THERMAL PROCESSING PASTEURIZATION MANUAL

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Preface

The delightful taste and aroma of meat from cooked blue crabs have been known for quite some time. Records indicate that markets for crabs were being developed as early as the 1800's. The blue crab meat is highly perishable, which may account for the fact that crabmeat was almost unheard of outside the coastal regions.

In the 1940's, J. V. Anzulovic and R. J. Reedy, both bacteriologists with the U. S. Fish and Wildlife Service, published their findings in Fishery Market News on a water-bath method of pasteurizing crabmeat in sealed metal containers. Later C. R. Fellers and S. C. Harris experimented with an improved procedure which increased shelf life; and in the early 1950's, G. C. Byrd patented a method of pasteurizing crabmeat in cans.

The pasteurization of crabmeat in sealed containers has come a long way in its acceptance by processors and consumers alike. First produced by a few inventive processors who realized its potential in smoothing out inventory problems and expanding their marketing radius and thus marketing opportunities, pasteurization is now thought by many to have been the industry's salvation.

As would be expected of any process which offers the marketing flexibility, pasteurization is being used with increasing frequency in the crabmeat processing industry. But many processors adopted the procedure without fully understanding the basics of 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 careless processing habits have brought the pasteurization industry to the attention of regulatory agencies. It is the intent of this manual to introduce to the crabmeat pasteurization industry good manufacturing and thermal processing methods which are currently practiced by other segments of the food industry. It behooves the industry to use this manual to increase their understanding of the pasteurization process and improve their procedures to comply with what will assuredly be stricter controls 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 can seam evaluation also is discussed. This is an area which will undoubtedly be given greater attention by processors and regulatory agencies in the future. Finally, the importance of adequate documentation of the various processing parameters is covered.

Acknowledgement

We thank John Chandler, Department of Food Science and Technology and Don Massie of the Photo Lab of Virginia Polytechnic Institute and State University for their assistance.

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Thermal Processing Principles
Bacteriological Aspects

The traditional pasteurization process that has been recommended (Tri-State) and practiced by a fairly substantial portion of the industry entails heating one pound (401 x 301 cans) containers of crabmeat to a temperature of 185°F at the cold point (slowest heating point) and holding for one minute. The Tri-State recommendations then call for cooling of the product to a cold point temperature of 100°F in 50 minutes.

Inherent in these recommendations are the concepts of heating and cooling. Looking closely at the process questions such as these may come to mind:

1) What is happening during the heating phase that extends the product shelf life?
2) Why heat to 185°F? Would 190° F be better? Would 175° do the same job?
3) Why is the time one minute mentioned? Could the product be processed for a shorter time period?
4) Could a processor choose to use a lower temperature but heat the product for a longer time? Would advantage be gained or lost?
5) What is so important about cooling? Once the product has been heated sufficiently to pasteurize, isn't cooling of only secondary importance?

These are examples of just some of the questions processors have asked, but unless an individual has some understanding of the principles of pasteurization, answers to these questions can be difficult.

Pasteurization is a term that is used to refer to a mild heating process. By definition the term indicates that the product is not sterile but may continue to contain microorganisms (bacteria). Consequently, pasteurized products must be refrigerated continuously so that the surviving microorganisms will not multiply too rapidly and thus shorten the product's anticipated shelf life.

Sterilization refers to processes where severe heat treatments are used.

By definition, the term indicates that virtually all microorganisms have been destroyed and thus the product need not be refrigerated in order to achieve the anticipated shelf life.

D-value.

When microorganisms are heated to a lethal temperature as during the pasteurization of crabmeat, the death of most of the microorganisms can be shown to follow a rather orderly manner of destruction. Figure I-1 shows a hypothetical result of heating a species of microorganisms at 185°F. In this example, one minute is required to reduce the number of surviving microorganisms from 100 to 10, a 90% reduction. Similarly, one minute is required to reduce the number of survivors from 1,000 to 100 per gram of food.

Definition of D-value: Decimal Reduction Time (D-value) is the time to reduce the survivors by 90%.

In the example in Figure I-1 the D-value is one minute (D_{185}=1); simply stated, it means that at 185°F it took one minute to reduce the microbial population by 90%. The subscript after the D indicates the temperature at which the D-value was determined.

Z-value.

To continue on with the example, additional studies could be made on microbial inactivation at temperatures other than 185°F. Let us assume this was done and the D_{170} value was 10 minutes. (Remember from our example that the D_{185} was 1 minute.) These data could be summarized on a thermal resistance curve as shown in Figure I-2. In Figure I-2, a change of one log cycle (1 to 10) is equivalent to a 15°F change in processing temperature. The Z-value can be obtained from this curve. As the graph indicates, if the process temperature is raised 15°F, the processing time can be lowered one log cycle (10 to 1 minute in this example) and still have an equivalent process.

Definition of Z-value: Number of degrees Fahrenheit required for the thermal destruction curve to traverse on log cycle.

Accordingly, the Z-value is an indication of the relative resistance of microorganisms to thermal destruction. For example, an organism with a Z-value of 10 is more sensitive to heat than an organism with a Z-value of 15.

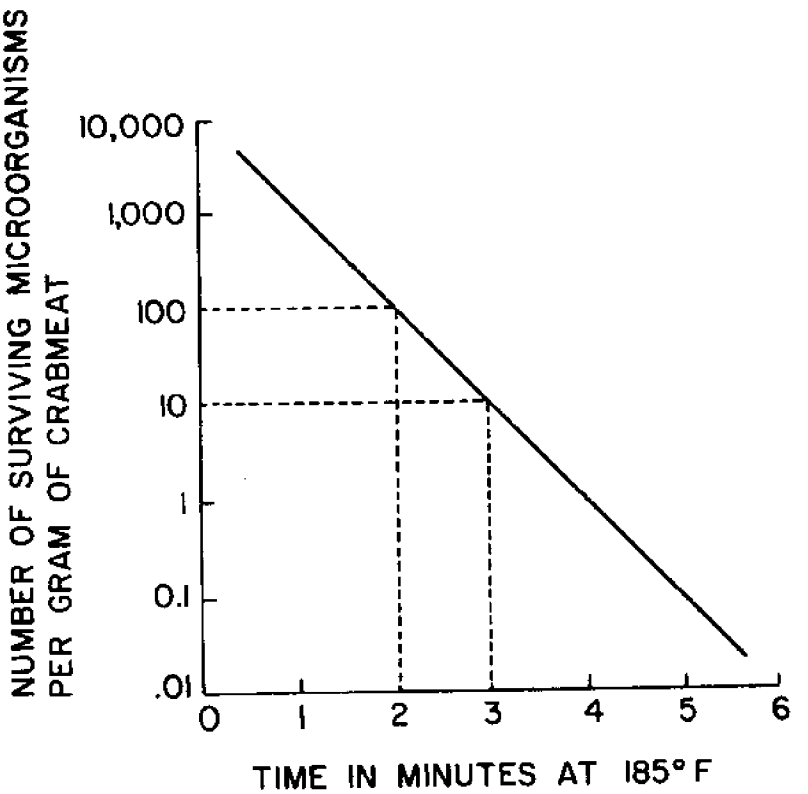


Figure I-1. Logarithmic survivor curve

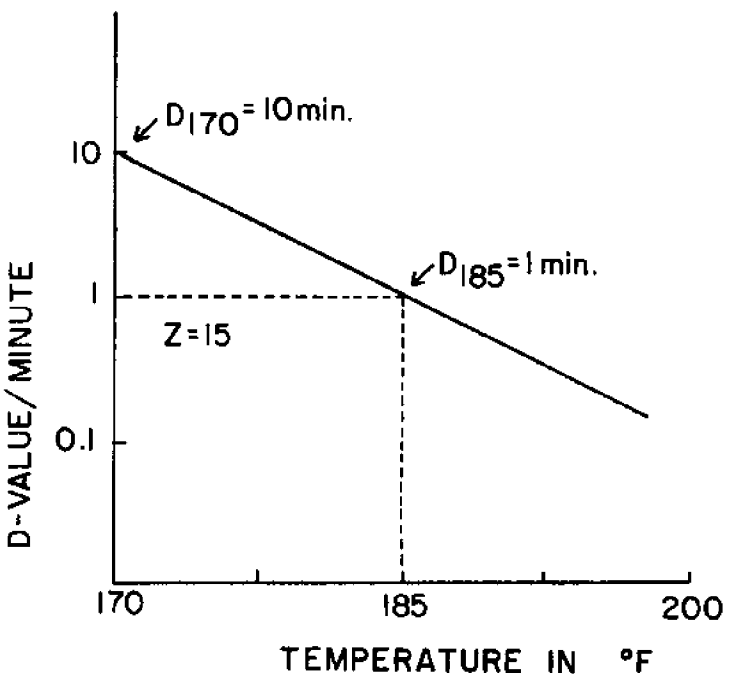


Figure I-2. Thermal resistance curve

F-value.

The F-value is a term which is useful in describing the total heating value of the process.

Definition of F-value: 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 for a process is the number of minutes required to kill a known population of microorganisms in a given food under specific conditions. In shelf stable (sterile) can food products, the F-value is usually set at 12 D-values to give a theoretical 12 log cycle reduction of the most heat-resistant species of mesophilic spores in a can of food. In our crabmeat example, if we start out with 1,000,000 microorganisms of a species in the entire can of crabmeat and a 12 D process was given, the initial 1,000,000 microorganisms (10^6 microorganisms) would be reduced to a theoretical 10^{-6} microorganisms per can, or one living microorganism in one million cans of product. In crabmeat, however, we don't even come close to approximating the 12 D process given the more traditional shelf stable products. In the latter products, the process times and temperatures are based on the heat resistance of "spores". Spores are the non-vegetative stages of certain bacterial genera which are much more heat-resistant than the vegetative stage. Additionally, the process is based on the most heat-resistant spore. Consequently, these processes are usually given at temperatures in the 240 to 250°F range at specific times, depending on the product, can size, and other variables.

While the F-value for the sterilization process of traditional foods differs markedly from the F-value for the pasteurization process of crabmeat, the thermal processing principles are the same. To further elaborate on the concept of F-value, consider the following hypothetical example in crabmeat: What does it mean when one pasteurized a 16 oz. (401 x 301) can to a value of F_{185}^{16} = 30.9 minutes? The symbols F_{185}^{16} indicate that the reference temperature is 185°F (traditional pasteurization temperature), and the heat resistance (or Z-value) of the microorganisms in question is 16. Most pasteurization heating and cooling curves in 16 oz. cans look very similar to the example in Figure 1-3. Note the shaded area under the curve. This is the portion of total process (both heating and cooling) which is making a contribution to

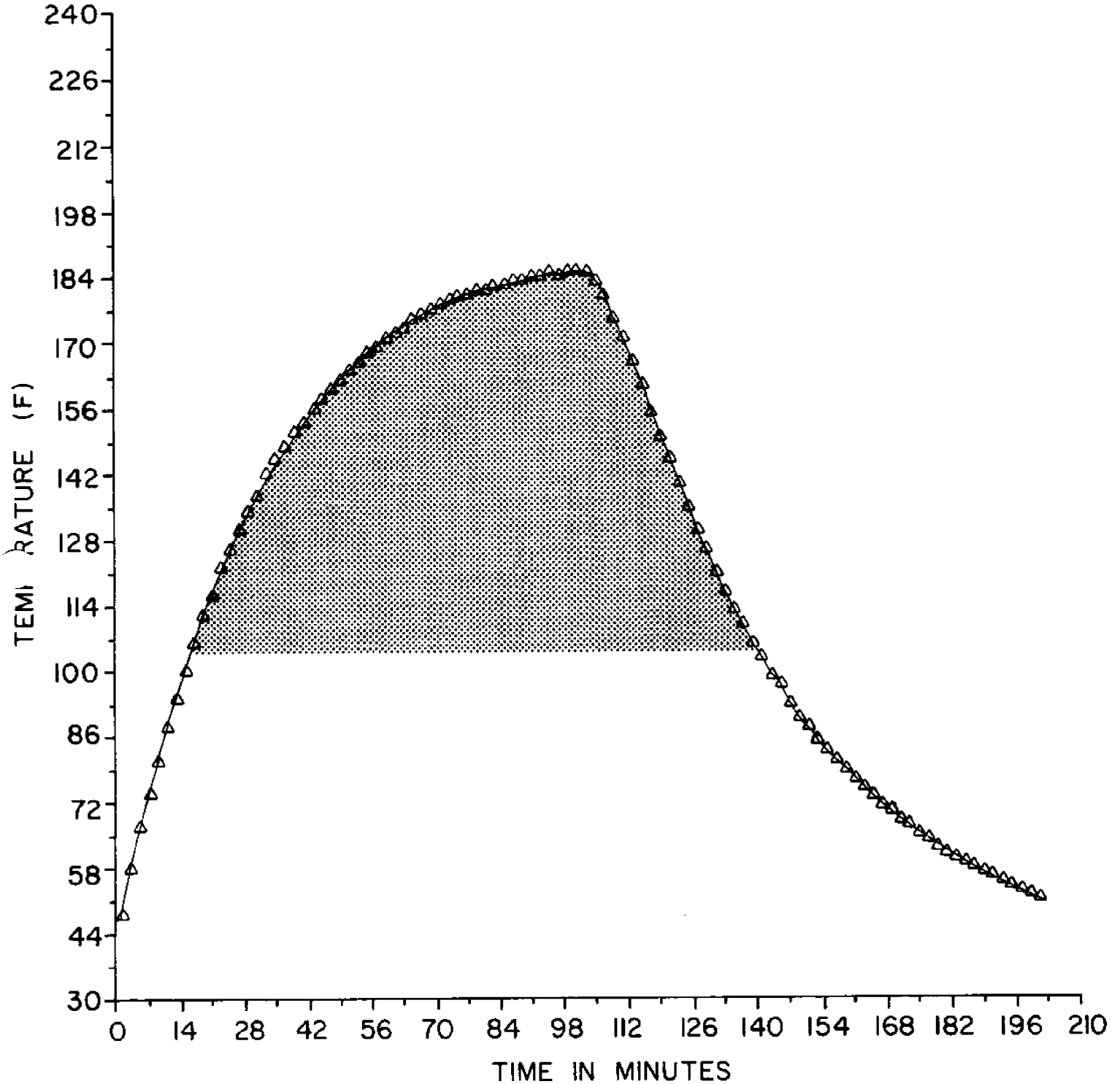


FIG. I-3 HEAT PENETRATION CURVE FOR 16 OZ. OF CRABMEAT IN A 401 X 301 CAN.

the destruction of microorganisms with a Z-value of 16 and below. Also, that area under the curve is equivalent to 30.9 minutes of processing at 185°F.

It may be easier to envision the concept of an F_{185}^{16} = 30.9 minutes by considering Figure I-4. If it was possible to instantaneously heat a 16 oz. 401 x 301 can of crabmeat to a cold point temperature of 185°F, to hold that temperature for a period of 30.9 minutes, and then to instantaneously cool the product, the result would be a F_{185}^{16} of 30.9 minutes. Obviously, it would be impossible to produce such a rapid heating and cooling effect. Nonetheless, despite the slow heating and cooling phases, the lethal impact of the heat begins at a temperature of approximately 111°F. As the temperature increases above 111°F, the destructive contribution of the heat also increases. As the internal temperature of the product approaches 185°F, the destructive impact becomes maximal. Even as the product cools microorganisms continue to get destroyed. During the cooling phase, the heat that remains in the can is contributing -- in decreasing proportions -- to the lethality of the process until the temperature drops below 111°F. (The amount of lethality contributed by the process at 111°F, however, is exceedingly small -- it would take over 166 hours at 111°F to achieve an F_{185}^{16} of 1 minute.) The sum total of all the heating effects of the process during heating and cooling is equivalent to 30.9 minutes at 185°F.

Effect of Container Size.

As mentioned earlier, crabmeat traditionally has been pasteurized at 185°F for 1 minute at the cold point and then cooled to 100°F within 50 minutes. This process has been based on the pasteurization of 16 oz. of crabmeat in 401 x 301 cans. The obvious question is: What would the effect be of using this same processing parameter on smaller cans? The answer to the question is, quite simply, underprocessing. This, of course, assumes that the traditional process in 16 oz. (401 x 301) cans is the reference process. Figures I-5 and I-6, representing the heating and cooling curves for 4 211 x 114 can and 8 oz. 307 x 206 can containers, respectively, demonstrate the problem. Since the containers are smaller, they do not require as much time to be heated to 185°F at the cold point. Consequently, the total exposure of the product to the lethal effects of the heat is significantly reduced. Hence the F_{185}^{16} values are smaller than the 30.9 minutes required of the 16 oz. 401 x 301

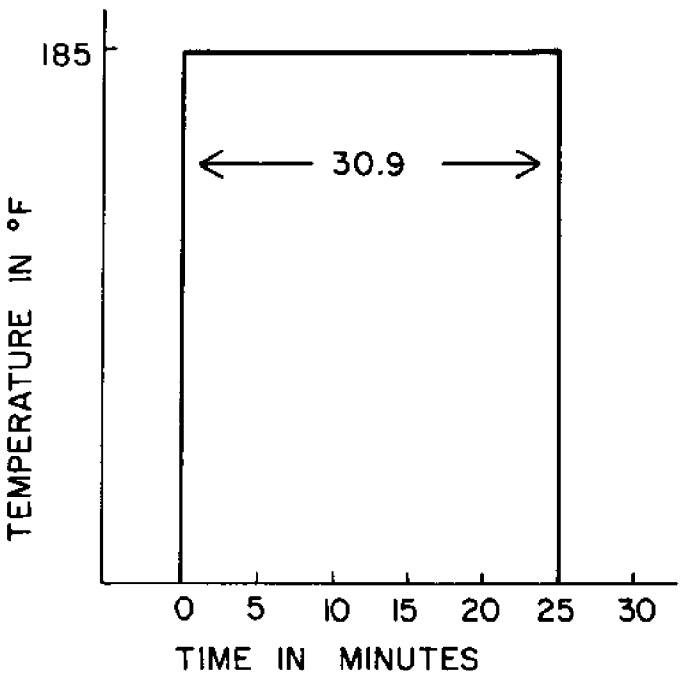


Figure I-4. Hypothetical heat penetration curve assuming instantaneous heating and cooling

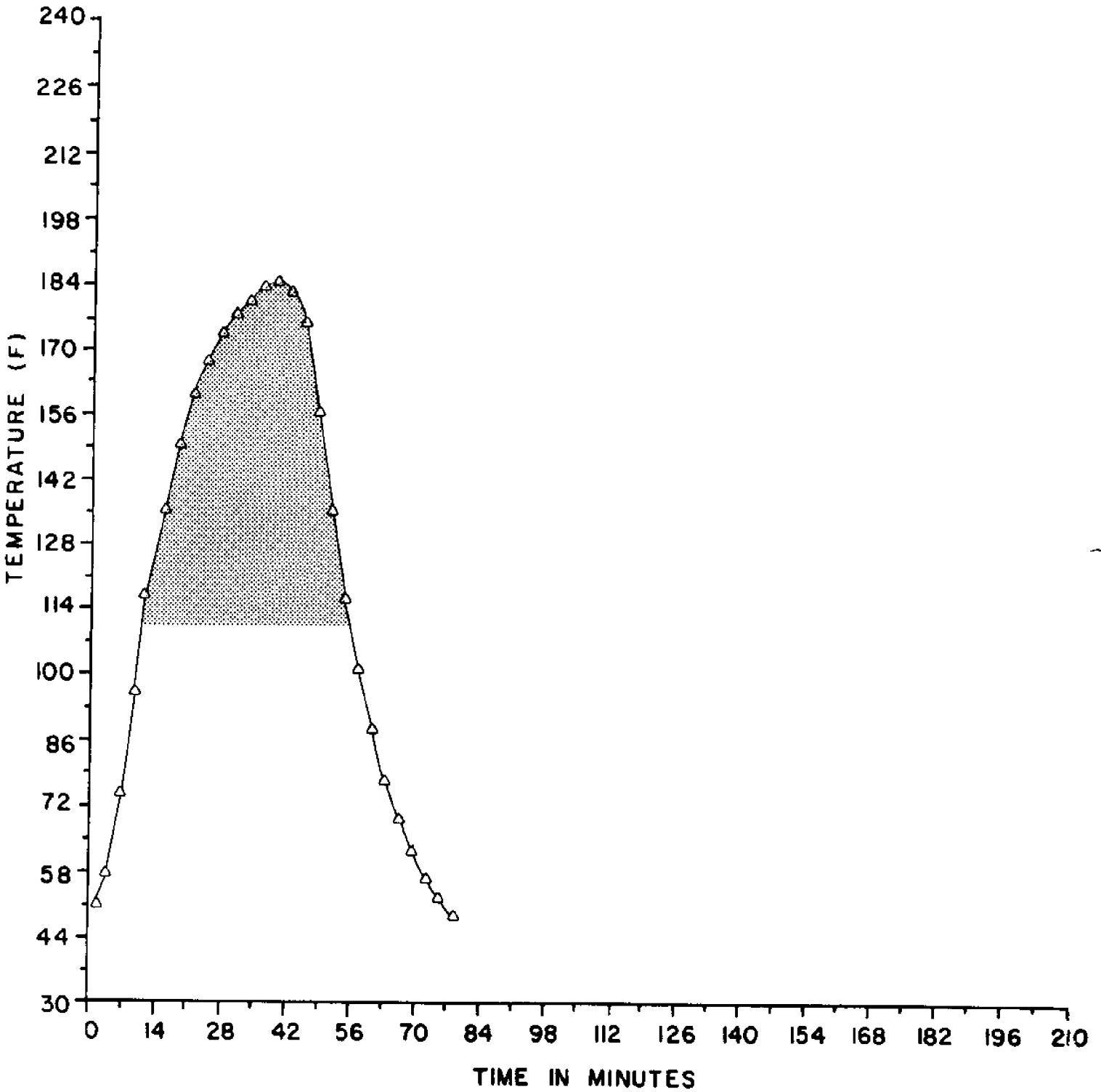


FIG. I-5 HEAT PENETRATION CURVE FOR CRABMEAT IN A 4 OZ. CAN

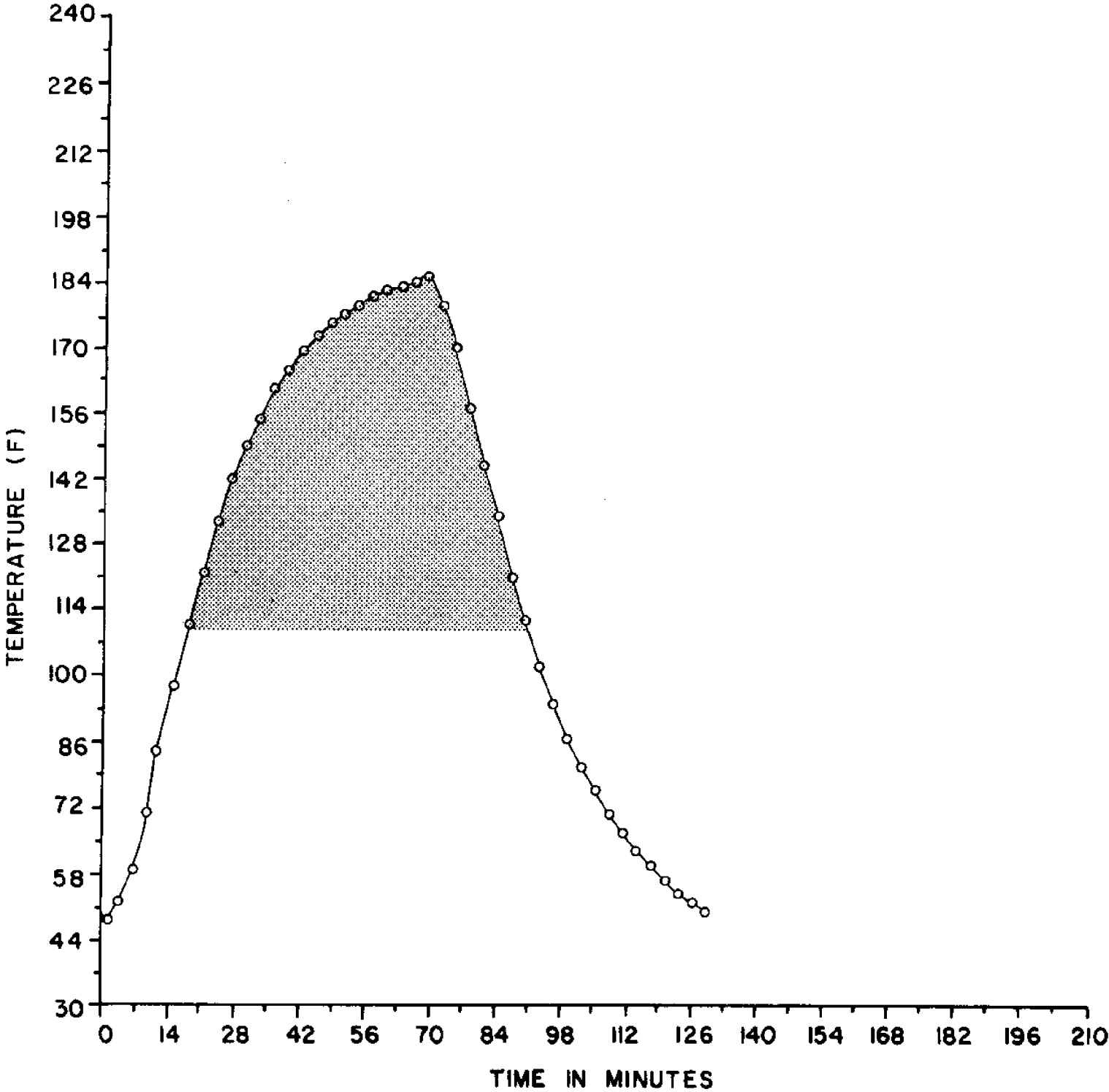


FIG. I-6. HEAT PENETRATION CURVE FOR CRABMEAT IN A 8OZ. CAN

cans. The F_{185}^{16} for the 8 and 4 oz. containers are 16.9 and 11.7 minutes, respectively. Furthermore, 16 oz. of crabmeat in a can of dimensions other than 401 x 301, the can commonly used by industry, may alter the process values. Figure I-7 shows an actual heating and cooling curve for 16 oz. crabmeat packaged in 303 x 406 cans. The cans were heated to an internal temperature of $185^{o}F$ for 1 minute. This resulted in an F_{185}^{16} of 24.5 minutes.

In the cases just cited, in order to achieve processes equivalent to the traditional cook in the smaller containers, the processor would need to heat the products to cold point temperature of $185^{o}F$ and hold for 14.0 minutes in the 8 oz. cans, 19.2 minutes in the 4 oz. cans, 6.4 minutes in the non-standard 303 x 406 16 oz. can, and then begin the cooling phase. The end result of these three processes would be an F_{185}^{16} of 30.9 minutes which would then be equivalent to the reference process.

Let's turn the situation around, and assume a processor cooks an 8 oz. can using the same time and temperature that he has always used for the standard 16 oz. cans. (We assume that the processor has had at one time or another thermocouples inserted into his 16 oz. cans and thus knows how long he must cook these cans to achieve $185^{o}F$ for one minute at the cold point). In this particular instance the processor is significantly overcooking the product. Previous work done at Virginia Tech has shown that 8 oz. cans cooked using the processing protocol for the traditional reference process in 16 oz. cans result in F_{185}^{16} in the 8 oz. cans of 44.63 minutes. In other words, the smaller cans were overprocessed by 13.73 minutes.

Process Variations between Plants.

If one were to survey the various plants pasteurizing crabmeat, and document such factors as those listed below, one would undoubtedly find a significant variation among plants.

1) size of tank,
2) size of steam lines entering tank,
3) boiler operating pressure (affects temperature of steam entering tank),
4) loading of tank - number of cans,
5) temperature of water in pasteurizing tank,
6) initial temperature of product, and
7) method of cooling pasteurized product.

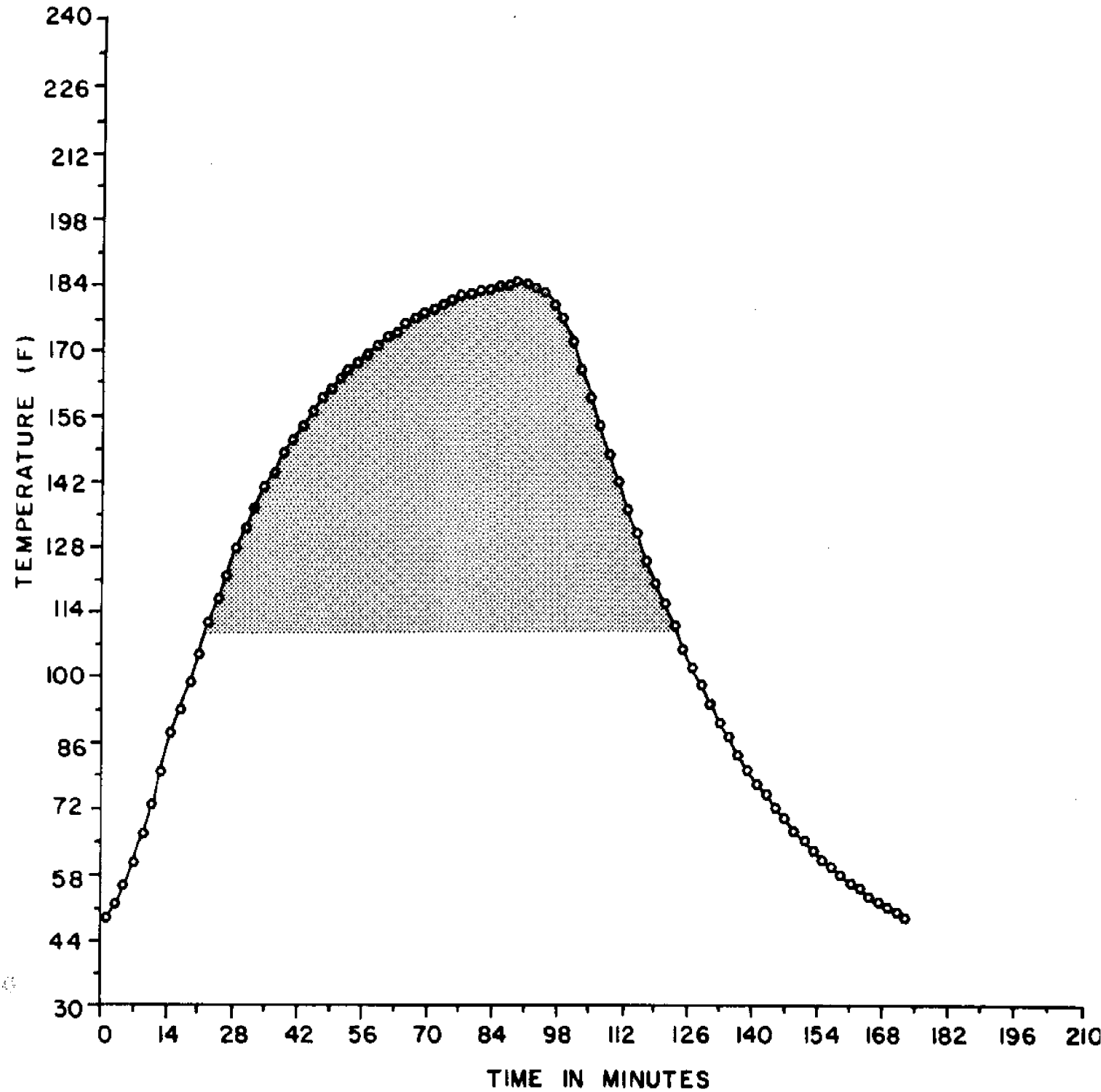


FIG. I-7. HEAT PENETRATION CURVE FOR 16 OZ. OF CRABMEAT IN A 303 X 406 CAN.

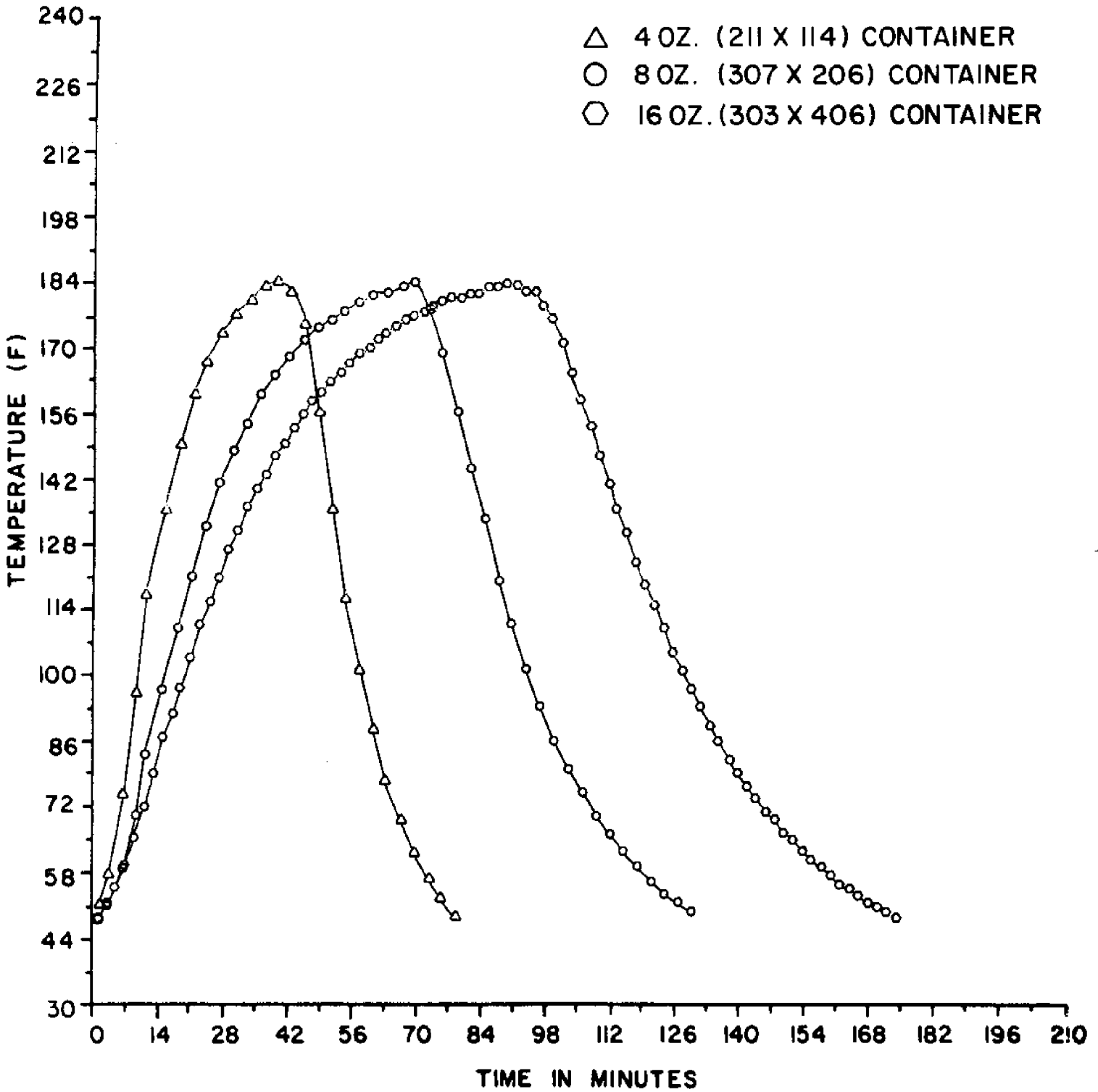


FIG. I-8. HEAT PENETRATION CURVES FOR CRABMEAT IN 4 OZ., 8 OZ., AND 16 OZ. CANS

The time-temperature relationship found to be true for one plant under its specific operating conditions probably will not be true for another plant. When the recommendation is made to one plant to cook its product for a specific period of time at the specified temperature in order to achieve an F_{185}^{16} of 31 minutes, that recommendation is good only for that plant. The difference may not be significant, but it could well be significant too. Naturally, a processor should want to know the specific heating and cooling profiles for his operation, and this can only be done through the use of thermocouples and temperature recorder.

Cooling.

All too frequently, the pasteurization process is regarded merely as the heating of the crabmeat to the desired temperature for the appropriate length of time. This, however, is a misconception which has proved costly to many processors. Pasteurization is not only the heating of the product but also the cooling of the product to temperatures at which the growth rate of surviving microorganisms is reduced. Also, even during the cooling phase the heat that remains in the can contributes to the lethality (F-value) in decreasing proportion until the temperature reaches 111°F.

Many different types of microorganisms grow in a wide range of temperatures. A temperature of 111°F may be hostile to some varieties of microorganisms while it may be a comfortable growth temperature to other varieties. Therefore, the assumption that microorganisms are slowly being destroyed at 111°F may not always be correct. Fortunately, those microorganisms which would ordinarily spoil crabmeat are very susceptible to destruction by the heat encountered in the normal pasteurization process. Conversely, those organisms which do survive are typically those which grow well at elevated temperatures but not at refrigerated temperatures - hence the importance of refrigeration after pasteurization.

This discussion points out the importance of cooling. If the product has been adequately heated but then is allowed to cool at a slow rate, the microorganisms that have survived the heating will start to multiply and thus reduce the normal shelf life expectation of the product. Therefore, it is imperative that processors reduce the internal temperature of the product as quickly as possible in order to get the product in the lower temperature regions

where the surviving microorganisms do not proliferate.

Tri-State recommends immersion of heated cans in an ice-water bath. Work done by Virginia Tech's Seafood Processing Research Laboratory supports this recommendation. Figure I-9 demonstrates the cooling curves in 16 oz. cans using four different cooling conditions. As evident from the graph, cooling in an ice-water bath is the most efficient method of cooling the product.

Tri-State previously recommended that the heated cans be cooled to $100^{o}F$ in an ice-water bath within 50 minutes of processing, then removed to refrigerated storage. The rationale for the recommendation was that some residual heat was needed to evaporate the moisture from the cans to prevent rusting. Rusting no longer is a problem with the vast majority of the cans being used today. The problem of microbial growth is of much greater consequence. A recommendation is now being considered that the heated cans remain in the ice-water bath until the cold point temperature reaches $55^{o}F$ within 180 minutes of processing before being removed to refrigerated storage at $35^{o}F$. This suggestion is intended to improve both the quality of the product and product safety.

Clostridium botulinum Type E.

In any discussion of pasteurized crabmeat and its safety, the principal consideration is the potential presence of Clostridium botulinum Type E toxin. Although unlikely, the possibility of the toxin's presence does exist and merits attention.

Some of the conditions that can contribute to the development of the botulism toxin are:

1) general unsanitary conditions,
2) underprocessing,
3) defective can seams, and
4) inadequate refrigerated storage.

Clostridium is one of the genera of bacteria that form spores. During a previous discussion, it was mentioned that spores are more heat-resistant than vegetative cells. The pasteurization process ($185^{o}F$ for 1 minute in 16 oz. cans) is adequate to destroy the spores of Type E in crabmeat. Work done at Virginia Tech indicates an F_{185}^{16} of about 31 minutes in 16 oz. cans. Work done

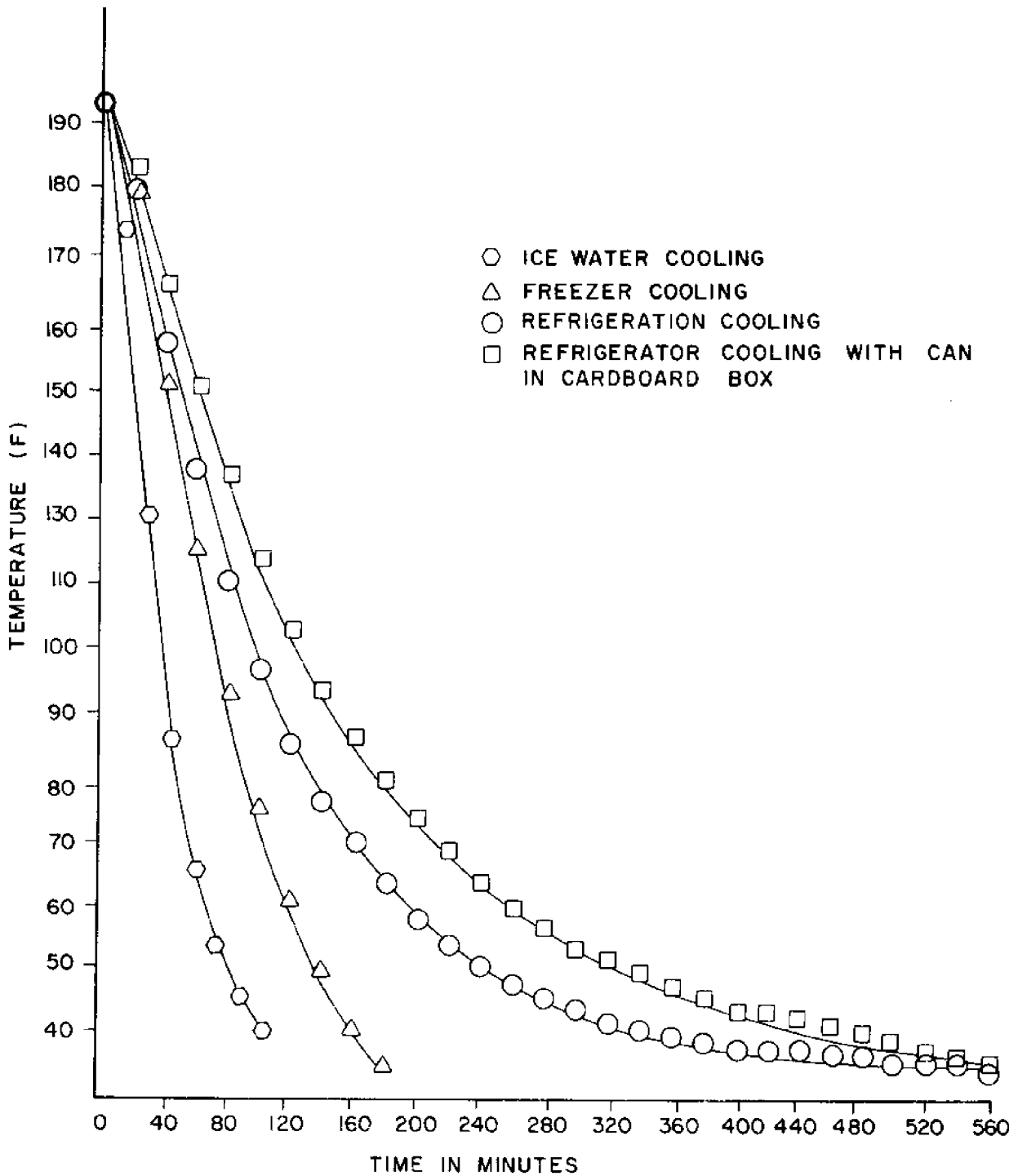


Figure I-9. Cooling rates of pasteurized crabmeat, in 16 oz. cans, in four cooling conditions

by the FDA (Lynt et al. 1977)[1] indicated that D-value for one of the most heat-resistant strains of C. botulinum of Type E spores is only 0.42 minutes. Therefore, underprocessing is not much of a problem with C. botulinum Type E spores.

The more likely source of problem is a combination of two factors, defective can seams and inadequate refrigerated storage. Even though the cans have been processed and any spores present destroyed, spores could potentially be drawn into the cans through faulty seams as the pressure in the heated containers drops due to cooling. If the cans are stored for extended periods at temperatures above 38°F, the spores could germinate into vegetative cells and produce toxin. Although chances of these events occurring are somewhat remote, it is important to recognize the problem potential and handle the product accordingly.

Acknowledgment

Some of the data in this section was supplied by Marianne Minnick as part of the research for her Master's Degree in Food Science and Technology at Virginia Polytechnic Institute and State University.

1. Lynt, R. K., H. M. Solomon, T. Lilly, Jr., and D. A. Kautter, 1977. Thermal Death Time of Clostridium botulinum Type E in Meat of the Blue Crab. J. Food Science 42:1022 - 1025.

Table I-1.

Time (min.)	Temperature (°F) Container Size (oz.) 211x114 4 oz.	307x206 8 oz.	303x406 16 oz.	401x301 16 oz.
1	50	48	49	48
2				54
3	57	52	52	58
4				63
5			56	67
6	74	59		71
7			61	74
8				78
9	96	71	67	81
10				85
11			73	88
12	117	84		91
13			80	94
14				97
15	135	98	88	100
17			93	105
18	149	111		109
19			99	112
21	160	122	105	116
23			112	122
24	167	133		124
25			117	126
27	173	142	122	130
29			128	134
30	177	149		136
31			132	138
33	180	155	127	142
35			141	145
36	183	161		146
37			144	148
39	184	165	148	151
41			151	153
42	182	169		155
43			154	156
45	175	172	157	158
47			160	160
48	156	175		161
49			162	162
51	135	177	164	164
53			166	166
54	116	179		167
55			188	168
57	101	181	190	169
59			171	171
60	88	182		172
61			173	172
63	77	183	174	173
65			176	175
66	69	184		175
67			177	176
69	62	185	178	177
71			179	178
72	56	179		178
73			180	179
75	52	170	181	180
77			182	180
78	48	157		181
79			182	181
81		145	183	181
83			183	182
84		134		182
85			184	182
87		121	184	183
89			185	183
90		112		184
91				184
93		102	183	184
95			183	185

Table I-1 continued.

Time (min.)	211x114 4 oz.	307x206 8 oz.	303x406 16 oz.	401x301 16 oz.	Time (min.)	211x114 4 oz.	307x206 8 oz.	303x406 16 oz.	401x301 16 oz.
96		94		185	147			70	93
97			180	184	149			67	90
99		87	177	185	151			65	88
101			172	185	153			63	85
102		81		185	155			61	83
103			166	185	157			60	81
105		76	160	183	159			58	79
107			154	180	161			56	77
108		71		178	163			55	75
109			148	175	165			53	73
111		67	142	171	167			52	71
113			136	166	169			51	70
114		63		163	171			50	68
115			131	161	173			49	67
117		60	125	155	175				65
119			120	150	177				64
120		57		147	179				62
121			116	145	181				61
123		54	111	140	183				60
125			106	135	185				59
126		52		133	187				58
127			102	130	189				57
129		50	98	126	191				56
131			94	121	193				55
133			90	117	195				54
135			87	113	197				53
137			83	110	199				52
139			80	106	201				51
141			77	103					
143			75	99					
145			72	97					

Temperature Measurements

Thermocouples.

A thermocouple is a device for the measurement of temperature. Its operation is based on the observation that a small electric current will flow in a closed circuit composed of two dissimilar metallic conductors when their junctions are kept at different temperatures. The pair of conductors, or thermocouple elements, which constitutes the thermoelectric circuit, is called a thermocouple. Simply stated, a thermocouple is a device which converts thermal energy to electric energy. The amount of electric energy produced can be used to measure temperature.

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 the life expectancy, drift, and response time requirements.
3) It may be flexible, rugged, and generally is 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) Unlike many temperature transducers, the thermocouple is not 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.

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 (-)

*Trademark - Hoskins Manufacturing Company

6) Type S - Platinum/10% Rhodium (+) versus Platinum (-)

7) Type B - Platinum/30% Rhodium (+) versus Platinum/6% Rhodium (-)

Table 1 gives recommended maximum temperature limits for various gage sizes of wire.

Table 1. Upper Temperature Limits (^{o}F) for Protected Thermocouples for Various Wire Sizes

Thermocouple type	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	-

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 (371 C) 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.

Type J -- These thermocouples are suitable for use in vacuum and in oxidizing, reducing, or inert atmospheres, at temperatures up to 1400 F (760 C). The rate of oxidation of the iron thermoelement is rapid above 1000 F (538 C), however, and the use of heavy-gage wires is recommended when long life is required at the higher temperatures.

Bare thermocouples should not be used in sulfurous atmospheres above 1000 F (538 C).

This thermocouple is sometimes used for subzero temperatures, but the possible rusting and embrittlement of the iron wire under these conditions makes its use 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 oxi-

dizing or inert atmospheres at temperatures up to 2300 F (1260 C). Because their oxidation resistance characteristics are better than those of other base metal thermocouples, they find widest use at temperatures above 1000 F (538 C). However, this thermocouple is suitable for temperature measurements as low as -420 F (-250 C), although limits of error have been established only for the temperature range 0 to 2300 F (-18 to 1260 C).

The Type K thermocouple may be used in hydrogen or cracked ammonia atmospheres if the dewpoint is below -40 F (-40 C). However, they should not be used in:

1) Atmospheres that are reducing or alternately oxidizing and reducing unless suitably 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 time 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. It can cause large negative errors in calibration and is most serious in the temperature range 1500 to 1900 F (816 to 1038 C).

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 (-250 to 871 C) in oxidizing or inert atmospheres. In reducing atmospheres, alternately oxidizing and reducing atmospheres, 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 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 2550 F (1399 C); intermittently up to 2700 F (1482 C).

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 which 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 (1704 C). They are also suitable for short term use in vacuum to this temperature.

They should not be used in reducing atmospheres, nor 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 Type R or S thermocouples.

The limits of error for the common letter designated thermocouple types, as listed in Table 2 are taken from ANSI Standard C96.1. Most manufacturers supply thermocouples and thermocouple wire to limits of error or better.

Table 2. Limits of Error for Thermocouples

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

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 gage. A variety of insulations and protective coverings is 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 thermocouple. 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. The 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 ±8F could occur in the Type K/KX & J/JX thermocouple-extension wire combinations, where the standard limits of error are ±4F for the thermocouple and the extension wires treated as separate combinations. Such errors can be eliminated substantially by selecting extension wires whose properties closely match that 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 extension wires of Category 2.

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.

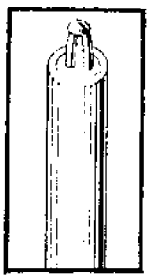
A fourth source of error concerns the use of connectors in the thermocouple assembly which has conductive characteristics which differ appreciably from those of the thermocouple extension wires. The magnitude of errors of this type can vary over a wide range depending on the materials involved and the 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 in construction and commonly referred to as thermowells
3) Connector
4) Miscellaneous hardware as for example; adaptor to join the protection tube to the head or thermocouple glands

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

1) Exposed a 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 which may be twist or butt-weld type.



a. fast response

b. exposed magnesia will not pick up moisture

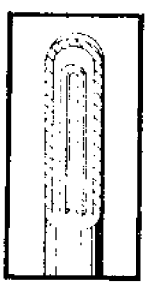
c. not pressure tight

d. wires subject to mechanical damage

e. wires subject to environment and usually will have a very short life

f. useful life shortened as a result of rapid calibration drift

2) Grounded junction -- A closure is made by welding in an inert atmosphere so that the two thermocouple wires become an integral part of the sheath weld closure.



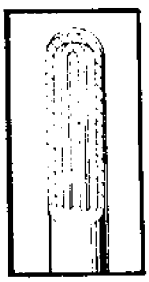
a. slower response than exposed wire

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

REFERENCES

Caldwell, F. R. Thermocouple Materials. National Bureau of Standards Monograph No. 40. Superintendent of Documents, U. S. Government Printing Office. Washington, D. C., 1962.

Committee E-20 on Temperature Measurement and Subcommittee IV on Thermocouples. Manual on the Use of Thermocouples in Temperature Measurement. American Society for Testing Materials. ASTM Special Technical Publication 470A. Philadelphia, PA, 1974.

Pollock, D. D. The Theory and Properties of Thermocouple Elements. American Society for Testing Materials. ASTM Special Technical Publication 492. Philadelphia, PA, 1971.

Recorders

One of the most universal functions of any scientific or engineering activity is the gathering of data to provide answers to immediate questions or information to be filed for future reference. Such data gathering may be achieved in various ways, depending on the nature and quantity of the information. One of the most prevalent of such data gathering methods is undoubtedly information recording.

Electrical recorders are available in a variety of sizes, speeds, sensitivities and prices. They are also suitable for recording any signal which is in, or can be converted to, electrical form. These recorders are found in almost every food processing plant.

It is true that various curves which are now traced automatically with a recorder can be plotted manually from point-by-point measurements. This procedure, however, is not only time-consuming but may cause valid bits of information to be overlooked entirely, simply because the points were taken too far apart.

Another factor favoring the use of recorders is the ability to pinpoint faulty operation of the data-gathering system. Artifacts that might not be observable at all in point-by-point observations will often be readily identifiable on a recording. Asymmetry of a peaked curve, as in a crab pasteurization process, is only clearly evident in a recording.

Recorders can be characterized in many ways. They may be capable of plotting one variable against another (X-Y recorders) or only against time (Figure II-1: Y-T or simply 'strip chart' recorders). They may be equipped to plot a single variable or two or more simultaneously (one-, two-, or multiple-pen recorders), or they may be designed to plot several variables consecutively as a series of points. Some of the newer type recorders (Figure II-2) are digital and capable of printing the variable(s) against other functions; as for example, time.

Perhaps most fundamentally, recorders are classified by the kinds of signals they will accept. Thus we have millivolt recorders, recording ammeters and wattmeters, either ac or dc, and many others. Frequently, the scale is designated in nonelectrical units, such as pH or degrees Fahrenheit, depending on specific transducers. The dc millivolt or microampere recorder is the most

versatile, since input circuiting can adapt it to almost any other application. These are the recorders usually employed in the food industry to record temperatures of unit processing operations.

The electrical or electronic mechanism for positioning the pen may be of varying degrees of complexity, from a simple moving-coil meter with its pointer extended to hold a stylus or pen, to a self-balancing servo system. To increase flexibility, peripheral circuits for zero suppression and range selection are often included.

As all too well known to many users, the pen-and-ink system may be the weakest link in an otherwise excellent recorder. To increase the reliability of this feature, designers have tried all sorts of devices for transferring information from pen to page. The most common continues to be the capillary pen delivering liquid ink. Also in use are ball point pens, heated styli, and electrical recording through sensitized paper, each with many modifications. In some instruments, writing is accomplished by a moving light beam impinging on photographic paper.

Another classification is based on the form of the paper employed. This may be supplied in continuous rolls or in separate sheets. The paper may be plain graph paper or it may be preprinted with coordinate scales for a particular instrumental application. Fan folded paper can often be substituted for roll paper with perhaps greater convenience.

Another recent development is the use of programmable recorders. These devices are highly flexible and can be adjusted for continuous monitoring or placed in alarm modes. They also have the capability of being interfaced with control or data handling peripheries on main processors. Recent technological advances have made these instruments affordable to even small food processors.

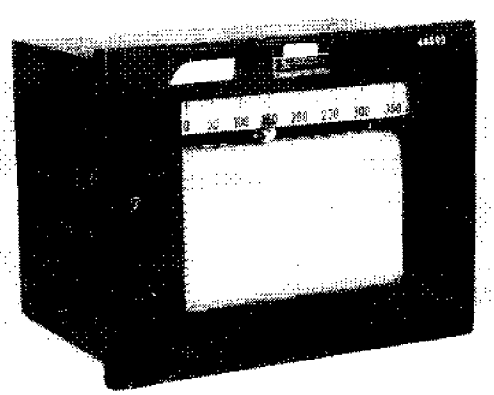


Fig. II-1

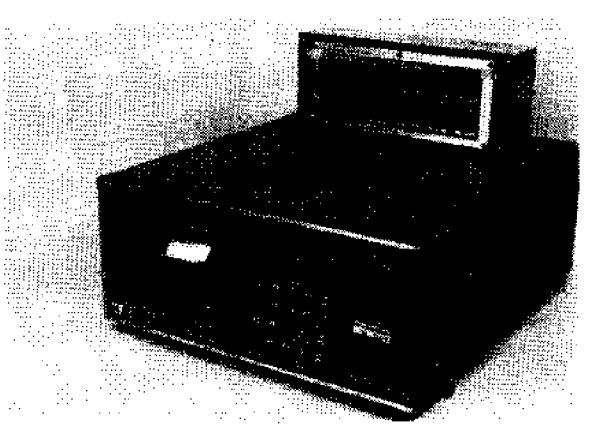


Fig. II-2

REFERENCES

Ewing, Galen, Wood, and Ashworth. The Laboratory Recorder. New York: Plenum Press, 1974

Thermocouple Installation

Since containers suitable for pasteurizing crab meat are available in a variety of shapes and sizes (Figure II-3), it is important that all pasteurization temperature measurements be individually determined. The two container types most commonly used for crab meat are of metal or polymer construction (Figure II-4). In order to record internal temperatures, various type and size thermocouples are required (Figure II-5). 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 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 (Figure II-6) and relatively inexpensive.

Procedures

Thermocouples can be easily installed if the following steps are followed:

Step 1
(Figure II-7 and 8)

Thermocouples should be installed in the geometric center of the can since heat transfer inside the can is accomplished through conduction rather than convection or radiation (See Figure II-8). This location is easily determined in containers where the width or diameter is uniform (as a can). However, it becomes more difficult when a variable width container (as the 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. Both measurements are critical.

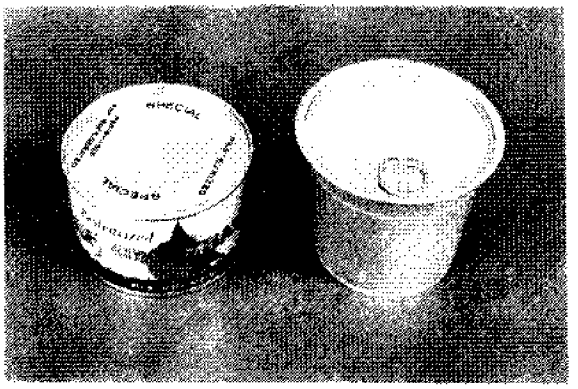


Figure II-3.

Figure II-4.

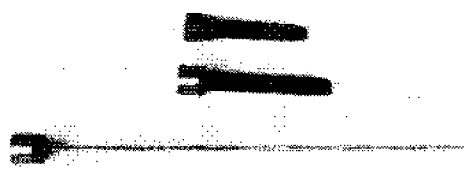


Figure II-5.

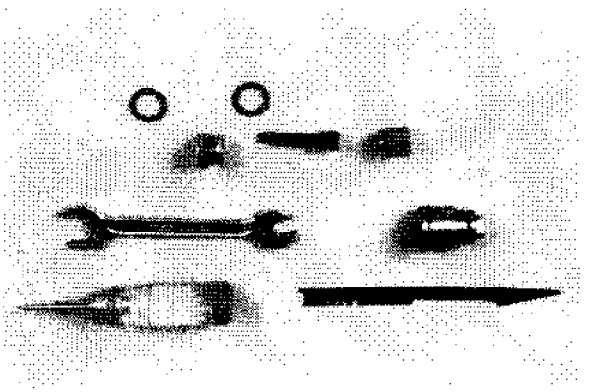


Figure II-6.

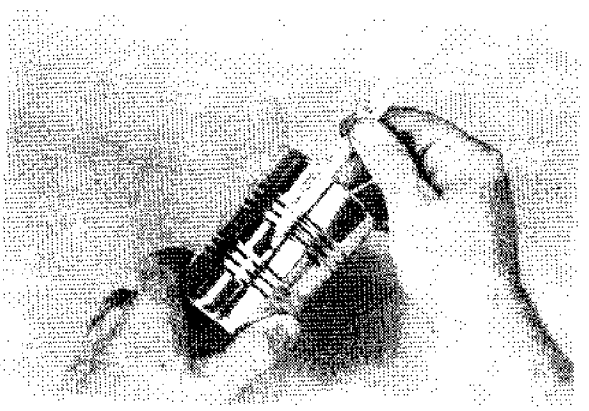
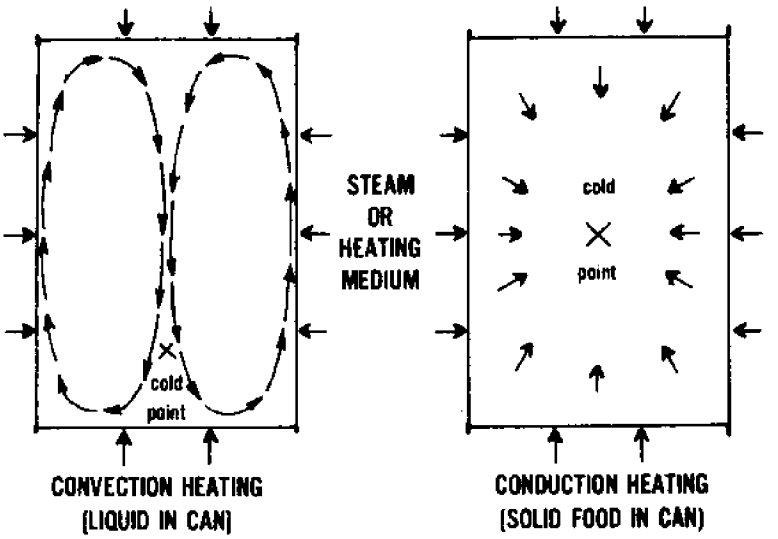
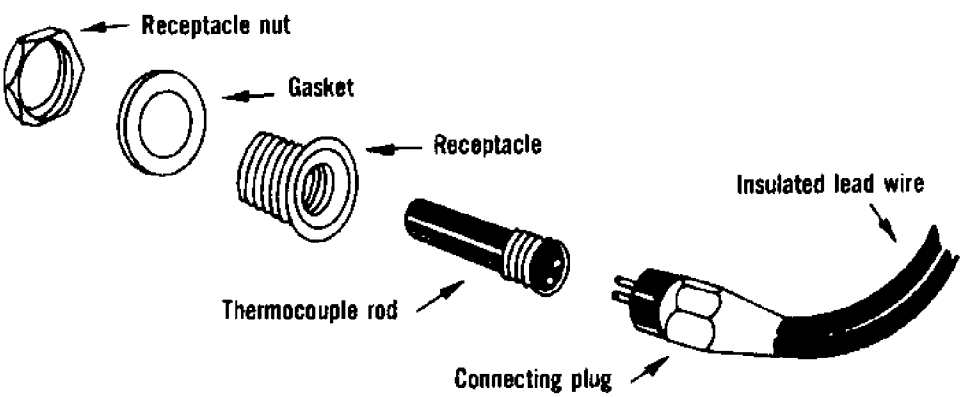


Figure II-7.



Cold point of heating for conduction type products.



Nonprojecting plug-in thermocouples.

Figure II-8.

Step 2 (Figure II-9)	Once the proper measurements have been taken, a hole is made with an awl in the container. The awl is used on both metal and polymer type containers. Care should be exercised in making the hole since excessive pressure will bend or damage the container.
Step 3 (Figure II-10)	After the pilot hole is made, a hole puller or cutter is installed and slowly tightened with a wrench. A round hole will be produced after the cutter penetrates the container. During this process, the metal container may develop a slight deformation near the hole but this is expected.
Step 4 (Figure II-11)	Insert the receptacle from outside the container. On the inside, install a gasket and receptacle nut. Tighten the nut with the wrench. The receptacle should fit snug but over-tightening should be avoided. Check the container since an improper installation may cause a leak, resulting in improper temperature measurements.
Step 5 (Figure II-12)	The thermocouple rod is then installed with a special tool. It is important that all gaskets be replaced periodically to prevent leakage. Thermocouples should also be examined for physical defects as well as electric conductance. A Volt-ohm meter is useful for the latter procedure.
Step 6 (Figure II-13)	A properly installed thermocouple may cause minor deformation in the metal container and stress marks in the polymer container. This is perfectly acceptable and does not interfere with the measurements.
Step 7 (Figure II-14)	This cross-section depicts an acceptable non-projecting plug-in thermocouple installation.

Figure II-15 provides a detailed description of a thermocouple assembly.

After the thermocouple has been installed, temperature measurements can be made using the proper recorder and supporting equipment.

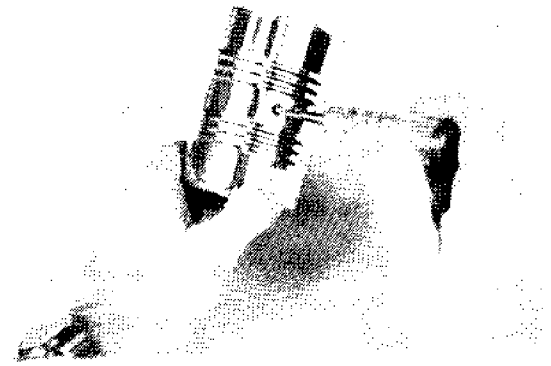


Figure II-9.

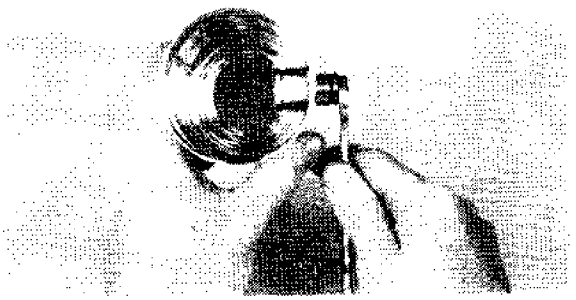


Figure II-10.

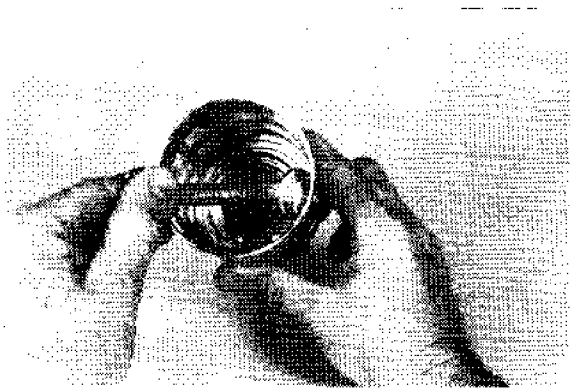


Figure II-11.

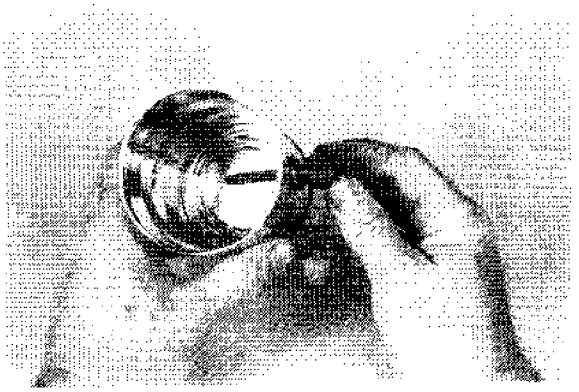


Figure II-12.

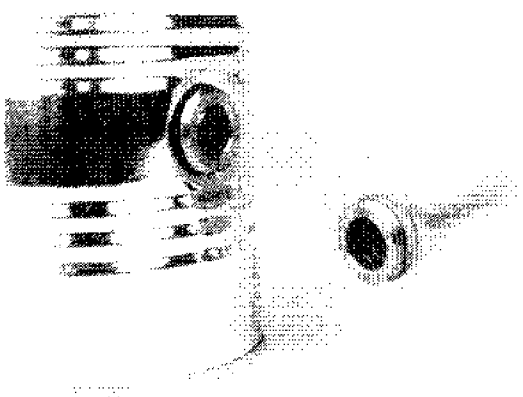


Figure II-13.

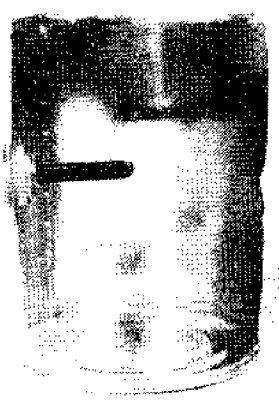


Figure II-14.

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 the baskets of crabmeat through long tanks of heated water.

Irrespective of processing technique, whether it be batch or continuous, the fundamentals of process control are the same. Several states have adopted the Tri-State recommendations regarding minimum pasteurization and control equipment requirements. Although the Food and Drug Administration does not have a specific GMP (Good Manufacturing Practice) 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.

Recording and indicating thermometers monitor the time-temperature relationship discussed earlier in this manual and are a crucial part of the equipment. The indicating thermometer assesses the accuracy of the recording thermometer. Although the recording thermometer, once calibrated, is fairly accurate, it is important to verify its accuracy. The FDA requires the low acid can food industry to use the mercury-in-glass (MIG) indicating thermometer. Although no such requirement is made of the pasteurized crab industry, it would be advisable for the industry to standardize its equipment and use MIG thermometers. In addition, the low acid can food industry is required to periodically assess the accuracy of the MIG thermometer with a standard reference thermometer.

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. The importance of record keeping will be discussed in a separate section.

The range and 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 recently revised by the National Blue Crab Industries Association (NBCIA) Standards Committee and included in the appendix.

Constant-Flow Steam-Control Valve.

Most crabmeat pasteurization operations use steam as the source of heat to raise the temperature of the water bath. A constant-flow steam-control valve is required in the operation. The use of the valve is absolutely essential in maintaining the desired water bath temperature. Without the valve, temperature fluctuations will not be detected and may be too extreme for a time-temperature based process.

Agitation of Water Bath to Maintain Uniform Temperature.

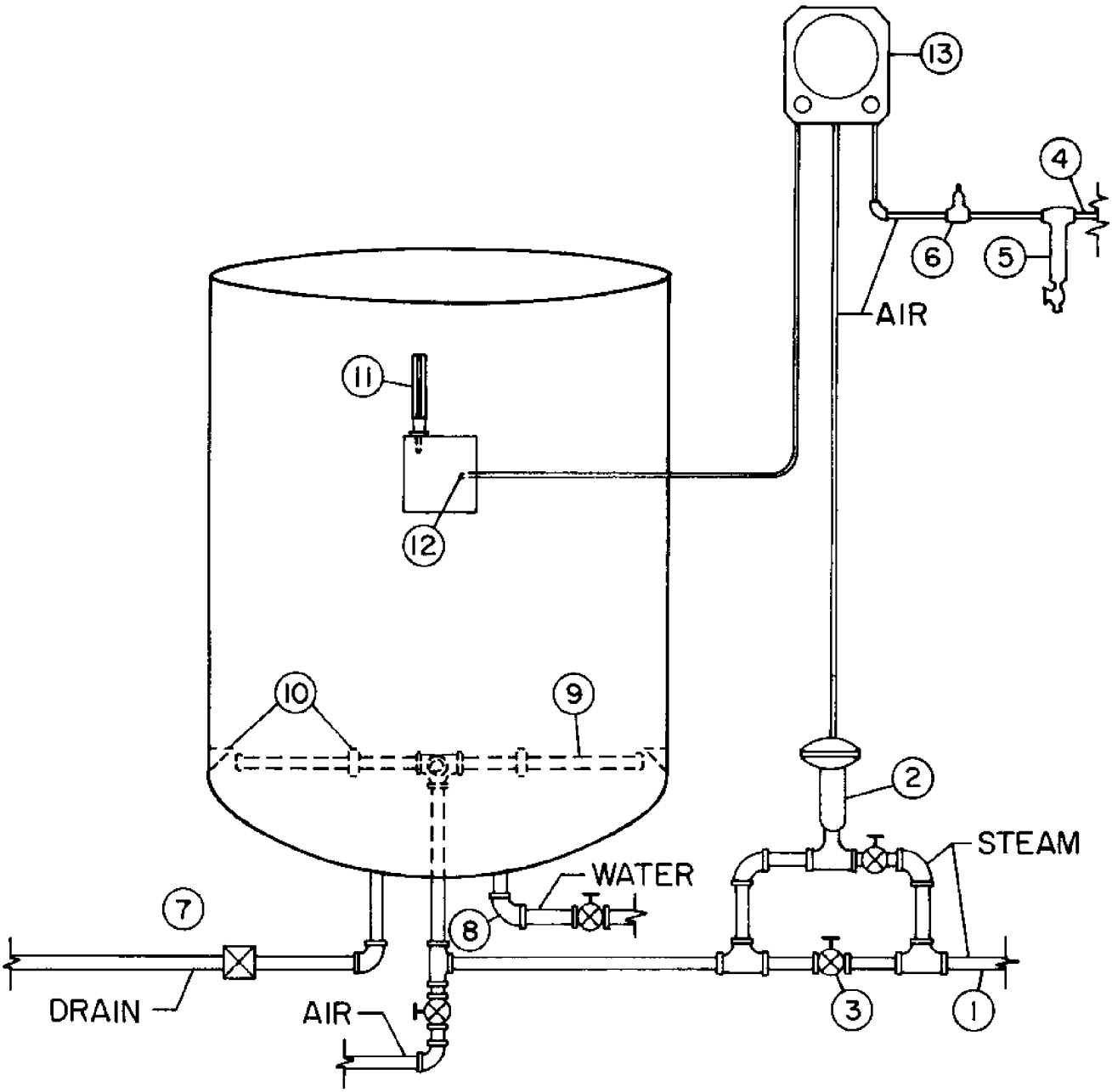
Uniform temperature throughout the water bath is crucial; without some means of agitating the water, cold spots and hot spots may develop. Water can be agitated with air injected into the bottom of the tank or by simply injecting steam from the sides of the steam discharge spreader at the base of the pasteurization tank. This results in the tangential release of steam and a swirling effect of the water within the tank.

Pasteurization Tank Hook-Up.

An idealized pasteurization tank hook-up is demonstrated in Figure III-1. Minor variations may exist depending on the requirements of individual plants; nonetheless, the fundamental elements of all operating plants should be the same. It has become apparent in recent years that many plants do 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 never installed or never changed.

Servicing of Equipment.

The old axiom, "If it's not broke, don't fix it", has a great deal of merit. There is, however, another axiom which may not be quite as widely ac-



1 Steam inlet
2 Steam control valve
3 By-pass
4 Air, instrument
5 Filter
6 Pressure regulator
7 Drain
8 Water inlet
9 Steam air spreader
10 Basket supports
11 Thermometer
12 Control element
13 Control, steam

Manual Valves:
⊗ globe
⊠ gate

Figure III-1. Pasteurization tank hook-up

cepted; "If it's working, is it really working?" As with most equipment, periodic maintenance and calibration is necessary with the equipment used in the pasteurization process. Manufacturers of the recording thermometers and clocks suggest semi-annual servicing. Maintenance requirements of the individual processors depend on the frequency of use and environmental conditions in the area of operation. Periodic servicing is necessary to insure that the equipment is working properly.

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. Therefore, it is appropriate to emphasize in this section the importance of monitoring the temperature of refrigerated storage areas. As is the case with the indicating thermometer in the pasteurization process, all thermometers used to monitor refrigerated areas should be mercury-in-glass (MIG) and should be periodically checked with a standard reference thermometer. The industry must monitor these storage areas because the storage temperature of pasteurized crabmeat is a critical factor in the production of high quality product.

Cooling and Storage of Pasteurized Crabmeat

The importance of cooling and storage of pasteurized crabmeat at proper temperature was discussed in the earlier section on "Thermal Processing Principles". Since the subject is important, additional discussion is presented here.

The principal concern of any food processor should be product safety and quality. Most processors are knowledgeable in the proper handling of fresh product; they know that the product must be kept clean, cold, and moving in order to have any sort of reasonable shelf life expectation. Furthermore, most processors are well aware of the role microorganisms play in the spoilage of improperly handled fresh crabmeat. However, a lack of understanding exists on the importance of proper handling of pasteurized crabmeat. This information gap is found not only among processors but also throughout the product's distribution channels; transporter, distributor, wholesaler, retailer and consumer.

As discussed earlier, the heating of crabmeat to pasteurization temperatures destroys many of the microorganisms. Those organisms which do survive usually grow quite well at elevated temperatures. Figure IV-1 graphically demonstrates the problem potential created by slow cooling of the pasteurized product and subsequent temperature abuse during storage. Obviously, the product should pass through the "Danger and Critical Zones" (Fig. IV-1) as quickly as possible. The Tri-State recommendation merely states that, after pasteurization, the crabmeat should be cooled to 100^{o}F within 50 minutes of processing, then moved to refrigerated storage. This recommendation is well intended and, if practiced with proper vigilance, would more often than not result in acceptable product. The problem, however, is that proper vigilance is not always practiced and cooling short-cuts often are attempted. The reason for these poor cooling practices has not been a lack of concern on the part of the industry, but rather a lack of information.

Rapid cooling is important. As evidenced from a graph presented in a previous section and repeated here as Figure IV-2, the most practical method of rapidly cooling pasteurized crabmeat is an ice-water bath. Contrary to the

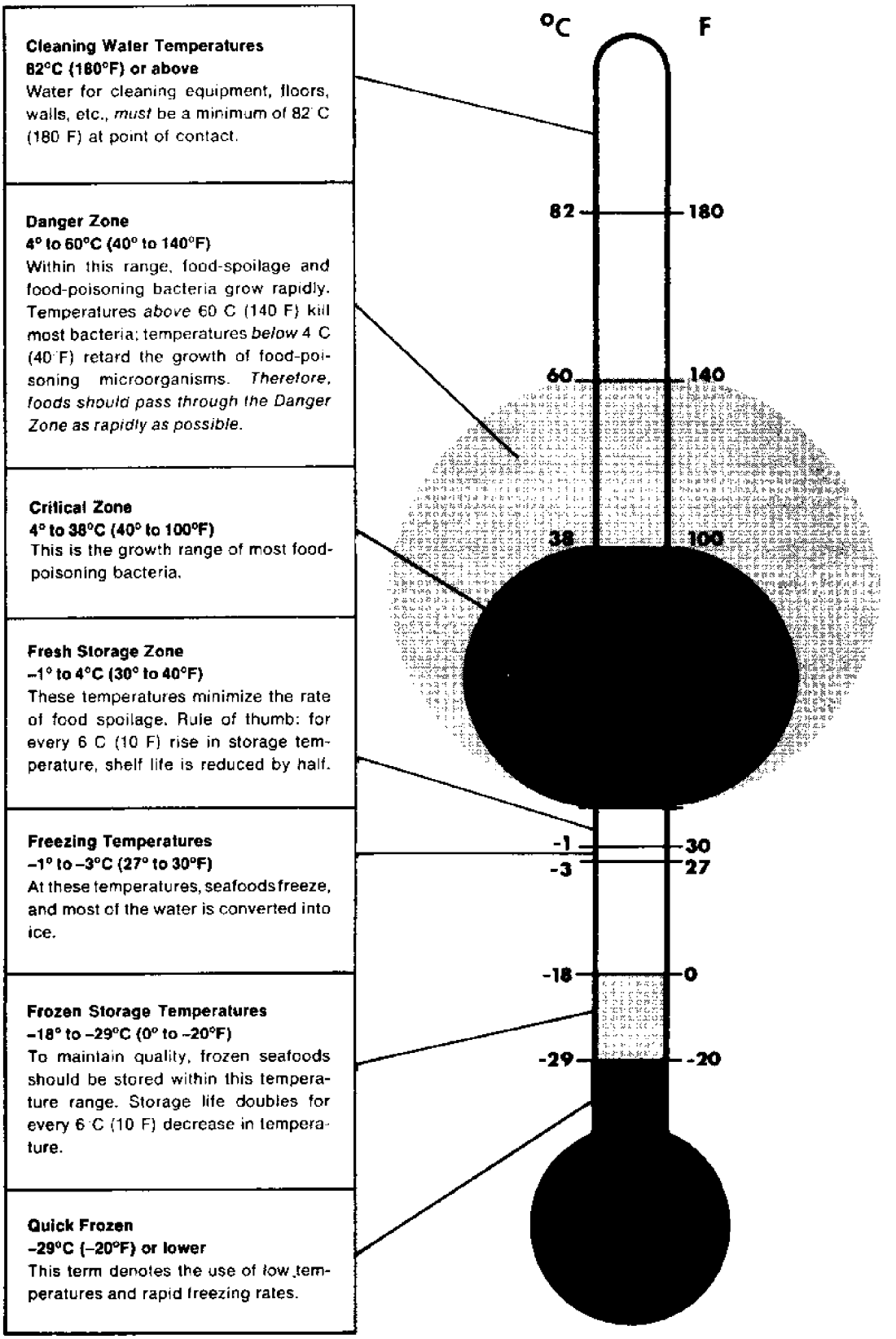


Figure IV-1. Seafood handler's thermometer

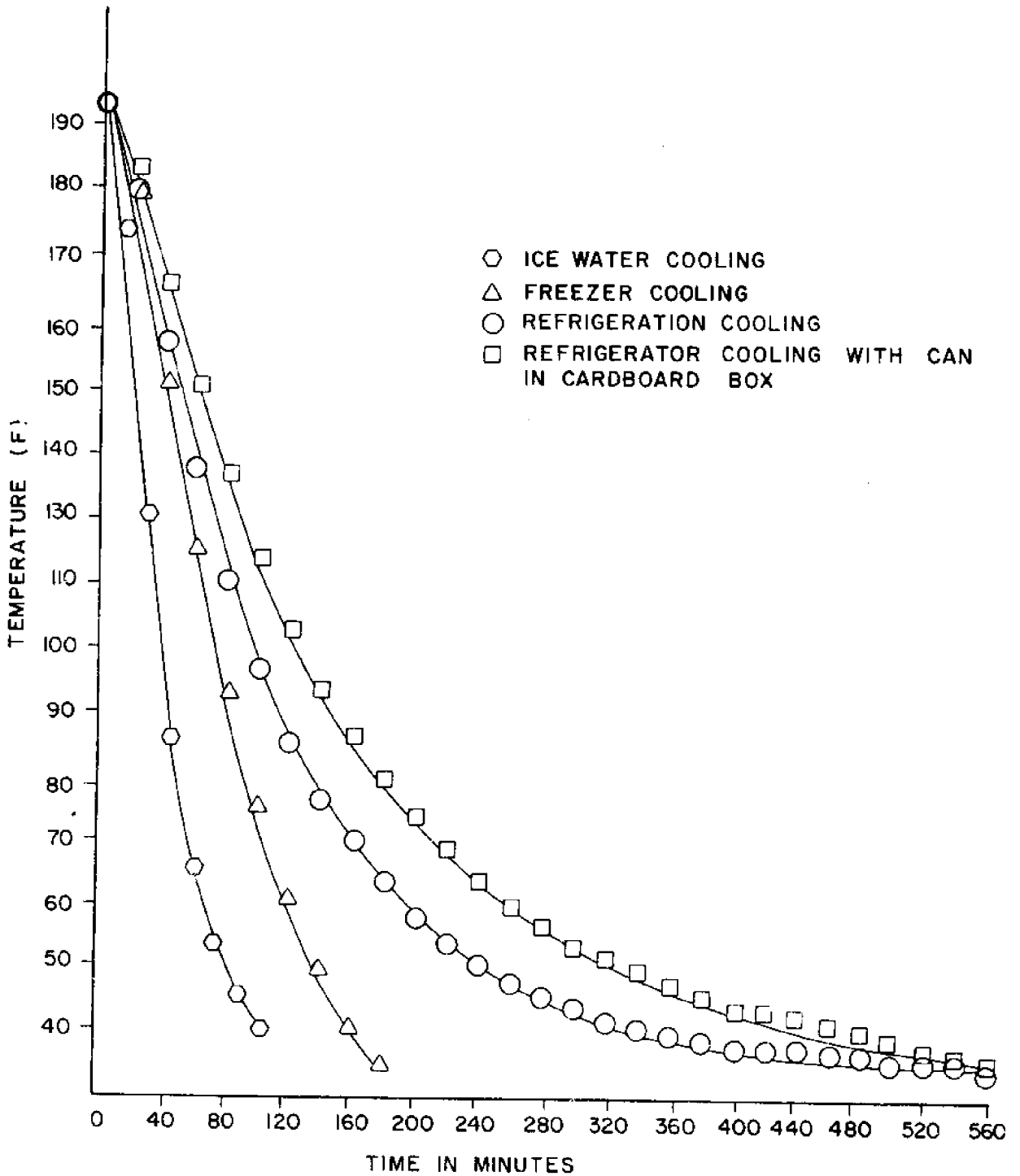


Figure IV-2. Cooling rates of pasteurized crabmeat, in 16 oz. cans, in four cooling conditions

old Tri-State recommendation, the revised recommendation of the NBCIA Standards Committee allows the product to remain in the ice-water bath until the cold point temperature reaches 55°F within 180 minutes of processing to allow refrigerated storage at 35°F after processing. This method facilitates a much faster passage through the "Danger and Critical" temperature zones.

Several years ago, the staff at Virginia Tech's Seafood Processing Research Laboratory received a number of telephone calls from processors who had problems with unusual numbers of swollen pasteurized crabmeat cans. The staff found that the heating processes were in order and the can seams were intact but that the method of can cooling was deficient in all cases. The processors were giving the heated cans a brief exposure to ice-water cooling, then dumping the cans in boxes (some with lids), and placing the boxes in refrigerated storage. This practice in effect insulated the cans and protracted an already slow cooling process. Hence, surviving microorganisms grew to substantial numbers and produced gases, causing many of the cans to swell.

Proper refrigerated storage of pasteurized crabmeat is also important with respect to both quality and safety. It relates to quality in that the colder the temperature at which the product is stored, the longer the shelf life. It relates to safety in that proliferation of Clostridium botulinum Type E becomes a concern with extended storage at temperature above 38°F. (Clostridium botulinum Type E discussed in Section I). Accordingly, pasteurized crabmeat should be stored at a temperature of 35°F.

Looking at the potential distribution chain of pasteurized crabmeat, it becomes apparent that the processor is but one facet in a multi-faceted marketing channel. As with most aspects of life, the more complicated it 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 as to which party is at fault. Therefore, it is imperative for the processor to periodically remind all members of his distribution chain of the importance of proper refrigeration and handling of pasteurized crabmeat.

Discoloration in Pasteurized Crabmeat

Although substantial research has been devoted to the causes for discoloration of pasteurized blue crabmeat, there has been no general agreement on the chemical mechanism(s) involved. The most common discoloration is called blueing although the actual color may range from blue to blue-gray to black. This type of discoloration also occurs in several other crab species. Some of these are the:

King	Paralithodes camtschatica
Dungeness	Cancer magister
Horse Hair	Erimacrus isenbeckii

The blueing that occurs in pasteurized crab meat occurs during the heat treatment and intensifies during storage. It has been observed that meat processed above 190°F develops the off-color more readily than that produced at 175°F. Consequently, many processors have adopted alternative processing schedules to the previously recommended 185°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 the pasteurization temperatures are reduced from the recommended 185°F the 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 present a health hazard.

Cause and Prevention of Blue Discoloration

The blue discoloration is believed to be caused by some constituent in the crab blood. The following five specific mechanisms have been proposed but the cause may not be mutually exclusive:

1. iron compounds
2. copper compounds
3. melanin
4. copper proteins or biuret complexes
5. hemocyanin compounds

Most investigators agree that copper is related to the blue discoloration since the discoloration is inhibited by chemicals that react with copper.

The addition of 0.03-0.1% weak organic acid (as citric) has prevented the formation of blue complex in Blue and Rock (Sand) crabs. Other additives as Ethylenediaminetetraacetic Acid (EDTA) have also been effectively used. It is also possible to use a combination of organic acid and additive. The use of additives is not encouraged since today's consumers are looking for food products which are "natural" or "contain no additives". Also, the use of additives would require additional quality assurance programs. The possibility exists that an additive may be found to be toxic, mutagenic, or carcinogenic (cancer causing) at some future time. Any undesirable publicity could cause consumer rejection of the product for an extended time period.

Recommendations to Minimize Discoloration:

1. All crab meat should be processed at internal temperatures lower than 190°F.
2. Pasteurization water temperatures should not exceed a range of 192-195°F.
3. Pasteurized crab meat should be stored for reasonable time periods and the "First-In - First-Out" rule should be followed.
4. Cans should be stored in the top up position. The liquid produced in the can during thermal processing accelerates the discoloration (blueing) process. If a can were stored in the inverted position (top down), a consumer opening the can in the usual manner (top up) may reject the product.

Can Seam Evaluation and Quality Control

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.

The various state regulatory agencies, which have responsibility for the crabmeat industry, have neither inspected can seams nor required processors to inspect them. There are several reasons for this: first, the significance of the problem was not recognized; second, the various 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 becoming aware of the problem, and are beginning to train their personnel in can seam evaluation.

Unlike low-acid can foods, pasteurized crabmeat must be refrigerated. And this is why the crabmeat industry has been exempt from 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 them and thus hasten spoilage of the product. 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.

Air or water droplets usually gain entry though these leaks, or micro leaks, in the can seams during the cooling phase of the pasteurization process. During the heating phase pressure within the container increases due

to the expansion of gases. When the heated containers are immersed in cold water, the rapid cooling causes the internal pressure to drop and, if there are leaks in the seams, may cause water to be sucked into the containers through the leaks.

Defective can seams create a problem for the industry and, in fact, they have. What is in question, however, is the extent of the problem. As mentioned earlier, very few processors in the pasteurized crabmeat industry 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. As a result, the NBCIA Standards Committee has recommended that all companies pasteurizing crabmeat have at least one employee who has had training in can seam evaluation, and that the employee be responsible for teardown examinations of a can every four hours of operation. The NBCIA also recommends that a record be kept of these evaluations 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[1], a product code at a minimum should include:

a) Product coding for easy identification and at frequent enough intervals to keep the lots small.

b) Relating codes to processing records so that lots which may need to be recalled for a process deviation may be identified quickly and completely.

c)[2] Keeping of raw product and quality control records in such a way that the product in a batch of any one code can be identified with them.

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1. Martin, Roy E., and Gail Pitts. 1982. Handbook of Product Recalls and Package Coding and Equipment. National Fisheries Institute, Inc., Washington, D. C.

2. This requirement has little application to the pasteurized crab industry.

It is to the processor's advantage to keep each lot small. If lots are kept small in size, only the lots in question can be recalled instead of an entire day's production. There are several coding systems and methods that can be used according to the requirements of the plant, and the choice should be left up to the individual processor.

Evaluation of Double Seams

A. Double Seam Defined.

The double seam consists of five thicknesses of plate (seven thicknesses at the juncture of the end and side seam) 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 V-1. 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. See Figure V-2.

The names of the various parts of the double seam are shown in these 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.

B. Visual Inspection of External Seam Formation.

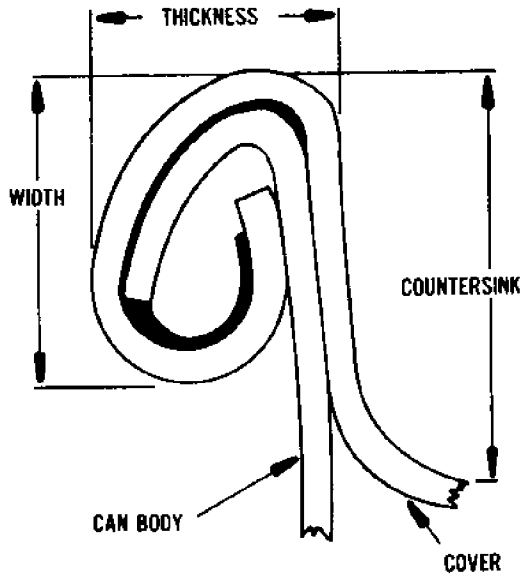
1. Introduction

Visual inspection of the cans coming from the closing machine should be should be examined carefully around the entire periphery to detect any seam malformation or defects such as cut overs, cut seams, droops, 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 is operated. At a minimum, visual external seam inspection of cans from each seaming head must be made at intervals of thirty minutes and recorded.

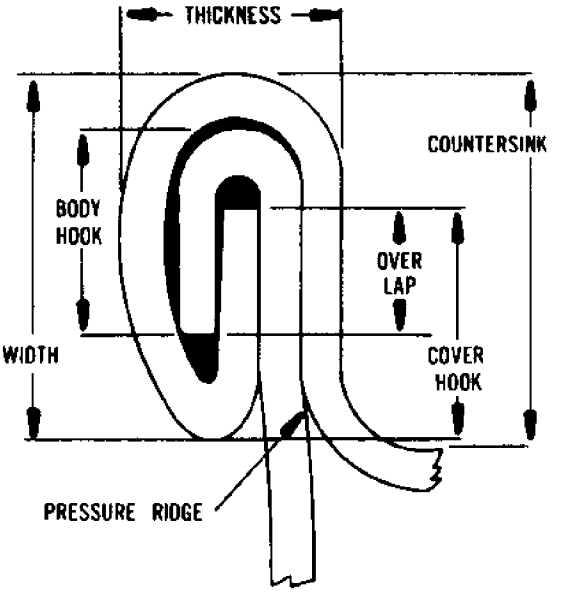
2. Cut Over (Sharp Seam)

A cut over is a sharp fin of the cover formed over the top of the seaming chuck flange during the seaming operation as illustrated in Figure V-3. This condition usually occurs at the can body lap, 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 aggravation of this sharp condition could result in a more serious cut over. A sever cut over con-



First Operation

Fig. V-1



Second Operation

Fig. V-2

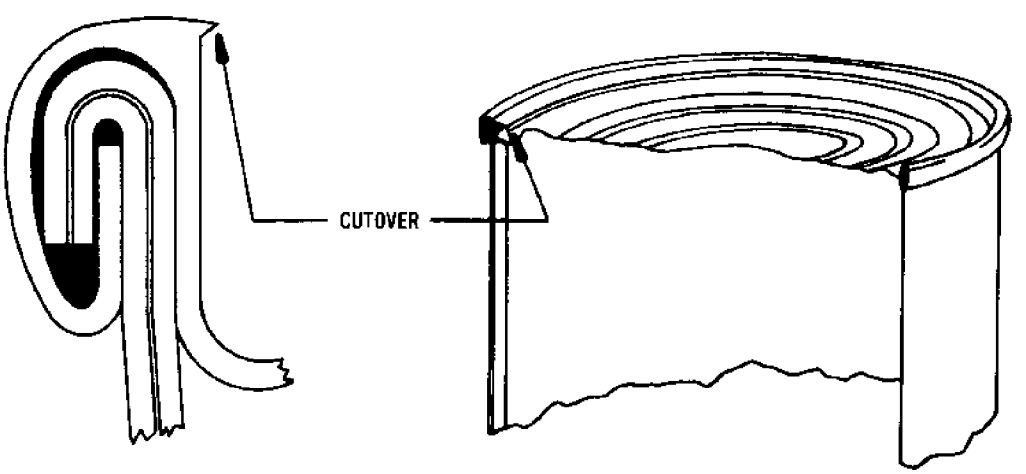


Fig. V-3

dition is dangerous with fracture likely to occur resulting in a cut through cut over. Correction is mandatory when severe cut overs are encountered.

Possible Causes of Cut Overs:

1) Incorrect vertical alignment of first operation seaming roll groove to seaming chuck. Seaming chuck and first operation seaming roll groove should be set to maintain .001" to .002" vertical running clearance between top of chuck flange and lead-in angle of seaming roll groove, as illustrated in Figure V-4.
2) Vertical play of first operation seaming roll. Roll should revolve freely but verticle play in excess of .002" should be avoided.
3) Vertical play in seaming head assembly.
4) Worn seaming chuck flange. Usually caused by first operation seaming roll groove lead-in angle riding 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, it can force the seam formation beyond the ideal limits of the seaming roll groove profile and 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 maximum wear life of the groove. Incorrect setting of seaming rolls, even though the seam formation produced is acceptable, should be avoided as it will reduce the life of the roll grooves and hasten the development of seam defects. Any seaming roll, when suspected of creating cut overs because of possible worn groove conditions, should be replaced only after determining the roll is set correctly.
7) Solid or semi-solid product trapped in seam.
8) Excess solder at can body lap.
9) Excessively long body hooks forcing too much metal into the seam often results in sharpness all around the seam as well as at the crossover.

3. Cut Seam (Fracture).

A double seam, wherein the outer layer of the seam is fractured, as illustrated in Figure V-5, is known as a cut seam. Immediate correction must be made when this condition exists.

Possible Causes of Cut Seam:

1) Seam too tight.
2) Excess solder at can body lap.
3) Defective end plate.

4) Excess sealing compound.

5) Long body hook.

4. 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. See Figure V-6. A slight droop at the side seam lap or crossover may be considered normal because of additional plate thicknesses incorporated in the seam structure.

A droop at the crossover exceeding 1/2 the cover hook length should not be tolerated and 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.

Possible Causes of Droop:

See under "Lip".

5. Lip.

An irregularity in a double seam showing as a sharp "V" projection below the normal seam, as illustrated in Figure V-6; is called a lip. This is sometimes referred to as 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 square.

6) Excess solder at can body lap.

7) Excessive amount or unequal distribution of end lining compound.

6. False Seam.

A false seam is a seam or portion of a seam which is entirely unhooked and in which the folded cover hook is compressed against the folded body hook as in Figure V-7. This is a serious defect which 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.

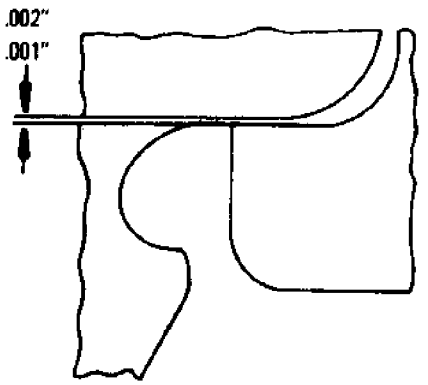


Fig. V-4

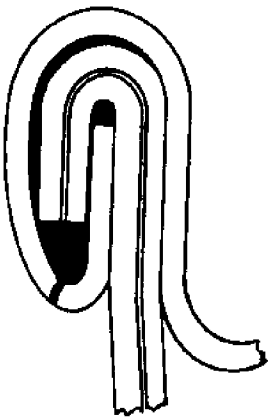


Fig. V-5

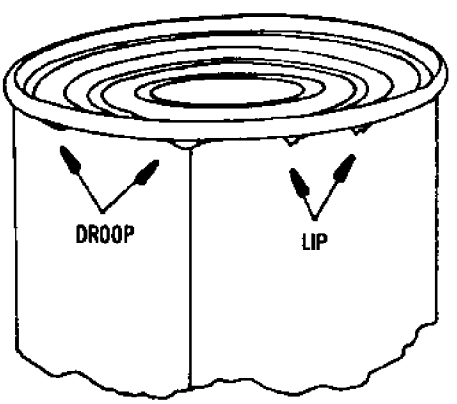


Fig. V-6

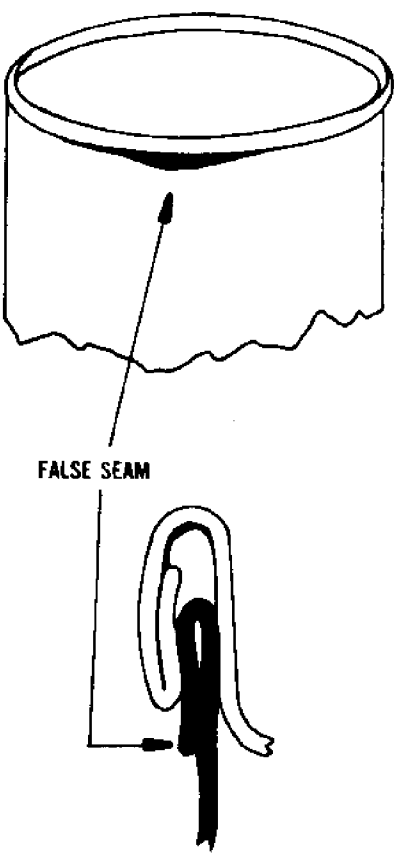


Fig. V-7

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.

7. Spinner (Slip, Skid, Dead Head).

An incompletely rolled finished seam, as illustrated in Figure V-8, is known as a spinner, slip, skid, or dead head. Correction must be made immediately.

Possible Causes of Spinner:

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

C. External Seam Measurements.

1. Introduction.

When the visual inspection of the external seam formation has been completed, 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 hours during production periods. 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.

Seam measurements should be made on round cans at three points around the periphery of the can, at least 1/2 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, Gage 5420, especially made for measuring double seams is shown in Figure V-9.

Care should be exercised that the micrometer is in proper adjustment. When the micrometer is set at zero position, the zero graduation on the movable barrel should match exactly with the Index Line on the stationary member. If, for any reason, the zero adjustment is more than one half a space from the Index Line at this setting, an adjustment should be made.

2. Seam Width (Height, Length).

To measure the seam width, hold the flat surface of the micrometer against the can body as shown in Figure V-10.

3. Seam Thickness.

The thickness of the seam should be measured as illustrated in Figure V-11 below. When taking this measurement, balance the micrometer with the index finger immediately above the seam until the anvil assumes the same angle as the taper of the countersink.

D. Inspection of Internal Seam Formation.

1. Introduction.

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 made at a minimum of once every four hours. As indicated in the preceding chapter, 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.

2. First Operation Seam Formation.

Figure V-12 shows the appearance of a correct first operation seam in cross section away from the lap. It should be noticed 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, however, the first operation seam will be somewhat tighter at this point only and will show a slight flat at the bottom. This is indicated by the arrow in Figure V-13.

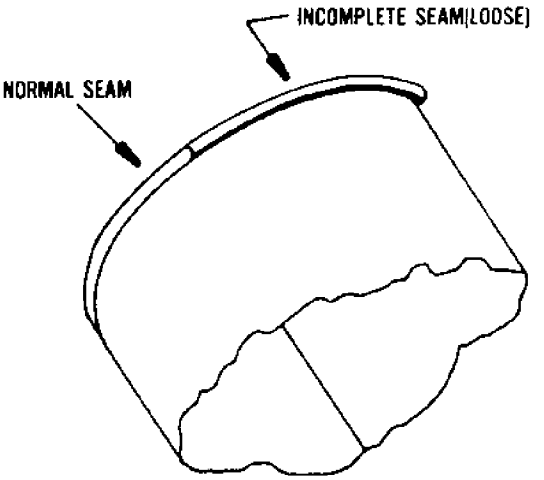


Fig. V-8

Fig. V-9

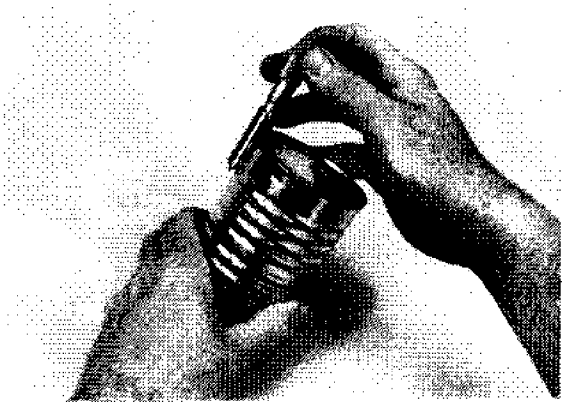


Fig. V-10

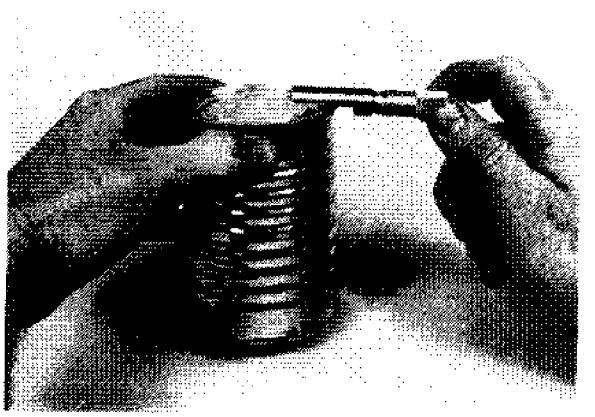


Fig. V-11

If the first operation seam is too tight, the bottom of the seam will be slightly flattened through its length, as shown by the arrow in Figure V-14. If the seam is too loose, the cover hook will not be in contact with the can body. This is shown by the arrow in Figure V-15.

Due to possible variations in end curl configuration, it may be necessary to vary from the set up aim. The ideal thickness should be determined by sectioning the seam so the portion of the cover hook relative to the body hook may be noted as shown in Figures V-12 and V-13. The seam may be sectioned either by filing radially across the seam or by use of a seam saw.

3. Second Operation Seam Formation.

The second operation roll groove flattens the seam and presses the folds together tightly enough to compress the compound and cause it to fill the parts of the seam not occupied by metal. This is illustrated by the solid black area around the body and cover hooks which shows a well formed seam in Figure V-16.

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 worn beyond the limit. Therefore, a seam which is rolled too tight is more likely to leak than one made with proper pressure. Figure V-17 illustrates an incorrect second operation seam which could be partially unhooked at some points.

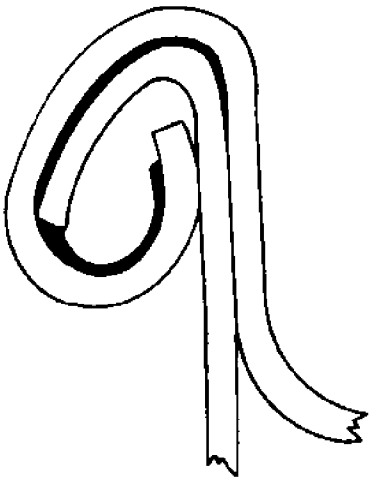
The degree of interlock of the cover hook and the body hook is known as overlap, as illustrated in Figure V-16. The integrity of the double seam is dependent in a large measure on the length of this overlap. Insufficient overlap may result in leakage, particularly at the crossover, if the cover is distorted due to internal pressure during filled can processing or when the double seam is disturbed due to rough handling.

4. Tearing Down the Double Seam for Inspection.

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

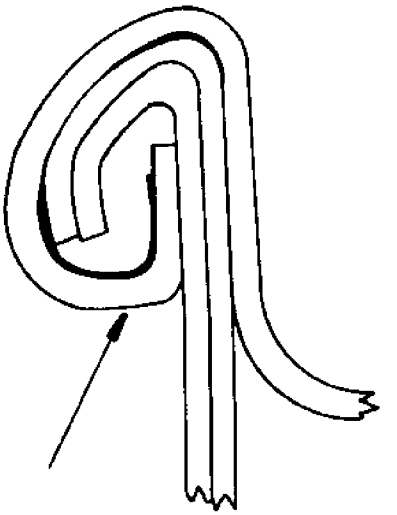
Use can opener WT 2437 to cut out center section of cover approximately 3/8" from double seam as shown in Figure V-18.

Use Nippers, A 2632, and remove remainder of center of cover as shown in Figure V-19.



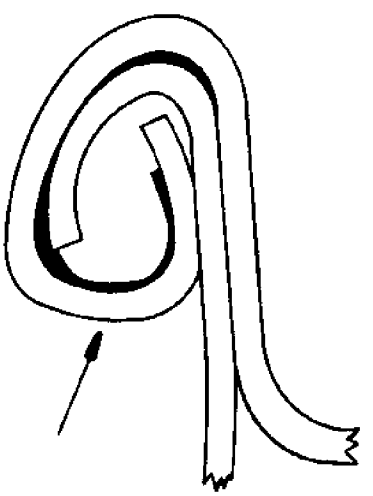
Correct First Operation

Fig. V-12



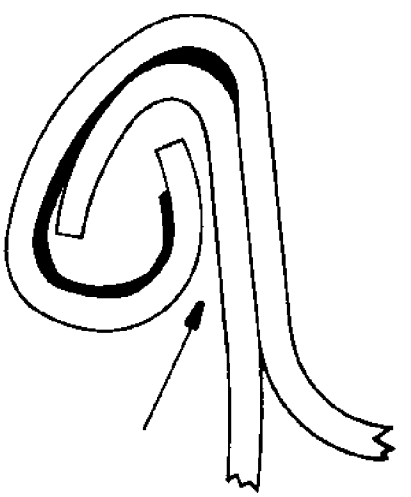
Correct First Operation At Crossover

Fig. V-13



Tight First Operation

Fig. V-14



Loose First Operation

Fig. V-15

Cut through double seam about 1" from lap, as shown in Figure V-20.

Remove stripped part of cover by gently tapping with Nippers, taking care not to distort can body hook. See Figure V-21.

5. Visual Inspection of Internal Seam Formation.

Visual inspection of the 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.

a. Cover Hook Tightness (Wrinkle) Rating.

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

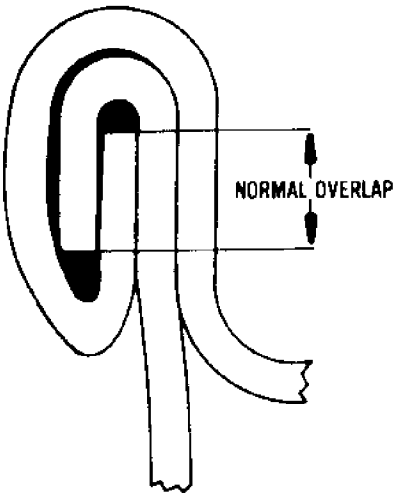
Wrinkles or waves have three basic dimensions. Height, which is the distance the wrinkle extends from the top edge of the cover hook to where it fades out towards the base; depth, which is the amount the wrinkle projects out from the face of the cover hook; and length, which is the distance the wrinkle 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 and 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.

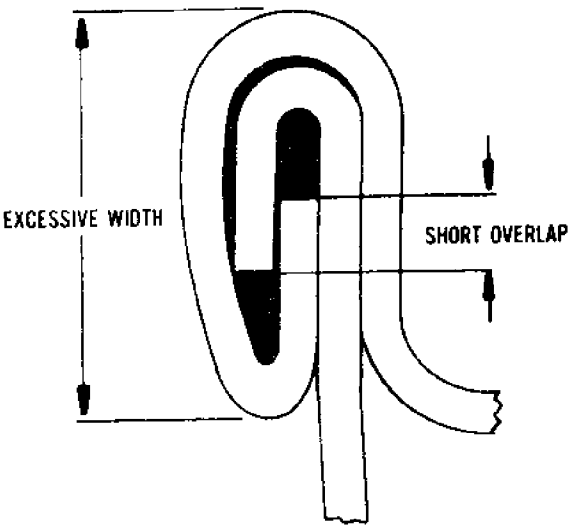
In small round cans, 300 diameter and under, it is important to note that ironed out first operation folds should not be confused with true seam wrinkles. The ironed out folds will be apparent only in tightly rolled seams.

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



Normal Double Seam

Fig. V-16



Wide Double Seam

Fig. V-17

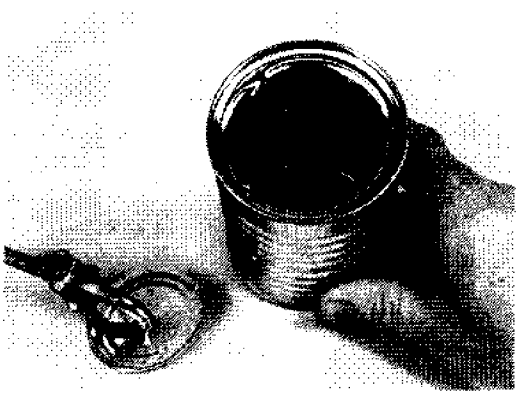


Fig. V-18

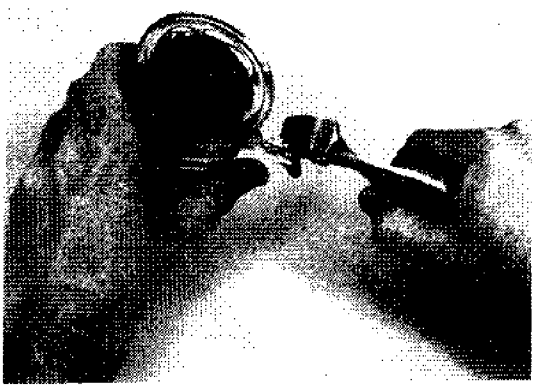


Fig. V-19

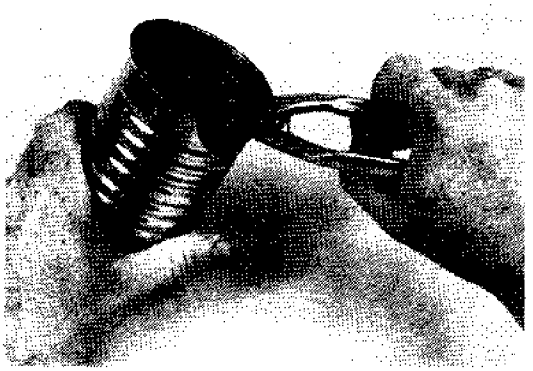


Fig. V-20

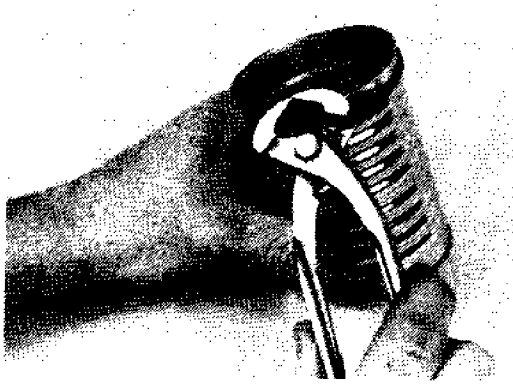


Fig. V-21

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.

Tightness (Wrinkle) Rating.

The tightness of a double seam is graded according to percentage figures as illustrated below.

Figure V-22 shows the cover hook with 0 to 100% tightness, with the former "Wrinkle Number" shown below it.

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 best be made on a cover hook removed from a seam which has been sectioned with a seam saw. See Figure V-23.

b. 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. It should, however, be present and visible.

Figure V-24 shows a cross-section of the finished double seam and a cross-section of a stripped seam which illustrates the pressure ridge produced in making a good commercial seam.

c. Crossover Droops.

The extra thickness of the lap of the side seam causes a normal slight deformation of the cover hook at this point. Excessive droop at this point, exceeding 1/2 the cover hook length, Figure V-25, requires immediate correction. See "Possible Causes of Droops and Lips", page .

d. Jumped Seam.

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, Figure V-26. A jumped seam is a double seam which is not rolled tight enough adjacent to the crossover and is caused by jumping of the seaming rolls after

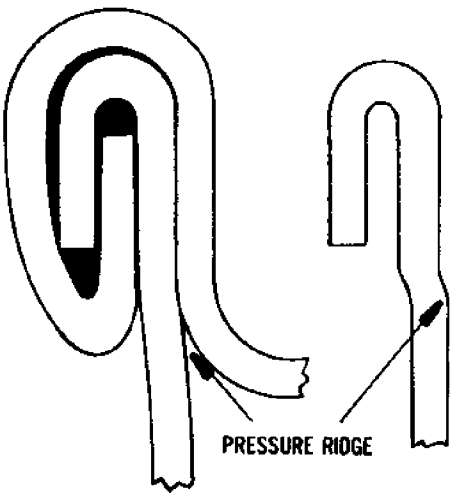


Fig. V-22

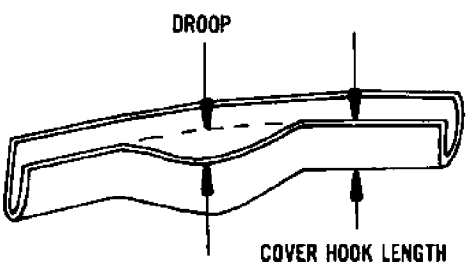


Fig. V-23

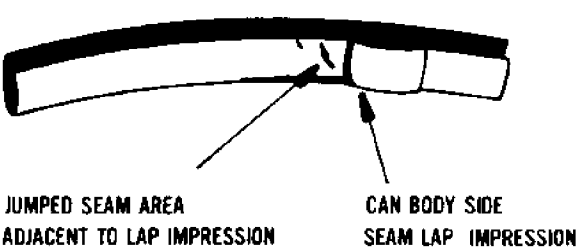


Fig. V-24

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.
6) Excessive external solder at can body lap.

E. Internal Seam Measurements.

1. Introduction.

The cans which 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 hooks, at least 1/2 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.

2. Long Body Hooks.

Possible Causes of Long Body Hooks:

1) Excessive Lifter Pressure.
2) Incorrect pin height setting. Seaming chuck too low in relation to Lifter Plate.
3) Mushroomed can flange.

3. Short Body Hooks.

Possible Causes of Short Body Hooks:

1) Insufficient lifter pressure.
2) Incorrect pin height setting. Seaming chuck set too high in relation to lifter.
3) First operation seaming roll set too tight.
4) Second operation seaming roll set too loose.
5) Improperly formed can flange.

4. Long Cover Hooks.

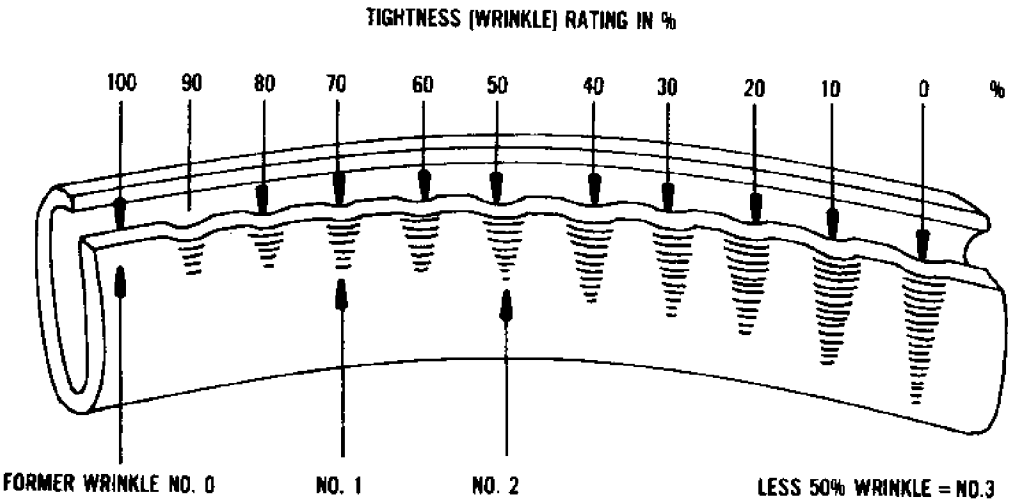


Fig. V-25

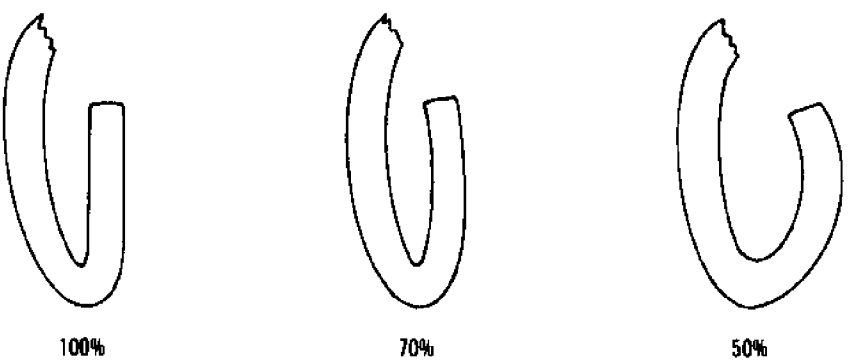


Fig. V-26

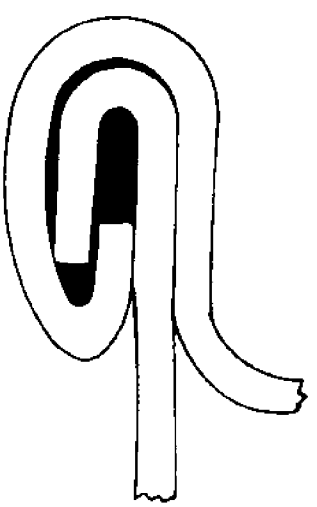


Fig. V-27

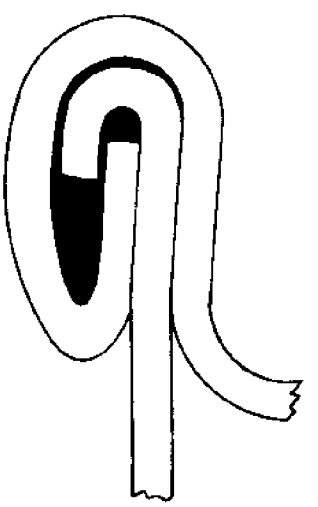


Fig. V-28

Possible Causes of Long Cover Hooks:

1) First operation seaming roll set too tight.

5. Measuring Body Hook Length Using Gage 5420.
See Figure V-30.

6. Short Cover Hooks.

Possible Causes of Short Cover Hooks:

1) First operation seaming roll set too loose.
2) Excessive lifter pressure.
3) Worn first operation seaming roll groove.
4) Excessive countersink depth.

7. Measuring Cover Hook Length Using Gage 5420.
See Figure V-32.

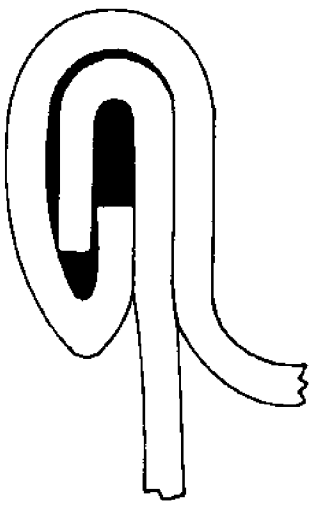


Fig. V-29

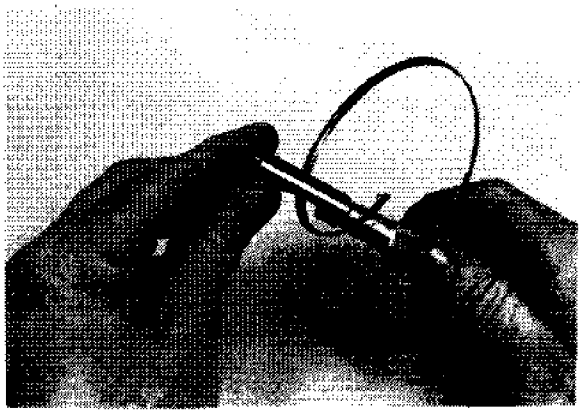


Fig. V-30

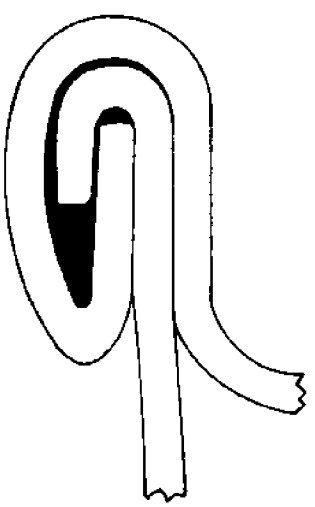


Fig. V-31

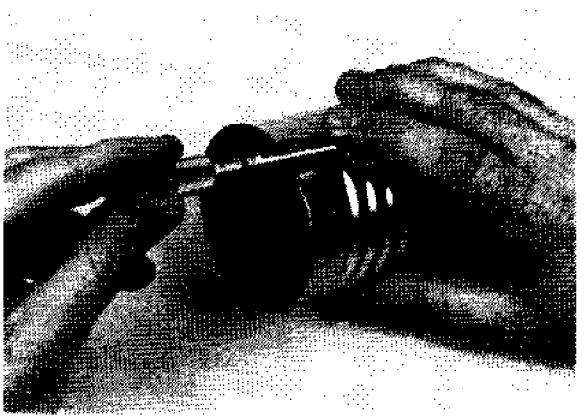


Fig. V-32

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 interest is the prevention of contamination with extraneous material.

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. The cans are transferred to the cannery on runways which lead directly to the fillers or to a 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 cat walks, 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 lines, cardboard separators should be left over the top of the open cans until they are fed into the distributory unit. Some canners also use plastic covers for palletized cans waiting for use. At the end of the day's operation all cans beyond the can washer or inverter should be removed from the can track. This prevents 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, main-

tenance 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 which 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. Recently, the National Canners 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 contamination and adding a measured quantity of the dyed contamination to the cans to be tested. The intensity of the dye is measured before and after the can washer as an index of contamination. The amount of reduction in the dye is a rough measure of the efficiency of the washing procedure. The results showed that there remained only one living spore for each 100 grams of food. The time to reduce the survivors by 90% is the Decimal reduction (D) value, or D_{240} = 1 minute (Figure II-2). The subscript after the D indicates the temperature at which the D value was determined. Many factors affect the D value, such as the species of spore, and the kind of food the spore is suspended in.

To continue on with the example, additional studies could be made on spore inactivation at temperatures other than 240°F. Let us assume this was done and the D_{222} value was 10 minutes and also the D_{240} value was 1 minute. Here we are interested in equivalent D values at other temperatures. A change of one log cycle (1 to 10) is equivalent to an 18°F change in processing temperature. The slope of this curve is called the z value. The z value for spore death time typically ranges between 16 to 20°F. Z = 18°F indicates that if a process is raised 18°F, the processing time can be lowered one log cycle (10 to 1 min. for this example) and still have an equivalent process.

Under conditions of industrial practice, however, the process is modified to take into consideration the characteristics of heat penetration into the in-container product, and to integrate this data with the microbial thermal resistance data to determine the actual sterilizing value of the new process. The F value for a process is the number of minutes required to kill a known population of microorganisms in a given food under specified conditions. This F value is usually set at 12 D values to give a theoretical 12 log cycle reduction of the most heat-resistant species of mesophilic spores in a can of food. For example, if there were 10,000 spores of a species of spore in a can of food and a 12 D process was given, the initial 10,000 spores (10^4 spores) preliminary tests indicate that hot water is more efficient than cold water, cold water more efficient than steam, and steam more efficient than air blast. However, the steam had a tendency to paste the larger particles of contamination to the can rather than remove them. While the use of water at 170-180^{o}F under 60 to 70 pounds of nozzle pressure will do a good cleaning job under laboratory conditions, the commercial application of this presents serious economic and engineering problems. Studies are under way to solve these problems, and our present suggestions are that all glass or metal food containers be at least inverted prior to filling with the food product.

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 detected.

Seam Examination.

Good double seams are essential in insuring against spoilage from leakage and the ingress of oxygen, which results 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. When significant seam defects are noted, closing machine adjustments should be made immediately.

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 personnel should visually examine, at intervals of not more than 30 minutes, the top seam of a randomly selected can from each seaming station, and should record his 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. All pertinent observations should be recorded. 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 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 which influence double seam quality:

(i) Condition of the seaming equipment -- whether or not the mechanical operation and adjustment of the closing machine give the proper seam contours,

(ii) can material -- variations in tinplate thickness, and

(iii) 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.

Essential and Optional Seam Measurements

(a) Optical System (use of seam scope or projector)

Required	Optional
Body Hook	Width, (length, height)
Overlap	Cover hook
Tightness (observation for wrinkle)	Countersink
	Thickness

(b) Micrometer Measurement System

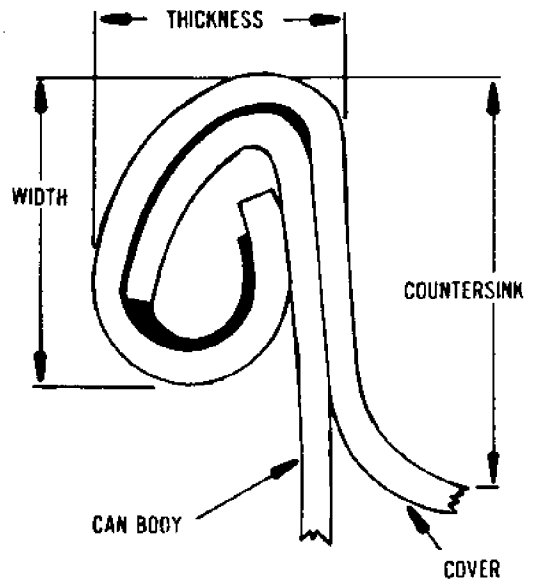
Required	Optional
Cover Hook	Overlap (by calculation)
Body Hook	Countersink
Width (length, height)	Thickness
Tightness (observation for wrinkle)	

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.

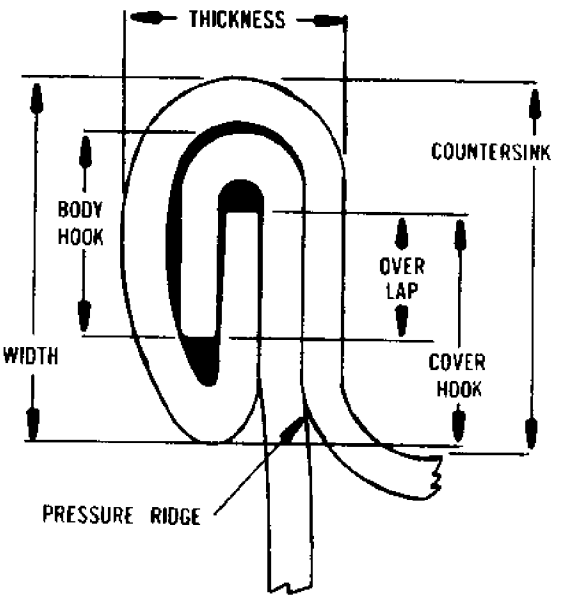
Two measurements should be made for each double seam characteristic if a seam scope or seam projector is used. If a micrometer is used, 3 measurements should be made at points approximately 120° apart, excluding the side seam. The high and low measurements must fall within limits considered to be normal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

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

Overlap length can be calculated by the following formula (see Fig. V-33):



First Operation



Second Operation

Minimum Measurements

Width* (not essential if overlap is measured optically)
Thickness (optional)
Countersink (desirable but not essential)
Body hook*
Cover hook* (required if micrometer is used)
Overlap* (essential if optical system 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 the tin plate thickness.

Figure V-33. Double seam terminology

The theoretical overlap length = CH + BH + T - W

where CH = cover hook
BH = body hook
T = cover thickness, and
W = seam width (height, length)

Figure V-33 is a cutaway diagram of a double seam, showing the measurements to be made and the terminology for the measurements. This should be displayed in the plant area where seams are to be examined. The required measurements are listed on the diagram and the formula for calculating the overlap length is listed as well.

Our recommended forms are shown in figures V-34, V-35, V-36, and 37. They meet FDA recordkeeping requirements and are available from the Virginia Tech Sea Grant Program. Order blanks are contained in the back of the manual. The forms can be adapted to meet the needs of individual companies.

Stripping Seams.

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 the cover hook portion of the seam stay fixed to the can, which assures 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^{o}), or at three points (120^{o}) 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.

The most convenient tools for stripping seams are:

(1) A can opener with a point on the end to pierce the center of the cover and acts as a fulcrum, and having an adjustable slide cutter

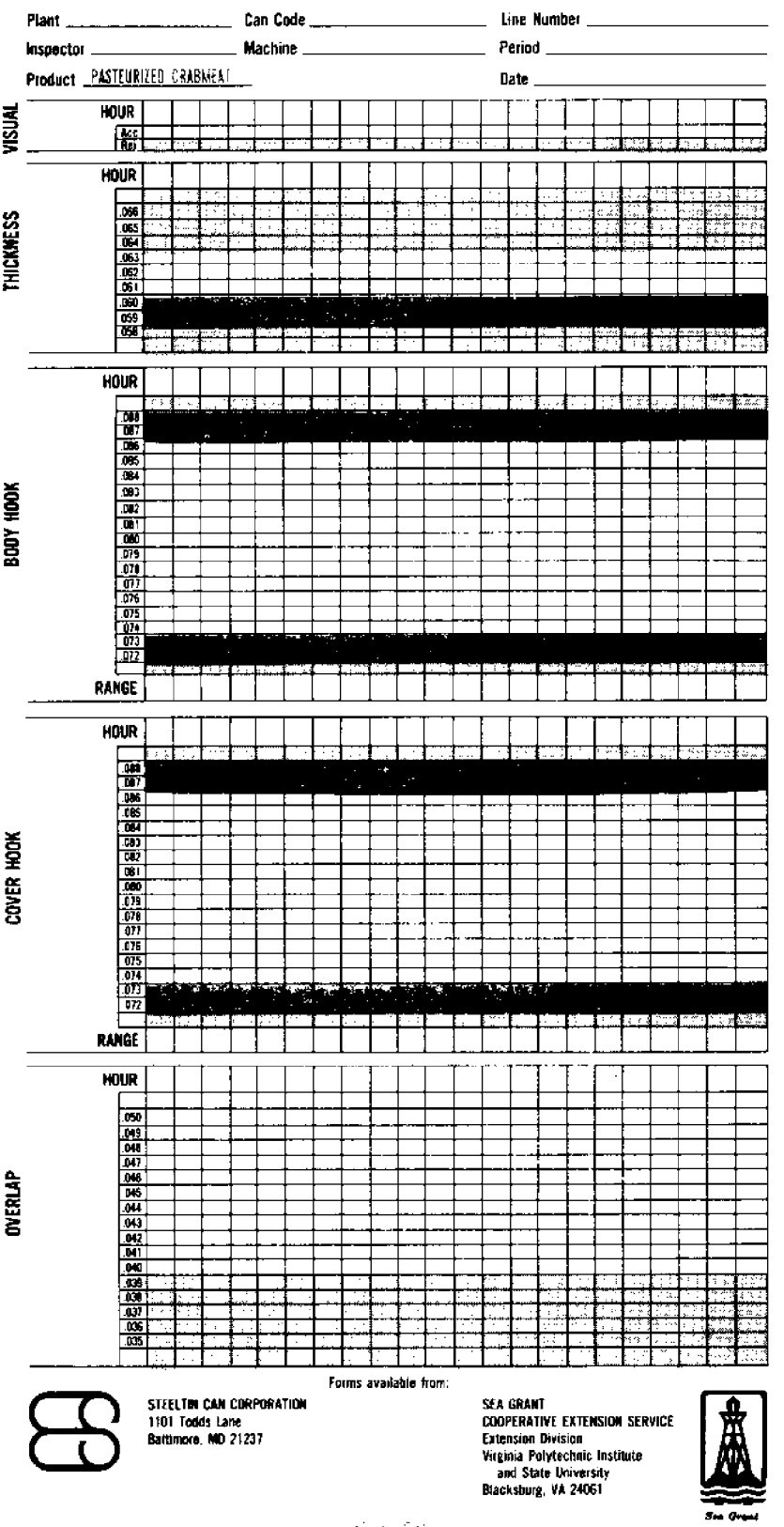


Figure V-34. Double seam inspection record - 3 piece can aluminum ends (front view)

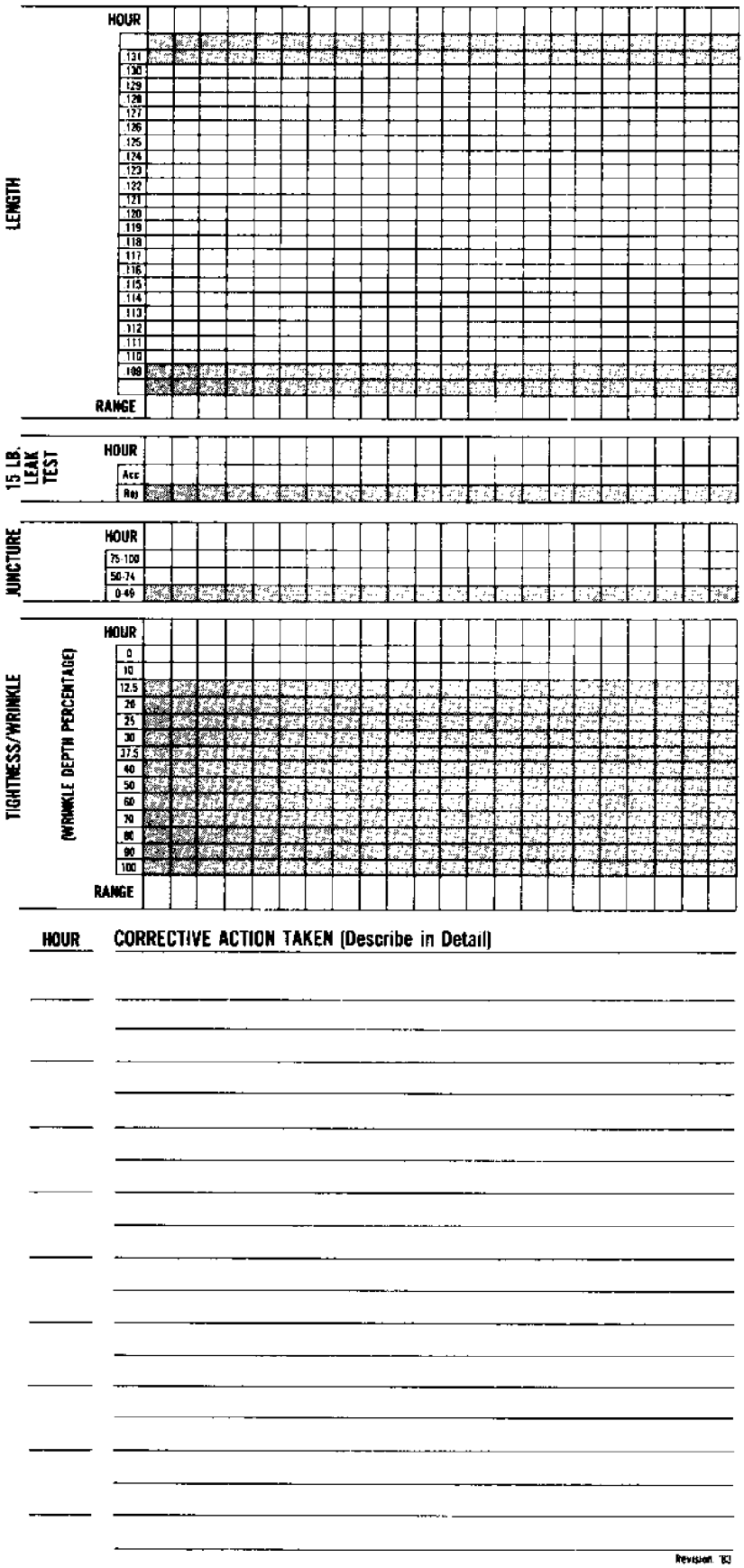


Figure V-35. Double seam inspection record - 3 piece can aluminum ends (back view)

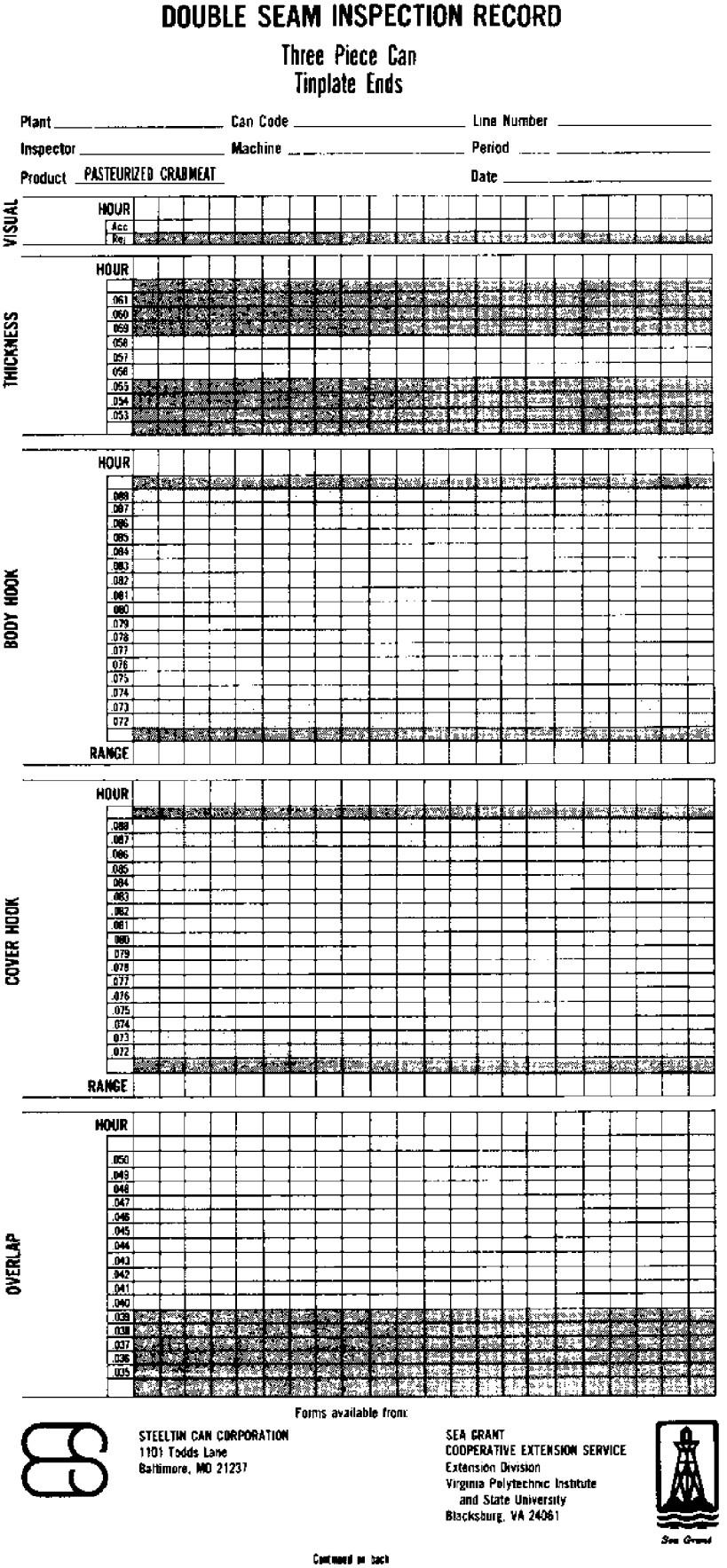


Figure V-36. Double seam inspection record - 3 piece can tinplate ends (front view)

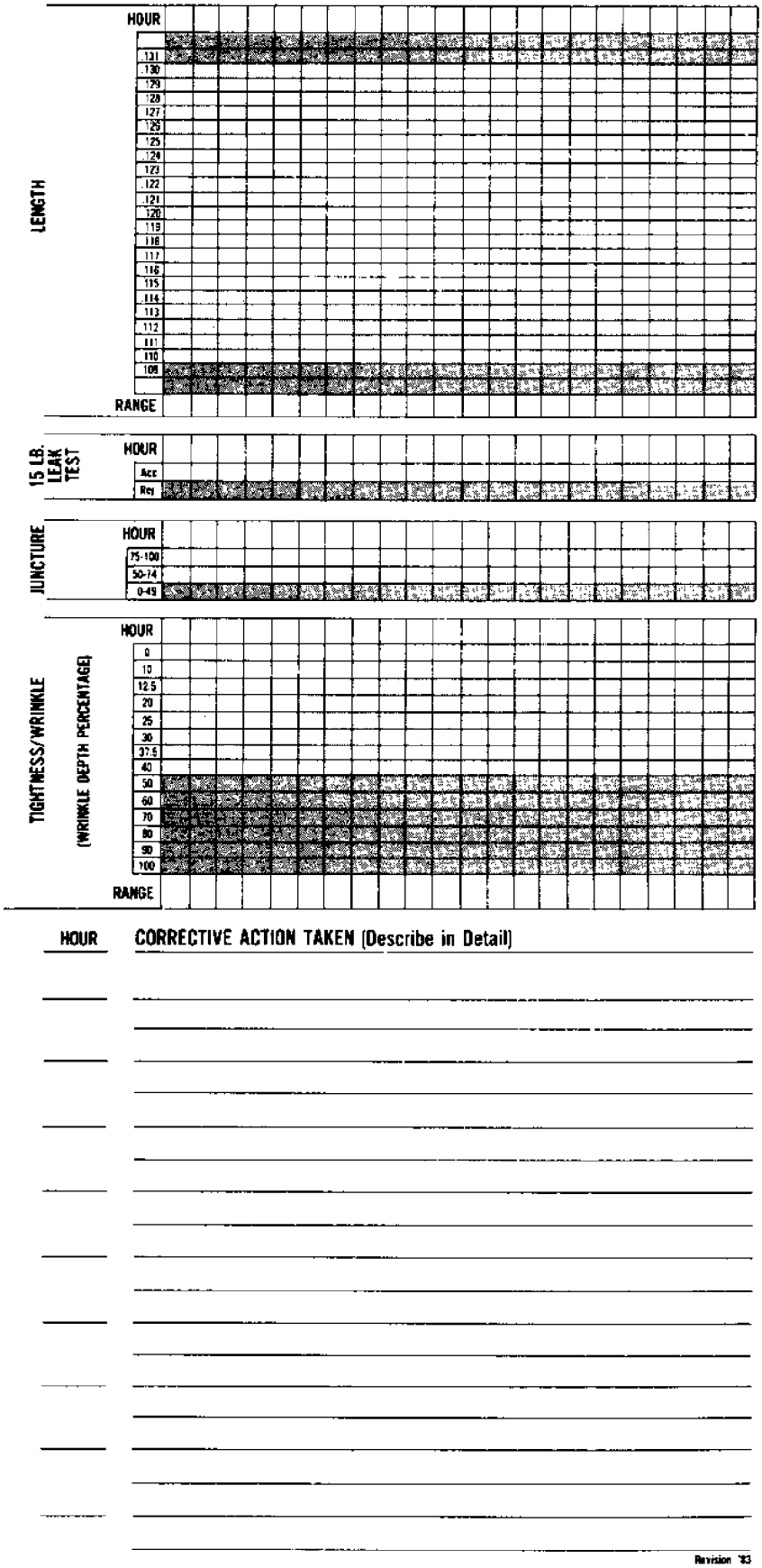


Figure V-37. Double seam inspection record - 3 piece can tinplate ends (back view)

to make a circular cut in the cover leaving a 3/8 to 1/2 inch strip attached to the seam; or a set of "Airplane" left-hand snips (Wiss 8 in.) which are very easily handled in cutting the top out of the can.

(2) A pair of 6 inch end nippers for tearing the seam apart.

(3) A hook gauge (or can seam micrometer) for measuring the can hooks.

(4) A pocket size magnifying glass or seam scope for close inspection of seams.

(5) A seam saw.

Seam specifications differ depending on the can size and the manufacturer. It is not possible, therefore, to list measurements which 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 no "cut-overs" 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 ruined by rolling it too tightly.

(3) Body and cover hooks should each 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 tin. A wrinkle is the degree of waviness occurring in a cover hook. Wrinkles are classified by number as follows (See Figure V-25):

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.

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 give wrinkles not greater than No. 1. No. 2 wrinkle is the borderline between a satis-

factory 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.

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 is placed between the plates so that, as the lugs are screwed down, the rubber gaskets make a seal against the top and double seams. The open end of the 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. With this equipment 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 than 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 which may occur naturally, a leak detector employing vacuum has been developed by Bee and Denny.

1. Steel Container

SEAM DIMENSION 401 x 301 CAN
(3 Piece Can)

	DIMENSIONS IN INCHES	
	ALUMINUM END	TINPLATE END 85 LB.
Thickness	.061 - .064	.056 - .058
Length	.115 - .124	.115 - .124
Body Hook	.074 - .086	.074 - .086
Cover Hook	.074 - .088	.074 - .088
Overlap	.040 - .050	.040 - .050
Juncture	75 - 100	75 - 100
Wrinkle	0 - 1	0 - 1

2. Aluminum Container

SEAM DIMENSION 307 x 113 CAN
(2 Piece Can)

	DIMENSIONS IN INCHES
	ALUMINUM END
Thickness	.057 - .061
Length	.125 maximum
Body Hook	.070 - .090
Cover Hook	.065 - .085
Overlap	.040 minimum
Wrinkle	0 - 2

General Record Keeping Requirements

In regard to most processors' attitudes on record keeping, it would be accurate to say that no one likes record keeping and no one really wants to be burdened with it. And many processors see no real need for or benefit of any additional record keeping. Regardless, it appears that some additional record keeping 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 and may do so on the pasteurized crabmeat industry in the future. Bear in mind that, while some or all of the suggestions discussed here may never become 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 Can
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

Some may find it difficult to include all of this information on the double seam inspection record (see pages V-31 through V-36), 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 which can later be attached to the recording chart and filed for reference.

Cooling Record.

Record the time containers are immersed in ice-water bath 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 the temperature 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, it would seem reasonable to retain process records for a period of at least 2 years before discarding.

Why Record Keeping?

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 credibility may needlessly be incurred. If adequate records are available this problem may be avoided.

Record Keeping to Comply with Federal
Regulations in the Pasteurized Crabmeat Industry

I. Introduction

The production of pasteurized crabmeat, packed into double-seamed metal containers, 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 is being attained on a daily production basis. In the final analysis, such a determination can only be made if some form of record-keeping 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 Food". A copy of this current good manufacturing practice regulation begins on page VI-17.

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.

It must be remarked, however, that a Class I recall of imported pasteurized crabmeat in 1981; and one Class I and a Class II recall of domestic crabmeat in 1982 clearly indicate the necessity, let alone the advisability, of ensuring better quality and public health control over this product.

II. The Hazard Analysis of Critical Control Points

Traditionally, food plant inspections by FDA personnel involved having a

fire investigator monitor manufacturing procedures during a very limited time frame; that is, conditions were recorded based upon what the investigator 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 an inspectional system had to be instituted whereby the adequacy of day-to-day line operations could be determined. This was in contrast to the aforementioned traditional approach which revealed only those conditions present during the investigator's in-plant time.

An idea for this different inspectional 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 record-keeping system.

This new control technique was designed to be preventative 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 of Critical Control Points (HACCP).

When regulations were being proposed for the LACF industry, it was recognized there were 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 basically every LACF process, a lack of control over which could cause, allow, or contribute to a microbiological hazard in the final product. From this it was decided that it was plant management's responsibility to:

1) Identify such critical elements or points
2) Control them through the use of certain processes and procedures and
3) Record the fact that such processes and procedures were performed.

Factor 3, above, is the only way the management has of proving - to itself as well as any regulatory agency - that two 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 to receive such assurance

than the regulatory authority, 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 how 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 which could adversely affect the safety of the finished product 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 crab meat industry. The reason for this is that pasteurized crab meat is a refrigerated product. To meet the definition of a LACF pasteurized crab meat would have to be shelf-stable at room temperature, i.e. approximately 70°F.

The record-keeping requirements in Part 113 would be of benefit as recommendations for the pasteurized crab meat industry. Accordingly, let us attempt to define what critical control points might be inherent in a pasteurized crab meat 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.

III. 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 crab meat line and how can they be controlled? A survey of a typical pasteurized crab meat line indicates the following areas:

A. 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 applicable food regulation and should provide adequate protection from contamination."

The pasteurized crab meat industry employs either a technologically-standard round, three-piece side-seam soldered can or a two-piece seamless aluminum container. Many, if not most packers, use an aluminum end or 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.[1] Some packers employ an all-steel, three-piece, soldered side seam container. Those packing 802 cans may use an all-aluminum "drain" 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 this manual (Chapter V).

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 teardown examinations be made at intervals not exceeding four (4) hours.

Recommendations made specifically for the pasteurized crab meat industry are:

1) Seam tear-down at start-up on each production day, approximately every 1000 cans thereafter and any time following a container jam[2]

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[1] Edmund Nelson, Vice-President, Steeltin Can Corp., Baltimore, Md. Presentation entitled "Comparison of Aluminum and Steel Container Ends" - Virginia Tech Seminar on proper processing techniques for the Virginia crabmeat industry, May 21, 1982.

[2] Ed Nelson, presentation at Virginia Tech Seminar on May 21, 1982.

2) An "inspection of can seams ... at the start of the process and at intervals of 250 cans".[3]

All results of container closure examination should be recorded on appropriate forms (see V-31 through V-36). 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 can manufacturer.

Another good inspectional technique 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 compound deposition or distribution. A record should be made of any abnormalities notes, 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 inspectional 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 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.

B. 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

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[3] Blue Crab National Industry Pasteurization Standard, Section 5: "Seam Sealing" Virginia Tech Manual "Thermal Processing/Pasteurization Manual for the Blue Crab Industry".

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.

Most, if not all, pasteurizers in the crab meat 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 proposed Blue Crab National Industry Pasteurization Standard (NIPS), 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 cool 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 crab meat. 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

proposed 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 placed in tank, time pasteurizer reaches scheduled process temperature, time the process ends, comparative indicating and recording thermometer readings, and operator's signature or initials. Additionally, any instance of equipment malfuncation of process deviation should be reported on the processing log, along with any corrective action taken.

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 when the batch is introduced, and at least once more prior to the end of the cycle. The purpose of this 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. Wrist watches and pocket watches are not considered acceptable time pieces because they tend to run fast or slow after a period of time.

C. Storage Temperature

The third critical control point in a pasteurized crab meat 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 crab meat 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 is that C. botulinum Type E has been shown to grow slowly at 38°F. Whether it will grow and produce toxin in pasteurized crab meat at that temperature has been, and continues to be, the subject of research. Accordingly, it will not be considered here. What we are concerned about is whether the processor can 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.

IV. 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 ensuring 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 proce-

dures are being applied in the pasteurized crab meat plant.

V. Coding Requirements and Records of Initial Distribution

Although not a critical control point in terms of the definition, we have established 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, which 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 has a code identifying, for example, only the year of the pack and a problem of potential public 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 confined to one particular month, then a recall of the entire month's production may be necessary. If, through the coding system, a problem is shown to be confined to a particular day or batch only, then the firm may have to recall only that particular day's or batch's production. 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 "s". Should distribution records not indicate which

accounts received the suspect code "s", it may be necessary, in the interests of public health, to contact all of a processor's customers.

VI. Summary

Adequate control of critical processing points along a pasteurized crab meat line entails first, identifying these points; second, establishing a record keeping procedure for monitoring the operation of the line at those points; and finally, ensuring that the records and properly filled out, accurately reflect what occurs at the processing point and are reviewed by qualified management with sufficient frequency, to ensure that the firm's quality control program is being met on a continuing basis. Although these are no current federal regulations requiring the maintenance of such records, the institution of such a program by the pasteurized crab meat processor would seem to be in the interests of everyone.

Finally, good, basic sanitary procedures are an important part of a pasteurized crab meat operation. Allowing the microbial load of the crab meat to significantly increase prior to pasteurization could adversely affect the pasteurization process. Allowing pasteurized product to come into contact with surfaces or mediums, 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.

Part 110--Current Good Manufacturing Practice in Manufacturing, Processing, Packing, or Holding Human Food

Subpart A--General Provisions

Sec.

Subpart B--Buildings and Facilities

Subpart C--Equipment

Subpart D--[Reserved]

Subpart E--Production and Process Controls

Authority: Secs. 402(a)(4), 701(a), 52 Stat. 1046, 1055 (21 U.S.C. 342 (a)(4), 371(a)), unless otherwise noted.

Subpart A--General Provisions

110.1 Current good manufacturing practice.

The criteria in 110.10, 110.19, 110.20, 110.35, 110.37, 110.40, 110.30, and 110.99 shall apply in determining whether the facilities, methods, practices and controls used in the manufacture, processing, packing, or holding of food are in conformance with or are operated or administered in conformity with

good manufacturing practices to assure that food for human consumption is safe and has been prepared, packed, and held under sanitary conditions.

110.3 Definitions.

The definitions and interpretations contained in section 201 of the Federal Food, Drug, and Cosmetic Act are applicable to such terms when used in this part. The following definitions shall also apply:

(a) "Adequate" means that which is needed to accomplish the intended purpose in keeping with good public health practice.

(b) "Plant" means the building or buildings or parts thereof, used for or in connection with the manufacturing, processing, packaging, labeling, or holding of human food.

(c) "Sanitize" means adequate treatment of surfaces by a process that is effective in destroying vegetative cells of pathogenic bacteria and in substantially reducing other microorganisms. Such treatment shall not adversely affect the product and shall be safe for the consumer.

110.10 Personnel.

The plant management shall take all reasonable measures and precautions to assure the following:

(a) Disease control. No person affected by disease in a communicable form, or while a carrier of such disease, or while affected with boils, sores, infected wounds, or other abnormal sources of microbiological contamination, shall work in a food plant in any capacity in which there is a reasonable possibility of food or food ingredients becoming contaminated by such person, or of disease being transmitted by such person to other individuals.

(b) Cleanliness. All persons, while working in direct contact with food preparation, food ingredients, or surfaces coming into contact therewith shall:

(1) Wear clean outer garments, maintain a high degree of personal cleanliness, and conform to hygienic practices while on duty, to the extent necessary to prevent contamination of food products.

(2) Wash their hands thoroughly (and sanitize if necessary to prevent contamination by undesirable microorganism) in an adequate hand-washing facility before starting work, after each absence from the work station and at any other time when the hands may have become soiled or contaminated.

(3) Remove all insecure jewelry and, during periods where food is manipulated by hand, remove from hands any jewelry that cannot be adequately sanitized.

(4) If gloves are used in food handling, maintain them in an intact, clean, and sanitary condition. Such gloves should be of an impermeable material except where their usage would be inappropriate or incompatible with the work involved.

(5) Wear hair nets, headbands, caps, or other effective hair restraints.

(6) Not store clothing or other personal belongings, eat food or drink beverages, or use tobacco in any form in areas where food or food ingredients are exposed or in areas used for washing equipment or utensils.

(7) Take any other necessary precautions to prevent contamination of foods with microorganisms or foreign substances including, but not limited to, perspiration, hair, cosmetics, tobacco, chemicals, and medicants.

(c) Education and training. Personnel responsible for identifying sanitation failures or food contamination should have a background of education or experience, or a combination thereof, to provide a level of competency necessary for production of clean and safe food. Food handlers and supervisors should receive appropriate training in proper food-handling techniques and

food-protection principles and should be cognizant of the danger of poor personal hygiene and insanitary practices.

(d) Supervision. Responsibility for assuring compliance by all personnel with all requirements of this Part 110 shall be clearly assigned to competent supervisory personnel.

110.19 Exclusions.

The following operations are excluded from coverage under these general regulations; however, the Commissioner will issue special regulations when he believes it necessary to cover these excluded operations: Establishments engaged solely in the harvesting, storage, or distribution of one or more raw agricultural commodities, as defined in section 201(r) of the act, which are ordinarily cleaned, prepared, treated or otherwise processed before being marketed to the consuming public.

Subpart B--Buildings and Facilities

110.20 Plants and grounds.

(a) Grounds. The grounds about a food plant under the control of the operator shall be free from conditions which may result in the contamination of food including, but not limited to, the following:

(1) Improperly stored equipment, litter, waste, refuse, and uncut weeds or grass within the immediate vicinity of the plant buildings or structures that may constitute an attractant, breeding place, or harborage for rodents, insects, and other pests.

(2) Excessively dusty roads, yards, or parking lots that may constitute a source of contamination in areas where food is exposed.

(3) Inadequately drained areas that may contribute contamination to food products through seepage or foot-borne filth and by providing a breeding place

for insects or microorganisms.

If the plant grounds are bordered by grounds not under the operator's control of the kind described in paragraph (a)(1) through (3) of this section, care must be exercised in the plant by inspection, extermination, or other means to effect exclusion of pests, dirt, and other filth that may be a source of food contamination.

(b) Plant construction and design. Plant buildings and structures shall be suitable in size, construction, and design to facilitate maintenance and sanitary operations for food-processing purposes. The plant and facilities shall:

(1) Provide sufficient space for such placement of equipment and storage of materials as is necessary for sanitary operations and production of safe food. Floors, walls, and ceilings in the plant shall be of such construction as to be adequately cleanable and shall be kept clean and in good repair. Fixtures, ducts, and pipes shall not be so suspended over working areas that drip or condensate may contaminate foods, raw materials, or food-contact surfaces. Aisles or working spaces between equipment and between equipment and walls shall be unobstructed and of sufficient width to permit employees to perform their duties without contamination of food or food-contact surfaces with clothing or personal contact.

(2) Provide separation by partition, location, or other effective means for those operations which may cause contamination of food products with undesirable microorganisms, chemicals, filth, or other extraneous material.

(3) Provide adequate lighting to handwashing areas, dressing and locker rooms, and toilet rooms and to all areas where food or food ingredients are examined, processed, or stored and where equipment and utensils are cleaned.

Light bulbs, fixtures, skylights, or other glass suspended over exposed food in any step of preparation shall be of the safety type or otherwise protected to prevent food contamination in case of breakage.

(4) Provide adequate ventilation or control equipment to minimize odors and noxious fumes or vapors (including steam) in areas where they may contaminate food. Such ventilation or control equipment shall not create conditions that may contribute to food contamination by airborne contaminants.

(5) Provide, where necessary, effective screening or other protection against birds, animals, and vermin (including, but not limited to, insects and rodents).

110.35 Sanitary facilities and controls.

Each plant shall be equipped with adequate sanitary facilities and accommodations including, but not limited to, the following:

(a) Water supply. The water supply shall be sufficient for the operations intended and shall be derived from an adequate source. Any water that contacts foods or food-contact surfaces shall be safe and of adequate sanitary quality. Running water at a suitable temperature and under pressure as needed shall be provided in all areas where the processing of food, the cleaning of equipment, utensils, or containers, or employee sanitary facilities require.

(b) Sewage disposal. Sewage disposal shall be made into an adequate sewerage system or disposed of through other adequate means.

(c) Plumbing. Plumbing shall be of adequate size and design and adequately installed and maintained to:

(1) Carry sufficient quantities of water to required locations throughout the plant.

(2) Properly convey sewage and liquid disposable waste from the plant.

(3) Not constitute a source of contamination to foods, food products or ingredients, water supplies, equipment, or utensils or create an insanitary condition.

(4) Provide adequate floor drainage in all areas where floors are subject to flooding-type cleaning or where normal operations release or discharge water or other liquid waste on the floor.

(d) Toilet facilities. Each plant shall provide its employees with adequate toilet and associated hand-washing facilities within the plant. Toilet rooms shall be furnished with toilet tissue. The facilities shall be maintained in a sanitary condition and kept in good repair at all times. Doors to toilet rooms shall be self-closing and shall not open directly into areas where food is exposed to airborne contamination, except where alternate means have been taken to prevent such contamination (such as double doors, positive airflow systems, etc.). Signs shall be posted directing employees to wash their hands with cleaning soap or detergents after using toilet.

(e) Hand-washing facilities. Adequate and convenient facilities for hand washing and, where appropriate, hand sanitizing shall be provided at each location in the plant where good sanitary practices require employees to wash or sanitize and dry their hands. Such facilities shall be furnished with running water at a suitable temperature for hand washing, effective hand-cleaning and sanitizing preparations, sanitary towel service or suitable drying devices, and, where appropriate, easily cleanable waste receptacles.

(f) Rubbish and offal disposal. Rubbish and any offal shall be so conveyed, stored, and disposed of as to minimize the development of odor, prevent waste from becoming an attractant and harborage or breeding place for vermin, and prevent contamination of food, food-contact surfaces, ground surfaces, and

water supplies.

110.37 Sanitary operations.

(a) General maintenance. Buildings, fixtures, and other physical facilities of the plant shall be kept in good repair and shall be maintained in a sanitary condition. Cleaning operations shall be conducted in such a manner as to minimize the danger of contamination of food and food-contact surfaces. Detergents, sanitizers, and other supplies employed in cleaning and sanitizing procedures shall be free of significant microbiological contamination and shall be safe and effective for their intended uses. Only such toxic materials as are required to maintain sanitary conditions, for use in laboratory testing procedures, for plant and equipment maintenance and operation, or in manufacturing or processing operations shall be used or stored in the plant. These materials shall be identified and used only in such manner and under conditions as will be safe for their intended uses.

(b) Animal and vermin control. No animals or birds, other than those essential as raw material, shall be allowed in any area of a food plant. Effective measures shall be taken to exclude pests from the processing areas and to protect against the contamination of foods in or on the premises by animals, birds, and vermin (including, but not limited to, rodents and insects). The use of insecticides or rodenticides is permitted only under such precautions and restrictions as will prevent the contamination of food or packaging materials with illegal residues.

(c) Sanitation of equipment and utensils. All utensils and product-contact surfaces of equipment shall be cleaned as frequently as necessary to prevent contamination of food and food products. Nonproduct-contact surfaces of equipment used in the operation of food plants should be cleaned as fre-

quently as necessary to minimize accumulation of dust, dirt, food particles, and other debris. Single-service articles (such as utensils intended for one-time use, paper cups, paper towels, etc.) should be stored in appropriate containers and handled, dispensed, used, and disposed of in a manner that prevents contamination of food or food-contact surfaces. Where necessary to prevent the introduction of undesirable microbiological organisms into food products, all utensils and product-contact surfaces of equipment used in the plant shall be cleaned and sanitized prior to such use and following any interruption during which such utensils and contact surface may have become contaminated. Where such equipment and utensils are used in a continuous production operation, the contact surfaces of such equipment and utensils shall be cleaned and sanitized on a predetermined schedule using adequate methods for cleaning and sanitizing. Sanitizing agents shall be effective and safe under conditions of use. Any facility, procedure, machine, or device may be acceptable for cleaning and sanitizing equipment and utensils if it is established that such facility, procedure, machine, or device will routinely render equipment and utensils clean and provide adequate sanitizing treatment.

(d) Storage and handling of cleaned portable equipment and utensils. Cleaned and sanitized portable equipment and utensils with product-contact surfaces should be stored in such a location and manner that product-contact surfaces are protected from splash, dust, and other contamination.

Subpart C--Equipment

110.40 Equipment and procedures.

(a) General. All plant equipment and utensils should be (1) suitable for their intended use, (2) so designed and of such material and workmanship as to

be adequately cleanable, and (3) properly maintained. The design, construction, and use of such equipment and utensils shall preclude the adulteration of food with lubricants, fuel, metal fragments, contaminated water, or any other contaminants. All equipment should be so installed and maintained as to facilitate the cleaning of the equipment and of all adjacent spaces.

(b) Use of polychlorinated biphenyls in food plants. Polychlorinated biphenyls (PCB's) represent a class of toxic industrial chemicals manufactured and sold under a variety of trade names, including: Aroclor (United States); Phenoclor (France); Colphen (Germany); and Kanaclor (Japan). PCB's are highly stable, heat resistant, and nonflammable chemicals. Industrial uses of PCB's include, or did include in the past, their use as electrical transformer and capacitor fluids, heat transfer fluids, hydraulic fluids, and plasticizers, and in formulations of lubricants, coatings, and inks. Their unique physical and chemical properties and widespread, uncontrolled industrial applications have caused PCB's to be a persistent and ubiquitous contaminant in the environment and causing the contamination of certain foods. In addition, incidents have occurred in which PCB's have directly contaminated animal feeds as a result of industrial accidents (leakage or spillage of PCB fluids from plant equipment). These accidents in turn cause the contamination of food intended for human consumption (meat, milk, and eggs). Since PCB's are toxic chemicals, the PCB contamination of food as a result of these accidents represents a hazard to human health. It is therefore necessary to place certain restrictions on the industrial uses of PCB's in the production, handling, and storage of food. The following special provisions are necessary to preclude accidental PCB contamination of food:

(1) New equipment, utensils, and machinery for handling or processing

food in or around a food plant shall not contain PCB's.

(2) On or before September 4, 1973, the management of food plants shall:

(i) Have the heat exchange fluid used in existing equipment of machinery for handling or processing food samples and tested to determine whether it contains PCB's, or verify the absence of PCB's in such formulations by other appropriate means. On or before Sept. 4, 1973, any such fluid formulated with PCB's must be replaced with a heat exchange fluid that does not contain PCB's.

(ii) Eliminate from the food plant any PCB-containing food-contact surfaces of equipment or utensils and any PCB-containing lubricants for equipment or machinery that is used for handling or processing food.

(iii) Eliminate from the food plant any other PCB-containing materials wherever there is a reasonable expectation that such materials could cause food to become contaminated with PCB's either as a result of normal use or as a result of accident, breakage, or other mishap.

(iv) The toxicity and other characteristics of fluids selected as PCB replacements must be adequately determined so that the least potentially hazardous replacement is used. In making this determination with respect to a given fluid, consideration should be given to (a) its toxicity; (b) the maximum quantity that could be spilled onto a given quantity of food before it would be noticed, taking into account its color and odor; (c) possible signaling devices in the equipment to indicate a loss of fluid, etc.; and (d) its environmental stability and tendency to survive and be concentrated through the food chain. The judgment as to whether a replacement fluid is sufficiently nonhazardous is to be made on an individual installation and operation basis.

(3) For the purposes of this section, the provisions do not apply to electrical transformers and condensers containing PCB's in sealed containers.

Subpart D--[Reserved]

Subpart E--Production and Process Controls

110.80 Processes and controls.

All operations in the receiving, inspecting, transporting, packaging, segregating, preparing, processing, and storing of food shall be conducted in accord with adequate sanitation principles. Overall sanitation of the plant shall be under the supervision of an individual assigned responsibility for this function. All reasonable precautions, including the following, shall be taken to assure that production procedures do not contribute contamination such as filth, harmful chemicals, undesirable microorganisms, or any other objectionable material to the processed product:

(a) Raw material and ingredients shall be inspected and segregated as necessary to assure that they are clean, wholesome, and fit for processing into human food and shall be stored under conditions that will protect against contamination and minimize deterioration. Raw materials shall be washed or cleaned as required to remove soil or other contamination. Water used for washing, rinsing, or conveying of food products shall be of adequate quality, and water shall not be reused for washing, rinsing, or conveying products in a manner that may result in contamination of food products.

(b) Containers and carriers of raw ingredients should be inspected on receipt to assure that their condition has not contributed to the contamination or deterioration of the products.

(c) When ice is used in contact with food products, it shall be made from potable water and shall be used only if it has been manufactured in accordance with adequate standards and stored, transported, and handled in a sanitary manner.

(d) Food-processing areas and equipment used for processing human food should not be used to process nonhuman food-grade animal feed or inedible products unless there is no reasonable possibility for the contamination of the human food.

(e) Processing equipment shall be maintained in a sanitary condition through frequent cleaning including sanitization where indicated. Insofar as necessary, equipment shall be taken apart for thorough cleaning.

(f) 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. This may require careful monitoring of such physical factors as time, temperature, humidity, pressure, flow-rate and such processing operations as freezing, dehydration, heat processing, and refrigeration to assure that mechanical breakdowns, time delays, temperature fluctuations, and other factors do not contribute to the decomposition or contamination of the processed products.

(g) Chemical, microbiological, or extraneous-material testing procedures shall be utilized where necessary to identify sanitation failures or food contamination, and all foods and ingredients that have become contaminated shall be rejected or treated or processed to eliminate the contamination where this may be properly accomplished.

(h) Packaging processes and materials shall not transmit contaminants or objectionable substances to the products, shall conform to any applicable food additive regulation (Parts 170 through 189 of this chapter), and should provide adequate protection from contamination.

(i) 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 of time that exceeds the shelf life of the product, except that they need not be retained more than 2 years.

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

110.99 Natural or unavoidable defects in food for human use that present no health hazard.

(a) Some foods, even when produced under current good manufacturing and/or processing practices, contain natural or unavoidable defects at lower levels that are not hazardous to health. The Food and Drug Administration establishes maximum levels for such defects in foods produced under good manufacturing and/or processing practices and uses these levels for recommending regulatory actions.

(b) Defect action levels are established for products whenever it is necessary and feasible. Such levels are subject to change upon the development of new technology or the availability of new information.

(c) Compliance with defect action levels does not excuse failure to observe either the requirement in section 402(a)(4) of the Federal Food, Drug, and Cosmetic Act that food may not be prepared, packed, or held under insanitary conditions or the other requirements in this part that food manufacturers must observe current good manufacturing practices. Evidence obtained through factory inspection indicating such a violation renders the food unlawful, even

though the amounts of natural or unavoidable defects are lower than the currently established action levels. The manufacturer of food must at all times utilize quality control procedures which will reduce natural or unavoidable defects to the lowest level currently feasible.

(d) The mixing of a food containing defects above the current defect action level with another lot of food is not permitted and renders the final food unlawful regardless of the defect level of the final food.

(e) Current action levels for natural and unavoidable defects in food for human use that present no health hazard are as follows: (Levels that have been adopted on a temporary basis prior to publication as a regulation may be obtained upon request at the Office of Public Affairs, Food and Drug Administration, Room 15B-42, Parklawn Building, 5600 Fishers Lane, Rockville, MD 20857.) [42 FR 14338, Mar. 15, 1977, as amended at 46 FR 8459, Jan. 27, 1981]

NATIONAL INDUSTRY PASTEURIZATION STANDARD

The National Industry Pasteurization Standard is unavailable at this time. It will be available in August, 1983. To receive a copy, free of charge, fill out the bottom of this page and send it to:

Yvonne Holmes

VPI & SU Seafood Processing Research and Extension Unit

P. O. Box 369

Hampton, Virginia 23669

Please send the National Industry Pasteurization Standard to: (please print)

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Address _____

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