not taking necessary precautions to minimize contamination of foods with microorganisms or foreign substances (e.g., gloves not in sanitary and good condition; touching face, hair; picking product off the floor; not washing hands)		X			
51. Training of personnel in food hygiene is inadequate	X				
52. Appropriate supervisors (e.g., production, line, quality control, etc.) not held accountable for the cleanliness compliance of their employees		X			

4. PRODUCT RECALL SYSTEM

And finally, your HACCP plan will be required to include a suitable product recall system. Recall is an effective methods of removing or correcting consumer products that are in violation of laws concerned with the safe manufacture of food products in the United States and with their distribution to either domestic or foreign markets. Recall is a voluntary action that takes place because manufacturers and distributors carry out their responsibility to protect the public from products that present a risk of injury or gross deception or are otherwise defective.

The current Food and Drug Administration's (FDA) enforcement policy on product recall is provided in Section 21 of the Code of Federal Regulations (CFR). It is likely that this policy will remain essentially unchanged under any future mandatory seafood surveillance program regardless of the federal agency chosen to implement it.

In brief, a recall procedure starts with an evaluation by FDA scientists of the health hazard presented by a product being recalled or considered for recall. Next, a recall strategy is developed by FDA and by the recalling firm for a firm-initiated recall to suit the circumstances of the recall. A recall may be either an FDA-requested recall or a firm-initiated recall. In either case, it must address: 1) the level in the distribution chain to which the recall is to extend; 2) a public warning that the product being recalled presents a serious hazard to health; and 3) checks to verify that all appropriate consignees have received notification about the recall and have taken appropriate action.

Because a recall can disrupt a firm's operation and business, FDA provides the following guidance concerning the steps a prudent firm can take in advance to minimize the disruptive effect. They are: 1) prepare and maintain a current written contingency plan for initiating a recall in accordance with the recommended CFR; 2) use sufficient coding of regulated products to make possible positive lot identification; and 3) maintain product distribution records to aid in locating the products that are being recalled.

APPENDIX III

Example of a Processing Protocol for Moderately Thermal-Processed Crabmeat

This outline serves as a brief operations protocol containing the essential elements for producing safe, high quality pasteurized and moderately thermal-processed crabmeat. It represents concepts which might be included in a plant's operations/quality assurance plan, including HACCP. Not included are details of related GMP's, comprehensive HACCP analysis, or thermal processing principles and technologies used by other plants—such information is contained in several manuscripts that are referenced elsewhere in this document. This outline is provided for illustrative purposes and does not represent any existing operation.

Basis for Chosen Process

The procedures followed at XYZ Seafood Corporation for producing pasteurized refrigerated crabmeat have and will continue to meet the National Blue Crab Industry Association guidelines, entitled "National Crabmeat Industry Pasteurization Standards, 1984," published by the National Fisheries Institute. These standards assure a minimum process lethality of F_{185}^{16} = 31 minutes. This year, the National Advisory Committee on Microbiological Criteria for Foods endorsed these recommendations.

These standards were also recognized by the National Marine Fisheries Service and the seafood industry (National Fisheries Institute) in their draft blue crab HACCP report (1988). They identified four critical control points (CCP's) for pasteurization in addition to three for producing fresh crabmeat. Preventive measures, monitoring, and records were outlined for:

1. sealer operation
2. pasteurizer control (can seam inspection, time/temperature process, and operator training)
3. adequate product cooling rate
4. assurance of 32° to 36°F storage.

The XYZ Seafood quality assurance program has and will continue to monitor these CCP's.

The procedures followed for processing crabmeat in five-pound-net cook-in bags were developed by faculty at Pangea Institute of Technology jointly with the seafood industry and Vacfroze Packaging Corporation. They are currently implemented in at least five U.S. firms for processing frozen seafood in cook-in bags or plastic pouches. The process was established to meet an institutional market requirement for crabmeat that is guaranteed to be *Listeria* free. The process targets *Listeria* and other potential vegetative pathogens and is not intended for

extending refrigerated shelf-life. Products produced by this method at XYZ are stored and distributed only in a frozen form. The plastic film selected by XYZ is widely used in the meat industry and is durable over a broad temperature range.

In addition to the procedures outlined in the attached protocol, at least one individual responsible for pasteurization at XYZ will receive training in moderate thermal processing principles through a recognized institution.

A letter from a recognized process authority (attached) states that if XYZ Seafood follows these procedures, they will produce safe, high quality pasteurized and moderate thermally processed crabmeat. These processing procedures develop heat exposures considerably in excess (more than 40 decimal reductions) of what is required to destroy *Listeria monocytogenes*, other potential vegetative pathogens, and *Clostridium botulinum* type E at any level possibly present in crabmeat.

STANDARD OPERATING PROCEDURES FOR XYZ SEAFOOD

September 1, 1993

I. Moderate Thermal Processing Procedures for Frozen Crabmeat

A. Filling/Sealing

In the plant's packing room, coded cook-in bags are placed one at a time on a scale and hand filled with five pounds (plus or minus one percent) of fresh crabmeat. The bags are wiped free of water and crabmeat in the seaming area with disposable paper towels. The filled bags are (1) laid individually in a chamber style vacuum-sealing machine, (2) the meat distributed uniformly by manually shaping the bag and its contents externally; then they are vacuum sealed.

CCP: Sealing Operation

1. Head seal bonding must be sufficiently strong so as to be destroyed when film sides are forcibly spread apart rather than releasing cleanly along the contact zone. This test shall be performed on two or more empty bags when setting up the sealing machine at the start of operation (each time the sealer machine is turned on) and at least every four hours of operation. Additionally at least one test bag shall be filled with a small quantity of water, then sealed and hand squeezed for signs of leakage. In addition to start up testing, all filled bags should be inspected for signs of vacuum loss prior to pasteurization. If the product warms after sealing, slight package loosening is expected. However, vacuum level should be adequate to resist lifting of the film off of the product surface. Suspect bags shall be opened and the meat repackaged as described above or further tested by submerging in water (break-point chlorinated) and hand squeezed. The release of bubbles indicates leakage and the need to repackage the crabmeat as before. These methods are consistent, although not identical, with guidelines proposed by the National Food Processors Association's Flexible Package Integrity Committee (1989).
2. Prior to placing bags in the pasteurization basket, a minimum of ten percent of filled bags shall be inspected to assure that package thickness is uniform to within 3/4 inch differential in any two locations in each bag evaluated. These bags should be selected among those appearing to have the greatest thickness variation.
3. A HACCP reporting instrument (form #XYZ-1) shall be completed and filed with the process record, indicating that each test procedure was followed as appropriate.

Management shall review the records for each code lot within 48 hours of processing.

4. Corrective action involves repacking and reprocessing the crabmeat following all procedures and records maintenance as described.

B. Thermal Process (Includes Cooling)

The filled bags shall be carefully hand laid into the pasteurization basket. Bags in each layer may touch each other but should not overlap by more than two inches. (XYZ uses a shrink bag material that properly draws up during heating, reducing length by width dimensions. Process schedules account for this effect). Up to approximately 385 pounds of crabmeat is placed in each basket.

Each layer is separated by a rigid vinyl-coated steel perforated (1.25 inch holes on 3.75 inch centers) spacer on which are attached flanges that maintain 3.5 inch spacing. These assure waterbath circulation over and under each bag layer. All basket and spacer surfaces shall be inspected and maintained to eliminate sharp edges or burrs.

The basket is submerged in either of two single-basket batch pasteurizers at the plant, with the timed portion of the process beginning when the waterbath returns to 187°F or hotter. The waterbath in the heating tank is maintained in the range of 187°-190°F and uniformly agitated by compressed air injection (preset with a constant flow valve). The current process of heating for a minimum of 120 minutes is based on initial meat temperatures (I.T.) of 49°F or warmer. Colder I.T.'s require the establishment of a new process by a recognized process authority.

Continuous chart recorder/controllers on each pasteurizer record times and waterbath temperatures to document the heating portion of each batch. These devices shall be serviced and calibrated to assure clock and temperature accuracy and temperature control within the prescribed range. This service shall be conducted at least annually by a competent technician. MIG indicating thermometers are mounted on the tanks but read 2-4°F low, which is normal in submerged systems. Temperature readings from a hand-held digital thermometer are compared to the chart tracing as a check for accuracy (attachment). The portable thermometer will be calibrated weekly against agitated ice slush and rapidly boiling water, and against a standard reference MIG thermometer semi-annually.

After heating, the basket is transferred to vigorously agitated ice slush for 120 minutes prior to racking and placement of the bags in a freezer (-20°F). As before, bags shall be handled carefully. Cooling water must be potable and break-point chlorinated. A heavy ice slush should be maintained throughout the cooling period.

CCP: Thermal Process

1. Confirm product I.T. at time of loading pasteurization basket within 15 minutes of placing in the pasteurizer. This will be performed nondestructively by stacking two bags and laying between them a thermocouple or other calibrated temperature measuring device.
2. Indicate the following information on recorder charts:
   a. Times when baskets are submerged and removed from the hot waterbath pasteurizer (can be marked directly on the chart tracing if not obvious from the tracing).
   b. Number (or pounds) and type of package.
   c. Date of processing.
   d. Lot code.
   e. The reading of the digital thermometer after the recorder/controller set-point temperature is reached and during the holding period.
   f. Time that the batch is removed from ice slush.
   g. Signature of operator.

3. When the bags are lifted from the basket for placing, on the freezer racks all shall be visually inspected for evidence of leaks (e.g. water in bags) and, where indicated, firmly squeezed to confirm integrity. The release of air or water indicates a defect (a critical limit). Form #XYZ-2 shall be completed as verification that this check was performed.
4. Records shall be reviewed by management within 48 hours, initialed and dated to indicate such, and maintained for two years from the date of processing.
5. Critical limits and corrective actions involve the following:
   a. A thermal process deviation occurs if hot waterbath temperature drops below 187°F for more than five minutes after the waterbath has attained set-point temperature and stabilized. If this condition should occur for five to ten minutes, the controller set-point can be raised to 192°F and an additional 20 minutes added to the process (140 minutes total). Optionally a full 120 minute, 187°-190°F process can be repeated. If this condition should occur for longer than ten minutes, a full 120 minute, 187°-190°F process must be repeated.

b. Bag integrity failure requires that the crabmeat from the defective bag(s) be repackaged and fully reprocessed in another lot.
c. Any corrective action shall be performed by qualified personnel and must be fully documented, and records retained with others pertinent to the affected lot.

II. Pasteurization Procedures (401x301 tinplate cans)

These procedures are well established nationally and at XYZ. They will be given less detail here than was given to the cook-in bag process. The process schedules, CCP's, reporting instruments, review procedures, critical limits, and corrective actions are the same as for moderate thermal processing in bags except for the following:

A. Filling/seaming:

Cans are filled with crabmeat (16 ounces net) and closed on a seamer that produces a double seam. At start-up, following a jam, and after seaming 500 cans, one or more sealed cans shall be torn down using accepted can seam evaluation procedures, as currently performed by the XYZ quality assurance manager. Appropriate measurements shall be recorded and compared to the container manufacturers seam specifications. If seams are found to be out of specification, appropriate adjustments shall be made to the seamer and noted on the seam evaluation form. Any containers closed subsequent to the last acceptable seam report should be opened, packed into new cans, and re-seamed prior to pasteurization.

B. Thermal Processing:

Cans are stacked into pasteurization baskets side by side in layers. Each layer is separated by a perforated (3/8 inch holes on 1/2 inch centers) plastic divider.

The established process is based on fresh-picked crabmeat at ambient temperatures.

CCP: Storage

The refrigerated storage room should be maintained at 36°F or below. Occasional ambient increases to 40°-45°F shall not constitute a violation of a critical limit if storage temperature returns to below 36°F within 24 hours. A continuous, or at least daily, record of storage room temperature will be retained.

APPENDIX IV

National Blue Crab Industry Pasteurization Standard

National Crabmeat Industry Pasteurization Standards, 1984

Section 1: Cooking.

A. As soon after delivery of live blue crabs as possible, the crabs should be cooked in accordance with state regulations.

B. Unless crabs are cooked within 1-2½ hours after receipt at the processing plant, they should be refrigerated in live crab cooler at 40-50 degrees F.

Section 2: Cooling.

A. Cooked crabs, after removal from the retort, should be air-cooled to room temperature without being disturbed. If not picked within 8 hours, they should be refrigerated at 40 degrees F or less.

B. Cooked and raw crabs shall not be stored in the same cooler. It is further recommended that whole crabs be stored in the same container in which they were cooked. It is essential that the cooked crabs be protected from contamination from all sources. If continuous cookers are used it is recommended that the cooked product be stored in cleaned and sanitized non-porous containers.

Section 3: Picking and Packing.

The picking and packing operations should be performed such that contamination of the meat is avoided. Within one hour after picking, the crab meat should be delivered to the packing area and the cans sealed and placed in either refrigerated storage or into the pasteurization process.

Section 4: Pasteurization.

A. Crab meat for pasteurization shall be pasteurized within 36 hours of the time it is picked.

B. The minimum pasteurization specifications for a 401x301 can shall be the raising of the internal temperature of the container of crab meat to 185 degrees F and holding at that temperature for at least one minute at the geometric center of a container approved by the state regulatory authority. Because pasteurizing at this temperature may cause blueing in Gulf and South Atlantic crabs, nothing in this section shall be construed as barring any other pasteurization process which has been found equally effective and which is approved by the state regulatory authority, such as pasteurizing at a lower temperature but longer time to achieve an equivalent process. (See Section 4, E for further details on variables such as container size).

C. Each set of pasteurizing equipment shall be standardized so that the above pasteurization treatment can be obtained.

D. The plant operator shall keep on file the standardization report, and his pasteurization procedure shall be performed in accordance with it.

E. Temperature-time requirements must be determined for each water bath and for other conditions, such as the temperature of the meat, the size of the container and other variables. Alteration of the equipment or in the stacking of containers shall require that the procedure be restandardized. Plant operators are warned that time-temperature conditions for one water bath may not give satisfactory pasteurization on another water bath. The introduction of new containers will require the development of process controls in terms of F-values, integrating total heat penetration with time, instead of the traditional 185 degree F for one minute minimum at the geometric center of a one pound, 401x301, can. Proper determination of F-values should be performed by qualified individuals or institutions.

F. In the event of a power or equipment failure that interupts the normal pasteurization schedule it is recommended that all cans be removed from the pasteurization vessel and refrigerated. Once all product has equilibrated to the refrigeration temperature it can be pasteurized according to normal schedules.

Section 5: Seam Sealing.

A. When containers require a metal end seam, inspection of can seams shall be made at the start of the seaming process and again twice per day per closing machine in accordance with recommended procedures for examining seams. Should can seaming equipment malfunction, inspection of can seams shall be made before resuming operations.

B. At least one employee shall be trained in can seam inspection and in the adjustment of can seaming equipment. One person from management shall be responsible for reviewing records - within one working day.

C. Records shall be maintained by the processor on all can seam inspections.

D. The company supplying pasteurization cans to plant operators shall supply certification of can integrity for each lot of cans purchased.

Section 6: Cooling, Refrigeration, and Storage.

A. The containers of meat must be chilled by circulated cooling water to 55 degrees F within 180 minutes to allow refrigerated storage after processing. This should not be construed to preclude any other cooling procedures that can achieve the same rate of cooling.

B. Upon completion of the cooling process, the meat shall be placed in refrigeration and shall obtain a temperature maximum of 36 degrees F within 18 hours.

C. Pasteurized crab meat, whether in or out of shipping cartons, should be maintained continuously at or below 36 degrees F until shipped. Shippers, wholesalers, retailers, and consumers should maintain stored crab meat at or below 36 degree F, but above 32 degree F.

D. Shipping containers as well as product containers should conspicuously feature refrigeration instructions.

Section 7. Labeling.

A. All labels used shall clearly identify the contents of the container as pasteurized crab meat, and conform to other state and federal requirements.

B. Whenever the term "crab meat" (or its equivalent) appears on the label, the word "pasteurized" shall be used in immediate conjunction in type of equal prominence.

C. Each container shall be permanently and legibly identified with a code indicating the day, month, and year of processing.

D. The words "Perishable--Keep Under Refrigeration" or their equivalent shall be prominently displayed on the label.

Section 8. Pasteurization controls.

A. Both indicating and recording thermometer shall be provided on all pasteurization equipment and serve as time-temperature controllers. The bulbs of both thermometers shall be so located as to give a true representation of the operating temperature of the water bath. A representative of the state regulatory authority or qualified technician shall check the accuracy of both thermometers as installed and at least once each operating season. The recording thermometer chart must be at least a 12-hour chart and at least 10 inches in diameter.

B. The recording thermometer shall be installed so that it will be protected from vibration and from striking by loading operations or plant traffic. The thermometer mechanism shall be so located as to be protected from moisture under prevailing operating conditions. The thermometer case

shall not be opened during the pasteurizing cycle except for temperature check, or for emergency adjustment or repair, a record of which shall be made.

C. The recording thermometer shall have a range of at least 120-220 degrees F. It shall be accurate within plus or minus 1 degree F between 160 degrees F and 200 degrees F. The chart shall be scaled at a maximum of 2 degrees F intervals in the range 160 degrees F and 200 degrees F.

D. The indicating thermometer shall have an accuracy and readability of plus or minus 1 degree F between 160 degrees F and 200 degrees F and be a minimum of seven inches in length.

E. The recording thermometer shall be equipped with a spring-operated or electrically-operated clock. The recorded elapsed time as indicated by the chart rotation shall not exceed the true elapsed time shown by an accurate watch. A representative of the state regulatory authority or qualified technician shall check the accuracy of the clock as installed and once each operating season.

F. The pasteurization unit shall not be operated without a recording thermometer chart in place, the pen in contact with the chart and an inked record being made of the operating time-temperature cycle. Any indication of falsification of a thermometer chart shall constitute a violation. A new chart shall be used for each day's operations and the code number or date of each batch affixed to the chart for each pasteurizing cycle.

G. A permanent file of the used thermometer charts shall be maintained by the operator and kept available for inspection by the state regulatory authority for a period of two years.

The following information shall be recorded within the confines of the pen markings after the pasteurization cycle has been completed:

1. Date of processing.
2. Quantity of each batch processed (pounds of meat or number and size of containers.
3. Processor's code of each pack.
4. If the operator processes meat for someone else, then the packer's name, and license or certification number must be recorded.
5. Mechanical or power failure, or opening of the recording thermometer case for adjustment or repair during a pasteurizing cycle.
6. After the optimum temperature has been reached and during the holding time, the reading of the indicating thermometer and the time of reading shall be recorded.
7. Written signature of the operator.

NOTE: It would be permissible under point 4 to put required information on back of recording chart, however, it is preferable on the front; in any case, the information must be written on the chart and not attached to it.

H. An automatic constant-flow steam-control valve is required if steam is used as a source of heat. In addition, base covers should be perforated for water circulation. The water bath shall be provided with effective agitation to maintain a uniform temperature.

Section 9. Microbiological Standards.

Processors shall conform to such microbiological standards which may from time to time be established by state regulatory authorities.

Section 10. Record Keeping.

A. The processor shall maintain records of results of examinations and/or copies of suppliers' guarantees or certificates that varify compliance with Food and Drug Administration regulations, guidelines, or action levels on raw materials, food-packing materials, and finished foods.

B. The processor shall maintain processing and production records of the pasteurization process to permit public health evaluation of the product.

C. Records required by paragraphs "a" and "b" of this section shall be retained for a period of time exceeding the shelf life of the pasteurized crab meat or not to exceed 2 years from the date of pasteurization.

Section 11: Training and Certification of Pasteurization Technicians.

A. Each plant pasteurizing crab meat must have at least one responsible employee certified as a pasteurization technician.

B. In order to be certified as a pasteurization technician, an individual must have attended a pasteurization training program approved by the Shellfish Institute of North America.

C. The effective date of this portion of the National Industry Pasteurization Standards (Section 11) is June 1, 1984.

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