DESIGN AND OPERATING CHARACTERISTICS OF A NEW TYPE, CONTINUOUS, AGITATING COOKER AND COOLER AS APPLIED TO THE PROCESSING OF FREESTONE PEACHES

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INTRODUCTION

Nicholas Appert received a 10,000 franc award from the French government in 1809 for his method of preserving food by heating in hermetically sealed containers. His discovery, made approximately 40 years before Pasteur's discovery of wine yeast, has been one of the greatest single developments in preserving food in all history. His initial experiments were carried out by cooking bottles of food in a boiling water bath. Since that time there has been a great improvement in the methods for the heat sterilization of foods in hermetically sealed containers.

Among the improvements of better processing or sterilization procedures has been the development of continuous, agitating cookers and coolers for cans and jars. Agitation of cans containing fluid or semifluid foods is usually desirable in order to increase heat penetration, since the majority of foods canned are sensitive to heat and deteriorate in quality if cooking is too prolonged.

Continuous, agitating cookers and coolers have been used by the commercial canning industry for many years and are discussed in standard text books on food processing (6). These cookers and coolers, often referred to as rotary cookers (10), are available for processing cans or jars either in open, atmospheric type cookers or closed, steam pressure cookers. Cans are usually conveyed through such cookers at the perimeter of a revolving spiral reel rotating in a horizontal position. Some rolling and agitation of the cans is obtained as the cans progress through the cooker.

Another type of continuous, agitating cooker or cooler for fruits or high acid foods known as the "Thermo-Roto" (11) is composed of a number of horizontal rolls mounted in the form of an endless belt. These rolls are supported by suitable sprockets fastened to the machine framework. Cans are conveyed through the machine on the rolls which are in a transverse position to the direction of can travel. As the rolls rotate they cause the cans to rotate about their own axis, resulting in rapid heating or cooling.

Marshall (7) has also described methods for cooling cans of apple juice by rotating them on an endless rubber belt.

End-over-end rotation around an axis external to the can has also been used and is described by Roberts and Sognefest (9) and Clifcorn et al (5).

PRINCIPLE OF COOKER-COOLER DESCRIBED

This report is concerned with a new type of continuous, agitating cooker for the heat sterilization of acid foods. This new method for processing acid foods was conceived when G. A. Chissom and A. W. Gordon, production and maintenance superintendents, respectively, of Ploeger-Abbott Co., Leesburg, Florida, were watching a welder idly playing with a can held between two welding rods on the top of a horizontal rotating shaft. When the axis of the can was held at an angle to the axis of the shaft, the can would tend to travel from one end of the shaft to the other. These men reasoned that if cans under such conditions were placed in a cold water bath or under cold water sprays, the cans would progress through the cooler in a continuous manner, and cooling would be rapid due to the agitation of the contents of the can.

Following this principle, a cooler was designed and built at the Ploeger-Abbott Co. During the 1947-48 season 450,000 cases of citrus juice were cooled from approximately 195°F. down to 100°F. in about 1 minute. This unit was constructed from four 5-inch standard steel pipe 18 feet long. The pipes were rotating so as to give the cans a speed of about 250 revolutions per minute. The cans were held on top of the rolls by guide rails and the cans were cooled by a portion of the can being submerged in water while the upper part of the can was cooled by water sprays. Although this unit appeared to be satisfactory under the conditions where it was operating, there was no published information available on the design of the unit. This was true particularly for such factors as optimum speed of rotation, optimum size of pipe, angle of the can guide rails to obtain a certain length of cooking or cooling period, vibration of the unit, damage to can seams, and perhaps other unknown factors.

In order to obtain information about this type of equipment an investigation was started at the Horticultural Products Research Laboratory, Clemson Agricultural College, Clemson, South Carolina, in 1951.

THEORETICAL DESIGN OF CONTINUOUS AGITATING COOKER-COOLER

The theoretical design of such a unit insofar as length of the rotating shaft and the time which it takes the can to traverse the length of the roll is rather simple. Figure 1 shows a simple diagram indicating the position of the can, the can guide rails, and the rotating shaft (hereafter referred to as the roller). This diagram illustrates the principles involved and the essential components of the cooker or cooler which are new.

The theoretical relationships of the cooker or cooler and the time required for a can to travel the length of the roller may be illustrated by laying out a rectangle as shown in figure 2. The length of the roller is represented by two sides, and the other two sides as the distance which any particular point on the perimeter of the roller travels during a specific length of time.

The following symbols are employed to show the theoretical relationship of the factors involved:

L	Roller length in feet
T	Time in minutes
D	Diameter of roller in feet
d	Diameter of can in feet
θ	Acute angle between can and roller axes
rpm_r	Revolutions per minute of roller

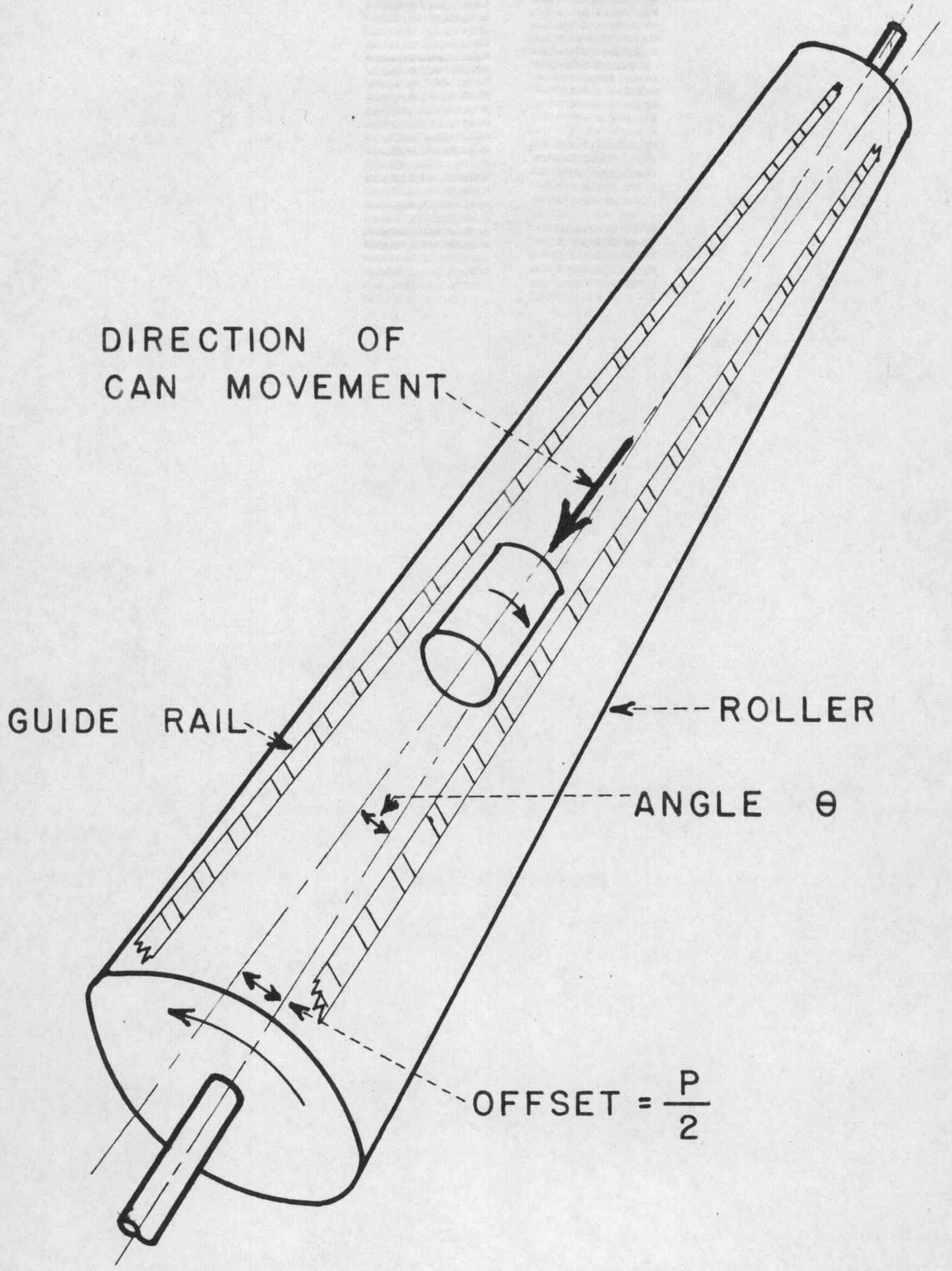

Figure 1: A diagram showing the essential relationship between the rotating can, guide rails, and roller.

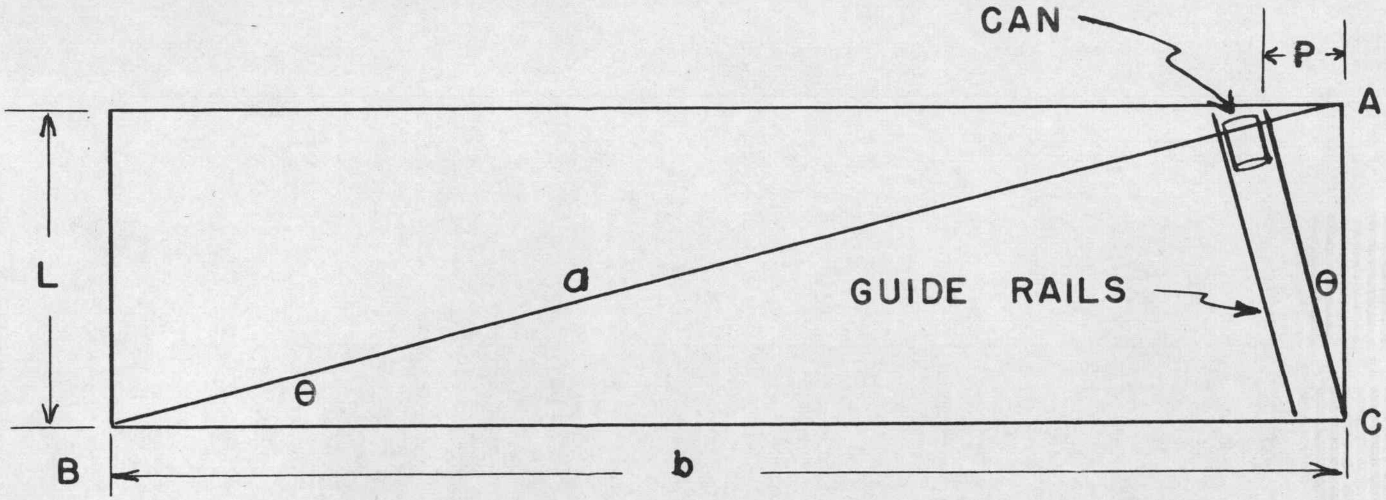

Figure 2: This rectangle illustrates the relationship between the can, guide rails, and the roller. Distance L represents the length of the roller. The distance which any point on the lateral surface of the roller travels in time T is b. P is the total distance or offset of the guide rails from the center line of the roller. Angle θ is the acute angle between the guide rails and the axis of the roller or the acute angle between the axes of the can and roller.

rpm_c Revolutions per minute of can

P Total offset of guide rails from center line of roller in feet

If the length of the can is disregarded, then it starts rolling at one end of the roller A, and continues rolling to the other end of the roller B, in time T. This distance is represented by a. Any particular point on the perimeter or lateral surface of the roller travels a distance represented as C to B during the same length of time T. The distance is b or:

$$b = \pi D \times rpm_r \times T \quad \text{(Equation 1)}$$

The acute angle between the axes of the roller and the can is indicated in figure 1 and figure 2 as angle θ.

Then:

$$\tan \theta = \frac{L}{b} = \frac{L}{\pi D \times rpm_r \times T} \quad \text{(Equation 2)}$$

This formula gives the information required to determine the length of roller, diameter of the roller within certain limits, revolutions per minute of the roller, and the time which it takes a can to travel from one end of the roller to the other.

From a practical standpoint it is extremely difficult for a machine shop to measure angle θ since it is so small. What the fabricator really needs to know is distance P or the distance to offset the guide rails from the center line of the roller. This can be found as follows:

$$\text{Tan}\ \Theta = \frac{L}{\pi D_r \times rpm_r \times T} \quad \text{(from Equation 2)}$$

Also $$\text{Tan}\ \Theta = \frac{P}{L} \quad \text{(Equation 3)}$$

Then $$P = \frac{L^2}{\pi D_r \times rpm_r \times T} \quad \text{(Equation 4)}$$

The guide rails would normally be offset at each end 1/2 P from the center line of the roller.

These formulas give the design information needed for building such a unit for the factors considered, except the speed of rotation of the cans. This may be expressed as follows:

$$rpm_c = \frac{D}{d} \times rpm_r \times \text{Sec}\ \Theta \quad \text{(Equation 5)}$$

However, Θ is so small that Sec Θ is nearly equal to one. For practical considerations the equation becomes:

$$rpm_c = \frac{D}{d} \times rpm_r \quad \text{(Equation 6)}$$

Thus the two equations No. 4 and 6 are the essential ones for design purposes.

The fabricator or canner has the opportunity of choosing the length of roller, size of roller, cooking time, and revolutions per minute of the can to suit the requirements of his particular situation and product. The length of the roller may be determined by space available or allotted for the equipment, or by the limitation of its capacity to support the can. Rollers may be placed end to end in a straight line but revolving in opposite directions to get increased capacity or a longer cook. The rollers may also be placed parallel to increase capacity. Diameter of the roller will be influenced by the time of the cooking period and offset of the guide rails.

There are limits to the size of roller which can be used. For example, it must be large enough so that the can will travel from one end of the roller to the other and still support the can and keep it rotating. A few simple observations in a machine shop can soon determine the size of roller required.

The time of the cooking or cooling period and speed of rotation of the cans will depend on the product being processed.

TESTING EXPERIMENTAL COOKER-COOLER

In 1951 a unit was constructed at the Horticultural Products Research Laboratory at Clemson College, South Carolina, to process freestone peaches grown on the experiment station farms at Clemson. A two-roller unit was constructed from 4-inch standard steel pipe (4.5 inch outside diameter), 24 feet long. Shafts 1 7/16 inches in diameter were welded into each end of the pipe and the roller then suspended by two bearings at the end and a bearing in the center. Outside guide rails were made of 2 x 2 x 1/4 inch angle iron and the center guide rail of one-inch standard steel pipe. Ten feet of the unit were used for cooking by using atmospheric steam, 10 feet were used for cooling by water sprays, and the remainder was used for getting the cans onto the roller, transferring them between the cooker and the cooler, and transferring them off the cooler at the discharge end. Figure 3 shows the discharge end of the cooler.

This unit was tested experimentally in the early peach season of 1951 in an effort to determine if such a unit would be practical. A short preliminary report (12) on observations made that summer has already been made.

The guide rails were adjusted using the formulas 4 and 6, and they appeared to be quite accurate. Most of the peaches processed in the laboratory in 1951 were

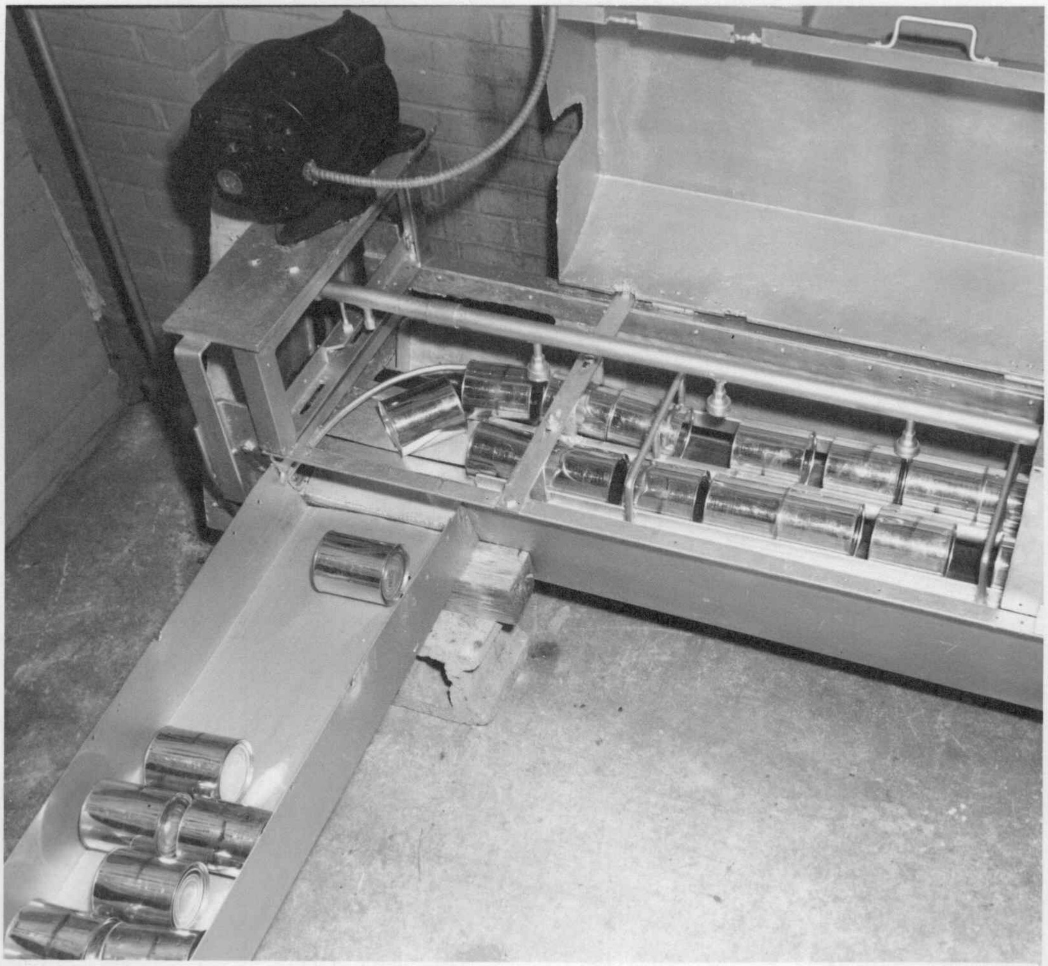

Figure 3: Cooler end of the experimental cooker-cooler.

cooked 5 minutes and the roller turned at approximately 156 revolutions per minute.

The following illustrates the use of equations 4 and 6 for the cooker and cooler:

$$P = \frac{L^2}{\pi D_r \times rpm_r \times T} = \frac{10^2}{0.375 \times 156 \times 5}$$

P = 0.1088 feet or 1.306 inches

Where L = 10 feet

$D_r = \frac{4.5}{12} = 0.375$ feet

T = 5 minutes

Also can rotation is shown by:

$$rpm_c = \frac{D}{d} = \frac{\frac{4.5}{12}}{\frac{4.6875}{12}} \times 156 = 150 \text{ rpm}$$

The cooker-cooler was rebuilt in the spring of 1953. A cooker 13 feet long was constructed and a separate cooler unit 11 feet long was added. Four-inch standard steel pipe was again used for the rollers. A can twist and can divider as shown in figure 4 was attached to facilitate the use of the unit during the canning season.

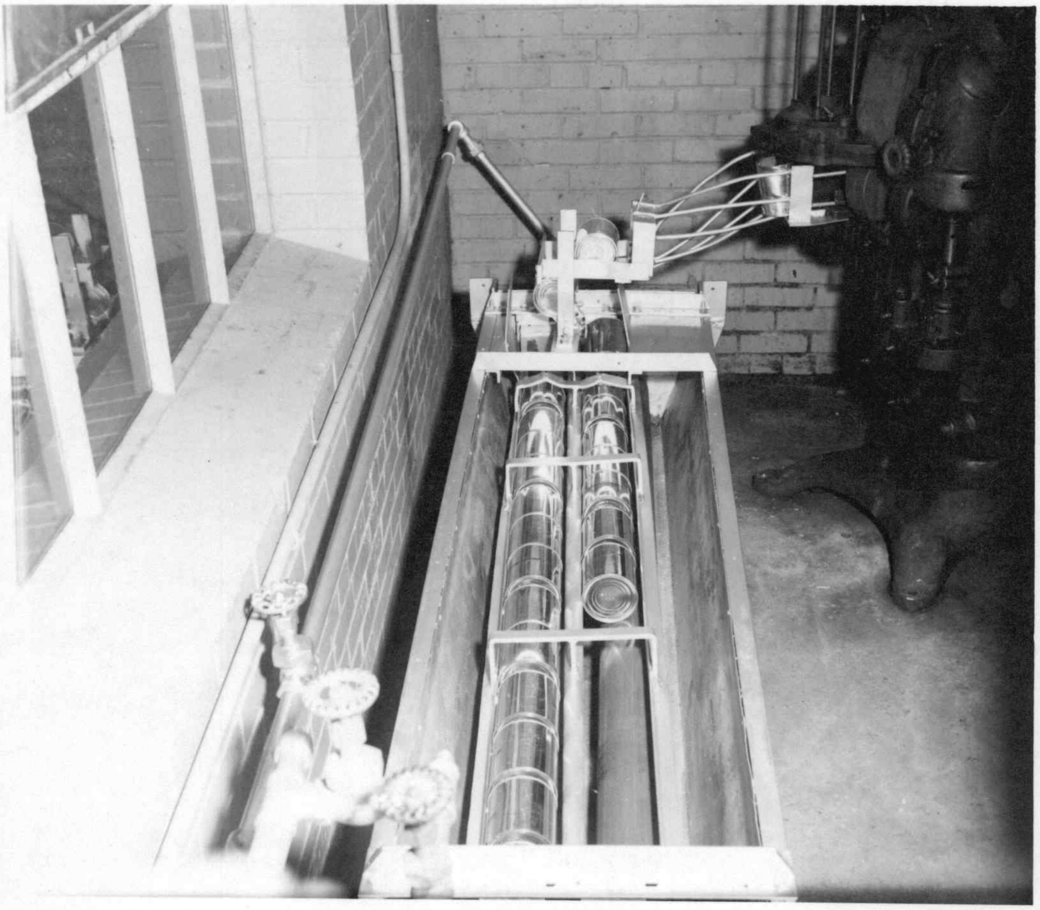

Figure 4: Cooker end of the experimental cooker-cooler with the cover removed. Cans from the sealer drop through a can twist and divider onto the two rollers.

Heat Penetration During Cooking

All experiments with canned peaches described in this report were conducted with No. 2½ size cans (401 x 411)[1]. Halehaven peaches were cooked for periods ranging from 0 to 20 minutes, and the speed of rotation ranged from 0 to 280 revolutions per minute. Eight cans were placed end to end on the pipe roller for each determination of center temperature during cooking. To eliminate variations which might arise from heating through the end of the can, the average of the six center cans was used. The cooker was maintained at 205°F. with steam from perforated pipes. Twenty-one ounces of peach halves were filled into No. 2½ cans, covered with 40° Brix syrup at about 100°F., exhausted 4 minutes, and run into the cooker immediately.

Initial temperatures after exhausting were measured on 25 cans selected at random. The temperature was measured by inserting the bulb of a mercury thermometer to a point just below the center of the can. The initial center temperatures ranged from 110 to 142°F. with a mean of 118.6°F.

The method used for determining center

[1] The can size is indicated in the industry by a single number and also by two numbers derived from the nominal dimensions. For example, a No. 2½ can is also a 401 x 411 can, which means 4 1/16 inches in diameter and 4 11/16 inches high.

temperatures after cooking was to punch a hole in the top of the can and insert a mercury thermometer into the can. The bulb of the thermometer was adjusted to be at the geometric center for all agitated cans. The method for doing this is indicated in figure 5.

Table 1 is a tabulation of the experimental data. A graph showing the relationship of can center temperatures and revolutions per minute is shown in figure 6. Only the data for 0, 24, 98 and 280 revolutions per minute are shown in figure 6. The center temperature tends to rise rapidly to 180°F. and above in the first 4 to 5 minutes for all the cans which are rotated during the cooking period, including the slowest speed of 24 revolutions per minute. As a 10-minute cook is approached, the curves for the cans which are rotating tend to come together near 200°F. Figure 6 would indicate that approximately 98 revolutions per minute was the optimum speed of rotation to get the highest center temperature in the shortest period of time. It is interesting to note that this agrees with the data obtained by Marshall (8) on optimum speed of rotation for the sterilization of apple juice.

Figure 7 is plotted from Table 1 and shows the center temperature obtained with a 4-minute cook at the different speeds of can rotation. This again shows an optimum speed of rotation of about 100 revolutions per minute. However, an important observation to be made from

Figure 5: Can center temperatures were measured by punching a hole in the top of the can and inserting a mercury thermometer.

TABLE 1

EFFECT OF CAN ROTATION ON CENTER TEMPERATURE OF HALEHAVEN PEACHES COOKED IN NO. 2½ CANS

Cooking Time in Minutes	Center Temperature - Degrees Fahrenheit 0 rpm	24 rpm	42 rpm	64 rpm	98 rpm	150 rpm	280 rpm
1		158		164	175	170	169
1		157		167	181	152	159
1		165		158	165	172	167
1		166		163	167	173	168
1		162		162	175	172	166
1		160		153	168	169	164
Ave.		161.3		161.2	171.8	168.0	165.5
2	143	173	173	185	190	179	178
2	137	168	181	181	185	179	179
2	131	172	172	181	184	178	177
2	121	175	176	182	184	163	174
2	134	170	176	182	183	179	173
2	135	180	172	175	182	179	177
Ave.	133.5	173.0	175.0	181.0	184.7	176.2	176.3
4	139	179	191	190	189	188	190
4	135	188	190	191	196	192	186
4	134	187	188	191	197	192	189
4	131	184	190	184	194	191	186
4	133	181	185	192	193	185	183
4	149		181	191	191	187	183
Ave.	136.8	183.8	187.5	189.8	193.3	189.2	186.2
10	153	200	188	189	194	199	199
10	163	200	200	199	202	199	197
10	137	200	200	196	202	200	195
10	163	197	196	196	199	199	196
10	146	199	199	195	199	198	199
10	155	198	199	195	199	196	197
Ave.	152.8	199.0	197.0	195.5	199.2	198.5	197.2
20	173						
20	175						
20	175						
20	155						
20	169						
20	171						
Ave.	169.7						

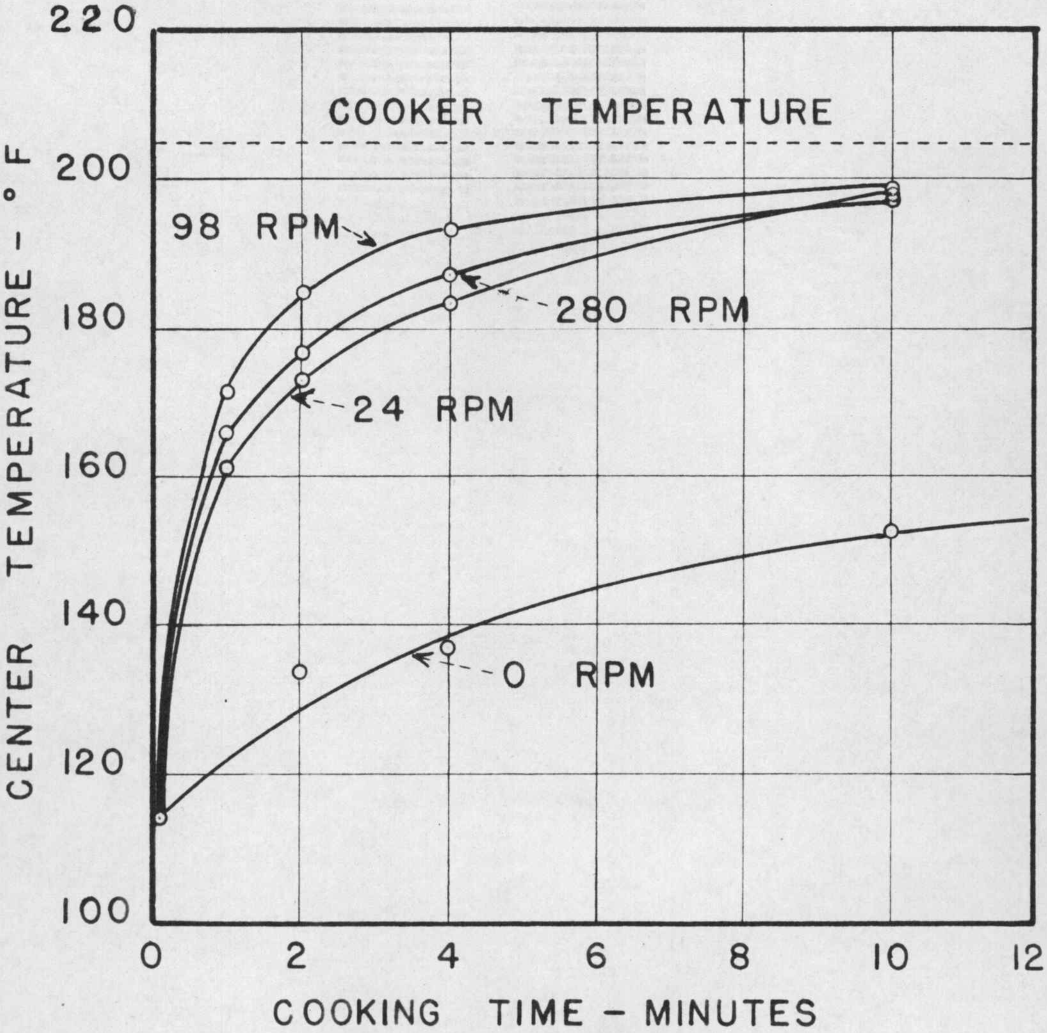

Figure 6: Can center temperatures obtained in No. 2½ cans of Halehaven peaches at various speeds of can rotation.

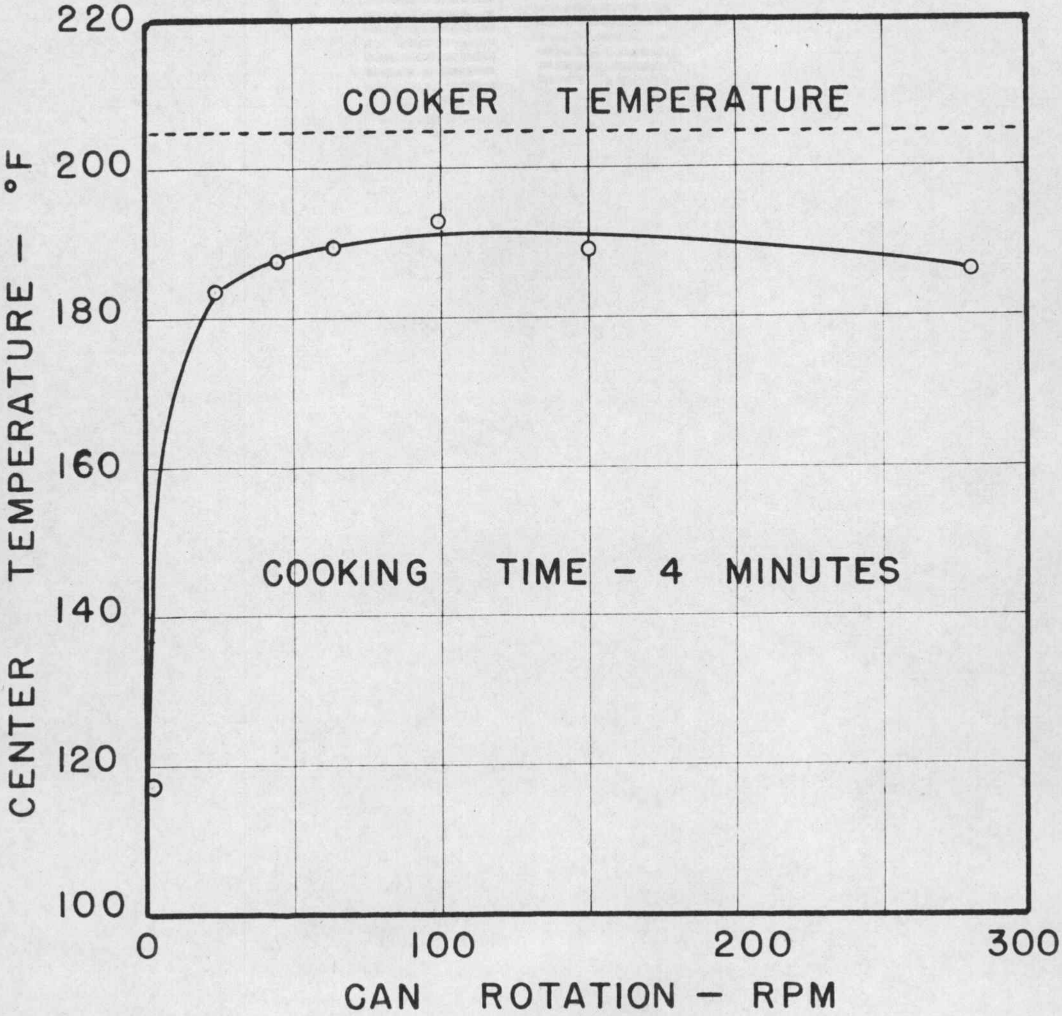

Figure 7: Can center temperatures recorded at the end of a 4-minute cooking period with different speeds of can rotation.

figures 6 and 7 is the rapid increase in heat penetration which is obtained with any rotation. For the purpose of designing cookers for peaches, any speed above 24 revolutions per minute should be satisfactory to get rapid heat penetration, provided other factors such as capacity and time of cook could be obtained.

Discussion of Pilot Plant Use of Cooker-Cooler

During the summer of 1951, approximately 5000 cases of 24 - $2\frac{1}{2}$ cans of peaches were processed on the experimental cooker-cooler at the Horticultural Products Laboratory at Clemson. The cooking period was approximately 5 minutes, followed by a 5-minute cooling period under water sprays. The speed of rotation of the cans was 150 revolutions per minute.

Operation of the cooker-cooler and sterilization of the cans appeared to be satisfactory. A slight turbidity developed in the syrup due to this 10-minute period of rotation, but it was not considered serious. A taste panel using 25 male college students indicated no difference in flavor with peaches cooked in the experimental cooker-cooler and those cooked in the conventional water bath for 25 minutes. Texture of the peaches cooked in the new cooker-cooler was firmer.

This unit was also used for processing peaches in the summer of 1952. However, during the latter part of the season some lots of peaches developed spoilage running up to as much as 10%. The question immediately arose as to whether this was due to an inadequate sterilizing period or whether it was due to damage to the seams of the cans rotating on the roller, or to some other cause. In addition to this, considerable interest had developed among several canners in the southeastern United States in this type of cooker-cooler. Therefore, a more thorough experimental test of the unit was made in 1953 in an effort to determine more accurately the cooking process required for peaches. These experiments are described later.

EFFECT OF ROLLER INCLINATION ON SPEED OF CANS THROUGH COOKER-COOLER

There are times when it might be desirable to place a cooker following the design suggested in this report on an incline. The purpose of this is to deliver cans at the discharge end onto a packing table or labeling machine. In order to get cans into the cooker they would have to drop through a can divider or incline such as indicated in figure 4. This places the cooker so low to the floor that cans being discharged from the end are too low to handle easily. Thus they would have to be raised mechanically or the cooker-cooler placed on an incline in order to get them to the desired height.

To study the effect on the forward speed of the cans through the experimental cooker-cooler, the end of the cooling section was raised with wooden blocks until an elevation of a little over 10° was obtained. Forward speed at various increments was determined by timing the cans to see how long it would take them to travel 100 centimeters on the roller. This was done when the roller was dry and also when wet. These data are shown in Tables 2 and 3 and figure 8.

The forward speed of the cans on the roller was affected markedly by the angle of inclination. The effect appears to be a direct relationship and amounts to a

TABLE 2

CAN SPEED AS INFLUENCED BY INCLINATION OF DRY ROLLER

Angle of Inclination Degrees		Seconds to Travel 100 Centimeters	Per Cent of Forward Speed
0		47.0	
0		47.5	
0		47.0	
	Ave.	47.2	100.0
0.92		48.2	
0.92		49.5	
0.92		49.0	
	Ave.	48.9	96.7
3.38		55.2	
3.38		55.0	
3.38		55.0	
	Ave.	55.1	85.7
4.87		60.0	
4.87		59.2	
4.87		59.0	
	Ave.	59.4	79.5
6.95		67.5	
6.95		67.0	
6.95		67.5	
	Ave.	67.3	70.0
10.13		82.0	
10.13		82.0	
10.13		82.0	
	Ave.	82.0	57.7

TABLE 3

CAN SPEED AS INFLUENCED BY INCLINATION OF WET ROLLER

Angle of Inclination Degrees		Seconds to Travel 100 Centimeters	*Per Cent of Forward Speed
0		48.5	
0		48.0	
0		48.0	
	Ave.	48.2	98.1
0.92		50.0	
0.92		50.0	
0.92		50.0	
	Ave.	50.0	94.7
2.11		53.0	
2.11		53.2	
2.11		53.0	
	Ave.	53.1	89.0
2.25		55.0	
2.25		54.7	
2.25		55.0	
	Ave.	54.9	86.2
3.55		60.0	
3.55		59.0	
3.55		59.0	
	Ave.	59.3	79.8
5.17		65.0	
5.17		65.2	
5.17		65.0	
	Ave.	65.1	72.7
6.95		80.0	
6.95		80.0	
6.95		80.0	
	Ave.	80.0	59.0
10.13		94.0	
10.13		95.0	
10.13		92.5	
	Ave.	93.8	50.3

* This figure is based on forward speed of cans on level dry roller.

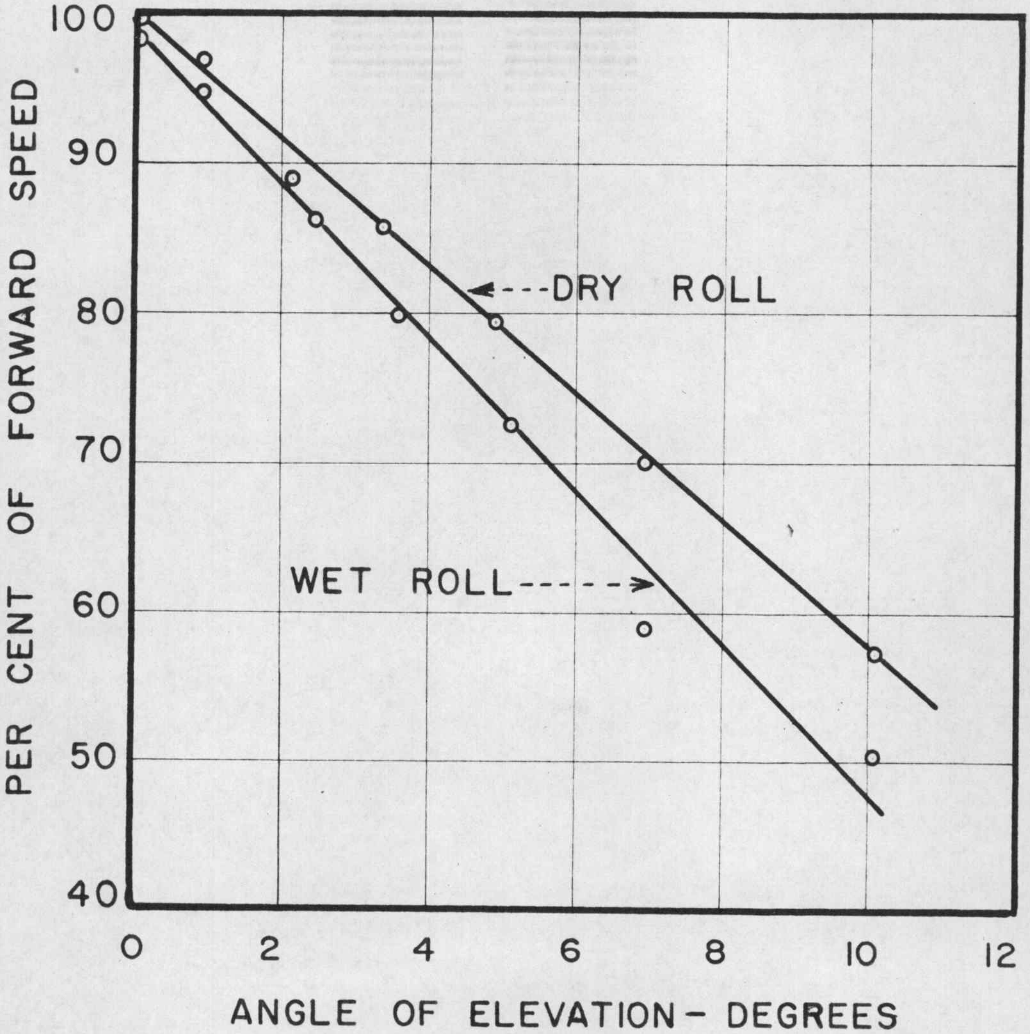

Figure 8: Forward can speed as influenced by the inclination of the rollers.

reduction in forward speed of about 50% at 10° on the wet roller. Slippage or reduction of forward speed was not so great on a dry roller. However, all processing in this type of cooker-cooler would probably be done on wet rollers.

This test also indicates one of the main disadvantages of this type of cooker. The progress of cans through the cooker is definitely influenced by the inclination of the roller. The cans are not delivered from the end of the cooker at a positive set rate, Undoubtedly other factors influence forward speed, such as friction of the cans on the guide rails, vibration of the unit, grease on the rolls, and ridges or other imperfections in the roller or guide rails. The effect of this is that cans do not proceed through the cooker with perfect timing. Where commercial canning lines are set up to run with speeds ranging from 60 to 300 cans per minute it becomes important that the lines be adjusted to maintain certain rates of speed. These can be regulated fairly closely with the experimental cooker shown, but it would probably be impossible to time them through the cooker with exact precision. In some cases this is a distinct disadvantage. For those canning operations where exact timing is not necessary, this disadvantage is not particularly serious.

ESTIMATION OF PROCESS TIME FOR FREESTONE PEACHES IN NO. $2\frac{1}{2}$ CANS

Factors Involved in Process Determination

Since the beginning of the commercial canning industry, process or cooking times have been determined by trial and error methods until a satisfactory time has been found to sterilize cans. This continues to be one of the most common ways of determining processing times. However, the uncertainties involved often result in large economic losses due to spoilage.

The determination of process times for the heat sterilization of canned foods by applying bacteriological and physical data was first proposed by work of Bigelow et al in 1920 (4) and Ball in 1923 (3). The development of these procedures since that time has greatly speeded up the scientific determination of process times, and many refinements and investigations have added to the knowledge of this subject. A brochure published by the American Can Co. (2) reproduces many of the scientific reports on the subject and summarizes some of the more important methods of process determination. Alstrand and Ecklund (1) have also summarized the methods for determining heat penetration data and applying the information to the determination of process time.

Nearly all of the published reports deal with the determination of process times for low acid foods. High acid foods, or those with a pH value of 4.5 and less are relatively easy to sterilize. However, methods of canning fruit vary widely among the various canning plants. Fruits vary greatly in character according to variety, yearly growing conditions, time of harvest, maturity, and location where grown. Also syrup density, fill of container, and other canning processes used affect the processing time required. As a result, there has been little application of mathematical procedures for process determination of fruits (10). Thus, the problem existed of determining a satisfactory cooking or sterilizing process for peaches in the experimental cooker-cooler.

Procedure Used for Process Determination

The process time for freestone peaches among commercial canners has ranged from about 22 minutes to 45 minutes in boiling water in the southeastern United States. The estimated average time has been approximately 25 to 30 minutes.

Process times used at the Horticultural Products Research Laboratory at Clemson have varied from 15 to 35 minutes over a period of twelve years on approximately 500,000 cans. A cooking time of 25 minutes has been quite adequate, although a shorter cooking time was also satisfactory. It has been possible to use shorter process times in the laboratory where sanitation has perhaps been better than under commercial conditions, and fill of container, syrup temperature and concentration, and exhaust times are also more closely controlled.

Many canners adjust their process until they obtain a can center temperature of 190°F. or higher. However, since sterilization depends on both time and temperature, the short time required in the experimental cooker to attain 190°F. center temperature might possibly be insufficient for sterilization.

Since there was no standardized or specific accepted process time for freestone peaches, it was decided to use a cooking time of 25 minutes for freestone peach halves in boiling water, followed by a cold water cooling period, as a standard process. This process time appears to be a good average on which to make a comparison. Using the 25-minute cook in boiling water as a standard, a process time could then be computed from heat penetration data for peaches processed in the experimental cooker and cooler.

Determination of Heating and Cooling Curves

Due to the large number of temperature determinations required and the expense involved in determining temperatures on so many cans by inserting a mercury thermometer through a hole in the top of the can, an effort was made to use thermocouples placed in the can. It was necessary to keep the test cans end to end, which meant that the thermocouple leads would have to be on the side of the can. However, no satisfactory method was found for mounting the thermocouple on the side of the rotating can. Therefore, it was again decided to punch a hole in the top of the can and insert a thermometer to determine can center temperatures as illustrated in figure 5.

Punching a hole in the top of the cans as shown does produce slight agitation in the can when the pressure in the can is released. However, any error in this case would be only in the non-agitated cans, and the result might possibly be a higher temperature. Since the non-agitated cans were the standard, any error was on the "safe side" when comparing the cook with the agitated cans.

It was decided to cut the number of temperature determinations for any particular cooking or cooling time to 4 cans. This was required because of the economic considerations of the study. The same method was used for the can center temperature of the peaches cooked in boiling water with the exception that the lower end of the bulb of the thermometer was placed approximately one inch from the bottom of the can. Experience over the past several years at this laboratory has indicated that this point was the slowest heating spot in canned freestone peaches.

Alstrand and Ecklund (1) have also indicated that the point of slowest heating for cans which heat by convection is 3/4 inch from the bottom in No. 2 cans and $1\frac{1}{2}$ inches from the bottom in No. 10 cans.

This point is also referred to in this report as the center temperature.

It was found necessary to complete a series of tests on the same lot of peaches on the same day in order to eliminate variations due to variety, maturity, and other factors which influence the rate of heat penetration. The peaches were lye peeled and 22 ounces plus or minus 1/4 ounce were filled into each No. $2\frac{1}{2}$ can. The cans were then filled with 40° Brix syrup which had been heated to 170°F. and then conveyed into a steam exhaust box for 4 minutes. The cans were then sealed on a commercial seaming machine known as a Panama Paddle Packer, manufactured by Continental Can Co. The paddles were adjusted to give a uniform head space. The gross headspace as measured from the top of the can varied from 11/32 to 13/32 of an inch after the cans were processed and cooled to room temperature.

After sealing the cans were conveyed into the experimental cooker-cooler. The cooker was maintained at a temperature of 205 to 207°F. with steam from perforated pipe. A full can was placed before and after the 4 test cans to provide heating only on the lateral area of the test cans. The cans were rotated at approximately 125 revolutions per minute. The test cans were held in one place in the cooker or cooler by a wooden barrier. It required a short time for the cans to run into the cooker and to be removed from the cooker for testing, but the time of cook was recorded as only that interval in which the cans were rotating.

In determining center temperatures during the cooling period, the cooker was stopped. The cans were transferred to the cooler, which required about 30 seconds, the cooler started, and after a total elapsed time of one minute, the first can center temperature was made for the cooling period. The data obtained from these tests are shown in Tables 4 and 5.

Heating and cooling curves from Tables 4 and 5 are shown in figure 9. Only the cooling curve for the 6-minute cook is shown for the cans cooked by agitation. The cans reached nearly 200°F. in 5 to 6 minutes. The temperature for those cans cooked without agitation in a boiling water bath reached a temperature of a little over 190°F. at the end of 25 minutes.

Estimation of Process Time

It has already been assumed that a 25-minute cook in boiling water followed by a cooling period in cold water is a standard process to produce commercially sterile freestone peaches in No. 2½ cans. In order to

TABLE 4

CENTER TEMPERATURES FOR ELBERTA PEACHES COOKED 25 MINUTES IN BOILING WATER IN NO. $2\frac{1}{2}$ CANS AND WATER COOLED

	Process Time Minutes	Center Temp. °F	Process Time Minutes	Center Temp. °F	Process Time Minutes	Center Temp. °F
	2	145	16	182	28	165
	2	150	16	180	28	160
	2	138	16	184	28	170
	2	127	16	173	28	168
Ave.		140.0		179.7		165.7
	4	149	18	183	30	163
	4	148	18	184	30	147
	4	123	18	184	30	149
	4	154	18	182	30	147
Ave.		143.5		183.2		151.5
	6	149	20	175	32	131
	6	165	20	188	32	136
	6	150	20	188	32	132
	6	148	20	189	32	160
Ave.		153.0		185.0		139.7
	8	171	22	190	34	136
	8	159	22	184	34	121
	8	171	22	188	34	124
	8	172	22	189	34	125
Ave.		167.0		187.7		126.5
	10	172	24	187	36	112
	10	170	24	191	36	120
	10	173	24	190	36	111
	10	170	24	185	36	126
Ave.		171.2		188.2		117.2
	12	177	25	185	40	118
	12	177	25	188	40	119
	12	171	25	194	40	107
	12	165	25	192	40	110
Ave.		172.5		189.9		113.5
	14	179	26	180	44	113
	14	170	26	183	44	118
	14	179	26	183	44	109
	14	169	26	180	44	100
Ave.		174.2		181.5		110.0

TABLE 5

HEATING AND COOLING DATA FOR ELBERTA PEACHES PROCESSED IN THE EXPERIMENTAL COOKER-COOLER IN NO. 2½ CANS

Initial Center Temperature After Exhausting °F	Cooking Time Minutes	Center Temp. After Cooking °F	Center Temperature After Cooling				
			Cooling Time - Minutes				
			1	2	3	4	5
129	1/2	158					
130	1/2	173					
127	1/2	155					
140	1/2	166					
Ave. 131.5		163.0					
161	1	189					
136	1	176					
148	1	174					
142	1	179					
Ave. 146.7		179.5					
147	1 1/2	182					
163	1 1/2	190					
141	1 1/2	175					
115	1 1/2	176					
Ave. 141.5		180.7					
146	2	176	150	143	137	114	109
165	2	189	155	140	123	111	109
127	2	169	162	136	121	111	115
158	2	179	155	132	118	112	108
Ave. 149.0		178.2	155.5	137.7	124.7	112.0	110.2
160	2 1/2	188					
149	2 1/2	183					
148	2 1/2	174					
148	2 1/2	188					
Ave. 151.2		183.2					
142	3	185	149	137	129	119	109
164	3	191	153	133	130	115	121
166	3	185	155	134	127	124	110
134	3	194	150	140	118	116	111
Ave. 151.5		188.7	151.7	136.0	126.0	118.5	112.7

TABLE 5 (Continued)

Initial Center Temperature After Exhausting °F	Cooking Time Minutes	Center Temp. After Cooking °F	Center Temperature After Cooling — Cooling Time - Minutes: 1	2	3	4	5
145	3 1/2	192					
140	3 1/2	192					
160	3 1/2	192					
151	3 1/2	183					
Ave. 149.0		189.7					
140	4	197	159	140	124	120	117
147	4	193	167	145	120	120	115
125	4	197	160	155	130	119	118
163	4	189	154	141	126	118	111
Ave. 143.7		194.1	160.0	145.2	125.0	119.2	115.2
160	4 1/2	198					
126	4 1/2	197					
120	4 1/2	197					
139	4 1/2	187					
Ave. 136.2		194.7					
157	5	200	144	130	141	136	112
165	5	197	149	150	128	122	96
150	5	199	152	150	124	116	129
162	5		157	141	126	111	111
Ave. 158.5		198.7	150.5	142.7	129.7	121.2	112.0
160	6	201	150	140	125	137	120
160	6	198	145	142	127	120	108
146	6	197	165	134	152	119	106
164	6	198	152	142	128	124	112
Ave. 162.5		198.5	153.0	139.5	133.0	125.0	111.5

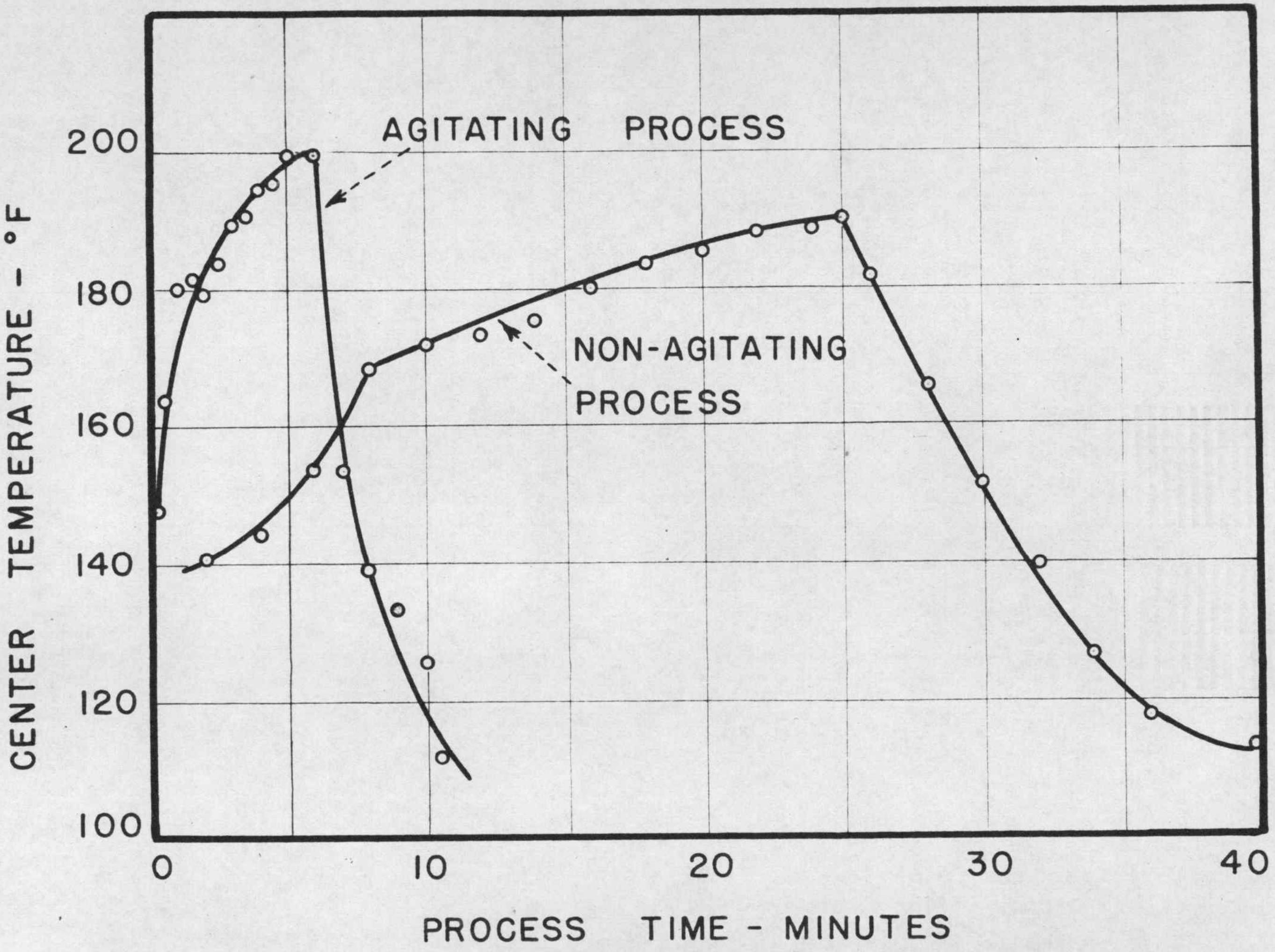

Figure 9: Heating and cooling curves for No. $2\frac{1}{2}$ cans of Elberta peaches processed with agitation in the experimental cooker-cooler and without agitation in boiling water followed by water cooling.

calculate lethal death rates for spoilage organisms, a thermal death time curve slope must be known (1, 2). This slope is known as <u>z</u> and will be assumed to be 18 degrees which is most commonly used for low acid foods. With these two assumptions, lethal rates for the process in boiling water may be computed and a sterilizing value known as F_{212} obtained. This value can then be used as a comparison for estimating the process time for peaches in the experimental cooker-cooler. The sterilizing value (F_{212}) is computed from the equation:

$$F_{212} = \frac{t}{\log^{-1} \frac{212 - T}{18}}$$

Where F_{212} = Sterilizing value with a temperature of 212°F. as a reference temperature.

t = time of process in minutes (for any one minute during the process $t = 1$)

T = center temperature or temperature at the coldest spot in the can in degrees Fahrenheit.

18 = z = thermal death time curve slope (1, 2).

In this case, a sterilizing value or F_{212} is solved by computing a lethal rate for various one minute intervals from the heating and cooling data. These lethal rates are then plotted, and the sterilizing value, F_{212}, obtained by measuring the area under the curve.

The lethal rate, L, or sterilizing value for one minute is then obtained by the formula:

$$L = \frac{1}{\log^{-1} \frac{212-T}{18}}$$

Following is an example of the computations using data at the end of the 5-minute cooking time in the experimental cooker from Table 5:

$$L = \frac{1}{\log^{-1} \frac{212 - 198.7}{18}} = 0.18243$$

The computed lethal rates, L, are recorded in Tables 6 and 7 and the lethal rates plotted in figure 10.

Area under the curves was measured by the use of a planimeter.

The area under the curve for the non-agitating process in boiling water represents a sterilizing value of $F_{212} = 0.433$. The area under the agitating process represents a sterilizing value of 0.482 for a 6-minute cook and 0.320 for a 5-minute cook. If this is interpolated directly, a 5.7-minute process time in the agitating experimental cooker is comparable to a 25-minute process time in boiling water.

Discussion of Process Time Determination

An estimated cooking time of 5.7 minutes for No. 2½ cans of freestone peaches in the experimental

TABLE 6

LETHAL RATES FOR BOILING WATER PROCESS

COMPUTED FROM DATA IN TABLE 4

Process Time Minutes	Center Temp. °F T	Lethal Rate L
2	140.0	0.00010
4	143.5	0.00156
6	153.0	0.00527
8	168.2	0.00369
10	171.2	0.00541
12	172.5	0.00639
14	174.2	0.00813
16	179.7	0.01587
18	183.2	0.02512
20	185.0	0.03236
22	187.7	0.04447
24	188.0	0.04642
25	189.9	0.05921
26	181.5	0.02022
28	165.7	0.00268
30	151.5	0.00044
32	139.7	0.00007
34	126.5	0.00002
36	117.2	0.00000
40	113.5	0.00000
44	110.0	0.00000

TABLE 7

LETHAL RATES FOR THE EXPERIMENTAL COOKER-COOLER

PROCESS COMPUTED FROM DATA IN TABLE 5

Heating Period			Cooling Period					
			1 Minute		2 Minute		3 Minute	
Cooking Time Minutes	Center Temp. °F T	Lethal Rate F_{212}	Center Temp. °F T	Lethal Rate F_{212}	Center Temp. °F T	Lethal Rate F_{212}	Center Temp. °F T	Lethal Rate F_{212}
1/2	163.0	0.00199						
1	179.5	0.01565						
1 1/2	180.7	0.01700						
2	178.2	0.01325	155.5	0.00265	137.7	0.00007	124.7	0.00001
2 1/2	183.2	0.02512						
3	188.7	0.05761	151.7	0.00045	136.0	0.00006	126.0	0.00002
3 1/2	189.7	0.05770						
4	194.1	0.10129	160.0	0.00129	145.2	0.00019	125.0	0.00002
4 1/2	194.7	0.10937						
5	198.7	0.18243	150.5	0.00038	142.7	0.00014	129.3	0.00003
6	198.5	0.17783	153.0	0.00053	139.5	0.00009	133.0	0.00004

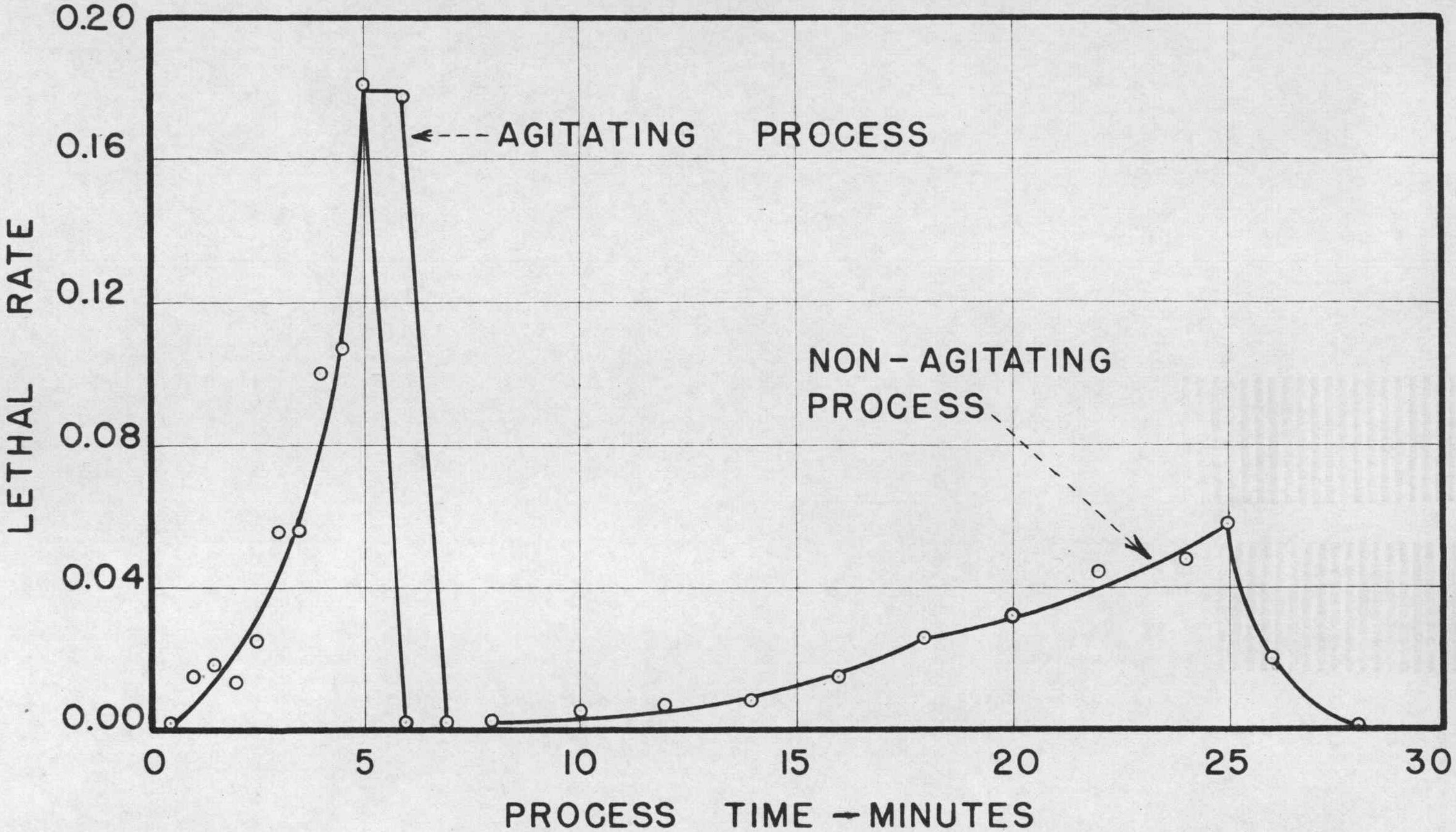

Figure 10: Lethality curves plotted from data in Tables 6 and 7. F_{212} for the non-agitating cook is represented by the area under the curve and is equal to 0.433 units. A 5-minute cook with agitation in the experimental cooker-cooler has an F_{212} of 0.320 and at 6 minutes an F_{212} of 0.482.

cooker-cooler under the conditions of the test has been made. It should be emphasized that this is a process estimation. However, it is believed that the estimate is fairly accurate and could be suggested as a process time for commercial canners under comparable conditions.

During the 3 years that this cooker has been tested process times have ranged from 3 minutes to 10 minutes under semi-commercial or pilot plant conditions. A total of about 200,000 cans have been processed. The amount of spoilage with a 3-minute cook ran to about 10%. From figure 9 it is seen that the average center temperature reached 190°F. at about 3 minutes. If a center temperature of 190°F. was used only as a criterion of an adequate process, then a 3-minute cook should be adequate. However, there was no question but that this was too short a cooking period for adequate sterilization in the experimental unit. When the peaches were cooked with approximately 4 minutes of agitation only occasional cans would spoil and some of these may have been due to poor seams or other causes. Cooks above 5 minutes using syrup above 170°F. and a 4-minute exhaust seemed to always give sterilization, with the exception of the spoilage which developed at the end of 1951. It is now felt that this spoilage was due to poor seams on the cans.

It should be emphasized that the process times estimated here for both the non-agitating and agitating cook have been satisfactory under the conditions existing at this laboratory. Commercial practice has often called for a cooking time in excess of 30 minutes for safe sterilization of freestone peaches in No. $2\frac{1}{2}$ cans. This has been necessary due to variations in the amount of raw peaches filled into each can, density in the syrup, low temperature of the syrup going on the peaches, short exhaust periods, and sanitary conditions resulting in high bacterial contamination. Thus, if commercial canners are to use these data presented here they should take into consideration the factors just mentioned.

EFFECT OF FILL-IN WEIGHT ON HEAT PENETRATION

The amount of semi-solid food placed in a can greatly affects heat penetration. This is fairly well understood among technical workers and practical commercial canners. Specific information on the heat penetration in freestone peaches during canning is not available. For this reason a test to study the effect of fill-in weight of the peach halves during cooking was made. Cans were prepared and run into the cooker as previously described under "Estimation of process time."

The influence of fill-in weight on center temperature was obtained by varying the fill-in weight of prepared peach halves from 18 to 25 ounces. Cans were then filled with 40° Brix syrup and immediately exhausted, sealed, and run into the experimental cooker where all cans were cooked for 4 minutes at 125 revolutions per minute. Can center temperatures were then obtained as previously described by placing the bulb of a mercury thermometer at the geometric center of the can. The results of the tests are shown in Table 8. A graph from the data is shown in figure 11. The graph indicates that center temperatures at the end of the 4-minute test cook fell off quite rapidly as the fill-in weight increased.

The amount of fill-in weight varies widely among commercial canners, particularly in the southeastern

TABLE 8

CENTER TEMPERATURES AT END OF 4-MINUTE COOKING PERIOD IN EXPERIMENTAL COOKER-COOLER AS INFLUENCED BY WEIGHT OF ELBERTA PEACHES PACKED IN NO. $2\frac{1}{2}$ CANS

Cooking Time Minutes	Fill-in Weight Ounces	Center Temp. °F	Cooking Time Minutes	Fill-in Weight Ounces	Center Temp. °F
4	18	184	4	22	193
4	18	192	4	22	191
4	18	195	4	22	185
4	18	195	4	22	180
Ave.		191.5			187.0
4	19	190	4	23	190
4	19	192	4	23	190
4	19	195	4	23	164
4	19	187	4	23	187
Ave.		191.0			182.7
4	20	197	4	24	180
4	20	184	4	24	180
4	20	190	4	24	181
4	20	197	4	24	179
Ave.		192.0			180.0
4	21	196	4	25	169
4	21	178	4	25	180
4	21	195	4	25	175
4	21	196	4	25	184
Ave.		191.2			177.0

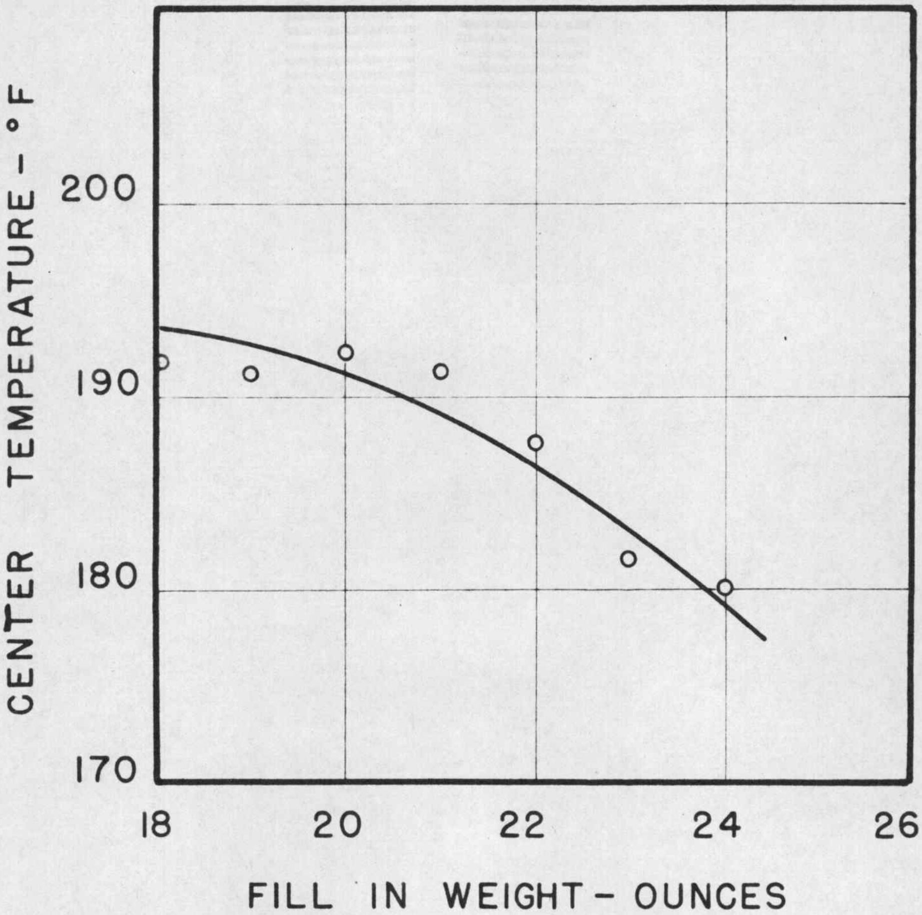

Figure 11: Center temperature at the end of a 4-minute cooking period in the experimental cooker as influenced by the weight of Elberta peaches packed in No. $2\frac{1}{2}$ cans.

United States. Variation of fill-in weight is due to varietal differences, maturity and methods of packing the halves in the can. Machine or mechanical filling particularly results in wide variations. Thus figure 11 indicates the necessity for closely checking fill-in weights if the suggested processing times indicated in this report are to be followed.

SUMMARY

A new type of cooker or cooler for processing fruit in cans is described. The unit is composed of a horizontal rotating shaft or roller large enough to support the cans to be processed. The cans are held in a horizontal position on top of the roller with guide rails so the axes of the cans are at a small acute angle to the axis of the roller. As the roller and cans rotate, the cans travel from one end of the roller to the other. If this unit is placed in a steam chest it becomes a continuous agitating cooker. Likewise, if the unit is equipped with cold water sprays or partially submerged in cooling water it becomes a cooler for cans.

For purposes of design or construction, equation No. 4 on page 9 gives the relationship of length, diameter, and revolutions per minute of the roller, the time of process, and the distance to offset the can guide rails above the roller. The revolutions per minute of the can is determined by equation No. 6 on page 9.

An experimental cooker-cooler based on these theoretical relationships was constructed in 1951 from 4-inch standard steel pipe. The unit was tested experimentally for canning freestone peach halves in No. $2\frac{1}{2}$ cans. The cooker-cooler was satisfactory for processing approximately 5000 cases of 24 - $2\frac{1}{2}$ cans of peaches that

year. Optimum speed of rotation for the cans was about 100 revolutions per minute.

The cooker-cooler was used again in 1952. However, some spoilage developed during the latter part of the peach canning season, and there was some doubt about the adequacy of the process time. As a result, further tests were made in 1953 to determine more accurately the process time required for freestone peach halves in No. $2\frac{1}{2}$ cans.

It was assumed that a 25-minute, non-agitating cooking process in boiling water was satisfactory for freestone peach halves in No. $2\frac{1}{2}$ cans. Heat penetration data was then obtained on the non-agitated cook and on cans in the experimental cooker-cooler with the cans being rotated at 125 revolutions per minute. Comparison of the two cooks by use of the graphical method of process determination indicated a 5.7-minute cook in the experimental cooker was equal to a 25-minute cook in the boiling water.

An increase in fill-in weight or the weight of peach halves per can rapidly decreases heat penetration. Due to this and other factors, use of a 5.7-minute cook under commercial conditions should be made with caution, unless such factors as fill-in weight, cooker temperatures, maturity, varietal differences, exhaust temperatures, syrup density and temperatures are fully understood and compensation made for variation of these factors.

One disadvantage of this type of cooker-cooler is the fact that cans cannot be regulated to go through the cooker at a positive rate. The rate is accurate enough for most cannery conditions, but it is not possible to time the cans with mechanical exactness.

If the cooker-cooler is put on an incline, the cans will slip, depending on the angle of incline. Slippage is nearly 50% on a wet roller when the incline is 10 degrees.

Cookers or coolers based on the principles described should be practical for fruit canning. Such units are simple and easy to construct, and can be made in maintenance or machine shops of commercial canneries.

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