## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER



## FAIR USE POLICY



## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

05487

Distr.
LIMITED

ID/WG.172/11
16 May 1974

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

AFRIFOODS - Regional Consultation on
Promotional and Technical Aspects of
Processing and Packaging Foods for Export

Casablanca, Morocco, 23 - 28 June 1974

# MODERN METHODS OF ASEPTICALLY PROCESSING AND PACKAGING FRUIT AND VEGETABLE PRODUCTS [1/]

V. Mills *

* Technical Manager, Cherry-Burrel Corporation, Chicago, Illinois, USA.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This paper has been reproduced without formal editing.

id.74-3777

CONTENTS

## ASEPTIC PROCESSING

Aseptic processing was initially developed to improve the quality of products which were to be canned aseptically. Typically, retort or hot pack operations had been used as a preservation technique in conjunction with a glass or metal container. With the development of the aseptic canning system, a cold sterile product could be filled and sealed in a sterile container and the advantages of indefinite shelf life from a bacteriological standpoint could be realized. Product quality was improved because continuous HTST[1/] techniques were used minimizing thermal degradation.

The advantages to be gained by using aseptic processing with aseptic packaging as opposed to retort or hot pack operations are:

a. Improve flavor.
b. Improve color.
c. Reduced loss of nutrients.
d. Control texture.
e. Maintain a consistent product regardless of container size.
f. Eliminate container cooling problems and stack burn.
g. Pack heat-sensitive products (which could not be processed using conventional retort or hot pack techniques) by providing for a cold, sterile fill. This has allowed the warehousing, transporting and selling of many products without using refrigeration.

Aseptic processing of the product requires inactivation or removal of the undesirable microorganisms, and maintenance of the product free from undesirable organisms. The processing system must be designed to allow this in a commercial economical manner.

Until fairly recently, heat was the only method used to commercially sterilize products aseptically processed. Filtration has been used on beer with success and other approaches, such as irradiation and pressure, have been investigated. Heat has proven successful and satisfactory for a wide range of products because of mechanical aspects and microbiological phenomena concerning thermal inactivation of bacteria. Mechanically, heat has the attribute of lending itself to measure and control. Bacteriologically, a great deal of information has been compiled over the years which allows close definition

1/ High-Temperature Short-Time

of the processing parameters necessary for various processes. A good many products can be continuously sterilized with heat without adversely affecting their quality. Such is not the case with retort or hot packed items where the container size and configuration, product viscosity, physical structure, etc., have a bearing on heating and cooling rates possible. Continuous heat exchangers can be designed and arranged so that practically any temperature profile desired may be obtained. Whether "in container" or continuous heat is applied to the product, the same basic principles of thermal inactivation of organisms apply. Because of mechanical aspects, different approaches to the application of bacteriological data are sometimes used.

Bacteria are the most resistant to heat in the microorganism world; yeast, molds and enzymes being less resistant. This discussion which follows will therefore deal primarily with the inactivation of bacteria with heat.

Spores are more heat resistant than respective vegetative cells. Hence, most thermal processes are designed to inactivate spores which may be present. Because of the extra heat resistance of some spores, certain special procedures may be required. These usually involve either "conditioning" the spore to be more resistant to the actual process, or causing germination of the spore to a vegetative cell which will be more resistant.

In essence, bacteria are inactivated at a logarithmic rate by heat, once a predetermined minimum temperature is reached. As the temperature is raised, the rate of inactivation increases reducing the time required. For many organisms, elevating the product 18°F. or 10°C. reduces the time required for inactivation of the population by ten fold. For example: If five minutes were required to inactivate a population of organisms at 250°F., then thirty seconds would be required to do the same job at 268°F. (250° + 18°F.)

The number of degrees Fahrenheit to alter the time required for equivalent inactivation ten fold is referred to as the Z value. As mentioned, for many products it is around 18°F., but may be more or less.

By definition, the time in minutes required to inactivate a population of organisms in a specified environment at 250°F. is referred to as the F value. This does not allow for, or consider, the

time-temperature relationships existing in heating the population of organisms to 250°F. or cooling it to the final temperature.

Various types of bacteria react in different manners to heat, and variances occur within a population of given organisms so that some are more heat resistant than others. Factors affecting heat resistance of spores and cells are:

1. Initial concentration – the more cells or spores present, the greater the heat treatment required to kill all of them.
2. Previous history –
   a. Culture medium – in general, the better the medium for growth, the more resistant will be the cell or spore.
   b. Incubation temperature – the resistance usually increases as incubation temperature is raised toward the optimum for the organism. It increases further as the temperature approaches the maximum for growth.
   c. Phase of growth or age – cells are least resistant during the logarithmic growth phase, and most resistant during the late lag phase and maximum stationary phase.
   d. Desiccation – some spores have increased resistance after drying, while with others this is not a factor.
3. Composition of substrate (product) in which cells or spores are heated.
   a. Moisture – moist heat is more effective than dry heat. This is probably related to the increased amount or efficiency of the thermal energy and the rate of coagulation of proteins in the cells or spores.
   b. pH – generally cells or spores are least resistant in acid mediums, followed by alkaline mediums. They are most resistant in neutral mediums.
   c. Other constituents – NaCl and sugar render a certain degree of protection for cells and spores up to a certain concentration. Increased amounts tend to reduce the resistance. Colloidal materials, such as proteins and fats, offer protective characteristics thereby increasing the resistance. Antiseptic and germicidal agents aid heat in the destruction of cells or spores.
4. Type of cell or spore –
   a. Those with high maximum optimum growth temperatures are usually more resistant than those with lower optimum growth temperatures.

b. Bacteria that clump or form capsules are more resistant than those that do not.

c. Cells with high fat content are more resistant than others.

d. Many cocci are more resistant than rods, but there are many exceptions.

The above factors, correlated with the time and temperature of exposure, will affect the death rate. Products retort or hot packed processed, have many factors affecting process time which include the thermal death time and the heat penetration rate. The thermal death time can be determined by tests and transposed using well established procedures for determining the process. A typical thermal death time curve illustrates how this data may be transposed. (Figure 2)

From this curve it can be seen that inactivation of this particular population of organisms requires 15 minutes at 250°F. The F value is 15 and the Z value (slope of the thermal death time curve) is 18. The same sterilization effect can be obtained by using 268°F. for 1.5 minutes or 286°F. for .15 minutes (9.0 seconds).

Thermal death time curves are prepared for the specific product and interpreted for the process.

Aseptic processing usually uses HTST techniques to produce products having the best characteristics from the color, flavor, odor, stability, etc., standpoint. Hence, temperatures in the 280° - 300°F. range are used for periods from 1 to 30 seconds.

The temperature to be used in the process is always correlated with time. When indirect heat exchange systems are used, it is possible to consider lethality effects during the come-up and the cooling portions of the cycle in addition to the holding time. This is not possible with direct systems. The come-up and cooling portions of the process at temperatures high enough to affect the lethality are infinitesimal.

Over-processing can be very detrimental to the product. The graph (Figure 3) indicates lethality for a typical non-acid product versus thermal degradation when processed two different ways. If the product is extremely heat sensitive, thermal degradation beyond that associated with meeting conditions for lethality may be excessive.

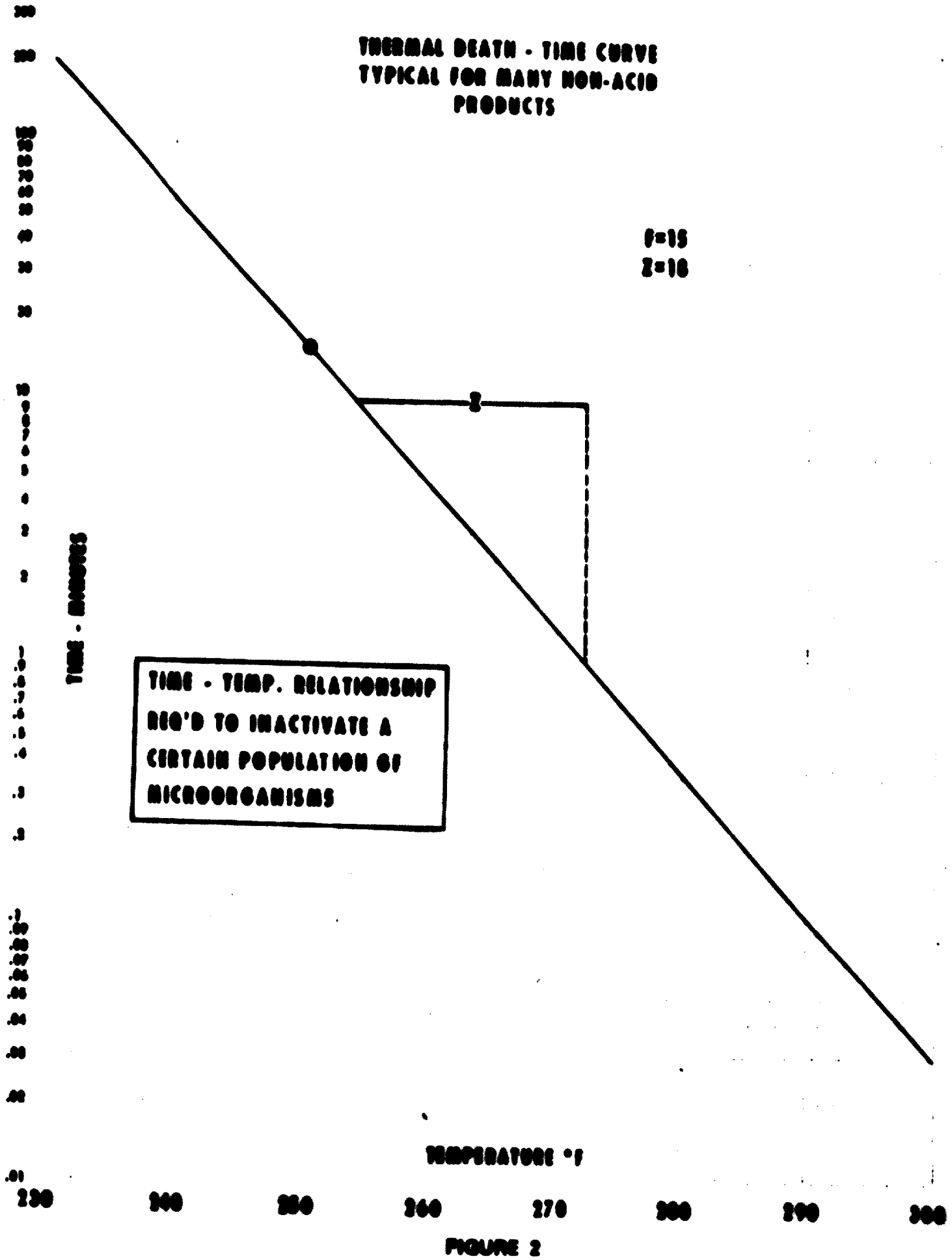

THERMAL DEATH - TIME CURVE
TYPICAL FOR MANY NON-ACID
PRODUCTS
F=15
Z=18
TIME - MINUTES
TIME - TEMP. RELATIONSHIP
REQ'D TO INACTIVATE A
CERTAIN POPULATION OF
MICROORGANISMS
TEMPERATURE °F
250
260
270
280
290
300

FIGURE 2

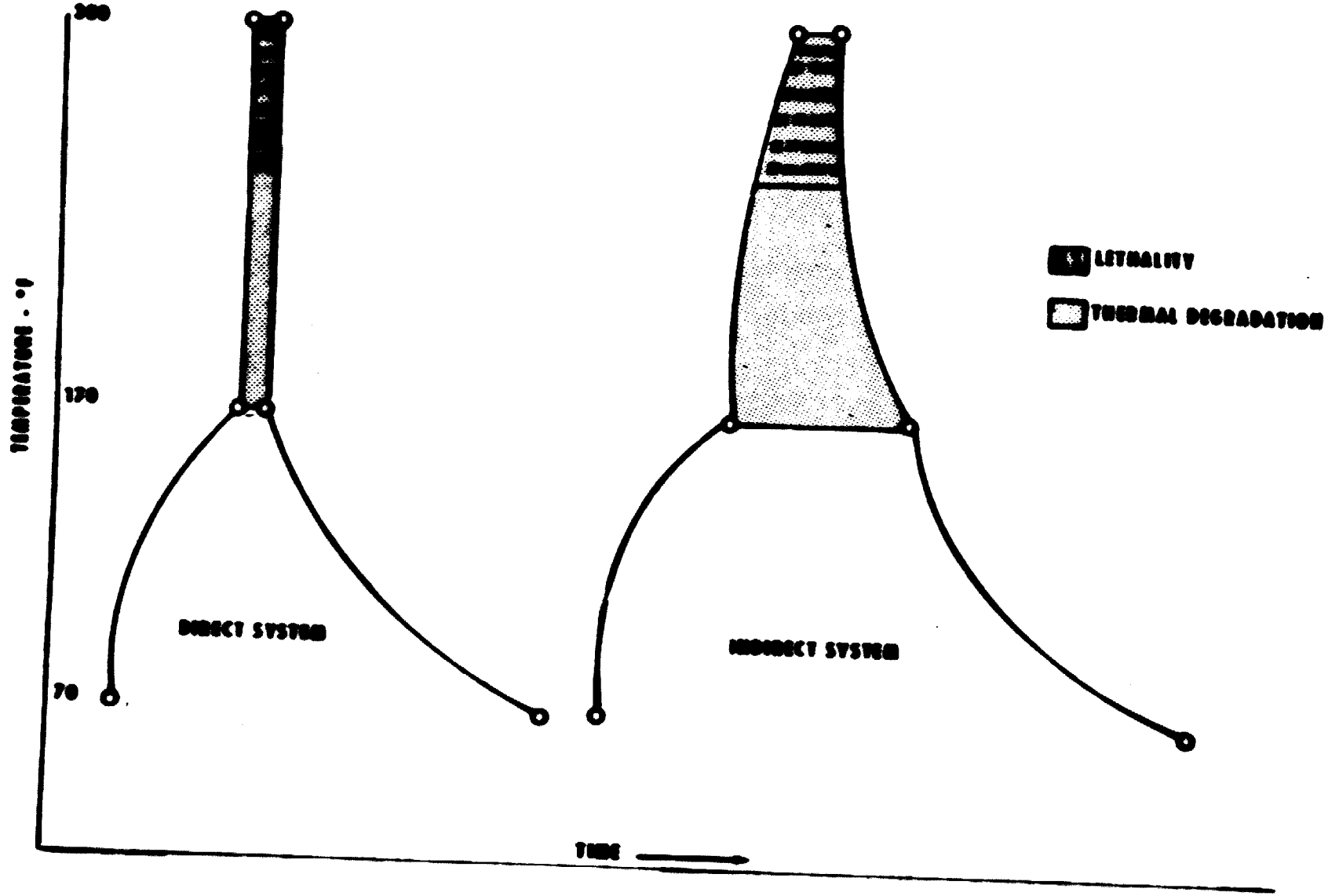

300
120
70
TEMPERATURE - °F
DIRECT SYSTEM
INDIRECT SYSTEM
LETHALITY
THERMAL DEGRADATION
TIME

FIGURE 3

Many considerations enter into which type of system should be used. Regardless of the system, it is necessary that certain conditions exist when relating system and equipment design to the process desired. Once the basic design of the system (direct or indirect) has been established, it must be arranged properly to produce sterile products of the desired quality. It is necessary to determine the process parameters and consider certain mechanical aspects.

Factors which must be determined include:

a. F value required and Z value existing.
b. Heat penetration rates (viscosity, particles, etc.).
c. Maximum allowable temperatures the product will withstand.
d. Allowable heating and cooling time in the lethal temperature range, which will not be detrimental to the product.
e. Time-temperature relationship in the holding tube and the lethality effect.
f. Lethal effect during heating and cooling and whether to use.
g. Holding tube size (length and diameter).
h. Product vapor pressure and required back-pressure.
i. Possible changing process conditions and their affect on lethality and thermal degradation.

The F value required, and Z value associated with the product, can probably be determined from previous test work; assuming the product in mind is fairly common. Various research and service organizations have this type of information, which is also used in establishing retort processes. With this information, the time-temperature relationship can be determined.

The maximum temperature the product wil withstand, along with heating and cooling process profiles in the lethal range, should be considered in calculating the fixed holding time. Extremely heat-sensitive products such as bananas, should be processed so excessive heating and holding of the product is minimized. The majority of products aseptically processed are not this heat-sensitive and are "over-processed". In certain situations, this is thought to be an attribute of the process. This safety factor is believed to be advantageous because of varying raw product conditions and possible variations in the microorganisms present.

If an indirect system is used (and it is desired to include lethality effects during the heating and cooling portion of the process) the area under the lethality curve for these sections can be added to the area of the curve under the holding time. The area under the lethality curve must be equal to, or greater than, the area under the thermal death time curve required for a safe process. In other words, the F value of the process must be equal to, or greater than, the theoretical value required as determined from the thermal death time curve.

The thermal death time curve and generally the process profile curve (for indirect heat exchangers) in the heating and cooling area are logarithimic. It is possible to get an accurate estimate of the lethality effect by using the basic formula defining the thermal death time curve, and using values taken from the process profile curve for the appropriate periods of time.

The thermal death time curve expressed in minutes at any temperature "T" is designated as "t", and the equation for this curve is:

$$\text{Log } \frac{F}{t} = \frac{Z}{250 - T}$$

This is an empirical equation that has been established as being satisfactory. In this equation, F and Z represent the values described earlier and t is the thermal death time of the organism at temperature T, when F equals 1 or 1/t is the sterilizing rate at temperature T, or:

$$1/t = \frac{1}{F \text{ antilog } \frac{250 - T}{Z}}$$

$$1/t = 1/F \times 10^{\left(\frac{T - 250}{Z}\right)}$$

1/t then represents the lethal rate and may be used for calculating the process. At a given time $\Theta$ and temperature T, 1/t can be determined and plotted against $\Theta$. The area under this curve represents the F value. For practical purposes, the lethal rate many times is not figured below 250°F. in commercial applications where continuous heat exchangers are used. The reason for this is that the lethal rate below 250°F., considering the time involved, is usually insignificant.

To illustrate: assume a fluid material is to be processed in a tubular steam-heated heat exchanger. The process profile is shown in Figure 4. The hold is two seconds at 300°F. An average velocity sufficient for turbulent flow exists. The yield stress of the material is not significant from the standpoint velocity distribution in the tubes will affect the lethal rate, and heat penetration will be uniform and instantaneous. Assume Z = 18. Using the values existing in the process, the area under the lethality curve can be determined by integrating.

$$\int_{\theta} \frac{1}{TDT} \cdot d\theta = \int \frac{d\theta}{t}$$

Arithmetically, a close approximation of the area under this curve can be determined. If:

$$1/t = \frac{1}{F \text{ antilog } \frac{250 - T}{Z}}$$ equals the lethal rate at any temperature T

$$\text{or} \qquad 1/t = 1/F \times 10^{\left(\frac{T - 250}{Z}\right)}$$

$$\text{then} \qquad F = t \times 10^{\left(\frac{T - 250}{Z}\right)}$$

by substituting appropriate values of T at various time intervals $\theta$ (t), and adding the calculated F values, a total effect of the process may be determined. If the required F value is known, the process can be evaluated for its effectiveness.

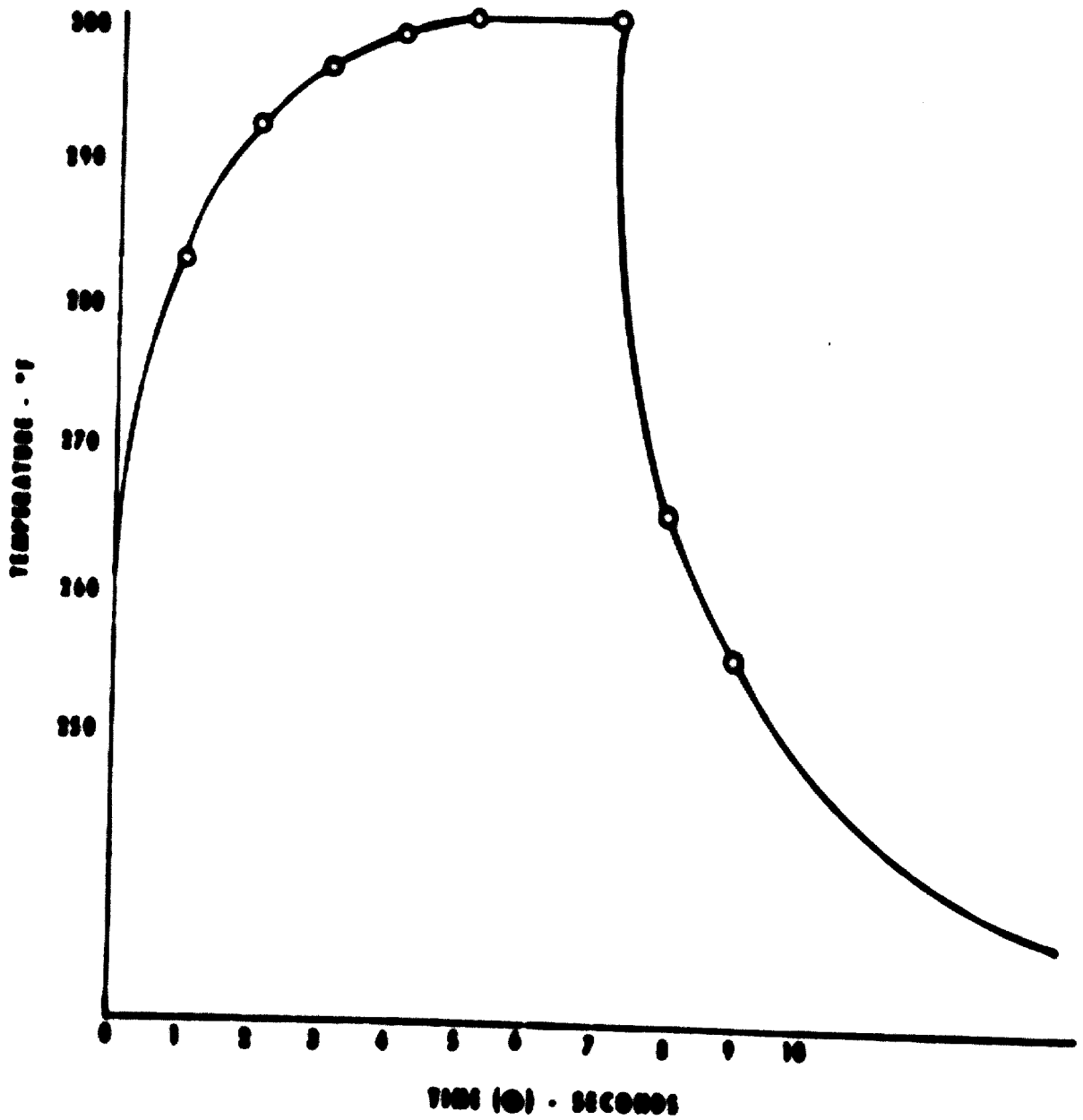



FIGURE 4

| | Time (Min.) | Temperature °F. | Contributed F |
|---|---|---|---|
| HEATING SECTION | 1/60 | 260 | .060 |
| | 1/60 | 283 | 1.131 |
| | 1/60 | 292 | 3.835 |
| | 1/60 | 297 | 6.751 |
| | 1/60 | 299 | 8.380 |
| HOLDING SECTION | 2/60 | 300 | 20.000 |
| COOLING SECTION | 1/60 | 266 | .093 |
| | 1/60 | 256 | .001 |
| TOTAL | 9/60 or 9 seconds | | 40.251 |

Accumulative F values -- Indirect Heat Exchange System

The values of 1/t can also be determined at regular intervals, plotted against time and the area under the resulting curve will give an approximation of the total F value of the process. This method requires determining the area under this curve, which in essence has already been done.

It can be seen that an accumulated or total F value considering the total time the process was above 250°F., and figured every second, is slightly greater than 40. If the F value is figured strictly on the hold time of two seconds and 300°F. using the basic formula for F, it would be equal to slightly more than 20. The arithmetical sum of F used for calculating total F gives a much closer approximation and yet allows some safety if calculated properly.

It can be seen there is a considerable difference in the two values. If an extremely heat-sensitive product or otherwise physically or chemically sensitive product was being processed, the lowest possible safe F should be used. Assuming indirect heat exchangers are used, and both patterns within the heat exchanger are known, the F contributed in come-up and cooling portion are significant.

It is obvious the calculation of F for the process with direct steam injection-flash cooling, must be based on the hold only as the times involved in the come-up and cooling portions of the process above lethal temperatures are insignificant.

Determination of F value to evaluate or develop a process was used, as it is a universally recognized approach. Much of the technical data relating to inactivation of bacteria is available in a form which will allow the use of this technique. Other methods could have been used, such as the D value where probability of surviving organisms is involved. It is not the purpose of this discussion to explore all the various bacteriological aspects of aseptic processing; rather to explore factors relating to process design.

In all heat exchangers and holding tubes, the minimum time any particle is at a specified temperature must be known. If turbulent flow conditions exist, it can be safely assumed that all particles have a maximum velocity of the entire mass. Hence, the residence time in the holding tube can be figured on the actual calculated velocity where it is assumed various velocities do not exist in the tubes.

It is highly desirable that turbulent flow conditions exist in holding tubes in particluar, and in smooth-walled tubular heat exchangers. If such conditions do not exist in heat exchangers, fouling may be increased. If residence times within the heat exchanger during the come-up and cooling cycles are used to contribute to the overall F, they may be impossible to actually determine. Fouling causes a reduction in the effective tube I.D., increases in velocity, and a reduction in residence time.

The sizing of holding tubes should be done in such a manner that turbulent flow exists. This principle has been followed in many "legal" processing parameter definitions established for certain food processes. The technical reasons, as with smooth tube heat exchangers, are to reduce fouling, insure constant velocity for all particles, insure against possible sloughing of deposits, etc. These factors should be considered when designing holding tubes:

a. Base hold on the temperature of the product in the holding tube; not on the displacement of the pump transferring the product through the system, which is probably operating at a different temperature. The specific volume of the product will change with temperature.
b. Back-pressure in the holding tube should be 5 - 10 p.s.i.g. above theoretical vapor pressure at the temperature of the hold. If fluctuating flow rates are anticipated, create back-pressure with a compensating device.
c. Many holding tubes (and tubular heat exchangers) are CIP. Tubes, therefore, should be sized with this consideration.

d. If product viscosity is such, that creating turbulent conditions in the holding tube is impractical, consider an agitated holder.

e. Fibrous, particulated, or highly viscous products require time to distribute heat to all particles. It is often best to reduce the temperature and increase the time, to insure that equilibrium conditions have been met.

Flows through scraped surface heat exchangers do not present the same problems as with smooth-tube types. Turbulence is mechanically induced by the mutator. Hence, using the come-up and cooling cycles for contribution to the total F, is quite acceptable. Often, holding tubes furnished with such units are not properly sized to provide turbulent conditions, and the process may either be insufficient or some particle of the product will be overheated. An agitated holding tube can remedy the situation.

It is possible to determine the various velocities in smooth tubes when turbulent conditions do not exist (such as with viscous products), if enough information is known about the product. The following formula will give the ratio of the maximum velocity (V max.) – minimum hold – to the average velocity:

$$\frac{V_{max.}}{V} = \frac{\left(\frac{P}{2\,LB.}\right)^{1/s} \left(RW^{1/s+1}\right) \left(\frac{1}{1/s+1}\right)}{\left(\frac{P}{2\,LB.}\right)^{1/s} \left(RW^{1/s+1}\right) \left(\frac{1}{1/s+3}\right)} = \frac{1/s+3}{1/s+1}$$

where s = pseudoplasticity factor

It is necessary to determine "s", which can be a problem. If this value is not known, it must be determined by viscometer tests and the results plotted. A question always comes up as to whether the conditions present while determining the viscosity can be accurately assumed or established, considering holding tube conditions. Factors such as temperature, fouling, bends in tubes, surface conditions of the tube, and changing conditions within the tube, all can have some effect. For this reason, practical sizing of holding tubes (where possible) dictates agitated holding tubes or sizing smooth tubes with turbulent conditions existing.

## ASEPTIC EQUIPMENT DESIGN

Formal design codes for aseptic processing equipment do not exist. Various principles which must be followed in the design of aseptic processing equipment, however, have been determined. These principles have been developed over the years through experimental work in food and dairy processing operations, laboratories and other similar facilities.

Originally, standard food or dairy processing equipment was modified to suit the individual aseptic application required. Many times this was done by the food processor because of his intimate knowledge of the problems involved. The main criteria was to insure that the equipment could be operated safely from a bacteriological standpoint, and sometimes mechanical considerations were overlooked or neglected.

Modern design principles incorporate consideration of the food processing problems, including unit operations involved and aseptic factors, along with mechanical factors. Because of the increased activity in this field, it is hoped that standard design principles will be established to alleviate certain regulatory problems now existing. Depending upon the industry, the local area, the method of marketing the product, the type of product, etc., various nonapplicable regulations may be applied to the equipment and system involved. Often, such regulations are not compatible with the food processing operation and cause a hardship on those involved.

## THE BASIC REQUIREMENTS FOR ASEPTIC PROCESSING EQUIPMENT ARE:

1. The equipment must be sanitary either from the standpoint that it can be cleaned in place, or readily dismantled for manual cleaning. All other specific sanitary aspects typical for standard food processing equipment apply.
2. The equipment must be capable of being initially sterilized. This infers that it must be capable of withstanding and operating at high temperatures and pressures, and it should be free from cracks or crevices so the sterilizing media contacts all product contact surfaces. Providing for the sterilizing media to contact all product surfaces is particularly important if chemical sterilization is to be used.
3. The equipment must be capable of being maintained in a sterile condition, which means it should be completely closed or sealed positively; it should preferably be

operated so the product zones are under greater pressure than the surrounding atmosphere or heat transfer media. Any areas where seals are necessary, should be arranged in such a manner that an effective bactericidal media is provided.

4. The equipment must be capable of operating in a proficient manner from the standpoint the unit operation it is performing is accomplished in an effective manner, operating costs for performing the operation are not excessive, and maintenance is realistic.
5. The equipment should be designed for the application of clean-in-place techniques.
6. The equipment must be designed to conform to existing safety codes or in such a manner that it will operate in a safe manner in the event codes do not exist.
7. The equipment must be designed to consider local, state and federal regulatory or legal considerations if they exist.

Aseptic processing systems must be initially sterilized. Usually such initial sterilization cycles are based upon the premise that clean equipment is present. Sterilization cycles are not based upon a certain degree of dirtiness, or filth or soil being present on the equipment. It is impossible to develop a sterilization cycle considering certain percentages of filth or soil. It is impossible to assume how much is or might be present, hence, it is mandatory that the sterilization cycle be based upon the use of clean equipment.

If equipment is not in a good, clean, sanitary condition, the initial sterilization cycle may not be effective and all products processed will be contaminated. Economic implications alone do not allow this. Other facets considering the ethics, safety, etc., associated with producing food products in non-sanitary equipment, apply as they do with any other type of food processing operation.

One aspect of this area was discussed relative to sanitation aspects of the equipment. In addition, high temperatures are normally used and the equipment must be designed to operate efficiently during the sterilization cycles when temperatures may be as high as 300°F. This means the equipment must be designed to allow for expansion. Gasketing and seal materials must be capable of withstanding these temperatures without chemically breaking down or physically becoming softened.

Pressures will be associated with the application of hot water or steam at temperatures required for sterilization. At 300°F., water or steam has a vapor pressure of approximately 52 p.s.i.g. The equipment must be designed, therefore, to withstand the pressure that is associated with the temperatures used in the sterilization cycle.

If possible, the equipment should not include any cracks or crevices, excessive seals, etc. If seals, cracks, or crevices are required, the number should be kept to a minimum and they should be arranged in such a manner that sterilization can be accomplished without excessive difficulty.

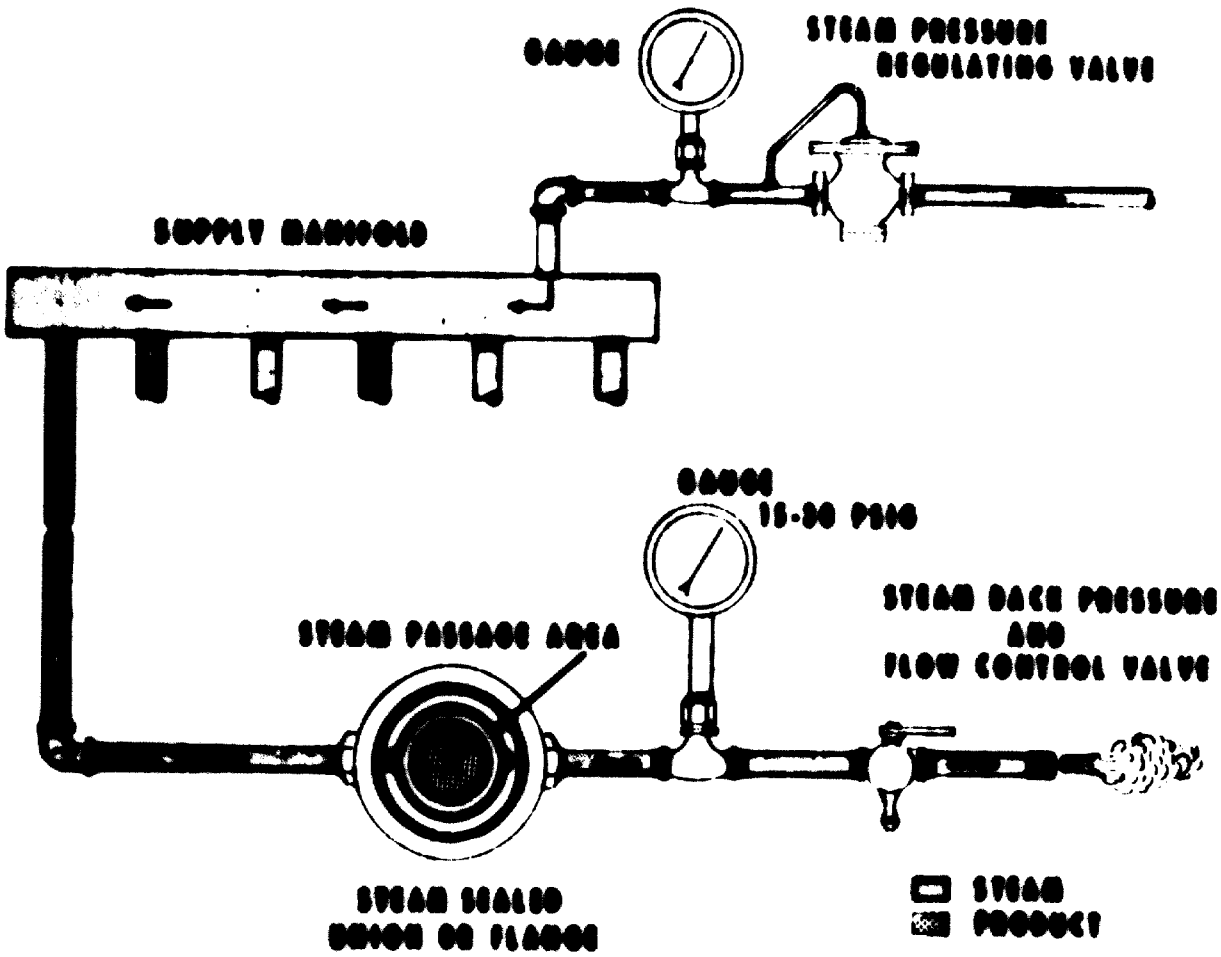
The exclusion of cracks, crevices, voids or pockets is particularly critical when chemical sterilization is used. Heat can be conducted to cracks and crevices, while chemicals may not be able to migrate to these surfaces. Yet if they are not initially sterilized, they can later cause contamination of the product as soil containing microorganisms can possibly work into the product zone.

Moving parts (particularly those which may have to move in and out of the sterile zone) should be arranged so they are initially sterilized and maintained in a sterile condition.

Sterility is best maintained by having a completely closed system, such as an all welded tank or pipe. This principle should be employed whenever possible to reduce the chances of contamination due to mechanical failure or human error.

If a system or equipment can be arranged in such a manner that all sterile product zones are at greater pressures than the surrounding atmosphere or heat transfer media, this is desirable. Any leakage which does develop will be from the sterile product to the surrounding area, as opposed from a contaminating area to the sterile zone. This is not possible in all types of systems, and seals must be utilized.

Bactericidal seals are recommended at any joint or juncture where the product zone is under less pressure than the surrounding areas which can contain contaminants, and wherever reciprocating or rotary seals or similar moving parts are present. It is essential that the seal area not only provide a barrier so contaminants cannot enter the sterile zone, but also a bactericidal agent which will inactivate any organisms migrating to the seal should be used. If a bactericidal agent is not used, there is nothing to prevent microorganisms from surviving in the barrier media and migrating to the sterile zone if a leak should develop. This is based on the premise that the seal area is kept at a higher pressure than the product zone.


GAUGE
STEAM PRESSURE
REGULATING VALVE
SUPPLY MANIFOLD
GAUGE
15-30 PSIG
STEAM BACK PRESSURE
AND
FLOW CONTROL VALVE
STEAM PASSAGE AREA
STEAM
PRODUCT

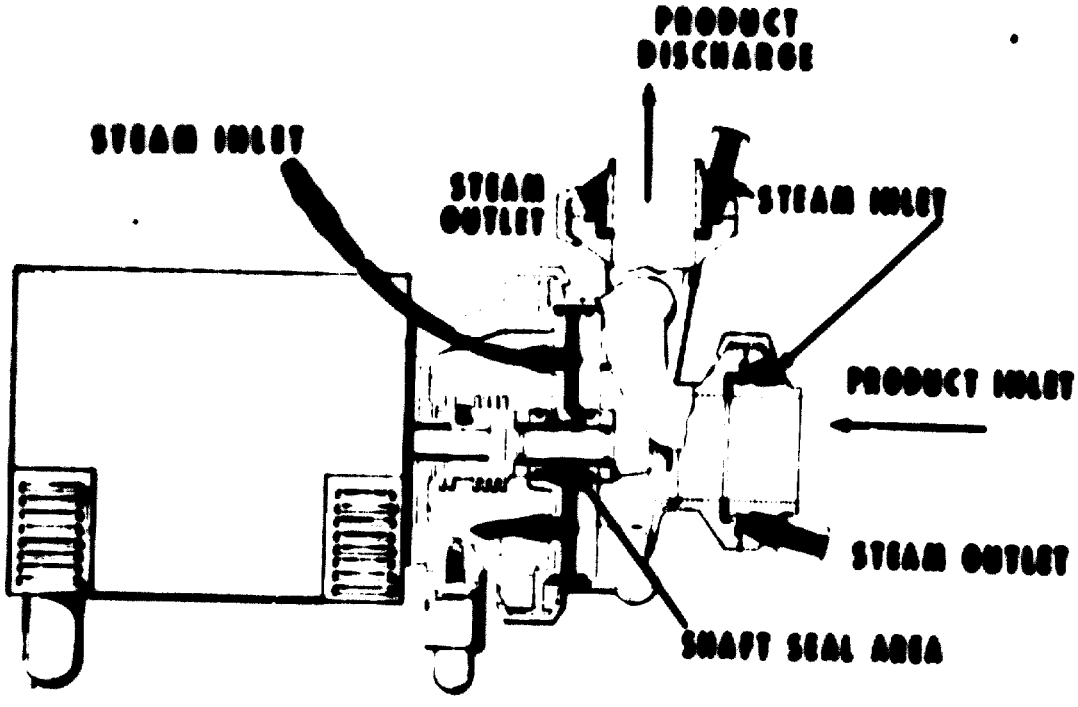

PRODUCT
DISCHARGE
STEAM INLET
STEAM
OUTLET
STEAM INLET
PRODUCT INLET
STEAM OUTLET
SHAFT SEAL AREA

FIGURE 7

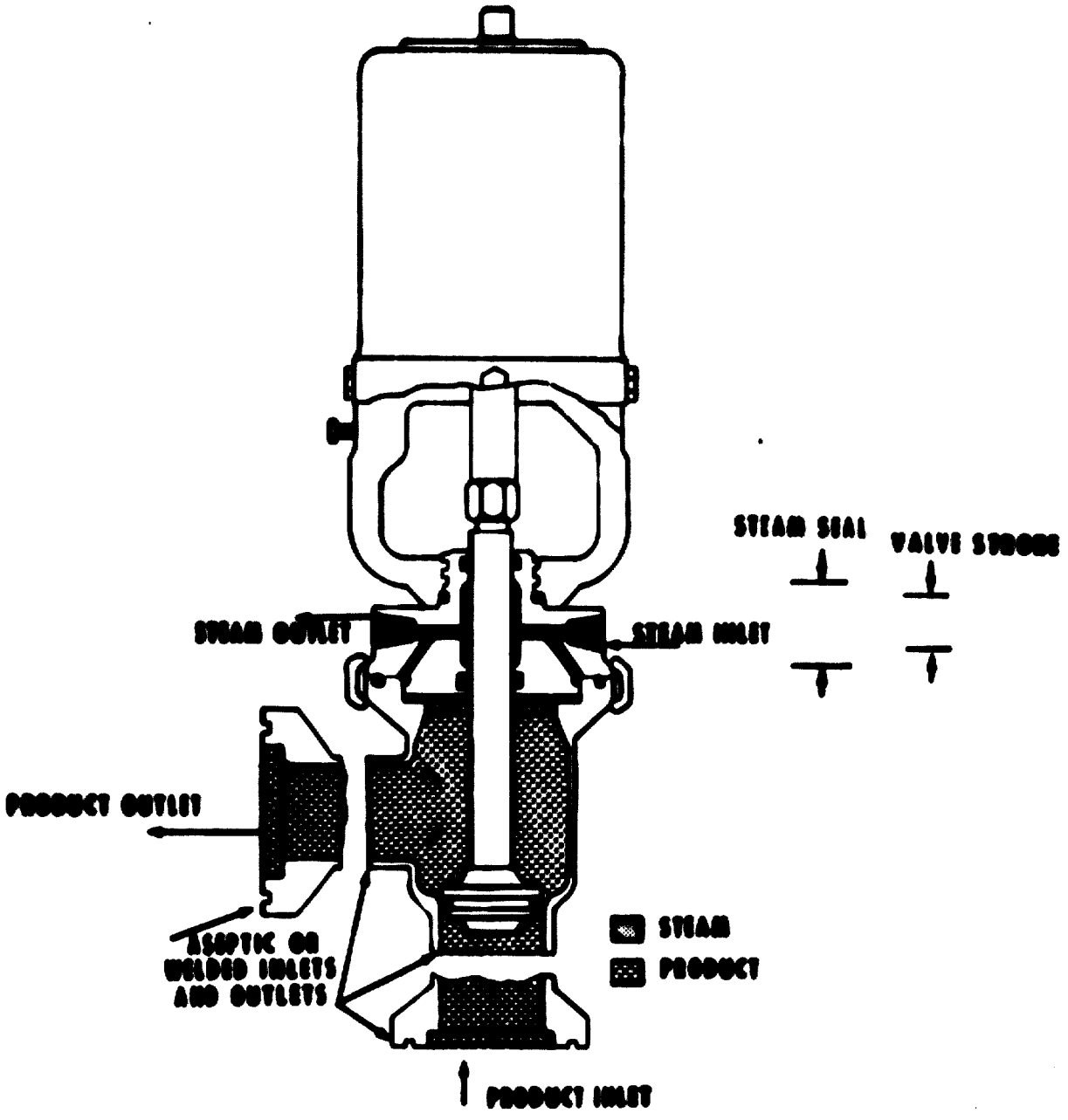

STEAM SEAL
VALVE STROKE
STEAM OUTLET
STEAM INLET
PRODUCT OUTLET
ASEPTIC OR
WELDED INLETS
AND OUTLETS
STEAM
PRODUCT
PRODUCT INLET

FIGURE 8

Common sealants for seals include steam, chlorine solutions, and iodine solutions (Figure 6). Bactericidal seals are mandatory if reciprocating parts are moving in and out of the sterile zone. In this situation, it is necessary to provide a seal area of greater length than the stroke of the reciprocating member to insure that no portion of the reciprocating member in the product zone is ever exposed to atmosphere where it could possibly become contaminated. At one time, a philosophy was used that the reciprocating member could be resterilized before entering the sterile zone. With most designs, this is not practical as reciprocating members may move at a faster rate than sterilization can be effected (Figures 7 & 8).

Other approaches, relative to seals, have been used successfully. The use of lower pressures and a non-bactericidal media can be used if the pressure differential relationship between the product zone and the seal zone can be maintained so leakage will be from the product zone to the seal zone. The theory behind this approach is: Any leak in the seal will be from the product zone to the seal area, and contamination will not result. This philosophy does not apply where a sealing media is required for other purposes, such as lubrication of reciprocating plungers, mechanical sealing of rotating seals, etc. Also , it is not always practical to maintain low enough pressure to have an adequate pressure differential between the product zone and the seal area. This is particularly true when the seal is applied in vacuum vessels.

Another approach has been used which provides a sterile media, but not necessarily a sterilizing media, in the seal area. If a sterile media is placed in the seal area utilizing proper techniques, and is maintained at a constant pressure, any fluctuation in the pressure in the seal area will indicate a malfunction of the seal. This will alert the operator to make the necessary corrections, which may require shutting down the equipment (or the entire system), and replacing the seal materials or taking some other corrective action. The problem lies (1) in the requirement of relying on the operator to notice any change in seal pressure (if minute breaks develop this change may not be noticed) and (2) if any contaminating organisms enter the seal area they can survive, and if a leak develops between the product zone and the seal area viable contaminants can enter the sterile zone.

# ASEPTIC DRUM FILLING & CORRELATED PROCESSING

## INTRODUCTION

Most of the products which are filled into 55-gallon drums should be classified as "Industrial" as opposed to consumer or institutional. What this means is that the products will probably be reprocessed more than "Institutional" or "Consumer" products, may have to hold up under storage for greater lengths of time, and may have to meet more rigid standards because of the final use or the sophistication of the purchasing processor as related to his quality standards. Mechanical factors related to the container are also different. Drums are larger than cans, are manufactured differently, and are subjected to greater stresses. Therefore, it shall be my purpose today to review with you the major technical considerations, the method of transforming these considerations from theoretical to a production or practical operation, and to illustrate these facts by reviewing existing successful drum filling operations.

## GENERAL BACKGROUND

For those not familiar with aseptic drum filling operations, you may be interested in the following information:

The products most filled in 55-gallon drums aseptically are various tomato products. These include tomato paste, tomato puree, and pizza sauce primarily. Many of the packers handling tomato products also handle other fruit products. Included are apricot puree, peach puree, etc.

Additionally, banana puree, apple concentrate, catsup, chili sauce, and pear concentrates are packed in 55-gallon drums.

Experimentally, chocolate, crushed and concentrated pineapple, grape juice, concentrated milk, ice cream mix, pumpkin, and sweet potato puree have been packed successfully from the processing and drum filling standpoint. In most cases, product quality was as anticipated and compatible with the drum liners and coatings. In certain cases, final product quality of the experimental packs was not suitable because of the techniques used. In these cases, techniques which would fit in with available laboratory equipment were used and, since most of the products had been packed successfully in aseptic canning operations, it was felt the processing aspect was not critical. Materials used in the drums did not appear to be factors.

Products various processors have expressed interest in packaging aseptically in 55-gallon drums include various fruit and vegetable purees for use in baby foods, jams and jellies, bakeries, and ice cream manufacturing. With the growth in the convenience food field, it is not difficult to understand their interest.

The drum filling field has grown significantly over the past 10 years as evidenced by the fact 14 companies now are in this business, while in the late 50's there was one. Continual growth is expected based upon market trends in the food industry and the degree of interest expressed by various food packers.

Considering products which are filled in 55-gallon drums may be exposed to additional processing by a food processor and then further heated by the housewife, it is important to keep high temperature exposure of the product to a minimum. The early drum fillers followed this principle by using direct steam injection coupled with flash cooling and a hold was used which was minimal for a safe process. If the product is exposed to extended thermal treatment, flavor, color, nutrient content, etc., may be markedly affected. In addition, the product may chemically and physically break down. In many instances, chemical and physical breakdown go hand in hand, such as the destruction of starch or pectin molecules cause lower viscosities which in turn may cause problems of physical separation. Hence, it is usually desirable to arrange the processing system in such a manner that the overall thermal treatment, including the heating, holding, and cooling portions of the sterilization cycle is kept to a minimum. This does not automatically mean that steam injection coupled with flash cooling should be used as the phy: al forces involved in condensing steam into a product and flashing the same from the product are many times great enough to cause physical destruction of some of the critical long chain molecules. Other factors such as enzyme inactivation must be considered also. It is also desirable to minimize oxygen and other gases to minimize undesirable chemical reactions which may occur during the storage period. Reactions which can produce undesirable results include rancidity types involving oxygen, non-enzymatic browning reactions, iron-oxygen, deaeration is desirable both during the processing and filling operation. It also gives another advantage of allowing more accurate and consistent fill weights.

Besides sterilization of the product which requires bacteriological inactivation, consideration should be given to inactivation of the enzymes systems present. If not inactivated, certain enzymes can cause adverse product characteristics. As you probably know, many enzyme systems exhibit Z values

considerably greater than bacteria. Also with enzymes the phenomena of regeneration must be considered, hence, the thermal inactivation process must consider the Z value required not only for initial enzyme inactivation, but also to insure regeneration does not occur. Z values as high as 100 have been reported for certain enzymes and it is conceivable others could have higher Z values. The amount of work done in this area is lacking and it would behoove those contemplating drum filling operations to investigate this area thoroughly.

Enzymes can be inactivated at lower temperatures than bacteria, hence, system designs can incorporate features which are compatible with enzyme inactivation, bacteriological inactivation, and production of high quality products. The total process or sojourn time above the minimal temperature required to inactivate the enzymes present should be considered and the system should be arranged accordingly. Another consideration is the amount of shear the product is subjected to before, during, and after sterilization. The term shear in food processing operations normally is associated with homogenization of milk, the use of colloid mills in mayonnaise and salad dressing emulsions, or some similar operation. Processing equipment not specifically designed to induce shear can, however, develop considerable amounts of shear. With the use of continuous processing techniques at higher temperatures and longer storage periods the effects of shear should be understood. Mention was made earlier of the physical forces involved with condensing steam into products followed by flashing it from the same product. The physical energy causes shear which results in the breakdown of some of the long chain molecules. Scraped surface heat exchangers induce a certain amount of shear which can be varied considerably by the design of the scraper blades and mutator, and by altering the speed of the mutator.

Shear after sterilization is particularly important with products containing long chain protein, starch, or pectin molecules. If shear is present after gel formation, the matrix forming the gel may be disturbed and consistency or viscosity changed. This is particularly true if a non-thixotopic material is being processed. Other examples of ways to produce shear unintentionally during processing include pumping (particularly if cavitation is present), transferring the product through lines at high velocities (turbulence), transferring the product through some types of fill valve arrangements, etc.

From the discussions earlier today, it is obviously necessary to consider bacteriological inactivation when processing products aseptically and it is also necessary to prevent contamination from re-entering the sterile product. As these are basic fundamentals which have been reviewed, I will not dwell

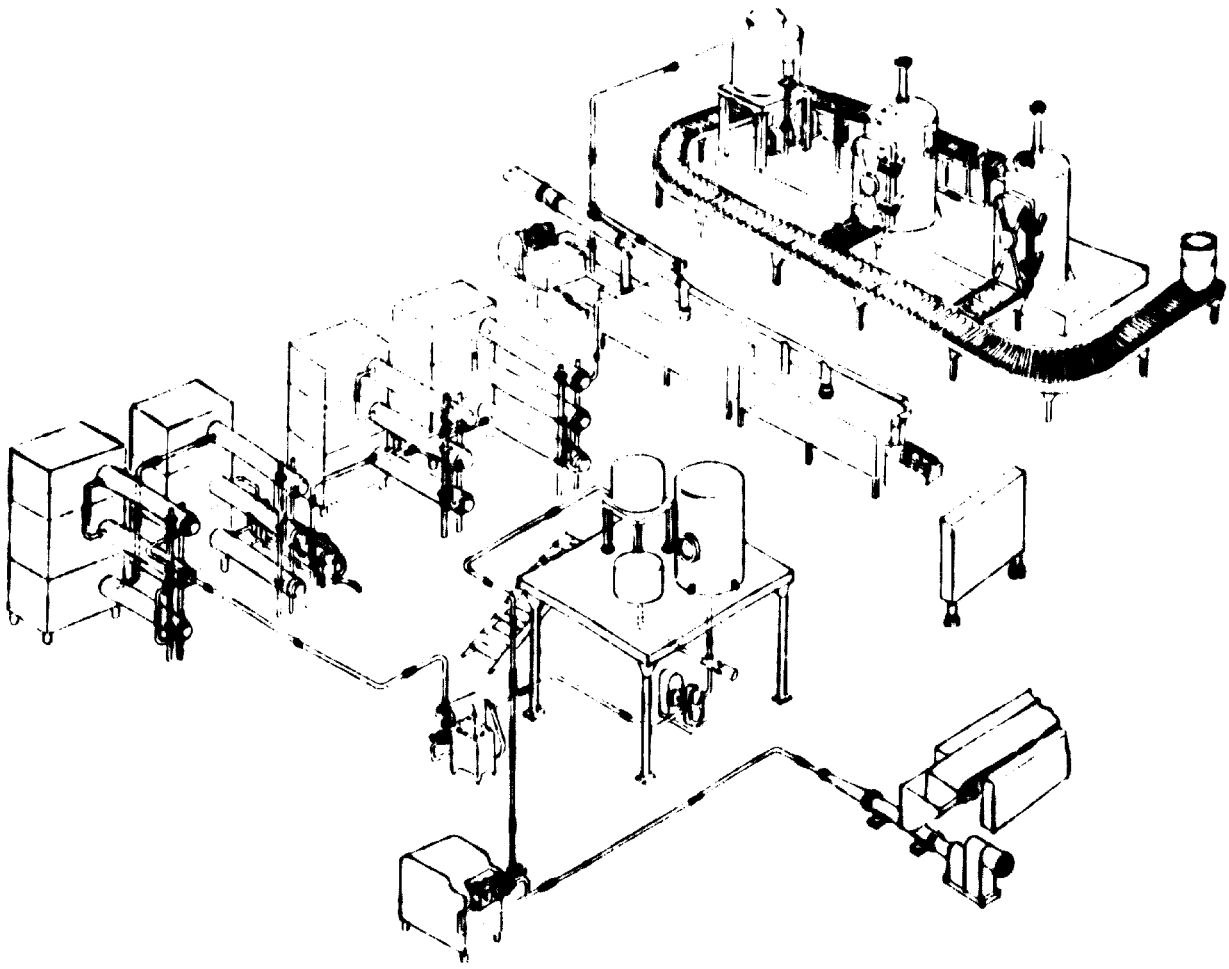


FIGURE 10

on them. Suffice it to say that the same essential principles apply to drum filling operations and related processing system as with any aseptic packaging system whether it be cans, flexible containers, glass, etc.

## PRACTICAL APPLICATIONS OF PERTINENT TECHNICAL FACTORS

To illustrate the employment of the technical factors discussed, a commercial drum filling system will be examined from the design standpoint. The systemwas applied to the processing of banana puree.

This system illustrates how the aforementioned factors are resolved in a production system. The need for proper system design was also illustrated in the same article by suggestions for the use of the product - most of which involved additional heat treatment by the user. Some of the suggested uses of banana puree included banana applesauce, banana syrup and topping, and banana cake donuts, all which involve additional heat treatment (thermal degradation of the product) by a second food processor before the product will be consumed by the housewife. Considering two food processors will be involved with the product before it reaches the final marketplace for the consumer, the time of storage of the product may be increased also. Hence, a second reason for insuring the processing and packaging system is correctly designed.

Bananas, as you can probably appreciate, are quite difficult to handle. Much of the difficulty is based upon the characteristics listed below:

1. Non-acid
2. Contain high quantities of air in the raw state
3. Oxygen sensitive (discoloration)
4. Contain enzyme systems which, if not inactivated, can cause problems
5. Heat sensitive - delicate flavor
6. Contain volatile aromatic
7. Have a tendency to burn or adhere to heated surfaces

Considering the characteristics of this product, the following system design was developed. Some of the major design features and the reason for approaching the processing system design used follow:

1. Indirect heat exchangers were required because of the aromatic volatiles the product contains, and must retain, to give the characteristic banana flavor.

Shear had to be minimized, particularly after sterilization, to prevent breakdown of the starch system which could adversely effect the consistency of the product.

Because the product does have a tendency to burn, or adhere to heated surfaces, and its viscosity, scraped surface type heat exchangers were in order.

2. Because of the high oxygen content of the raw product, it was necessary to deaerate the product. From your own experiences, you know what will happen to a banana if it is exposed to air or oxygen. Because of the problem of removing desirable volatiles, it was necessary to deaerate the product while it was cold, immediately after mashing. Because of the temperature, extremely high vacuums were required. Homogenization to break the product into small particles was incorporated to facilitate the deaeration process. Once the product is deaerated, it is not exposed to air or any other source of oxygen until the filled sterile drum is opened by the final user.

3. Because of the sensitive flavor and the problem of inducing cooked or heated flavors, special scraped surface heat exchangers were provided. These units minimize the sojourn time in the high temperature range. The total time/temperature relationship required for inactivation of the enzyme system(s) to insure that reactivation of enzymes did not occur was determined and provided. The holding tube length for holding time had to be correlated with bacteriological inactivation requirements, enzymes inactivation requirements and be consistent with product flavor and color requirements.

The product is cooled as fast as possible, however, the shear during this operation is balanced with the cooling rate to insure excessive shear is not present. This allows for the production of a good flavor and color but at the same time does not break down the starch molecules to a point that consistency is lost.

The Drum Filler is operated in such a manner that the product does not enter the drum until the atmosphere surrounding and within the drum are at a pre-set specified vacuum. This insures oxygen cannot re-enter the product and protects its quality. Proper, consistent fills are also obtained.

The principles employed in the design of this banana processing system must be considered in the design of any aseptic processing system. Certain products may not be as difficult to process because of their characteristics but all the facets discussed should be considered.

In some cases, existing product quality may not be high and the standard required for the aseptically processed and filled product will not be great. In other cases, you may wish to exceed existing product quality and incorporate those features in the processing system which will maximize the quality of the product.

In certain situations products that are to be used within a single organization do not have to be as high quality because a captive market exists. Unfortunately, this is not a situation many of us have the luxury to enjoy.

Fruit puree and tomato pastes are available primarily in #10 or #12 tins or 55-gallon drums. Certain processors store paste in larger tanks and may ship from these tanks in aseptic type tank cars. The recent trend of industry has been to the 55-gallon drum as one of the more economical and flexible containers, considering the vast majority of users.

As a reference point, 32% paste is used. Higher solids paste is available and may become more common in the future. The processing and packaging systems described below are sized based upon 32% paste, although higher solids content paste can be handled at reduced rates with the same equipment, or the rates may be maintained by altering or modifying the equipment specified.

In normal operations the paste will come from the evaporator at 130 - 140 deg. F. minimum. Certain evaporators produce paste with a higher discharge temperature. The processing system is sized to accept paste at 140°F., transfer the paste through the sterilizing system, cool the paste to the filling temperature of 90°F. and fill the paste in 55-gallon drums. A nominal capacity of 12,000#/hr. has been established for this system.

The heart of the processing system is a specific type of heat exchanger which is supplied nickel tubes and epoxy scraper blades. Mutator speeds are set to maximize heat transfer without causing excessive blade, tube or seal wear.

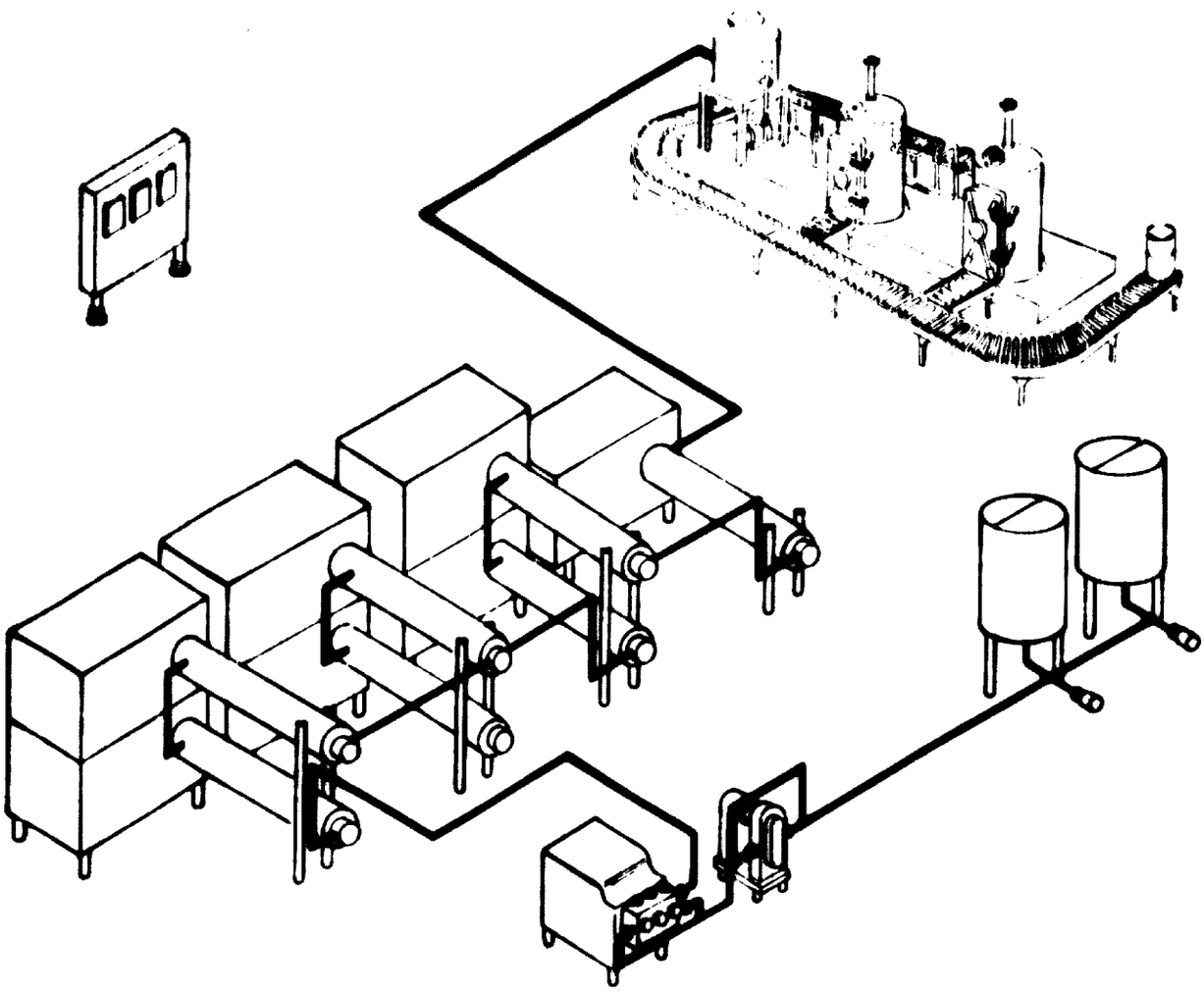


FIGURE 11

Other types of heat exchange systems are possible, such as steam injection coupled with flash cooling, tubular, possibly plate, or some combination of these. Scraped surface has been selected because of its flexibility and versatility, its efficiency, and to allow processing of the product under positive pressure, thereby improving the aseptic integrity of the system. An agitated type holding tube is based on the same design provided to insure complete turbulence and equal holding of all particles without increasing the pressure losses noticeably.

A piston type positive displacement pump, fed by a lobed pump with a pressure relief valve, is used to maintain exact flow rates. Varying flow rates due to slippage of the pump do not occur, hence, product quality and sterility is assured. Maintenance costs on this type of pump will be considerably less than with a gear type pump also.

The controls are designed to provide a safe, automatic operation while minimizing operator attention and errors. They are tied in with the product supply system to safeguard the processing system by switching from product to water should the product supply fail, temperature be lost, or some other malfunction occur.

The basic flow through the system is depicted by the attached isometric view, piping and control schematic, and the floor plan layout. A description of the system and its operation follow.

The supply system provides a constant supply of product or water. The water (140°F. supply) is kept at this temperature with steam. The probe system on both tanks senses when the product supply fails, and switches to water when this happens. The operator is alerted through an enunciator and light when this situation occurs. The supply valves feeding the tanks with water or product are automatically opened and closed as required and the position of these valves is indicated by running lights.

Product is transferred from the supply system via a transfer pump to the positive displacement piston type timing pump. A spring loaded pressure relief valve insures a constant pressure of 40 psi on the suction of the timing pump. The timing pump is sized to deliver up to 1500-GPH at 400 psi pressure, which is the pressure rating of the heat exchangers. A variable speed drive is supplied so that the flow rate may be dropped to 375-GPH. The nominal rating of the heat exchange system is 1200 U.S. gallons or approximately 12,000#/hr. of 32% paste.

The product is heated from 140°F. to 205°F. in the tube, high pressure steam is used as the heat transfer medium and the tube is arranged with stacked cabinets to allow for future expansion.

The sterilizing temperature is sensed with a thermocouple and controlled with an electronic recorder controller and pneumatic steam valve. In the event the sterilizing temperature should fall, the operator is alerted. Should it go below a pre-set temperature, a second alarm is sounded and the system automatically switches from product to water in the supply system. After the product is diverted from the filler automatically. Actuation of the divert valve is through a timer connected to the automatic valve in the supply system. If the product temperature is re-established without sterility being lost, the operator can switch back to product.

A "sterilization inter-lock" is provided to further assure a safe operation. Initial sterilization of the system must be accomplished by subjecting the coldest spot on the sterile side to a pre-set minimum temperature for the proper time period. Until this is accomplished product cannot be processed. After the initial sterilization is completed, the cooling water can be started and the system is "ready" to process product. During the processing operation proper, if product sterilization temperature is lost, the system diverts to water and must be re-sterilized before forward flow can commence.

Following the heater, the product is held for 30 seconds in an agitated holding tube which insures all particles are held properly without excessive velocity, frictional losses (pressure drop), or particle attrition. This holding tube is recommended in place of a conventional stainless steel high velocity tube because of the length of hold, viscosity of the product, and the velocity required for a turbulent flow.

Temperature of the product is sensed at the end of the holding tube with a thermocouple sensor and indicated and recorded on a multi-point recorder to provide a check on the main controller-recorder and thermocouple sensor. The product temperature is also sensed and continuously recorded in the surge tank on the filler, and the discharge of the processing system.

From the holding tube the product transfers through the coolers where it is cooled to the filling temperature using 80°F. and 35°F. water. Refrigerated water requirements can be reduced

if higher fill temperatures are possible. If 100°F. fill temperature instead of 90°F. is acceptable, refrigeration requirements can be reduced from 50 to 33 tons.

From the final cooler the product transfers through the back pressure and divert valve to the surge tank on the filler. It is suggested this tank be mounted with 12-15 ft. of head maintained on the aseptic fill pump. The standard mounting stands can be located in this manner and the proper length of discharge leg furnished. If a special stand is required, this can be furnished. If it is not practical to elevate the surge tank, head can be developed with a gas sterilising system where air, nitrogen, or some other suitable gas is heated to 600°F., held, and cooled. The system to do this includes the air compressor, controls, filters, flow meters, heat exchangers, etc., pre-assembled as a complete unit.

The filler is designed to sterilize drums at up to 300°F. at 60p.s.i.g. and fill the same drum under pressure or vacuum conditions. The sterilization temperature and time, and fill pressures and temperatures will be dependent upon product and container requirements. Warranties on various containers which stipulate filling under vacuum can be met without any problem. Obviously, the capacity of the unit will be dependent upon the product filled and the pressure or vacuum conditions required at the initiation of the filling cycle. At the rate of 12,000#/hr. of 32% paste a 5" vacuum can be obtained in the retort proper before filling commences without any problem whatsoever. When non-acid products are filled which require higher drum sterilization temperature and lower vacuum before filling can commence, nominal capacities of 24 - 26 drums per hour can be obtained.

Whilst it is not the intention of the present work to cover the design and operation of machines involved in preparing tomatoes to produce tomato paste, descriptions will be given of some typical modern plant, representative of present day practice in many establishments.

Flumes. Tomatoes may be conveyed from the receiving area into the factory by means of flumes, and this method is becoming increasingly used. The fruit is transported by water which flows along the flumes, assisted by a slight fall in level along their length. The dimensions of flumes vary, probably because they are often made locally to suit the particular requirements of the plant, but usually consist of sheet-metal U-shaped troughs about 12 in. deep and from 12 in. to 18 in. wide. The material used may be painted steel or light alloy, although short runs may be made in stainless steel. One flume may convey tomatoes to one or more washing lines, and side branches fitted with gates enable the flow to be directed where desired. Water enters the flume through a valve at the feed end and flows out with the tomatoes into the primary tank of the washer. The water therefore serves the double purpose of conveying and pre-washing the fruit. Recirculated cooling water, or water from a subsequent washing operation, may be utilized as flume water if desired.

Tomato washing unit. Almost all manufacturers of washing equipment have produced tomato washers of basically similar design. This consists of a pre-washing vat fitted with a false perforated bottom on to which the tomatoes are tipped, either directly or from the flume. The water in this vat is continuously agitated by submerged jets of compressed air. Dust, dirt and foreign matter washed from the fruit pass into the sump of the washer through the perforations. A rotating transfer reel, or 'propeller' fitted with stainless steel blades, transfers the tomatoes from the pre-washing vat into a second washing tank and, according to its speed of rotation, so the rate of feeding tomatoes into the plant can be controlled. The design of this transfer reel permits the fruit to be moved from one tank to the other with the minimum carry-over of washing water. In this way the water in the second tank does not become unduly contaminated with dirty material from the pre-washer.

The water level is maintained constant in the second tank by means of over-flow ports and thorough washing is accomplished by further agitation with compressed air jets. The tomatoes are picked up from below the surface in this tank by the upward sloping roller conveyor which transfers them to the sorting table. On most modern units the roller conveyor forms an integral part both of the washer and the sorting table. As the tomatoes are lifted out of the washing tank they are subjected to a high pressure water rinse from nozzles placed under a transparent plastic hood.

Tomato Sorting Tables. Although there are many types of sorting belt in use for conveying the tomatoes along in front of the sorters, the modern practice is to use roller conveyors on which the fruit is made to rotate, thereby enabling the sorters to see all surfaces. This consists of a roller conveyor fitted with aluminium rollers 36 in. wide and from four to seven yards in length. The sorters stand on either side of the rollers and waste material is placed in stainless steel chutes which discharge on to a small rubber-canvas conveyor under the sorting table. Some units are also fitted with a second conveyor placed above the sorting table on to which are placed tomatoes fit for use after trimming and this conveyor transfers these tomatoes to a separate trimming operation.

The construction of these roller conveyors is generally very robust and being entirely of metal construction (apart from the belts for removing waste and trimming tomatoes) they are relatively easy to clean and sterilize.

Crushers. The equipment used for breaking or crushing the tomatoes to form pulp may be of various types. The tomatoes are made to pass between two stainless steel rollers with roughened surfaces which break the fruit without seriously damaging the seeds.

Crushers which work on the principle of rotating beaters which drive the fruit against fixed racks form part of some makers' assemblies, whilst others chop the tomatoes by rotating knives.

Tomato juice extractors may also be utilized for pulp production for paste manufacture, but this type of 'break' is more usual in plants which make tomato juices or composite tomato cocktail beverages.

The crushed fruit in this case falls into a small stainless steel tank which provides a 'working head' of pulp for pumping into a tube-type heat exchanger. This head of pulp is not necessary in one type of equipment because the tomatoes are conveyed through the horizontal cylindrical heater by means of a screw-type impeller.

Pre-heaters. All pre-heaters utilize steam as the heating medium and, as indicated above, are usually of the tubuair or impeller type. The tubular heaters consist of a series of horizontal stainless steel pipes of about 2 or 2-1/2 in. diameter and about 8 ft. in length, evenly spaced in a cylindrical shell.

Steam circulates around the pipes inside this shell. The ends of the pipes fit into removable covers at each end of the cylinder which connect them to form one continuous length, through which the tomato pulp flows. The ends may be opened and the pipes cleaned by long brushes, as required, and detergent solution may be circulated in regular cleaning procedures.

Tomato pulp, roughly broken and pre-heated, is pumped to a series of two or three cyclones for the removal of skins and seeds and texture refinement. The first of these is often referred to as a 'pulper' and consists of a truncated cone-shaped sieve provided with a device to regulate the setting of the beaters. The latter rotate inside the sieve screen and force the pulp through the holes which have a diameter of about 1 mm. The waste passes from the interior of the screen into a chute fixed to the endplate of the cyclone. This chute is of fairly large cross-sectional area to reduce the chances of becoming blocked which can seriously impair the efficiency of screening.

The second and third cyclones complete the work of the pulper in removing impurities and small dark coloured specks, and break down the fibres of the pulp so that the resulting material is of a very fine texture. These are known as finishers and have sieve hole diameters of about 0·7 mm. and 0·4 mm. respectively. The screens are almost always cylindrical in shape with internal beaters.

Evaporators. In the process of evaporation, or concentration, of the pulp, various types of evaporator are available but some equipment (such as falling film evaporators), which may be suitable for juices of low viscosity, cannot be used for tomato products because of the 'sticky' nature of the concentrating pulp which readily gives rise to fouling of the heating surfaces.

Evaporators may be:

(a) Single pass or recirculating,

(b) Single or multiple stage,

(c) Single or multiple effect.

The product may be circulated by convection or by pumping and the heat exchange surfaces may be tubes, cylinders or flat.

Forced circulation evaporators employ pumps to circulate the product through heat transfer tubes, or along the inside surface of a jacketed cylinder where whirling vanes on a central shaft move the pulp and maintain a turbulent condition, so preventing burn-on of the sticky material.

Inverted double-effect evaporation systems consisting of large capacity pre-concentrators followed by two or more vacuum pans are the 'traditional' methods in Italy and most other producing countries in Europe, and may be found in almost every tomato paste factory. They have not been completely replaced by the more modern continuous systems and, very often, both types of plant may be found side by side. The two-stage evaporation is essentially a batch process and is therefore extremely versatile, particularly for short production runs. The vapours from the vacuum pans (generally known as 'boules') are used as the heating media for the vertical-tube pre-concentrator, hence the term 'inverted double-effect'. Evaporation to a solids content of about 12% takes place in the pre-concentrator with little effect on the colour of the pulp despite relatively high temperature and, after transfer to the vacuum pans, agitation by rotating paddles is applied and further concentration to the desired degree continues in the thickening paste.

The concentration of pulp in continuous evaporation systems is being carried out in more and more factories and these have many advantages over the traditional methods particularly in establishments handling large quantities of similar quality material. One of the principal benefits claimed for this type of plant is better flavour in the finished product due to the lower temperatures employed throughout the concentration cycle. The maximum temperature is reached in the final stage of concentration and does not exceed about 62°C.

The first drum fillers were developed for use with tomato paste and related products. They were complete packaged units including not only the drum filling operation, but also the aseptic processing system. Four drums were sterilized at a time in a pressurized retort where saturated steam performed the sterilizing operation. Filling was accomplished in the same retort under vacuum conditions. The use of pressurized steam allowed lower temperatures which undoubtedly eliminated or reduced problems with stresses in the drum and lining and breakdown of the lining materials, sealing compounds, etc., used. Vacuum filling cooled the drums, flashed steam from the drums - thereby reducing residual moisture, and offered an oxygen-free atmosphere to minimize chemical reactions within the product and between the product and the container.

One specific process consists basically in sterilizing a food product with pressurized steam to 60 psi, at approximately 300°F, cooling the product under 20 to 26 in. of vacuum, and filling it also under vacuum into 55-gallon, electrolytically tin plated containers. The process is applied to pumpable food products, such as tomato, apricot, peach, and pear concentrates of different densities. Other fruit and vegetable concentrates and purees can also be handled and packed.

Operating sterilization temperatures assure a thermal treatment that will commercially sterilize both acid and low-acid foods. Product sterilization takes place in a heat exchanger. As product flows through the heat exchanger, product temperature is elevated to 220° to 300°F, depending upon pH of food. The more acid the product, the less it needs to be heated. After holding the food at the sterilization temperature for a prescribed period of time, it flows on to another heat exchanger where the food product is cooled to between 90° and 110°F. The cooled, sterile product is then held in a surge tank for transfer to pre-sterilized 55-gallon drums which hold over 500 pounds of the food concentrate.

The filling operation takes place in a retort. Containers are sterilized inside and out with pressurized steam at 100 psi. Filling is by weight, to about 1-1/4 in. headspace, under vacuum. While the filled drums are still in the retort, sterile closures are swedged into the drum's filling opening. Next, vacuum is released, and when the retort gauge pressure reaches zero, the door

is opened. An interlock control system prevents sterile products from entering the 55-gallon drum until the sterilization cycle is satisfactorily completed, thus product, package, and sealing of drum cannot occur in other than an aseptic atmosphere. Vacuum filling in the retort, after the drum is sterilized, has the advantages of producing a slight evaporative cooling of the product and container, of making possible a more uniform fill, and of obtaining a uniform vacuum in the drum after closing. These features are positive factors in obtaining uniform product color, and in preventing flavor changes and losses of nutritive value.

The 55-gallon drum has been especially designed. The body, top and bottom of the container are made from electroplated 18-gauge steel. The thickness of the tin coating is 6 to 10 times that used generally for tin cans. The drum's side seam is welded during fabrication prior to plating. Top and bottom are double-seamed to the body. A 24 gauge electroplated cap seals off the 4-1/2 inch opening in the center of the head through which the drum is filled. The drum withstands a vacuum of 27 inches. The interior may be coated with a sanitary lining.

Several significant economic advantages are claimed for this sterilization process, as follows: (1) improved product quality; (2) one drum replaces 75 No. 10 cans (603 x 700), which brings about lower handling and transportation costs; (3) 30% less warehouse space used; (4) direct labor saving, as only one container need be opened and emptied, instead of 75; (5) reduced product loss as one drum has 84% less surface area than 75 No. 10 cans; (6) empty drums are sold whereas empty cans involve an expense to dispose of them.

The unit as a through put of 25 - 30 drums per hour when packing 32% tomato paste or fruit puree. In addition to the drum filler utilizing vacuum during the filling operation, two additional types are now available. One system uses atmospheric steam for sterilizing the drums and basically includes a shroud to contain the steam which provides for initial sterilization of the drum, a steam enclosure for filling and a steam enclosed third section for closing. Basically the design approach is similar to another aseptic canning system except saturated steam at atmospheric pressure is used for sterilizing the containers. This unit is limited to applications with high acid or similar products.

A second type of unit utilises pressurised steam for sterilisation but does not provide for vacuum filling. The unit is most applicable to high acid products as the drum itself is actually used as the retort or the pressure vessel which limits the steam pressure which can be used.

In this study a commercially demonstrated aseptic canning process was chosen and compared with two "in-can" sterilization methods (1) Still Vertical Retort and (2) Continuous Hydrostatic.

Only those steps in the processing and canning which are different were estimated. These steps are:

1. Filling of can
2. Closing of filled can
3. Sterilization - Product
4. Cooling - Product
5. Empty can and cover sterilization

Step #5 is not necessary in the "in-can" method since it occurs as a part of Steps #3 and #4.

All process steps for product preparation including preheat to 175°F, empty can handling, filled (sterilized) can handling, warehousing, and distribution of services to the process were all assumed to be identical in cost and therefore not a part of this comparison.

Process conditions —

1. 350 (cans per minute) #2 can (307 x 409)
2. Product — condensed soup or pudding
3. Aseptic processing employs high-temperature-short-time sterilization of product
4. Hydrostatic — 40 min. sterilizal time — 75 min. for sterilization-cool
5. Vertical Retort — 112 min. cycle — 70 min. sterilizal time
6. Preheat product to 175°F
7. Finished sterile canned product temp. 100°F
8. Cooling water temp. 55°F

Fixed capital cost comparison summary (three steps where different equipment is involved).

| | | Installed Cost |
|---|---|---|
| I | Vertical Retorts | 325,000 |
| II | Hydrostatic – Continuous | 450,000 |
| III | Aseptic System | 210,000 |

I Equipment cost detail – VERTICAL RETORT SYSTEM

Assume Retort Cycle

| | |
|---|---|
| Retort come up time | 5 min. |
| Process time | 70 min. |
| Cooling time | 30 min. |
| Loading time (last crate) | 2 min. |
| Unloading time | 5 min. |
| TOTAL | 112 min. |

112 min. x 350 cpm ÷ 1140 cans per retort = 35 retorts

Cost per Retort – installed

| | |
|---|---|
| Retort Delivered | $ 2,400 |
| Automatic Controls | 3,000 |
| Erection, Hook-up and Platforms | 2,000 |
| Crates | 500 |
| Crate Handling Equipment | 750 |
| Water, Steam, Air Distribution | 500 |
| TOTAL Cost/Retort Installed | $10,150 |

Total Fixed Capital Vertical Retort

| | |
|---|---|
| Retort Cost 35 x $10,150 = | $355,250 |
| Crate Can Loading System | 5,000 |
| Crate Can Unloading System | 5,000 |
| Filler installed | 15,000 |
| Closing Machine-Installed | 21,500 |
| TOTAL – 35 Retort System | $401,750 |

II Equipment Cost Detail — CONTINUOUS HYDROSTATIC

40 min. cook time — 75 min. in automatic continuous hydrostatic sterilizer.

| | | |
|---|---|---|
| Hydrostatic Cost Complete machine FOB | $250,000 | |
| Freight to site | 18,000 | |
| Duty 10% of FOB | 25,000 | |
| Installation cost Vendor est. 15% | 37,500 | |
| Total Hydrostatic costs | | $330,500 |
| Filler installed | | 15,000 |
| Closing Machine installed | | 21,500 |
| TOTAL — Hydrostatic | | $367,000 |

III Equipment Cost Detail — ASEPTIC SYSTEM

| | |
|---|---|
| Scraped surface heat transfer system for sterilizing and cooling the food product, 175°F product heated to 275°F and cooled to 100°F before filling, 6 inch diameter by 6 foot cylinders, 3 cylinders heating, 3 cylinders cooling. | $70,000 |
| — Aseptic canning — includes can and cover sterilizers, aseptic filler, aseptic closing machine and controls. | $112,000 |
| CIP (clean-in-place) System — installed | 10,000 |
| Piping for process — Connecting equipment | 9,000 |
| Centralized Control System — Push button shut-down and start-up, includes ingredient system in control, as well as pre-sterilization and CIP System. | 16,000 |
| TOTAL — Aseptic System | $215,000 |

## UNIT COST & YEARLY COST

As in Part "A" of this study only those steps of the canning process that are different were estimated; namely:

1. Filling of can
2. Closing of filled can
3. Sterilization of product
4. Cooling of product
5. Empty can and cover sterilization

Additional conditions at 350 cpm

1. 2000 hours production/yr. or 1,750,000 cases (24 can case).
2. Depreciation at 10% per year.
3. Direct labor at $4.00/hour. (No indirect labor estimated).
4. Water at $0.10/1000 gallons.
5. Steam at $1.00/1000 pounds.
6. Electricity at $0.02/KWH.
7. Gas (Nat.) at $0.16/100 cu. ft.
8. Process Building space valued at $5/sq. ft./yr.

Summary of Yearly & Unit Cost Factors Compared

| | Vertical Retort | Hydrostatic | Aseptic |
|---|---|---|---|
| Depreciation | $ 29,150 | $36,700 | $18,300 |
| Maintenance | 16,000 | 7,500 | 7,500 |
| Steam | 13,820 | 3,800 | 5,600 |
| Water | 4,200 | 1,100 | 1,100 |
| Electricity | 2,430 | 1,600 | 1,000 |
| Gas-Natural | — | — | 500 |
| Space (Building) | 15,000 | 3,000 | 3,000 |
| Direct Labor | 56,000 | 12,000 | 10,000 |
| Total Yearly Cost | $136,600 | $65,700 | $47,000 |
| Unit Cost/case | 0.0785 | 0.0375 | 0.0268 |
| Royalty — | — | — | 0.0168 |
| Unit Cost/case Incl. Royalty | 0.0785 | 0.0375 | 0.0436 |

## DETAILS ON YEARLY COST

1. Maintenance
   a. Retort. Estimated at $16,000/year based on information in another study, includes labor and materials for repair of retorts, controls, crates, filling and closing machines.
   b. Hydrostatic. Estimated at $7,500/year and based on information from supplier.
   c. Aseptic. Extimated at $7,500/year based on personal experience with equipment involved.

2. Steam at $1/1,000#
   a. Retort. 1.3 pound steam per 1# can (No. 2) on a 2,000 hr. year steam will cost — $ 13,000
   b. Hydrostatic. .09 pound steam/pound product - 800 pounds on other start-up days on a 2,000 hr. year. Steam will cost — 3,800
   c. Aseptic. 2,500#/hr. + 648#/hr. 3148#/hr. On a 2,000 hr. year - steam will cost — 5,600

3. Water. At 10¢/1,000 gallon. Capacity based on use of 55°F water so this temperature was used for all.
   a. Retort. Consumes one gallon per pound can (#2 can) water cost for 2,000 hr. year — 4,200
   b. Hydrostatic. 0.25 gal./# product (#2can). Water cost for 2,000 hr. year — 1,100
   c. Aseptic. 5 gpm, would expect the scraped surface to be more efficient in heat transfer than "in-can" cooling in the Hydrostatic. Lacking exact information, use same cost as Hydrostatic. — 1,100

4. Electricity. At $0.02/KWH for 2,000 hr. year
   a. Retort. From another study 60.7 KW for hoisting, automatic control, filler, closing machine and air supply. Cost for year — 2,430

## DETAILS ON YEARLY COST (Cont'd)

b. Hydrostatic. 30 KW for Hydrostatic + 10 KW for filler, closer and other — $ 1,600

c. Aseptic. 15 KW + 10 KW, Total 25 KW
Cost for year — 1,000

5. Gas Natural 16¢/1,000 cu. ft. only used for Aseptic

c. Aseptic — 1600 cu. ft./hr. per yr. — 500

6. Space. At a value of $5/sq. ft./yr.

a. Retort. Vertical Retort 5 ft. centers 2,000 sq. ft. including Retort work area. Crate loading, unloading and filling, and closing area 1,000 sq. ft. 3,000 sq. ft. @ $5.00 — 15,000

b. Hydrostatic. Hydrostatic System — allow 400 sq. ft. + 200 sq. ft. filling and closing — 3,000

c. Aseptic. 470 sq. ft.
and 130 sq. ft. Total 600 sq. ft. — 3,000

7. Labor. Direct at $4.00 per hour

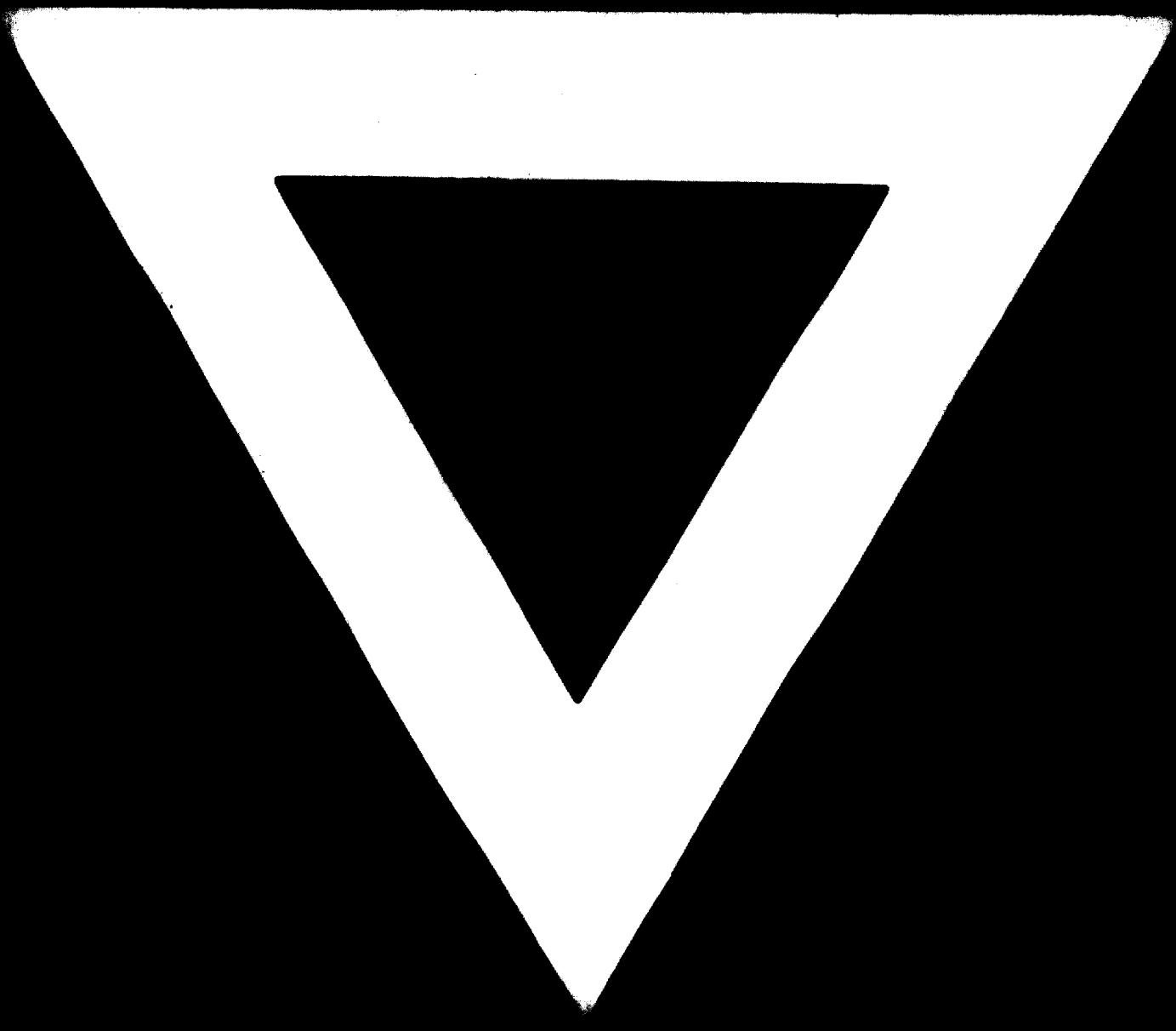
a. Retort. 4 men for 35 Retort operations, 2 men load and unload crates, 1 man for filling and closing machine. Total 7 men — 56,000

b. Hydrostatic. 1 man for filling and closing, 1/2 man for Hydrostatic
Total 1.5 men — 12,000

c. Aseptic. 1 man for one canner, 1/4 man for other
Total 1.25 men — 10,000

8. Royalty. Gallon cost $0.005/gallon for specific equipment 20,000/year or — $ 0.0168/case

[redacted]



74.10.2