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# Studies in oven canning

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## I. Introduction

The preservation of foods by oven processing is highly recommended and advocated by many public utilities companies and others interested in selling ranges, glass jars, or other equipment essential for such a method. Although the method has been in use for approximately twenty years, there has been very little research conducted to determine the factors affecting the preservation of food by oven processing.

## II. Historical

Stanley (12), in discussing oven canning in the United States Department of Agriculture Farmers' Bulletin No. 1471, states that the temperatures most often recommended range from 250° to 275°F., preferably 275° F. The use of higher oven temperature is not practical because of the greater loss of liquid through evaporation from the unsealed jars. She further states that jars should be far enough apart to allow for free circulation of air around them. Time should be counted as soon as the jars are placed in the oven and processed for a period 50 per cent longer than that

used for the boiling water bath. Stanley states, "A shallow container may be placed in the bottom of the oven to catch any juices that may boil out of the jar. The times given for processing in boiling water apply only to places with altitudes of 1,000 feet or less. For all altitudes above 1,000 feet the time should be increased 20 per cent for each additional 1,000 feet. The same correction for altitude should be made for the oven as for the boiling water bath."

A brief study by Steinbarger (13), made in the Bureau of Home Economics of the United States Department of Agriculture, showed that rates of heat penetration into jars of food in an oven vary with the consistency and initial temperature of the food and the temperature of the oven. The size of the jar was also a factor. According to Steinbarger, the temperature inside of the jars rose most slowly in foods which were thick in consistency, and in which liquid could not circulate easily. Heating the food before placing in the jars was very effective in reducing the period before temperatures near 212° F. were reached. She found heat penetration was more rapid in a 275°F. than in a 250°F. oven. The use of a pan beneath the jars retarded heat penetration. Jars heated as well in an

oven filled to capacity as when only one jar was present. In filling an oven to capacity about two inches of space for air circulation were left on all sides of the jars. Since 212° F. is the maximum temperature reached in the jars, this investigator believes that this method of canning, like the waterbath method, cannot be recommended for the non-acid vegetables, meat, and shellfish, and may be questionable for low acid fruits such as pears, although it may be used safely for tomatoes and the more acid fruits.

Work done at Purdue Agricultural Experiment Station (9) showed that the rate of heat penetration was, in all cases, slower in oven processing than in water bath processing.

Richardson (10), in a personal communication, states that oven processing appears to be satisfactory for fruits but not favorable for non-acid vegetables in Montana. Increasing the processing period to compensate for the high altitude decreases the quality of the product. Carrots became caramelized during the longer process required by a high altitude.

Research reported by Greer (4) of the American Stove Company showed that the maximum temperature reached in unsealed jars in an oven was approximately 212° F.

Since the temperature did not rise above 212° F., the canning of non-acid vegetables was not recommended. Initial temperature of the food was found to be an important factor influencing the rate of heat penetration to the center of the jar. She also reported concerning the rate of heat penetration when different numbers of jars were being processed in the oven at the same time. It was found that eight one quart jars in the oven at one time required approximately 20 minutes longer processing than only one quart jar required. From this data Greer concluded that if more than four quart jars, or if a number of pint jars filling two racks, are placed in the oven at one time, the time of processing should be increased by one-half hour.

Shank (11) of the American Stove Company later reported other work which seems to show that the rate of heat penetration is as rapid when the oven is filled to capacity as when a single jar is processed. It is likely that as the number of jars is increased, the heat currents in the oven are changed to circulate around the jars and accomplish equal penetration. It takes less time for the contents of a jar to come to the boiling point when the oven control is set for 275° than when it is set for 250°F. She found that heat penetration is as rapid when there is no water in the oven as when water is present in the oven.

The rate of heat penetration is practically the same for vegetables which have been heated above 140° F. regardless of the initial temperature. Shank points out, however, that the jars should be as hot as possible when put into the oven. She shows that because of the long coming-up and cooling periods used in oven-canning that bacteria are held for long periods of time at temperatures optimum for their growth. The nature of the product being tested is one of the main factors in determining the rate of heat penetration. She showed that the life of the jar rubber is not impaired by the Lorain Oven Method of canning at 275° F. The American Stove Company, (Apr. 1933), recommends oven canning of non-acid vegetables as well as fruits. The American Stove Company thus originally recommended oven-canning for fruits only, but now recommend its use for all canned food products.

Hamilton (5) writes, "In the oven method the jars are placed on a rack above the drip-pan. This method is quicker than the water bath as it takes a shorter period of time to bring the oven up to the desired temperature. No water except the liquid in the jars is used. No special equipment is needed, but this method is adaptable only to an electric or gas oven

fitted with a thermometer. Its disadvantage is that the finished product is not so attractive as the jars can be filled only to one inch of the top before processing. This is to prevent the liquid from boiling out of the jars."

Nye, Case and Rodenwald in Oregon State Extension Bulletin 450 (8), write the following: "The temperature of the product in the jar never exceeds 212° F. regardless of the oven temperature unless the jar is sealed. Oven canning is successful for cherries and berries. It is not recommended for meat, fish, and non-acid vegetables." The directions for oven canning, given by the Oregon Extension Service, include preparation of the food as for the water bath method, preheating of oven to 300° or 325° F. and placing jars in shallow pans containing about 1/3 inch of hot water. The water prevents burning the juice which is forced from the cans by expansion; it has no other function. The jars should not touch each other. The bulletin continues, "Sterilized lids may be placed on jars after the process period is ended. Uncovered jars do not boil over readily. If jars are not full after processing, boiling fruit juice or boiling syrup may be added immediately after removing jars from oven, just before sealing. Time tables for oven canning are still in the

experimental stage. The most satisfactory method of gauging the required time so far devised is to start counting time when bubbles are first observed in motion inside the jars, then reduce the temperature to 250° or 275° F. and process according to the water-bath time table."

There is considerable variation between different oven canning directions. The Universal Electric Range Cook Book (7) states that the oven should be preheated to 300° F. for fruit and to 350° F. for vegetables. Jars should be placed on a moist broiler pan 1/2 inch apart.

The Kerr Home Canning Book (6) gives the following: "Equipment - oven, preferably with an automatic heat control or use an oven thermometer which can be purchased at a reasonable price at your dealers. Set jars on rack in oven leaving space between jars for circulation of heat. Start with cold oven. Light oven, start counting time when oven is lighted. Temperature should not exceed 250° F.

The Wilcolator Cook Book (17) recommends oven canning only for tomatoes and fruits. A 250° F. oven is used.

Flavor Zone Electric Cookery (16) recoommends placing the jars in a shallow pan in a 250° F. preheated oven.

The Ball Blue Book (2) states "Oven canning is indorsed as a satisfactory method of canning if directions are followed and proper temperatures used. An oven thermometer can be used if the oven is not equipped with a regulator. The oven should always be preheated."

The Lorain Oven Canning directions (1) require placing the jars 2 inches apart in an oven preheated to 275° F.

Table I shows the difference in processing periods recommended by various companies.

Table II gives processing periods recommended by State Extension Service Departments. Only five bulletins out of twenty-six available from various states gave time tables for oven processing. One of these was copied from Lorain Oven Canning and one used the recommendation of increasing the processing period 50 per cent over that of the water bath which is made in United States Department of Agriculture Farmers' Bulletin 1471. Twenty bulletins made no mention of oven canning and one stated it was not recommended because of the difficulty of securing high temperatures in the jars and because of the extremely low rate of heat penetration in jars of food in an oven.

Table I. Processing Periods Recommended by Equipment Manufacturers

| | Ball 275° * F. | Boston Consolidated # 275°F. | Kerr 250° * F. | Universal # | Wilcolator * 250°F. | Home Canners * 275°F. | Lorain 275°F. # | Westinghouse * 250°F. |
|---|---|---|---|---|---|---|---|---|
| | min. | min. | min. | min. | min. | min. | min. | min. |
| Blueberries | 35 | 45 | 68 | 350° 35 | 60 | 30 | - | 45 |
| Raspberries | 35 | 35 | 68 | 300° 35 | 60 | 30 | 35 | 45 |
| Cherries | 30 | 30 | 68 | 300° 30-40 | 60 | 35 | 30 | 45 |
| Peaches | 35 | 35 | 68 | 300° 40 | 60 | 35 | 35 | 60 |
| Pears | 35 | 35 | 75 | 300° 45-60 | 60 | 45 | 35 | 60 |
| Plums | 45 | 45 | 68 | 300° 45 | 60 | 30 | 45 | 60 |
| Asparagus | 180 | - | 210 | 150 | - | 180 | 150 | 150 |
| Green or wax beans | 180 | - | 210 | 150 | - | 150 | 150 | 180 |
| Carrots | 150 | - | 150 | 150 | - | 150 | 150 | 150 |
| Corn | 180 | - | 210 | 180 | - | 180 | 180 | 180 |
| Greens | 180 | - | 240 | - | - | 180 | 180 | 180 |
| Peas | 180 | - | 240 | 180 | - | 180 | 180 | 180 |
| Squash | 180 | - | 180 | - | - | 180 | - | 120 |
| Tomatoes | 45 | - | 75 | 55 | 60 | 30 | 45 | 45 |
| Meats | 210 | - | 240 | 300° 150-180 | - | 240 | - | 180 |
| Poultry | 210 | - | 240 | 300° 150-180 | - | 240 | - | 180 |
| Fish | 210 | - | 300 | 300° 150-180 | - | 180 | - | 180 |

* For Quart Jars
\# For Size of Jar not Specified

Table II. Processing Periods Recommended by State Extension Service Departments

| | Iowa (1931) * 275°F. | Connecticut (1932) # 275°F. | Maryland (1930) * 275°F. | Kentucky (1926) + 250-275° F. | North Dakota (1926) * 250°F. |
|---|---|---|---|---|---|
| | Min. | Min. | Min. | Min. | Min. |
| Blueberries | - | 30 | 35 | 30 | 60 |
| Raspberries | 35 | 30 | 35 | 30 | 60 |
| Cherries | 30 | 38 | 35 | 30 | 60 |
| Peaches | 35 | 30(ripe)<br>45(firm) | 35 | 30 | 60 |
| Pears | 35 | 30 | 35 | 30 | 60 |
| Plums | 45 | 30 | 45 | 45 | 60 |
| Asparagus | 150 | Not recommended | Not recommended | 150 | 120 |
| Green or wax beans | 150 | " | " | 150 | 180 |
| Carrots | 150 | " | " | 120 | 90 |
| Corn | 180 | " | " | 180 | 240 |
| Greens | 150 | " | " | 120 | 120 |
| Peas | 180 | " | " | 180 | 240 |
| Squash | 180 | " | " | 180 | 120 |
| Tomatoes | 45 | 60 | 45 | 45 | 60 |
| Meats | 210 | Not recommended | Not recommended | - | - |
| Poultry | 210 | " | " | - | - |
| Fish | 210 | " | " | - | - |

* For quart jars
\# For pint jars
\+ For pint or quart jars

## III. Purpose of Thesis

These studies in oven canning were conducted with the hope of determining some of the factors involved in the preservation of food by oven processing. The effect of oven temperature; oven load; size of jar; position of jar in the oven; initial temperatures of the jar contents, etc., were to be studied. The data obtained from these investigations were to be used as an aid in evaluating the oven method of canning, particularly as to its feasibility and safety.

## IV. Equipment Used

### 1. Ovens

Two automatically controlled ovens (See Plates 1 and 2), one gas and one electric, were used for the experimental work. Both stoves were entirely new when the work was begun.

The Quality Gas Range had an oven measuring 18 x 17½ x 12 inches. Before adjustments were made, the temperature of the empty oven ran approximately 100° F. higher than the temperature for which the oven was set. (All temperatures given in this thesis are in degrees Fahrenheit). Even after the usual adjustments were made the temperature continued to run much too high when the

Ranges Used for Oven Canning Studies

Plate 1. Quality Gas Range

Plate 2. Universal Electric Range

oven was set for 250° - 275°. It required very careful adjustment and checking with thermocouples to regulate the oven so that it would approximate the temperature for which it was set. Figure 1 shows the temperature of the empty gas oven when the control was set at 350°, at 275°, and at 250°. This chart represents the temperature at the center of the lower rack, which was placed 2½ inches from the bottom of the oven. Temperatures were taken by means of copper-constantin thermocouples in three different positions in the oven:- center of lower rack, corner of lower rack (approximately 2 inches from the side of the oven), and center of the top rack which was placed 3 inches from the top of the oven.

The temperature at the center of the lower rack was the lowest and that taken in the corner was the highest at each of the three different oven temperatures, the only exception being during the preheating period when the temperature at the center of the top rack rose from 35 to 60° higher than either position on the lower rack and then dropped rapidly to a position midway between that of the center and that of the corner of the lower rack. After preheating from 20 - 30 minutes, the temperatures at the three different oven positions became parallel with a difference between each of from 1 - 4°.

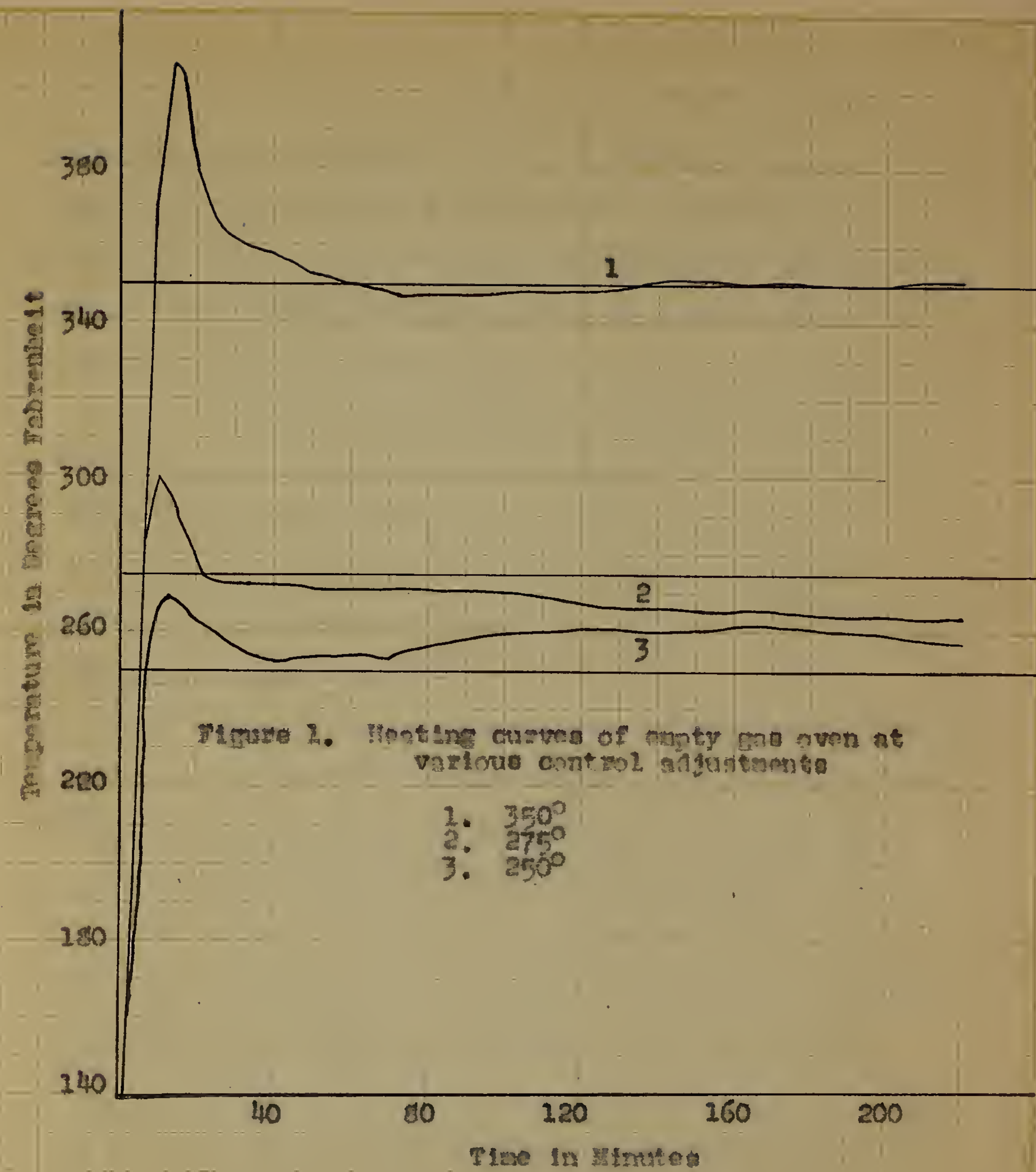


Figure 1. Heating curves of empty gas oven at various control adjustments

1. 350°
2. 275°
3. 250°

With the oven control set for 250°, the three thermocouples registered, after 30 minutes heating, temperatures ranging from 252 to 264°. With the control set at 275°, the temperatures after 30 minutes ranged from 265° to 290°. At 350°, after 30 minutes' heating, the range was from 347°- 366°.

The oven of the Universal Electric Table Top Range measured 19½ x 15¼ x 11½ inches. The oven, upon delivery, averaged approximately 50° higher than the temperature for which the control was set. Figure 2 shows the temperature curve of the oven set at 250°, both before and after a very careful adjustment was made. Figure 3 shows the temperature curves of the empty electric oven when the control was set at 350°, at 275° and at 250°. These curves represent the temperature at the center of the lower rack, which was placed approximately 2 inches from the bottom of the oven. Temperatures were taken at the center of the top rack (placed 3 inches from the oven top), and at the center and corner of the lower rack. The temperature fluctuated considerably, that at the center of the lower rack having a much wider range than that of either the center of the top rack or the corner of the lower rack. There was very little difference between the temperature of the corner and that of the top of the oven.

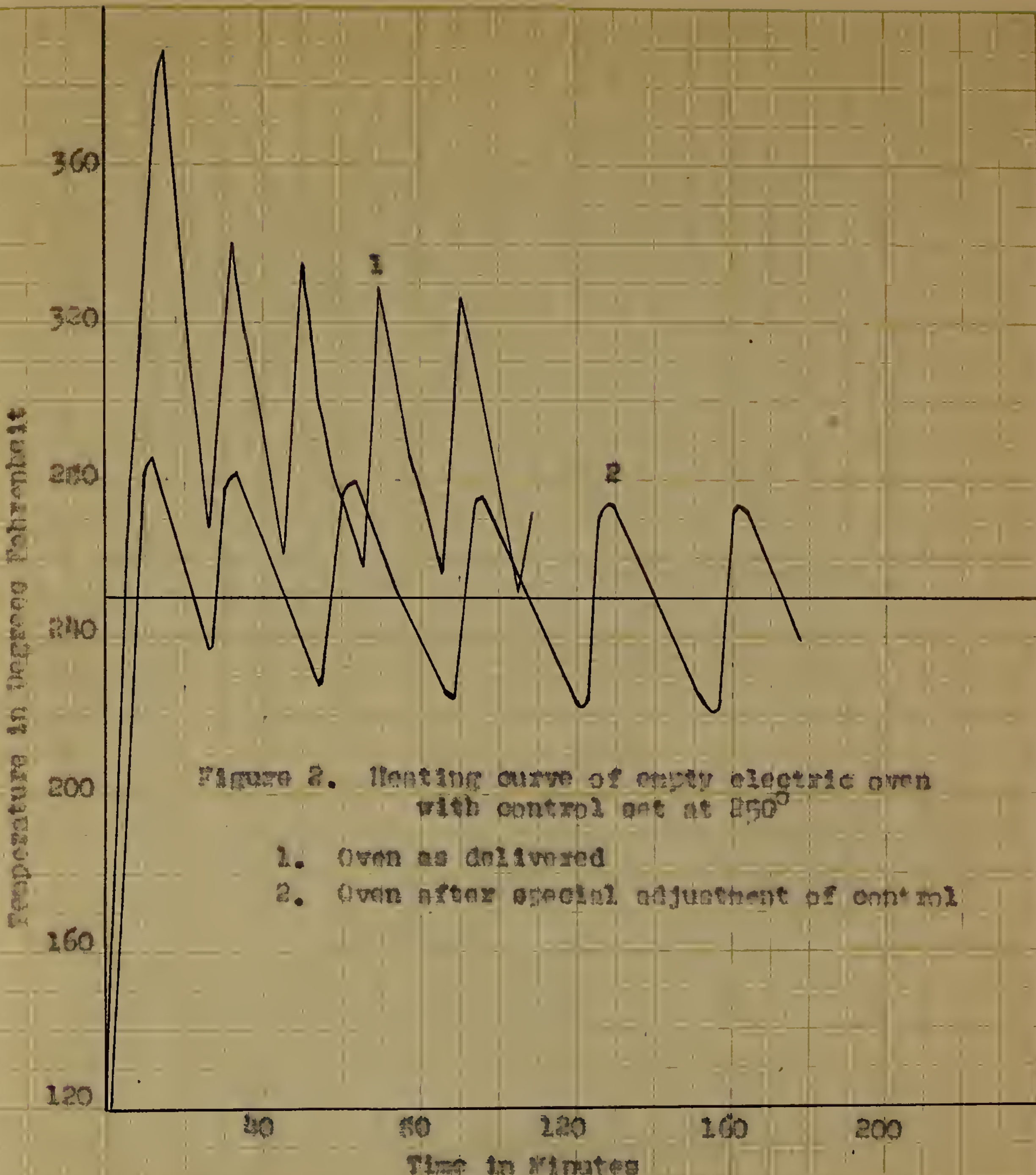


Figure 2. Heating curve of empty electric oven with control set at 250°

1. Oven as delivered
2. Oven after special adjustment of control

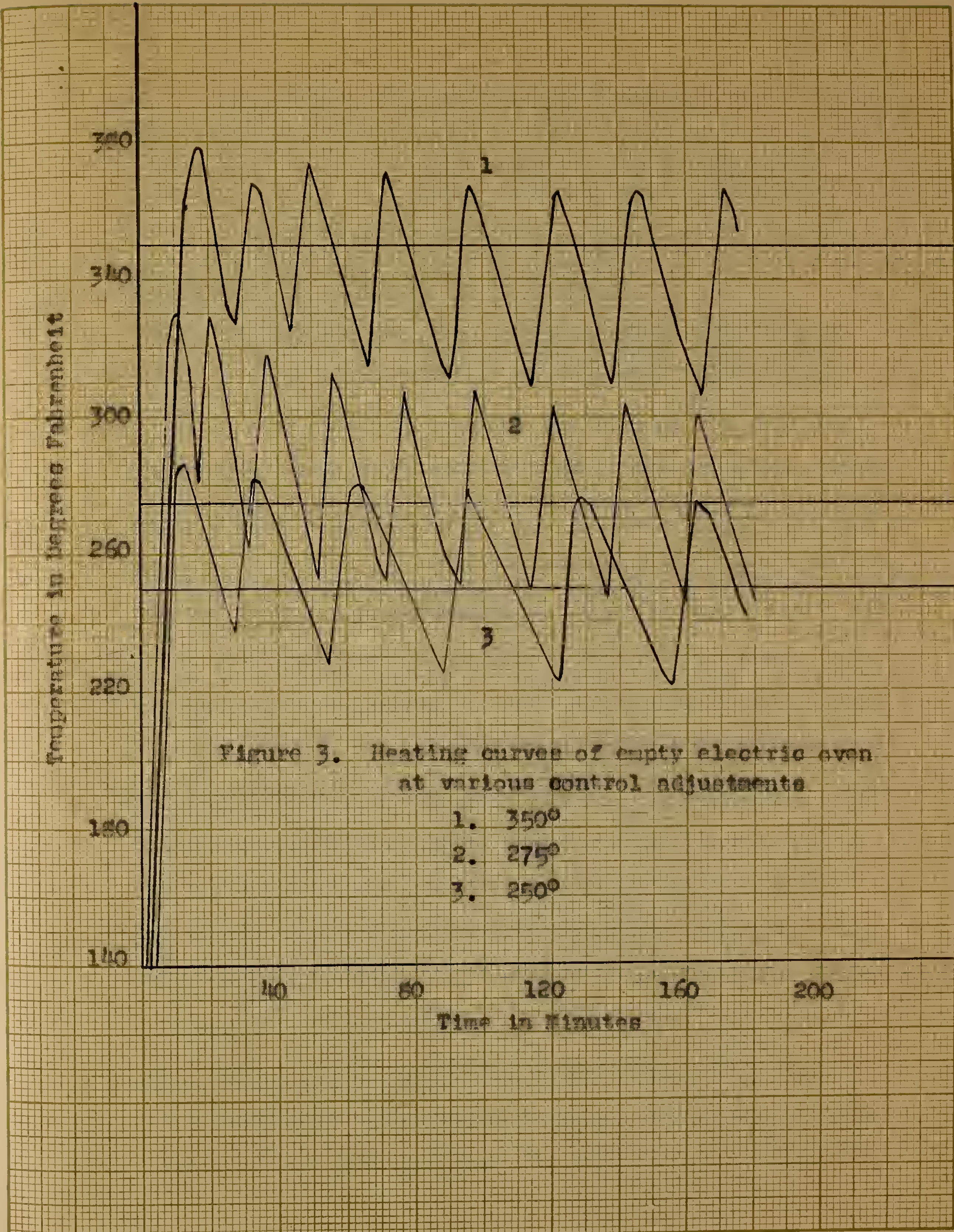


Figure 3. Heating curves of empty electric oven at various control adjustments

1. 350°
2. 275°
3. 250°

Their temperature fluctuation was approximately as follows:

| | | | | |
|---|---|---|---|---|
| Oven control set at | 250° | - 230° to 270° | (40° range) |
| " " " " | 275° | - 234° to 290° | (36° range) |
| " " " " | 350° | - 308° to 350° | (42° range) |

The temperature at the center of the lower rack fluctuated approximately as follows:

| | | | |
|---|---|---|---|
| Oven control set at | 250° | - 224° to 276° | (52° range) |
| " " " " | 275° | - 247° to 308° | (61° range) |
| " " " " | 350° | - 309° to 368° | (59° range) |

In order to compare the behavior of the two laboratory ovens with that of ovens used in homes, tests were made of a number of ovens in actual use in Amherst homes. Both gas and electric ovens of various makes were tested. The results are given in Figure 4. Ovens 5 and 6 had the controls set for 250°, the temperature recommended for canning by the oven manufactures. The controls of the other ovens were set for 275°. The temperatures were taken by means of a thermocouple placed in the center of the lower rack, a position comparable to that used in the laboratory ovens. All ovens were insulated and equipped with temperature controls. They represent the average, or perhaps slightly better than average oven, since most of the ovens had been in use less than a year. There was considerable difference in their behavior. Even ovens 2 and 7, identical in make, size, and age, did not have the same temperature curve.

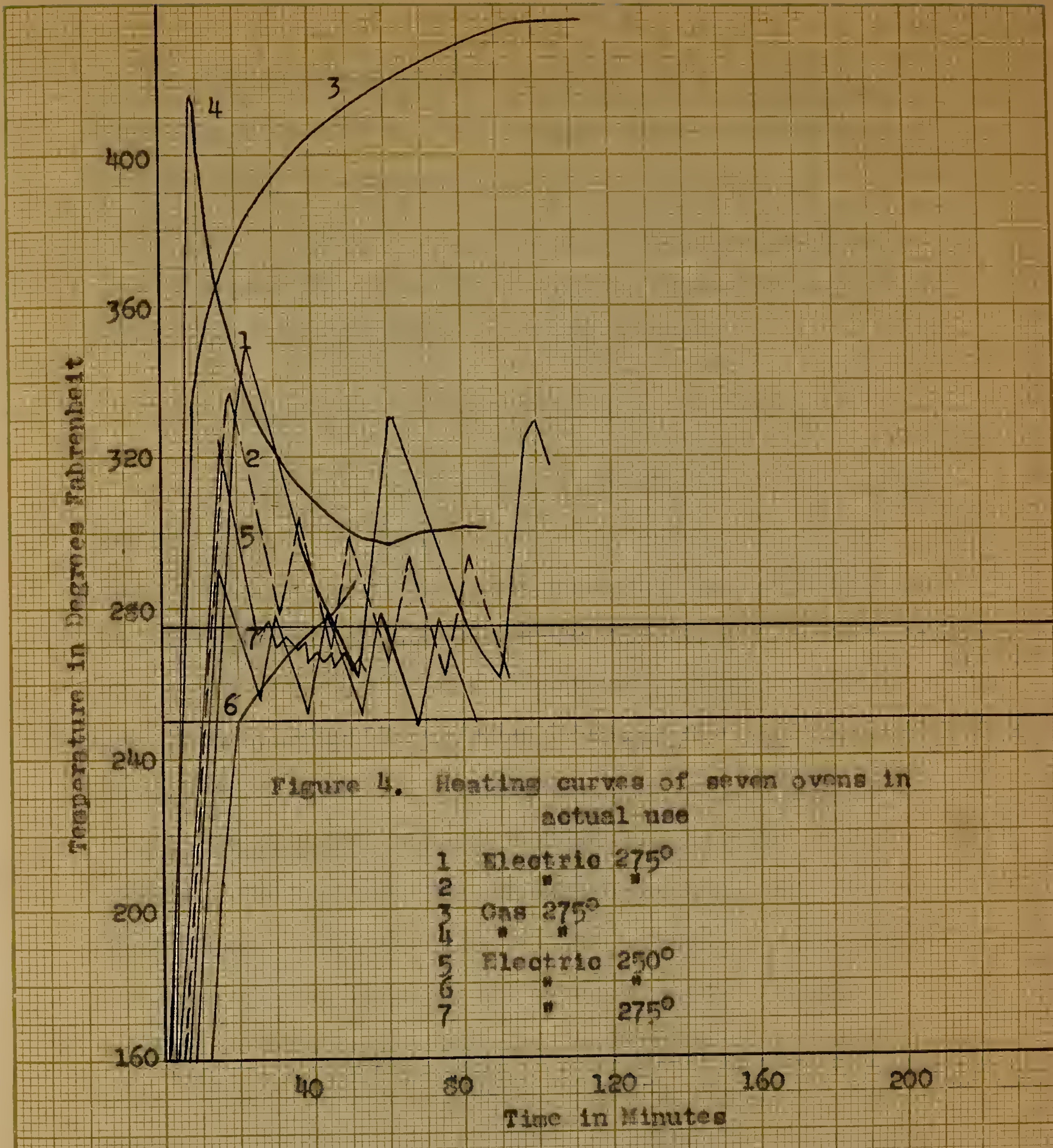


Figure 4. Heating curves of seven ovens in actual use

1 Electric 275°
2 " "
3 Gas 275°
4 " "
5 Electric 250°
6 " "
7 " 275°

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It is readily apparent that food canned by the homemaker in these ovens, even though the controls were set for 275° in all cases, would be subjected to various temperatures and conditions and the finished product would be extremely variable, depending somewhat upon the particular food being canned.

2. Apparatus for Measuring Heat Penetration

All oven temperatures and the heat penetration curves in jars of canned foods were determined by the use of copper-constantin thermocouples connected with a potentiometer (Plate 3). The use of a junction board and a switch board (Plate 4) made it possible to use six thermocouples at one time. Diagram 1 shows the arrangement of the heat measuring apparatus used. The thermocouple point was put through a specially constructed lid and into the center of a glass jar. The thermocouple wire was then led out of the oven through the vent and fastened to other wires at the junction board. An artificial vent had to be made in the gas oven. These in turn, led to the switch board and then to the potentiometer. The cold junction of the thermocouple was encased in glass tubing, which was closed at the end, and placed in a thermos bottle filled with

Apparatus Used for Heat Penetration Studies

Plate 3. Thermocouple, potentiometer, and cold junction.

Plate 4. Switch board

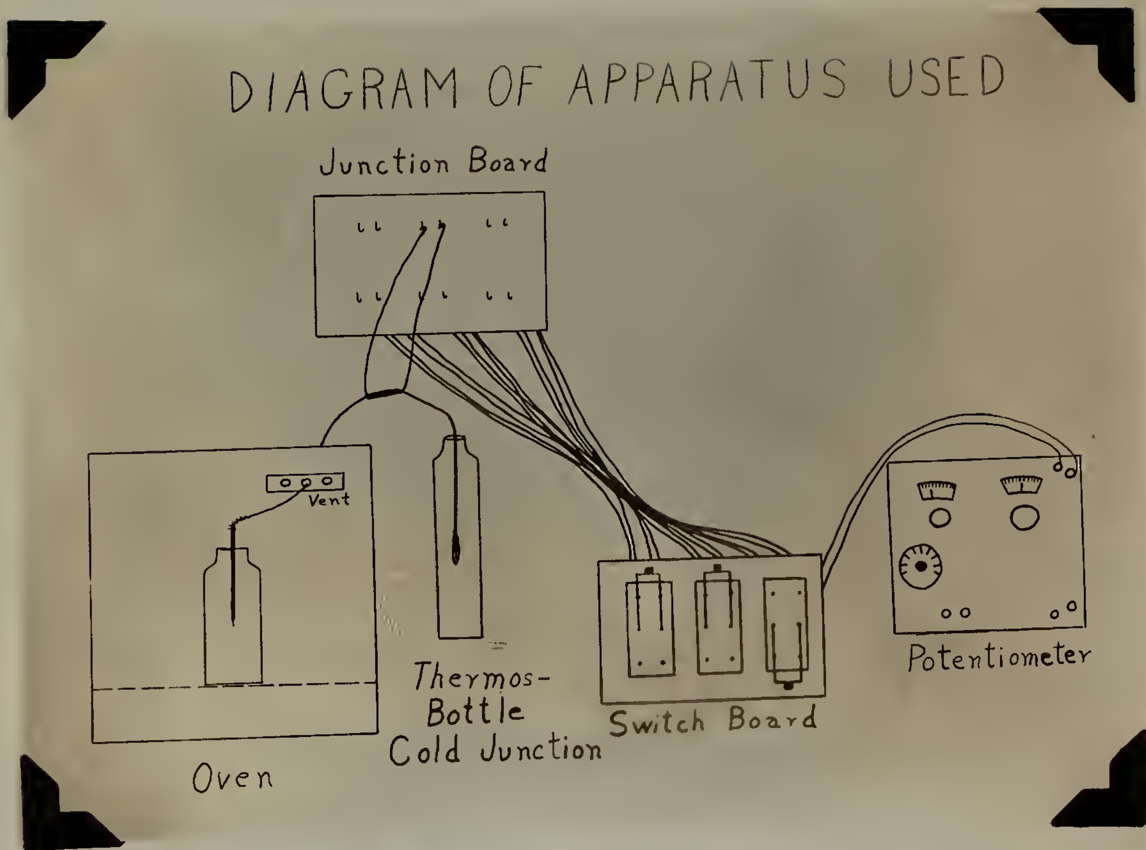


DIAGRAM OF APPARATUS USED
Junction Board
Vent
Oven
Thermos-
Bottle
Cold Junction
Switch Board
Potentiometer


Diagram 1.

crushed ice. According to Thompson (15), the glass on the junction does not prevent prompt attainment of the temperature.

Millivolt readings were taken on the potentiometer and converted into degrees Fahrenheit by means of a calibration table obtained by calibrating the thermocouple against a U. S. Bureau of Standards thermometer in an oil bath. Figure 5 shows a typical calibration curve of a thermocouple in an oil bath.

New pint and quart Mason jars were used throughout the experiment with the exception of one oven load of tomatoes canned in quart lightning type jars. New Good Luck jar rubbers were used for all tests except a few with corn and tomatoes done at the beginning of the experimental work. For these, rubbers that came with the Mason jars were used.

## V. Methods

### Experimental Results

#### 1. Effect of Oven Load Upon Heat Penetration into Jars of Canned Food

A series of experiments was planned to determine the effect of oven load upon the temperature of the oven and upon the rate of heat penetration into jars of food being processed in the oven. The tests were made using

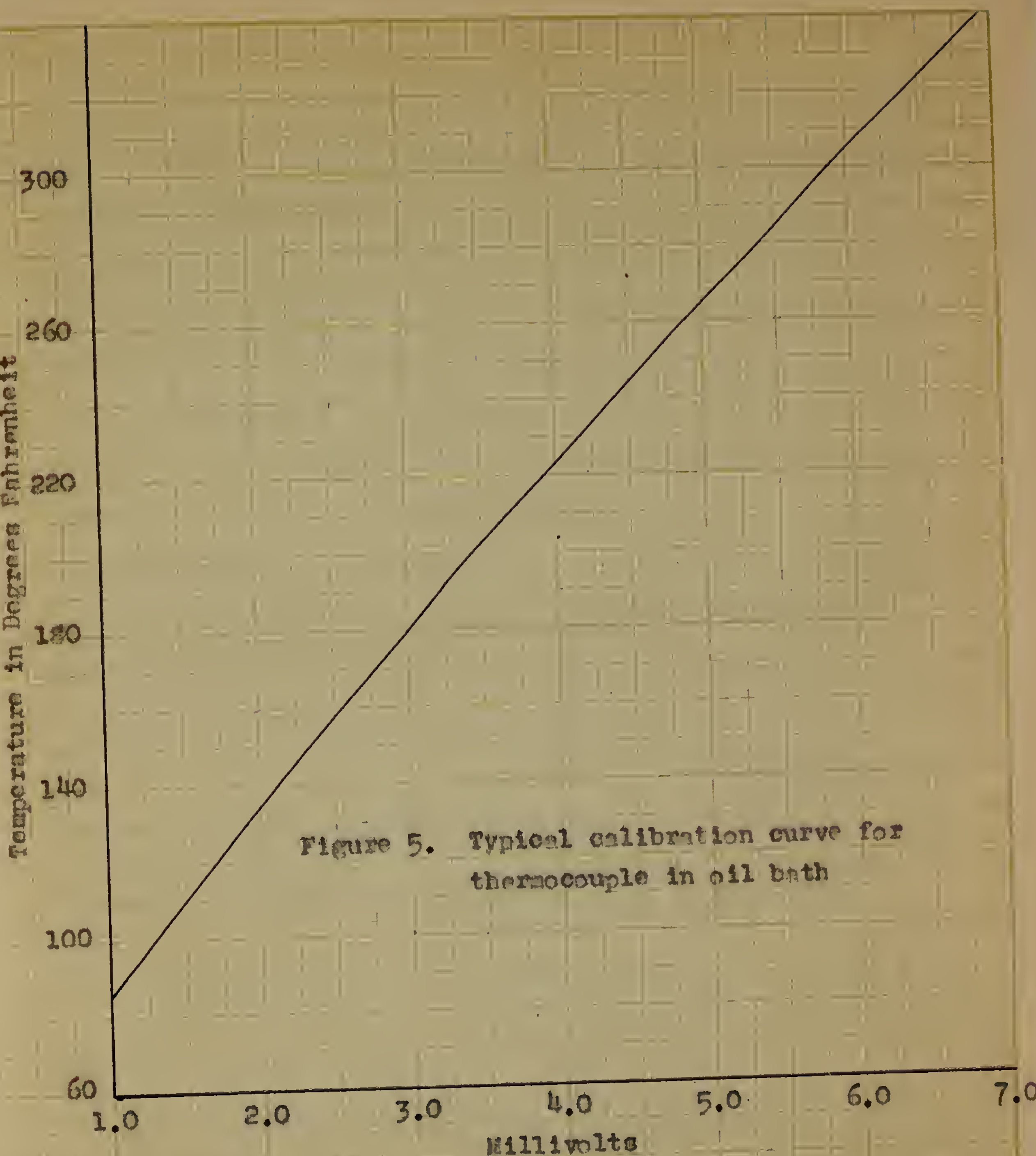


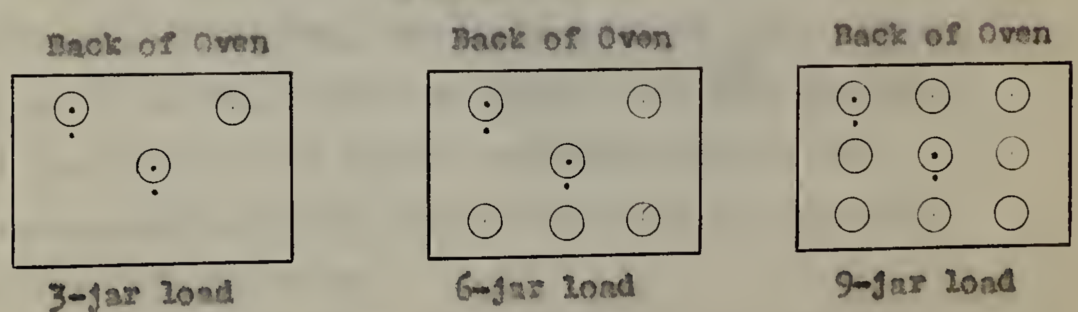

Figure 5. Typical calibration curve for thermocouple in oil bath

three, six and nine pint jars of tomatoes as the various oven loads. A 9-jar load was the capacity of both ovens when a 2-inch space was allowed between jars as well as between the jars and the sides of the oven. The ovens were not preheated for these tests made with pint jars of tomatoes. Only the bottom unit of the electric oven was used during all experiments reported in this thesis.

The tomatoes were washed, blanched in boiling water to loosen the skins, cold dipped, and then peeled. Sixteen ounces of tomatoes were packed in each pint jar, pressed down enough to express juice to fill spaces between the tomatoes, and one teaspoonful of salt was added. Fresh tomatoes were prepared for each test.

The following diagrams show the position of jars and thermocouples in the oven.

Figure 6. Diagram of Location of Jars in Oven Load Experiment




Note: Dots show the position of thermocouples.

Figure 7 shows the effect of load upon oven temperature and heat penetration in pint jars of tomatoes in the gas oven with the control set for 275°. There was a very definite relationship between load, oven temperature, and the rate of heat penetration. As the load was increased the maximum temperature reached in the oven became lower and the time required for the center of the jar to reach 180° was increased.

Figure 8 shows the results of similar tests made in the electric oven. The 9-jar load was effective in depressing both the oven temperature and the rate of heat penetration.

The above tests were repeated using carrots instead of tomatoes. The carrots were prepared by blanching in boiling water for 5 minutes. The skins were then removed by rubbing or scraping and the carrots were sliced approximately one-eighth of an inch in thickness. Ten ounces of carrots, one teaspoonful of salt, and six ounces of boiling water were packed into each pint jar. The jars were placed in the ovens immediately, the thermocouples adjusted, the oven control set for 275°, and the heat turned on.

Figure 9 shows the effect of load upon the temperature and heat penetration in the gas oven which

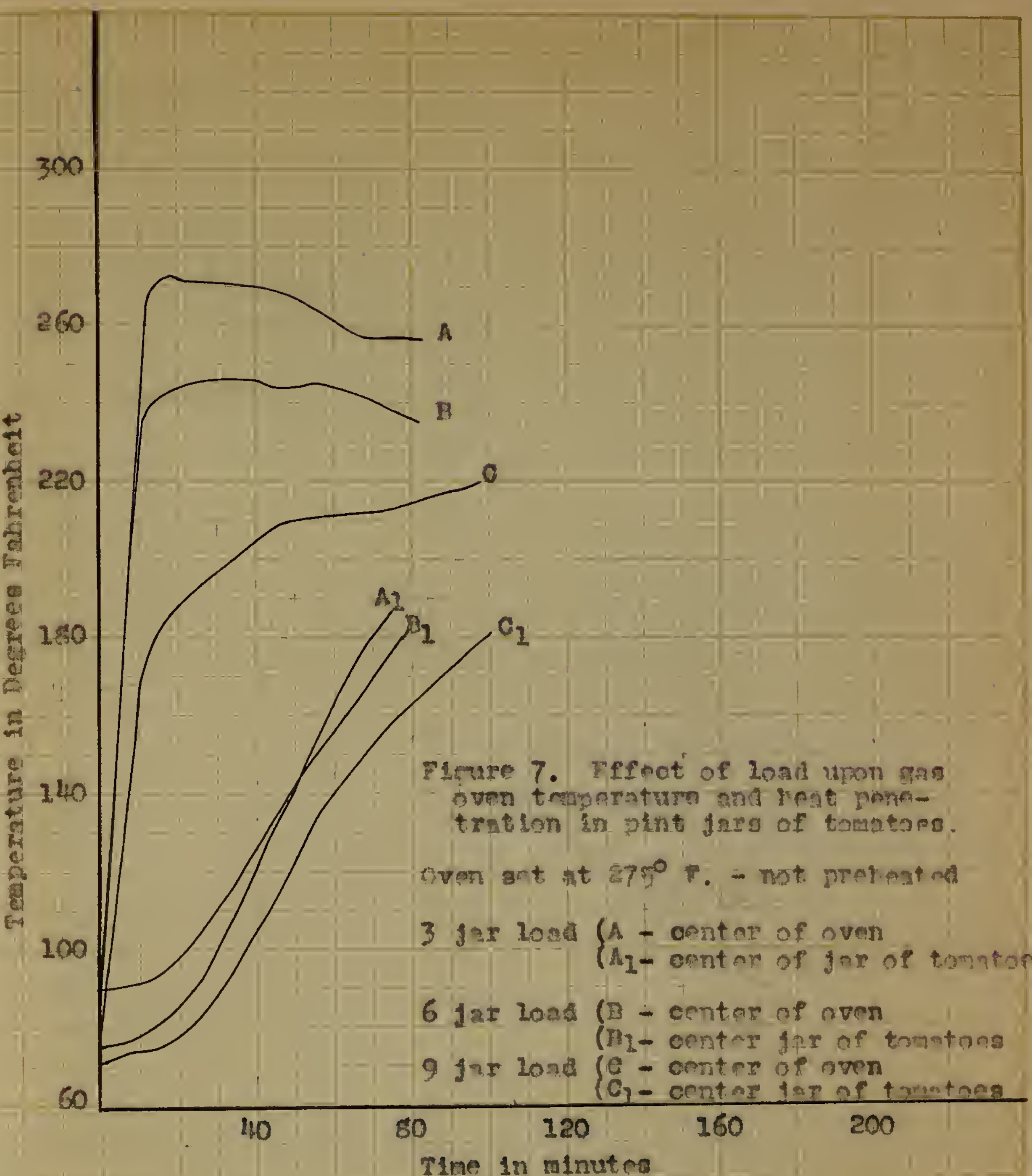



Figure 7. Effect of load upon gas oven temperature and heat penetration in pint jars of tomatoes.

Oven set at 275° F. - not preheated

3 jar load (A - center of oven
(A1- center of jar of tomatoes

6 jar load (B - center of oven
(B1- center jar of tomatoes

9 jar load (C - center of oven
(C1- center jar of tomatoes

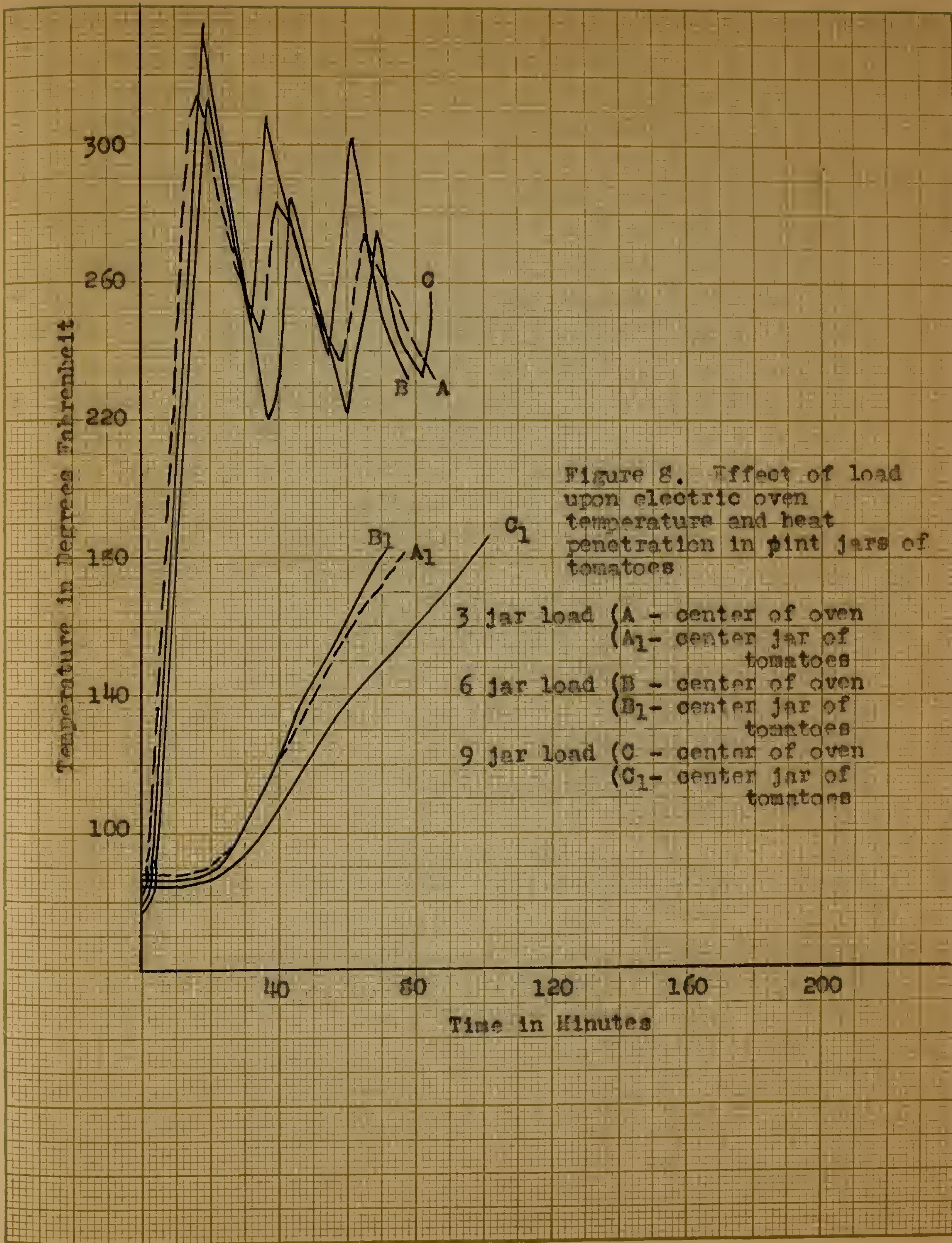



Figure 8. Effect of load upon electric oven temperature and heat penetration in pint jars of tomatoes

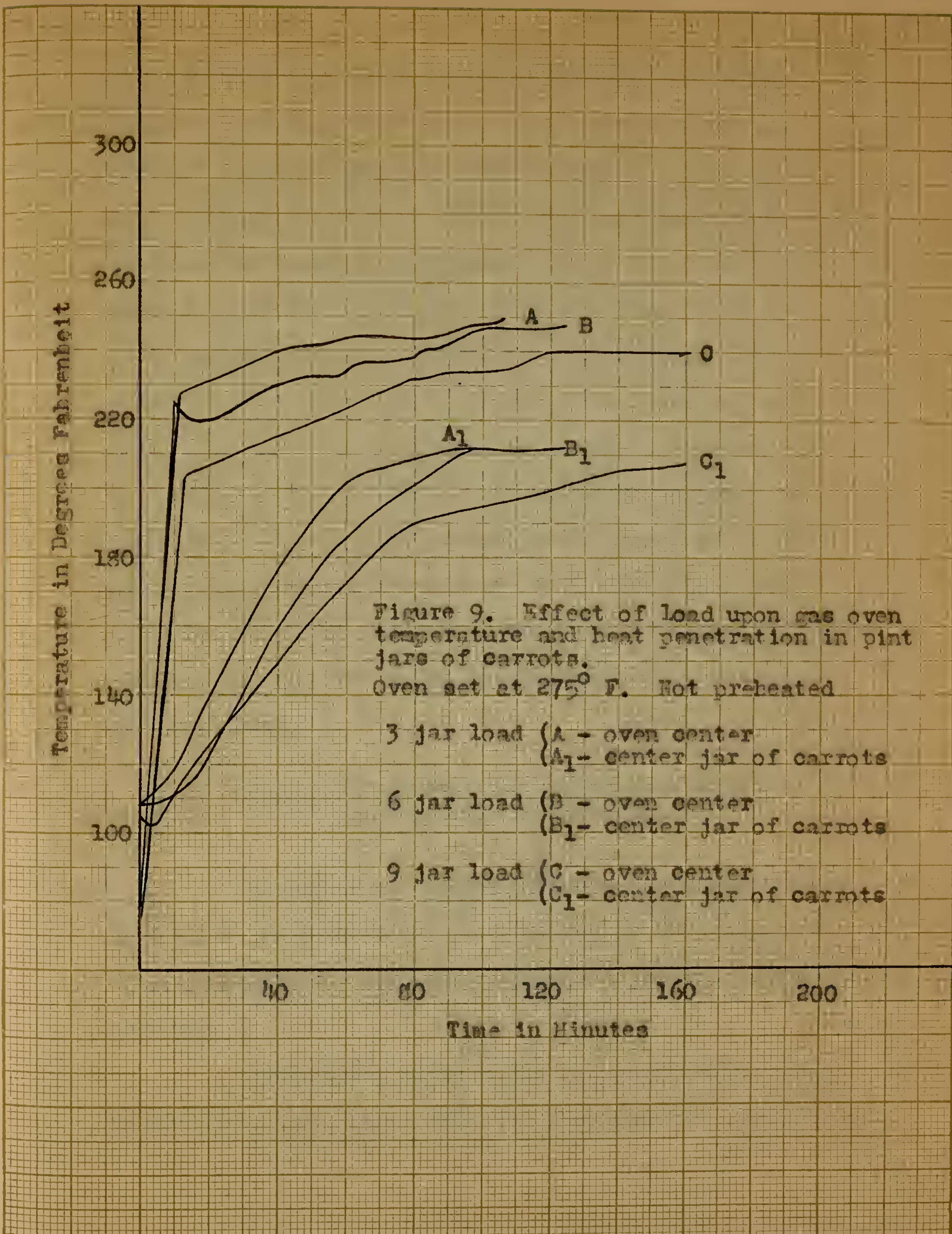



Figure 9. Effect of load upon gas oven temperature and heat penetration in pint jars of carrots.
Oven set at 275° F. Not preheated

has not been preheated. Figure 10 shows the effect of load on the preheated gas oven. The results are similar to those obtained with tomatoes. There is more difference between the 6 and 9-jar loads than between the 3 and 6-jar loads. The size of the oven load did not have such a noticeable effect upon the oven temperature and rate of heat penetration in the electric oven (Fig. 11 & 12) as it did with the gas oven. As the load increased there was a tendency for the range of fluctuation of the oven temperature to increase. This seemed to compensate somewhat for the extra load and, although there were variations both in the oven temperatures and in the rate of heat penetration, these could not always be correlated with the size of the oven load.

### 2. Effect of Position of Jar in Oven upon the Rate of Heat Penetration

A series of experiments were conducted to determine the effect of the location of the jar in the oven upon the rate of heat penetration to the center of the jar.

Tests were made in the gas oven using 3-jar, 6-jar, and 9-jar loads with the jars located as shown in

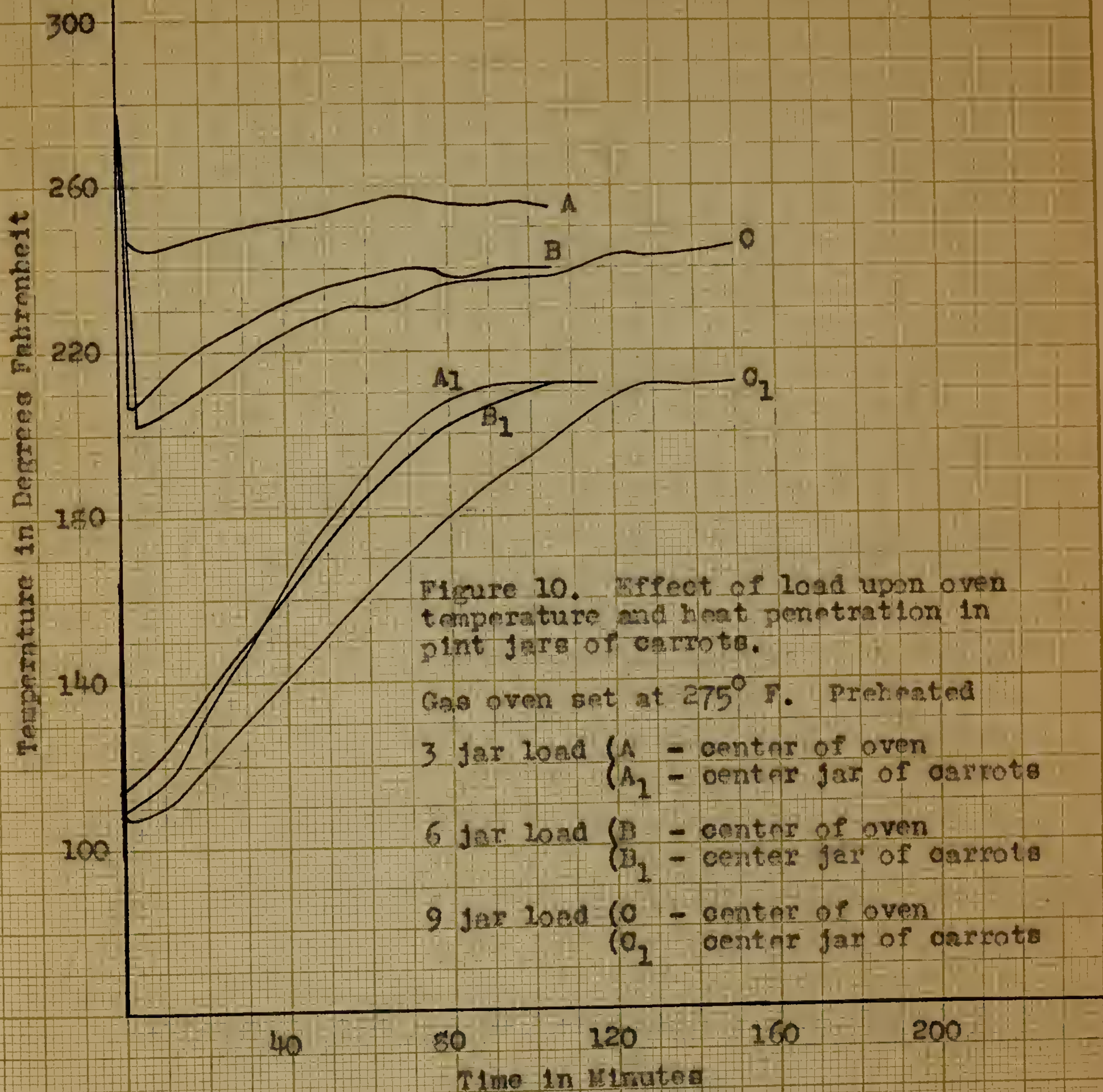



Figure 10. Effect of load upon oven temperature and heat penetration in pint jars of carrots.

Gas oven set at 275° F. Preheated

3 jar load {A - center of oven; $A_1$ - center jar of carrots}

6 jar load {B - center of oven; $B_1$ - center jar of carrots}

9 jar load {C - center of oven; $C_1$ center jar of carrots}

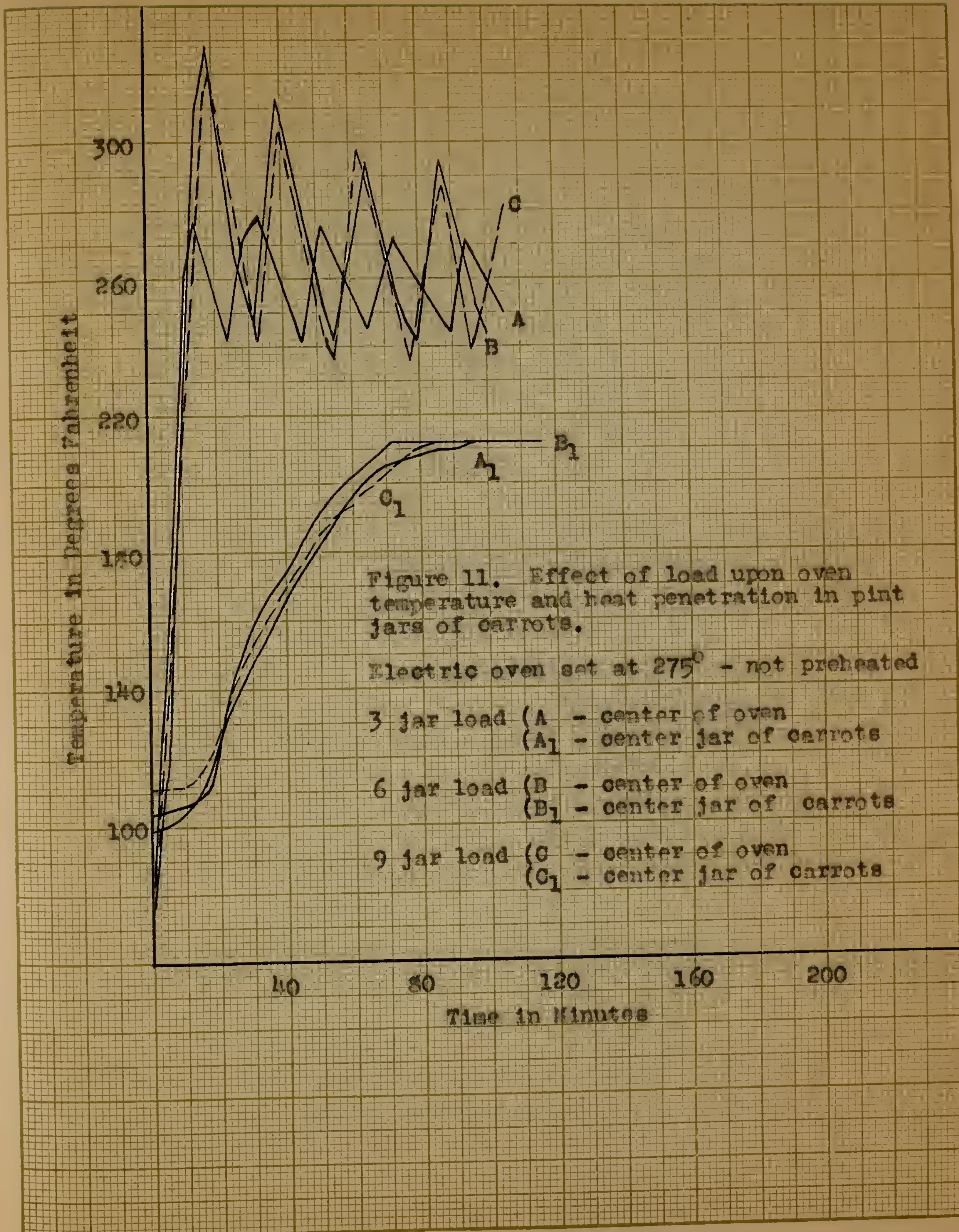



Figure 11. Effect of load upon oven temperature and heat penetration in pint jars of carrots.

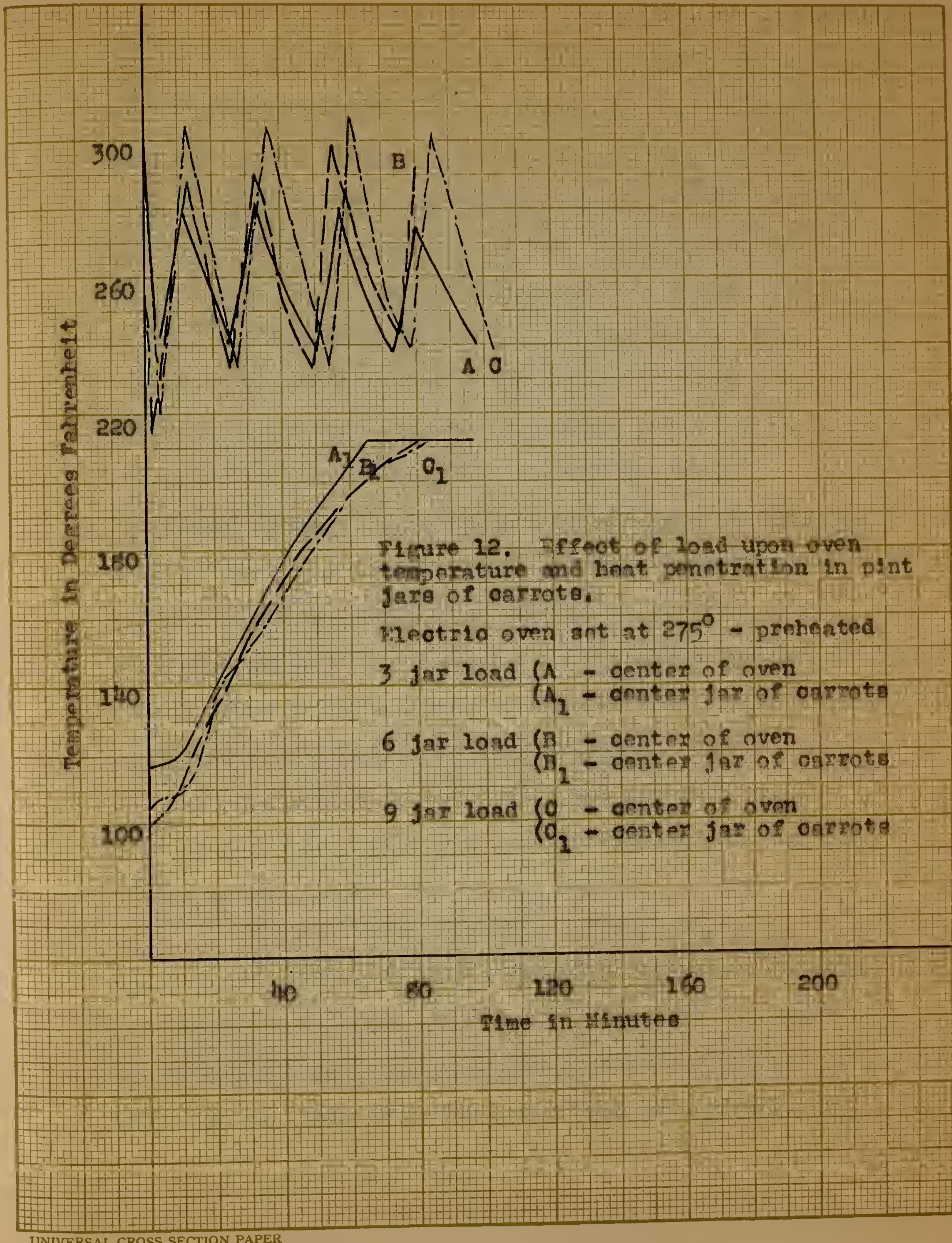



Figure 12. Effect of load upon oven temperature and heat penetration in pint jars of carrots.

Electric oven set at 275° - preheated

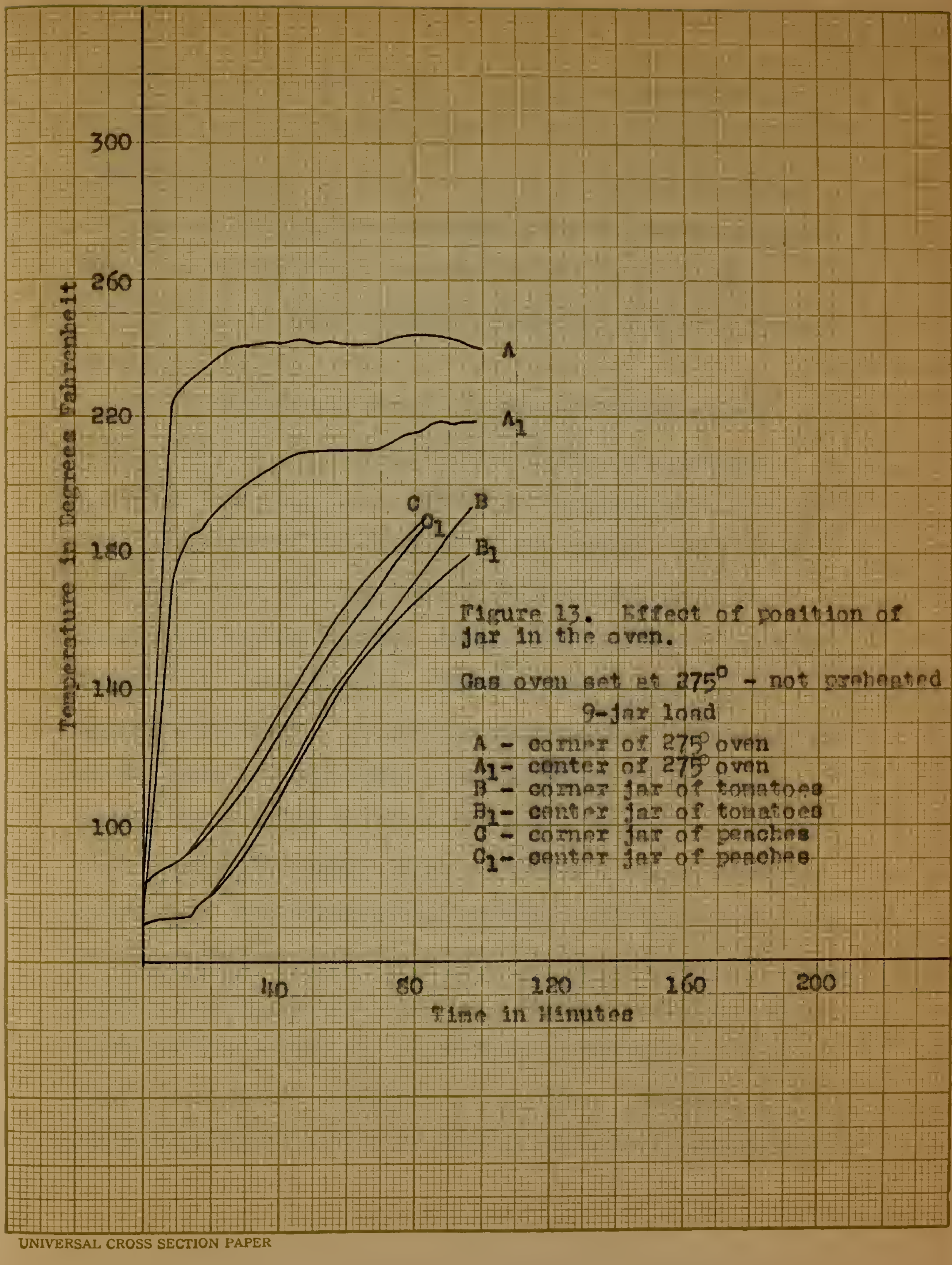
3 jar load (A - center of oven
(A₁ - center jar of carrots

6 jar load (B - center of oven
(B₁ - center jar of carrots

9 jar load (C - center of oven
(C₁ - center jar of carrots

Figure 6. The oven control was set for 275°. Tomatoes and peaches were used. The tomatoes were prepared as described under "Effect of Oven Load." The peaches were scalded, peeled, and cut in halves. Twelve ounces of peaches were packed in each pint jar, cup side down, and covered with 4 ounces of boiling 30 per cent sugar syrup. The thermocouples were adjusted and the jars placed in the oven at once. The results of tests with 9-jar loads of tomatoes and of peaches in the gas oven are shown in Figure 13. Not only was the oven temperature higher in the corner of the oven than in the center, but the rate of heat penetration into the corner jar was also more rapid than that in the center jar. Similar results were obtained from all tests made with either 6-jar or 9-jar loads in the gas oven. With a 3-jar load, however, the results were reversed. Here the rate of heat penetration in the center jar was more rapid than that of the corner jar and the oven temperature was higher in the center than in the corner.

Similar tests were made in the electric oven using 3-jar, 6-jar, and 9-jar loads of tomatoes, carrots and corn. The results were the same as with the gas oven. With 6 and 9-jar loads the corner was the hottest but with the 3-jar load the center was the hottest.

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This was true of both ovens regardless of whether or not the oven had been preheated. The difference in time required by jars in these two positions to reach the finish temperature averaged 9 minutes with extremes of 3 and 15 minutes. This difference would be more significant in short canning processes than in longer ones.

During all these experiments shallow pans were placed in the bottom of the ovens to catch any overflow from the jars. At first the pans were made to completely cover the bottoms of the ovens. This worked very well with the gas oven since the oven floor was solid with no ventilation vents and with the burner just beneath it. However, the electric oven presented a different problem. It had the heating unit in the center of the oven and the metal plate covering it had holes around the outside to allow for a circulation of air upward through the oven. With a large pan, such as was first made, these holes were covered. It was found under these conditions that the center of the oven was the hottest and the rate of heat penetration was always more rapid in the center jar regardless of whether 3, 6, or 9 jars were being processed at one time. As soon as the pan was reduced in size so that it no longer covered the

vent holes in the plate, the results obtained were the same as those for the gas oven.

3. Effect of Size of Container upon Oven Temperatures and the Rate of Heat Penetration in Tomatoes and Peaches

A number of tests were made to determine the effect of size of container upon the rate of heat penetration into jars of tomatoes and peaches. Tomatoes were scalded (blanched), cold dipped, peeled and packed into pint and quart glass jars - 16 ounces for pints and 33.5 ounces for quart jars. There was no water added. The tomatoes were pressed down firmly enough to express sufficient juice to fill the spaces between the tomatoes. Salt was added at the rate of one teaspoonful per pint. Fresh tomatoes were prepared for each test. A thermocouple was placed in the center of each jar, the temperature of which was to be recorded. The jars were then partially sealed.

The processing was done in both ovens, preheated for 30 minutes, with the controls set for 275°. Pints and quarts were processed separately. Nine pint jars were placed in the oven at one time and the rate of heat penetration into the center jar was recorded. The oven temperature was taken by means of a thermocouple

placed on the oven rack directly in front of the center jar.

The peaches were scalded, peeled, and cut in halves. Twelve ounces of peaches were packed in a pint jar (cup side down) and covered with 4 ounces of boiling 30 per cent syrup. Twenty-four ounces of peaches and 8 ounces of syrup were similarly filled into each quart jar. The thermocouples and lids were adjusted and the jars placed immediately into the ovens, which had been preheating for 30 minutes with the controls set for 275°. The temperature of the center jar and that of the oven center were recorded as in the case of tomatoes. Nine jars constituted an oven load in each case.

The results of these tests with tomatoes are given in Figures 14 and 15; the results for peaches in Figures 16 and 17. The size of the container had a marked influence not only upon the rate of heat penetration to the center of the jar, but upon the oven temperature as well. This effect was equally marked with peaches as with tomatoes and with the gas oven as with the electric oven. The temperature of the gas oven was 14 to 30 degrees lower for quarts than for pints. The electric oven averaged a temperature approximately 20 degrees lower for quarts than for pints. The quart jar

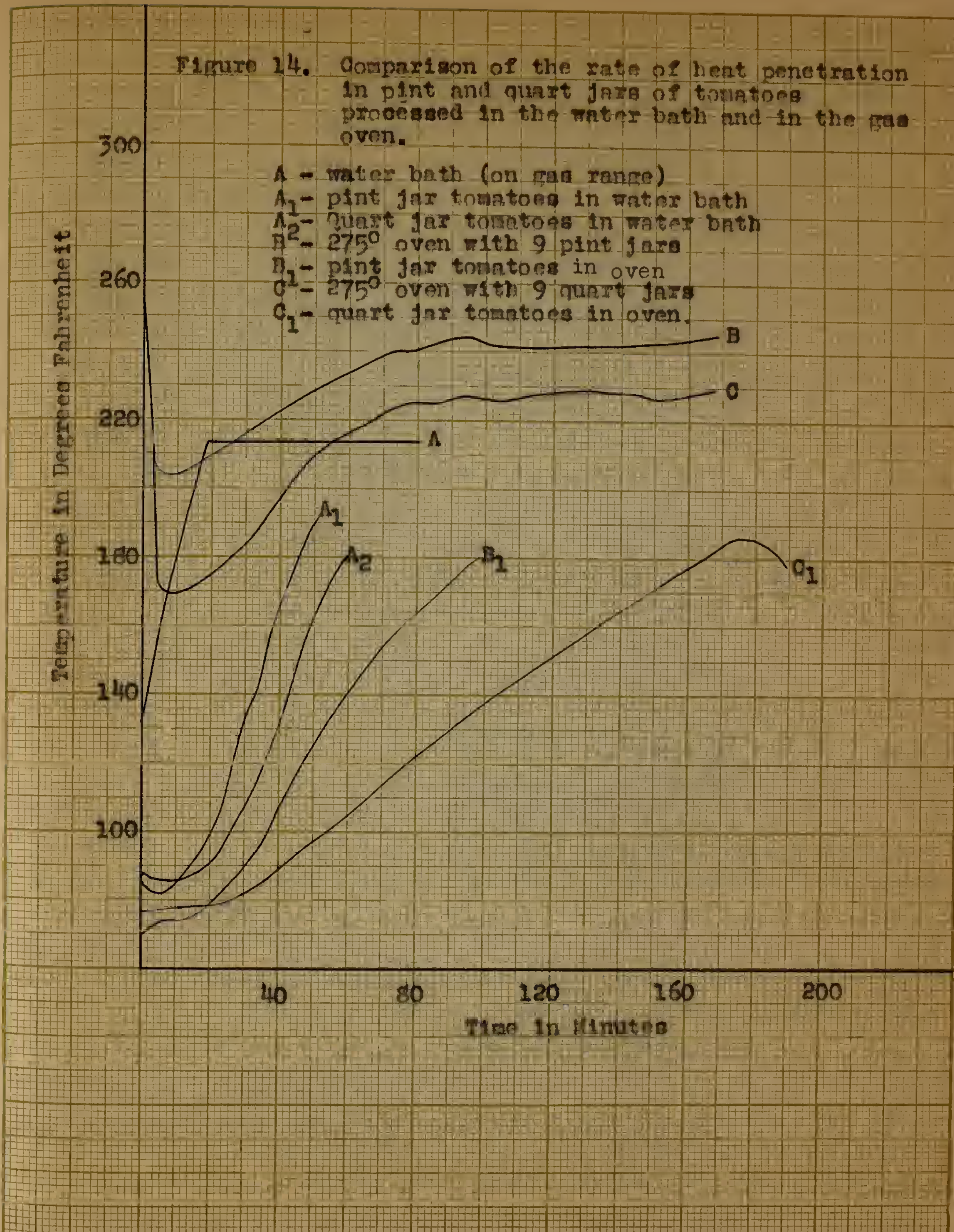
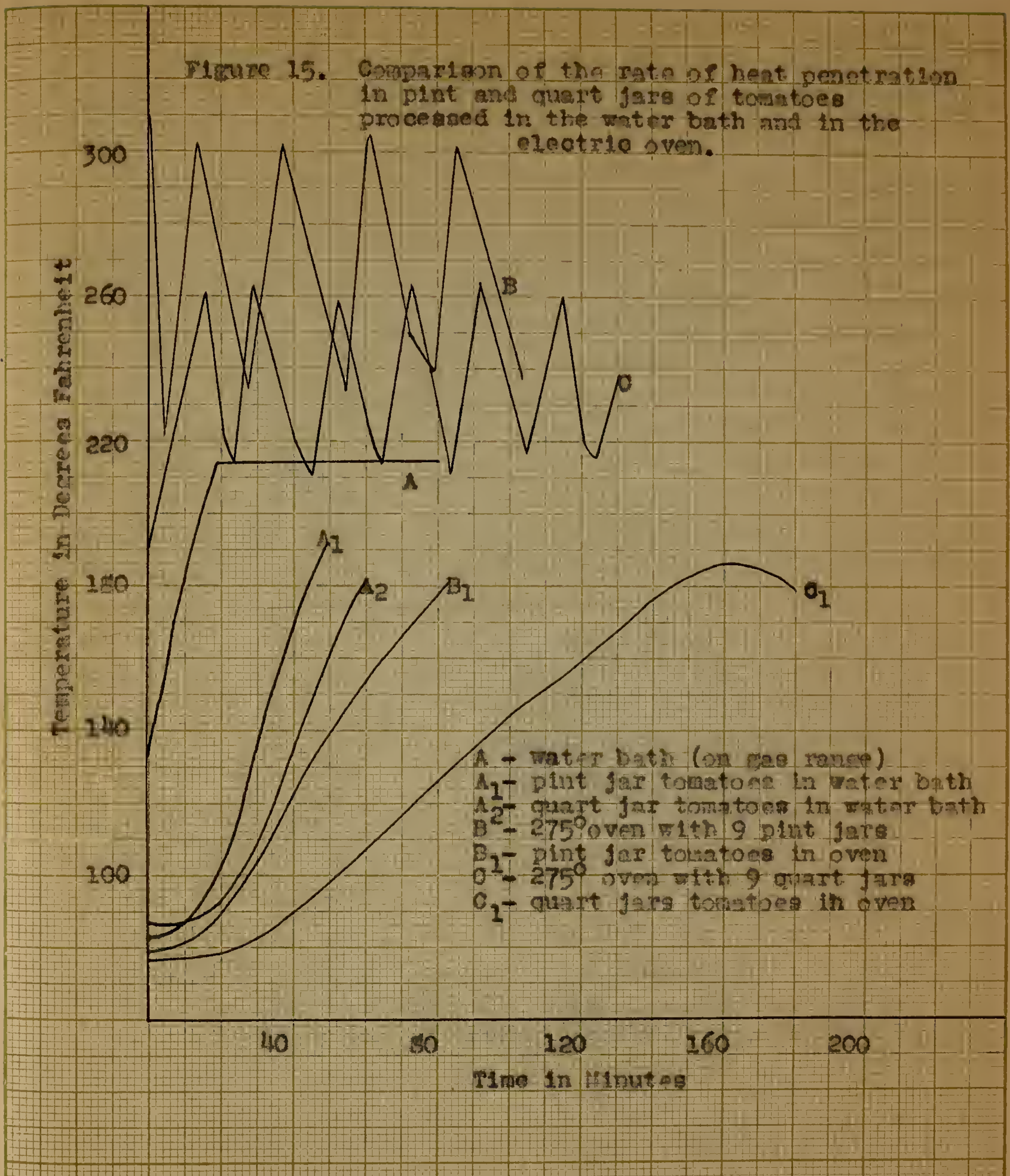



Figure 14. Comparison of the rate of heat penetration in pint and quart jars of tomatoes processed in the water bath and in the gas oven.



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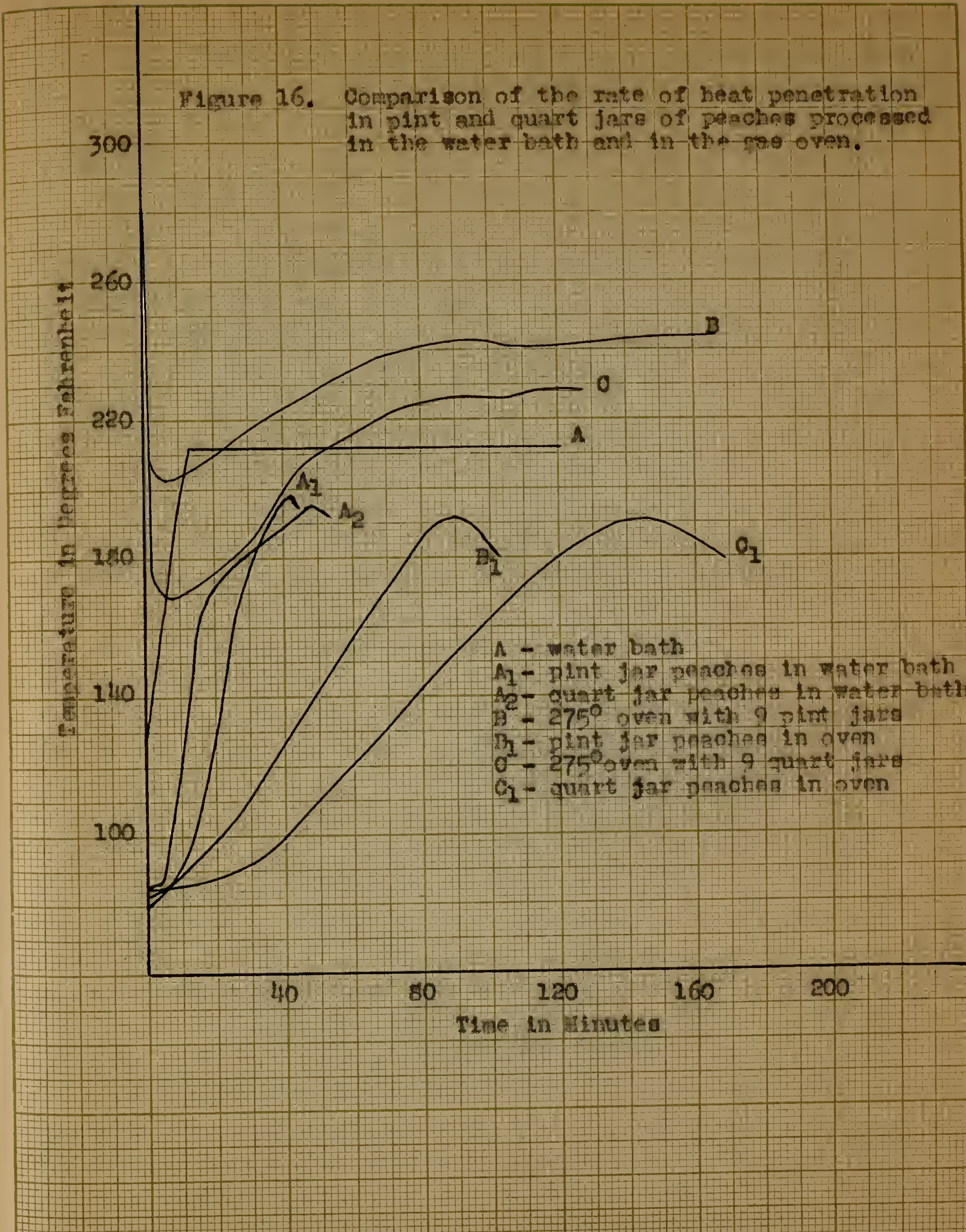
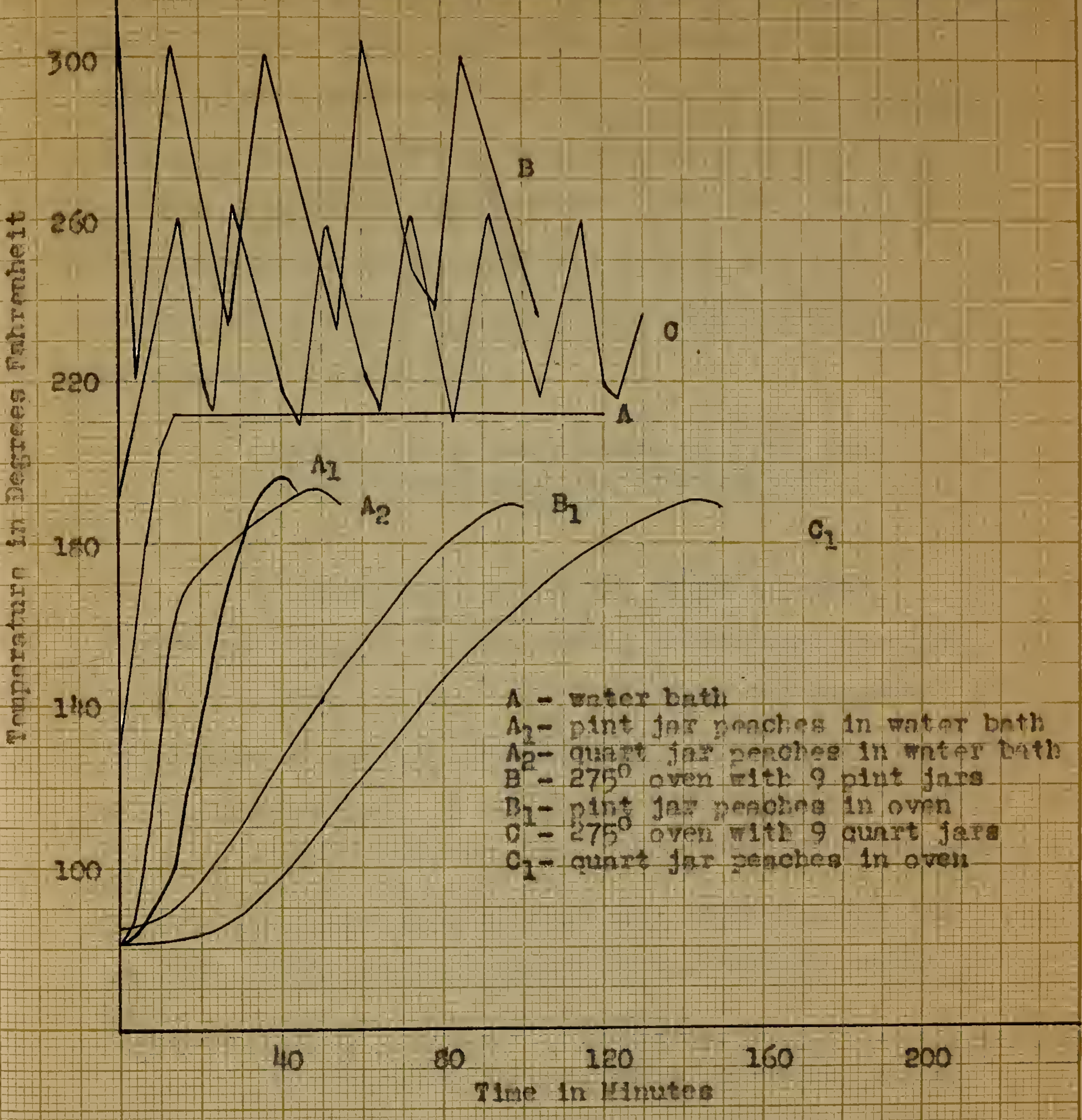



Figure 16. Comparison of the rate of heat penetration in pint and quart jars of peaches processed in the water bath and in the gas oven.

Figure 17. Comparison of the rate of heat penetration in pint and quart jars of peaches processed in the water bath and in the electric oven.



of tomatoes required 66 minutes more in the gas oven and 63 minutes more in the electric oven to reach an internal temperature of 180° than did the pint jars of tomatoes in these ovens. Similarly, the quart jar of peaches required 49 minutes more in the gas oven and 42 minutes more in the electric oven to reach an internal temperature of 187.5° than did the pint jars of peaches in these ovens.

### 4. Effect of Oven Temperature Upon the Rate of Heat Penetration in Tomatoes and Peaches

A study was made of the effect of oven temperature upon the rate of heat penetration in pint jars of peaches and tomatoes. The food was prepared and packed as previously described. Nine jars were used for each oven load. A record was made of the rate of heat penetration into the center jar. The tomatoes and peaches were processed separately. Oven temperatures of 250°, 275°, and 350° were used for peaches, while 275° and 350° were used for tomatoes.

The results of these experiments are given in Figures 18 and 19. The electric oven required 55 minutes at 350° and 87 minutes at 275° to raise the internal temperature of the pint jar of tomatoes to

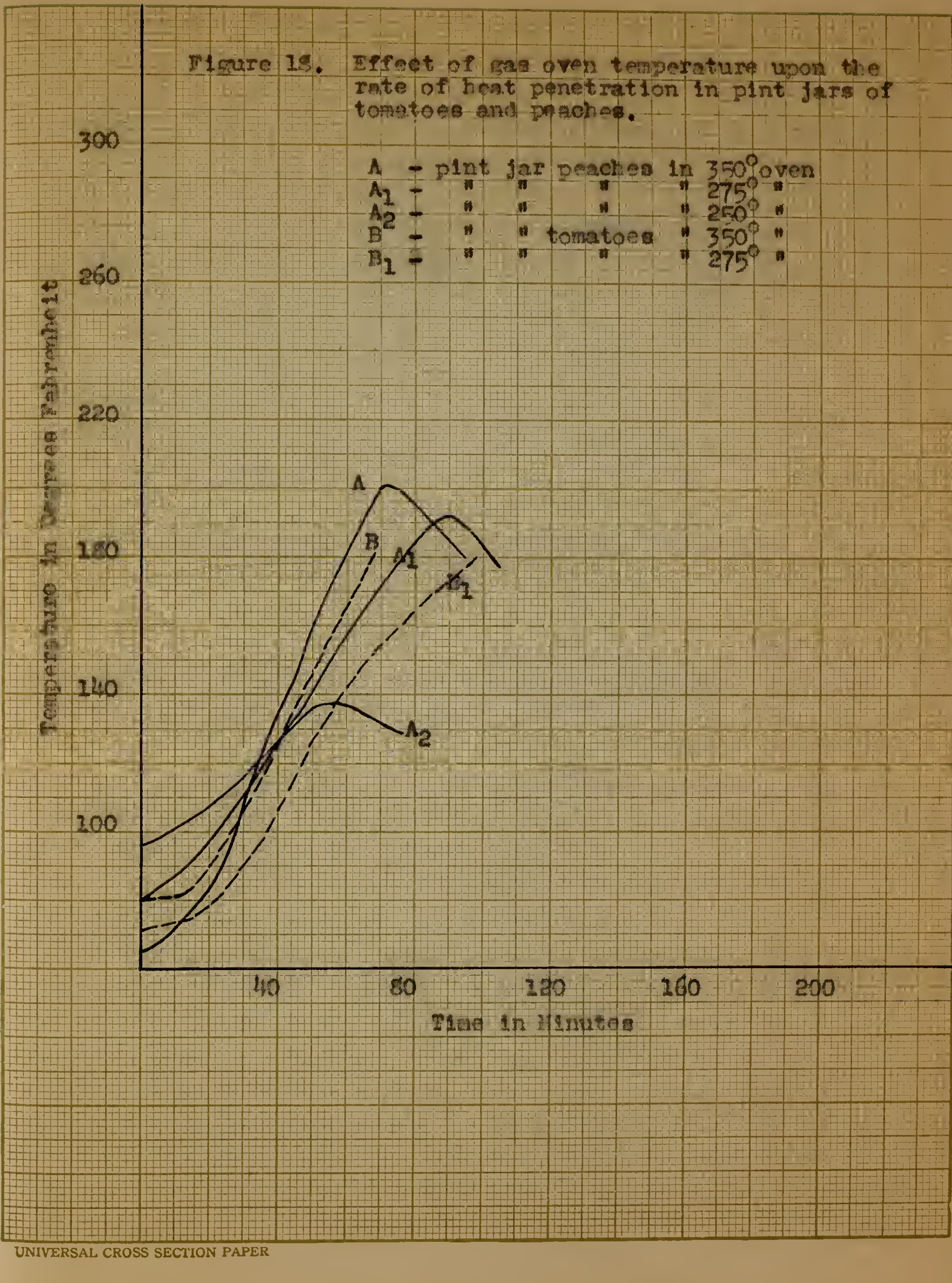
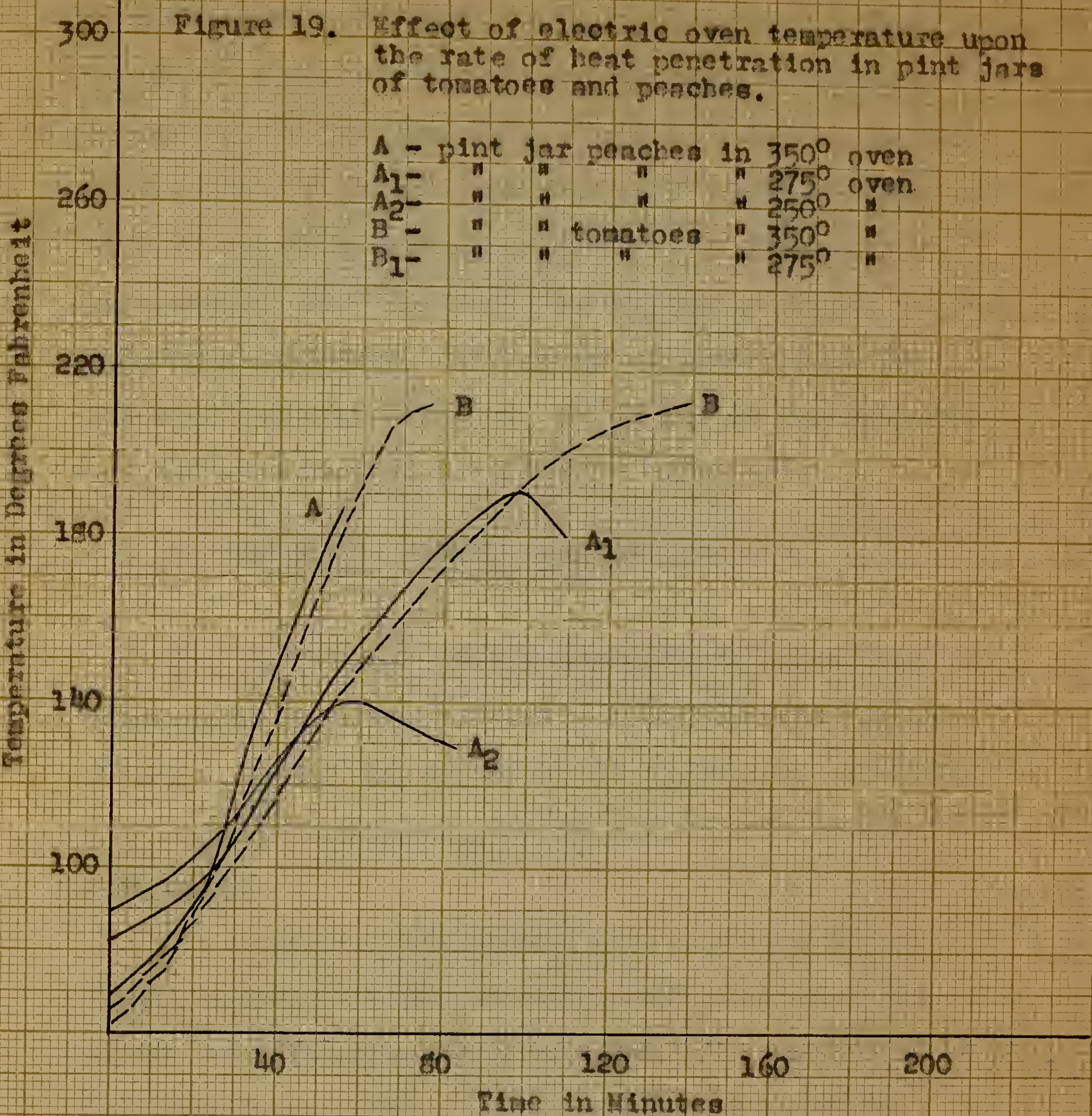



Figure 18. Effect of gas oven temperature upon the rate of heat penetration in pint jars of tomatoes and peaches.

Figure 19. Effect of electric oven temperature upon the rate of heat penetration in pint jars of tomatoes and peaches.

A - pint jar peaches in 350° oven
$A_1$- " " " " 275° oven
$A_2$- " " " " 250° "
B - " " tomatoes " 350° "
$B_1$- " " " " 275° "

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180°. It required 57 minutes at 350° and 92 minutes at 275° to heat the center of a pint jar of peaches to 187.5°. The gas oven heated tomatoes to 180° in 68 minutes at 350° and in 97 minutes at 275°. Peaches were heated in the gas oven to 187.5° in 63 minutes at 350° and in 81 minutes at 275°. The peaches were processed at 250° for only 40 minutes, as some companies recommend. At the end of that period the internal temperature of the center jar in the gas oven was 128° and that in the electric oven 126°.

### 5. Effect of Initial Temperature of Jar Contents

A thorough study of the effect of initial temperature upon the rate of heat penetration was not feasible during the course of this research. However, the initial temperature was studied to some extent with corn.

The corn was blanched and cut from the cob. Eleven ounces of corn, one teaspoonful salt and five ounces of boiling water were packed into a pint jar and processed at once. Corn packed in this manner had an initial temperature of 104 - 112°. Corn, water and salt were mixed in the same proportions as above and brought to the boiling point before packing. This

corn had an initial temperature of 148° - 164°. Figures 20 and 21 show the rate of heat penetration in both the hot and the cold packed corn in 275° preheated ovens, with a 9-jar load.

| | Initial Temperature °F. | Time to Reach 212° F. | Oven |
|---|---|---|---|
| Packed hot | 152 | 63 min | Electric (center jar) |
| " " | 148.8 | 54 " | " (corner " ) |
| " " | 163.3 | 82 " | Gas (center " ) |
| Packed cold | 109 | 137 " | Electric ( " " ) |
| " " | 112 | 148 " | " (corner " ) |
| " " | 104.2 | 130 " | Gas (center " ) |

The corn packed hot would be at the boiling temperature from 98 to 126 minutes during a three-hour process, while that which was packed cold would be boiling only from 32 to 50 minutes out of the same processing period.

6. Maximum Temperature Reached in Jars of Foods Processed in an Oven

The maximum temperature reached in jars of oven-processed foods during these experiments did not rise above 212° F. Since the jars were only partially sealed the maximum temperature could not be above that

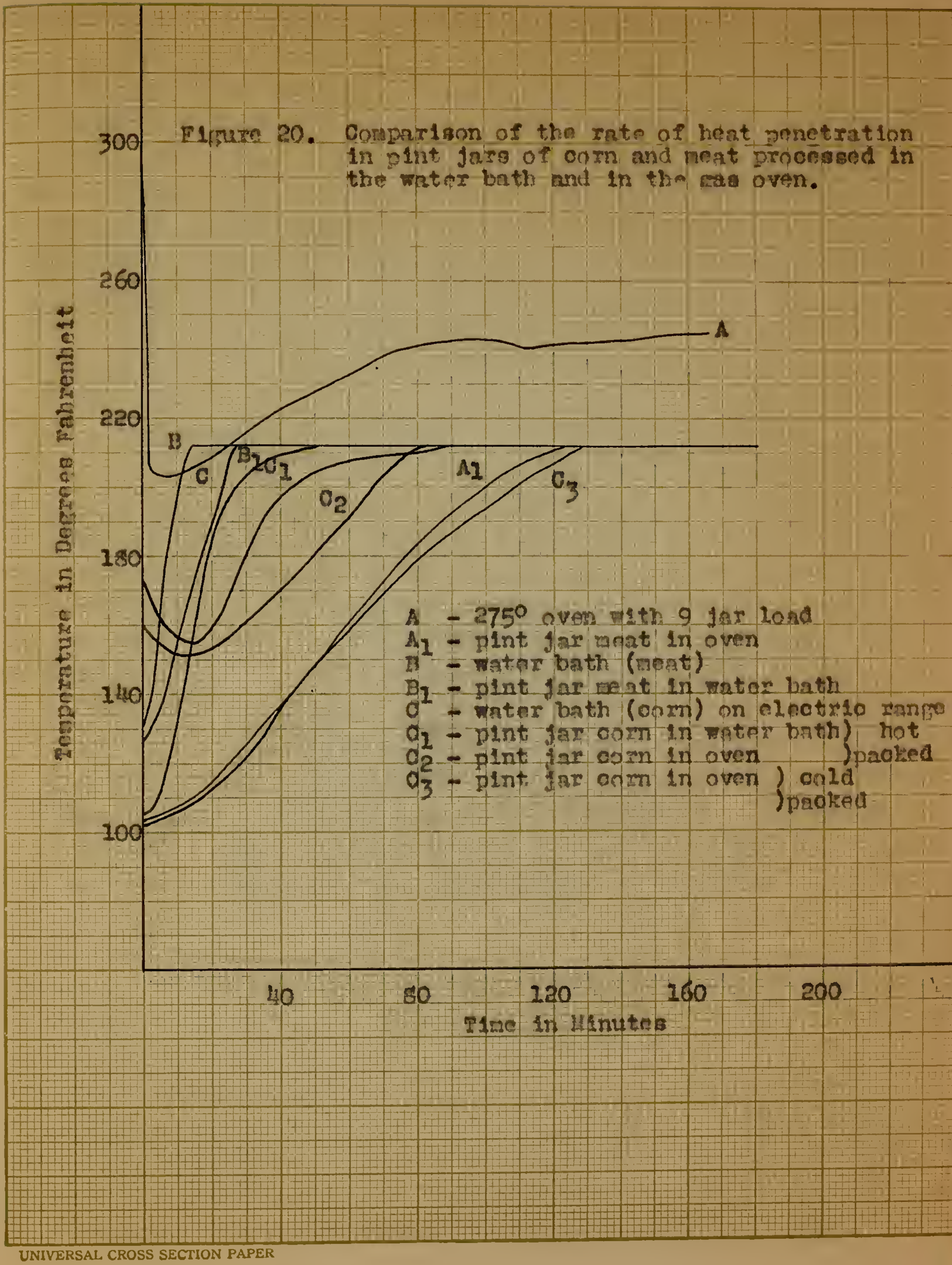


Figure 20. Comparison of the rate of heat penetration in pint jars of corn and meat processed in the water bath and in the gas oven.

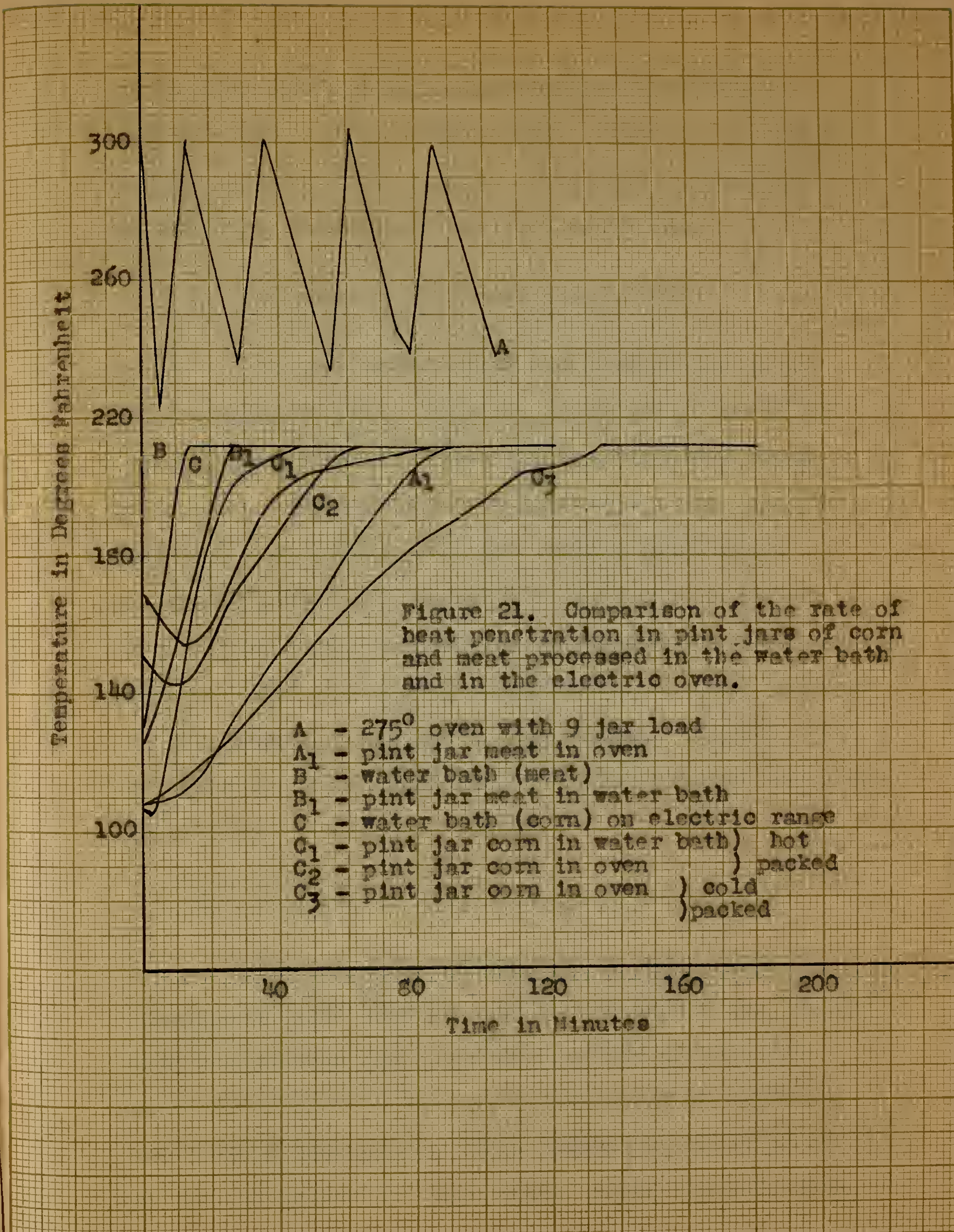


Figure 21. Comparison of the rate of heat penetration in pint jars of corn and meat processed in the water bath and in the electric oven.

of boiling water unless considerable quantities of sugar or some other material was present to raise the boiling point of the liquid. This agrees with work reported by Steinbarger (13) and Greer (4).

7. Preheated and Non-preheated Ovens

No particular study was made of the value of a preheated oven. However, in studying the effect of oven load both preheated and non-preheated ovens were used. The rate of heat penetration was somewhat variable, especially with the smaller oven loads. Preheating the oven, especially for loads no larger than 6 pint jars, is probably an unnecessary waste of time and fuel and can be eliminated by a small increase in the length of the processing period. However, with the oven filled to capacity, the preheating of the oven is probably a factor of safety.

8. Temperature in Various Parts of the Jar

It was observed during the processing of tomatoes to 180° that as soon as the center jar reached that temperature and the oven door was opened, the contents of some of the other jars would be bubbling and boiling vigorously. This raised the question as to the variations in temperature within the jar. This

was studied by the use of three thermocouples fitted into a jar through a specially constructed lid (Plate 5). One thermocouple was placed in the center of the jar, one three-sixteenths of an inch from the side of the jar, and the third half way between these two. The heat penetration into a pint jar of corn being processed in the oven was studied by this means. The results are given in Figure 22. The difference in temperature of these three positions became less as the temperature of the food increased. The center of the jar was 10 minutes longer in reaching the boiling point than was the outer portion of the jar. Similar results were obtained by Chenoweth (3) in water bath studies with corn, squash, tomatoes and spinach.

### 9. Effect of Oven Processing Upon the Elasticity of Rubber Rings

The effect of oven heat upon the elasticity of the jar rings was tested with a stretching device (Plate 6) which measured the length of the rubber at various tensions. A small spring scale was attached to a string which led over a pulley and fastened to a wheel. The rubber ring was attached at one side to a standard and at the other to the hook on the scale. The scale was

Plate 5. Apparatus used for determining the temperature in various parts of the jar.

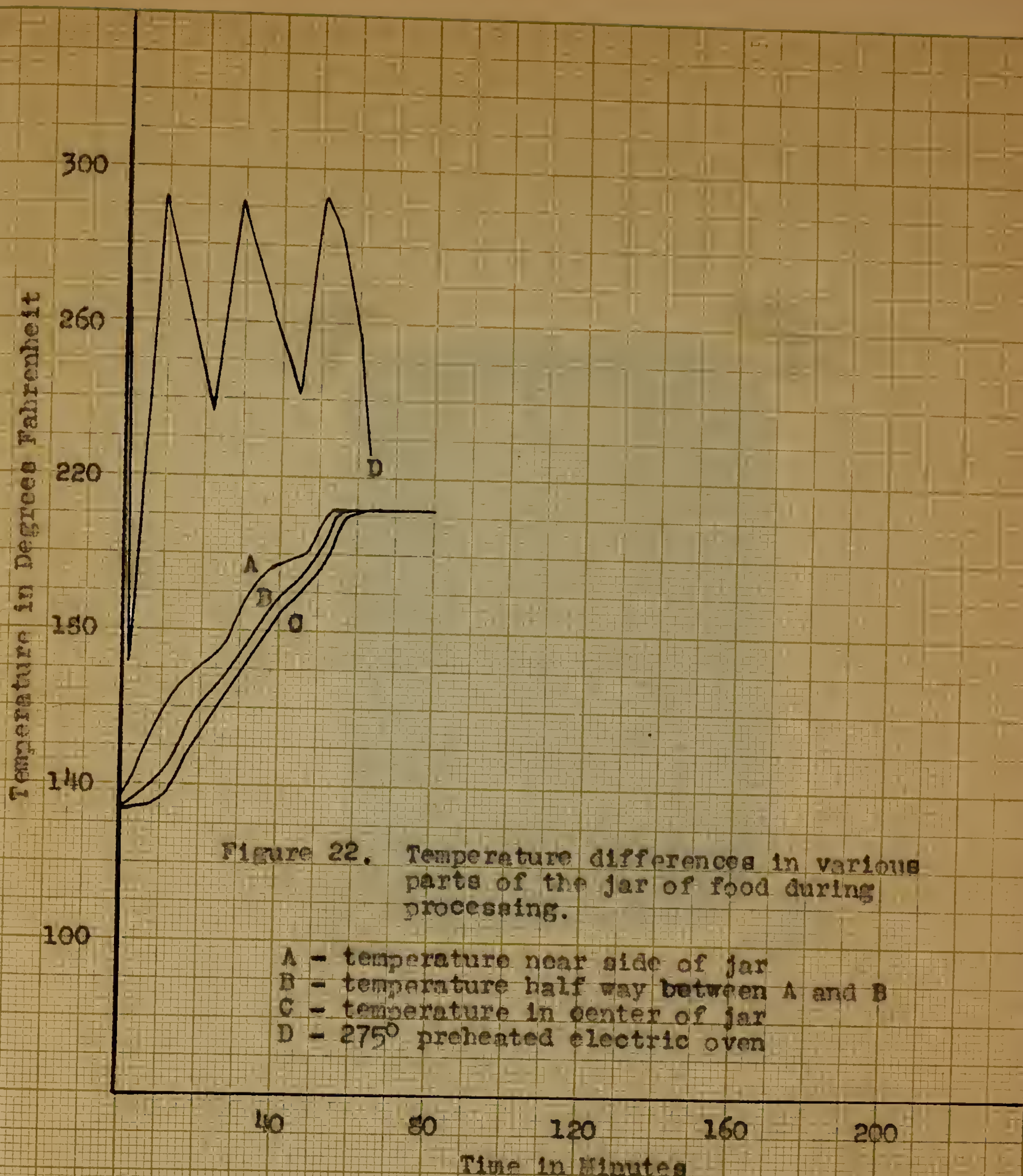


Figure 22. Temperature differences in various parts of the jar of food during processing.

Plate 6. Apparatus used to test elasticity of rubber jar rings.

raised by turning the wheel and the length of the stretched rubber was measured by means of a ruler attached to the front of the machine.

A number of the unused rubbers served in each case as controls. The limit of elasticity was determined for the controls by stretching them to a point where they would not quite resume their original shape and size. The number of pounds pull or tension for this stretch was used as a standard in testing the used rubbers. The reading of the scale changed so rapidly after the rubber was stretched that it was necessary to stretch the rubber with the required pounds pull, leave it for one minute, and readjust to the original pull before taking the measurement of the rubber.

The results of these tests are given in Table 3. The oven processing seemed to take the life out of the plain rings used on jars of tomatoes. The rings were stiff and cracked and they all broke during the first of the stretch before a tension of 15 pounds could be reached. Processing in either dry or moist heat destroyed some of the elasticity of all rings tested. Plate 7 shows the difference in elasticity between a stretched control ring and a stretched used

Table III. Elasticity of Used Rubber Jar Rings

| Type of Jar Ring | Product | Process | Number tested | Tension (pounds) | Average stretch (inches) | Extremes (inches) | |
|---|---|---|---|---|---|---|---|
| Plain (no lip) | - | Control | 6 | 15 | 7.2 | 7.06 - 7.37 | |
| " " " | Tomatoes | 275°F. oven for 145-165 min. | 5 | 15 | 9.45 | 8.75 -10.0 | Edges cracked - no life in rubber. All rings broke while being stretched. |
| Rings accompanying new jars | - | Control | 9 | 15 | 10.5 | 9.85-10.25 | |
| " " " | Tomatoes | 275°F. oven for 94 - 155 min. | 5 | 15 | 8.31 | 7.94- 8.62 | |
| " " " | Corn | 275°F. oven 3 hrs. | 14 | 15 | 13.36 | 12.25-13.75 | |
| New Good Luck | - | Control | 5 | 18 | 7.75 | - | |
| " " " | Meat | 275°F. oven - 4 hrs. | 12 | 18 | 12.6 | 11.75-14.5 | |
| " " " | Carrots | " " - 2½ " | 15 | 18 | 11.25 | 9.75-12.75 | |
| " " " | Carrots | " " Used repeatedly | 20 | 18 | 10.56 | 8.5 -11.5 | 1 ring broke |
| " " " | Meat | Water bath 4 hrs. | 20 | 18 | 10.7 | 9.75-11.75 | |
| " " " | Carrots | Water bath 2 hrs. | 10 | 18 | 10.3 | 10.0 -10.5 | |
| " " " | Meat | 10 lbs.- 90 min. Pressure cooker | 9 | 18 | 9.44 | 9.25- 9.75 | |
| " " " | Carrots | 10 lbs.- 35 min. Pressure cooker | 7 | 18 | 9.37 | 9.0 - 9.6 | |

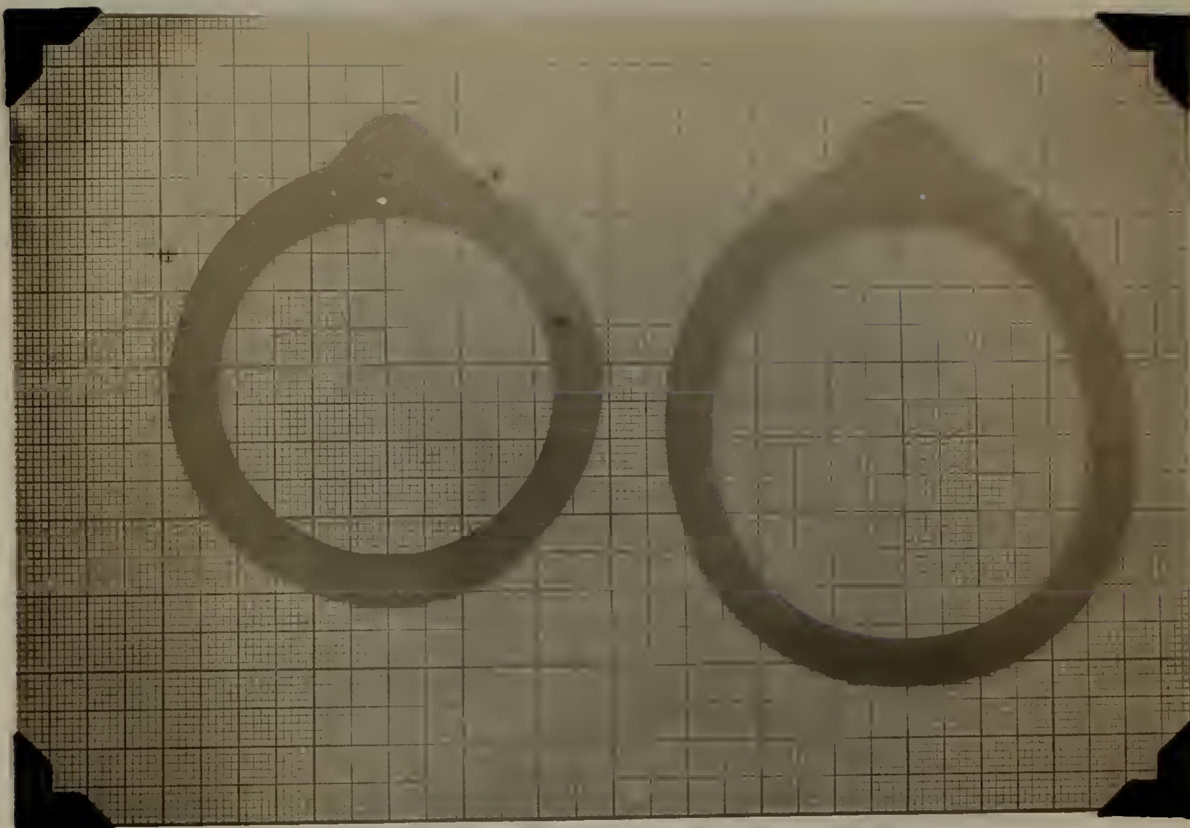

Plate 7. Good Luck rubber jar rings after being stretched to a tension of 18 pounds.

1. Unused rubber ring

2. Rubber ring from jar of meat processed in a 275° oven for 4 hours.

ring. The results of these tests indicate that oven processing has a greater destructive action upon the jar rings than does either steam pressure cooker or water bath processing.

### 10. Fuel Consumption of Oven Processing Compared to Hot Water Bath Method

A comparison was made of the fuel consumption of an oven canning process and that of a hot water bath process.

The water bath tests were made with a large rectangular processor which fully covered two of the top burners of either the gas or electric ranges. The processor (Plate 8) measured 18.5 x 12 x 10.5 inches and held 15 pint jars. It had a fairly close fitting cover. Five gallons of cold tap water were filled into the processor and heated as rapidly as possible. When the temperature of the water reached 130° the jars of food, prepared as for oven processing, were placed in the hot water bath. The lid of the processor was clamped on during both the preheating and the actual processing period. Water covered the jars to the depth of 1.5 to 2 inches. Time was counted from the moment the water began to boil. The fuel consumption was

Plate 8. Hot water bath processor

measured by means of meters attached to the ranges.

The fuel consumption of the ovens included the amount necessary to preheat the ovens for 30 minutes plus that required for a regular oven process. Thirty minutes were given for the preheating because that was the approximate time required for the ovens to become reasonably constant.

Carrots and meat were the two foods used for these tests. The carrots were prepared as previously described under "Effect of Oven Load." The meat was trimmed, cut in cubes, precooked by processing at 10 pounds pressure for 20 minutes, and allowed to cool. Twelve ounces of meat, one teaspoonful salt and four ounces of boiling liquor were filled into each pint jar.

The results of these tests are given in Table IV.

## 11. Temperature Equivalents of Water Bath Processing

It was necessary, during the course of these experiments, to have some standard for the end or finishing temperatures and length of processing periods. For this purpose, the generally accepted hot water bath processes were used as bases for comparison. The rate

Table IV. Results of Fuel Consumption Tests

| Test | Product | Length of process | Stove used | Fuel consumption for 30 min. pre-heating | Fuel used to heat the water bath 212° F. | Total consumption | Fuel consumption per jar |
|---|---|---|---|---|---|---|---|
| | | | | K.W. | K.W. | K.W. | K.W. |
| Water bath | 15 pints carrots | 90 min. | Electric | - | 3.0 | 4.8 | 0.32 |
| " " | 15 pints meat | 4 hrs. | " | - | 3.0 | 7.8 | 0.52 |
| Oven process | 9 pints carrots | 2½ hrs. | " | 0.4 | - | 1.9 | 0.21 |
| " | 9 pints meat | 4 hrs. | " | 0.3 | - | 2.4 | 0.266 |
| | | | | cu. ft. | cu. ft. | cu. ft. | cu. ft. |
| Water bath | 15 pints carrots | 90 min. | Gas | - | 29.5 | 44.5 | 2.966 |
| " " | 15 pints meat | 4 hrs. | " | - | 29.5 | 73.3 | 4.886 |
| Oven process | 9 pints carrots | 2½ hrs. | " | 8.75 | - | 31.25 | 3.47 |
| " " | 9 pints meat | 4 hrs. | " | 10.4 | - | 45.85 | 5.09 |

of heat penetration into the center of the jar processed in the water bath was recorded for each product used during these experiments.

In each case the food was prepared as for an oven process, the thermocouples were adjusted in the jars, the jars were placed in a water bath, which had a temperature of 130°, and the bath was heated to boiling as rapidly as possible. The water bath for the corn was heated on the large plate of the electric stove, that for tomatoes on the large burner of the gas stove, and the rest of the products were tested in a water bath processor heated by means of a steam coil.

After the water bath tests were completed, jars of the same products were processed in 275° ovens until they reached an equivalent finish temperature or until they had been at the boiling point for the same length of time as those canned in the water bath. The difference in the rate of heat penetration in the two methods is shown for peaches - Figures 16 and 17; tomatoes - Figures 14 and 15; carrots - Figures 23 and 24; corn and meat - Figures 23 and 24. They are summarized in Table V.

These figures show that the rate of heat penetration is much slower in a jar of food processed in the oven than in one processed in the water bath. For

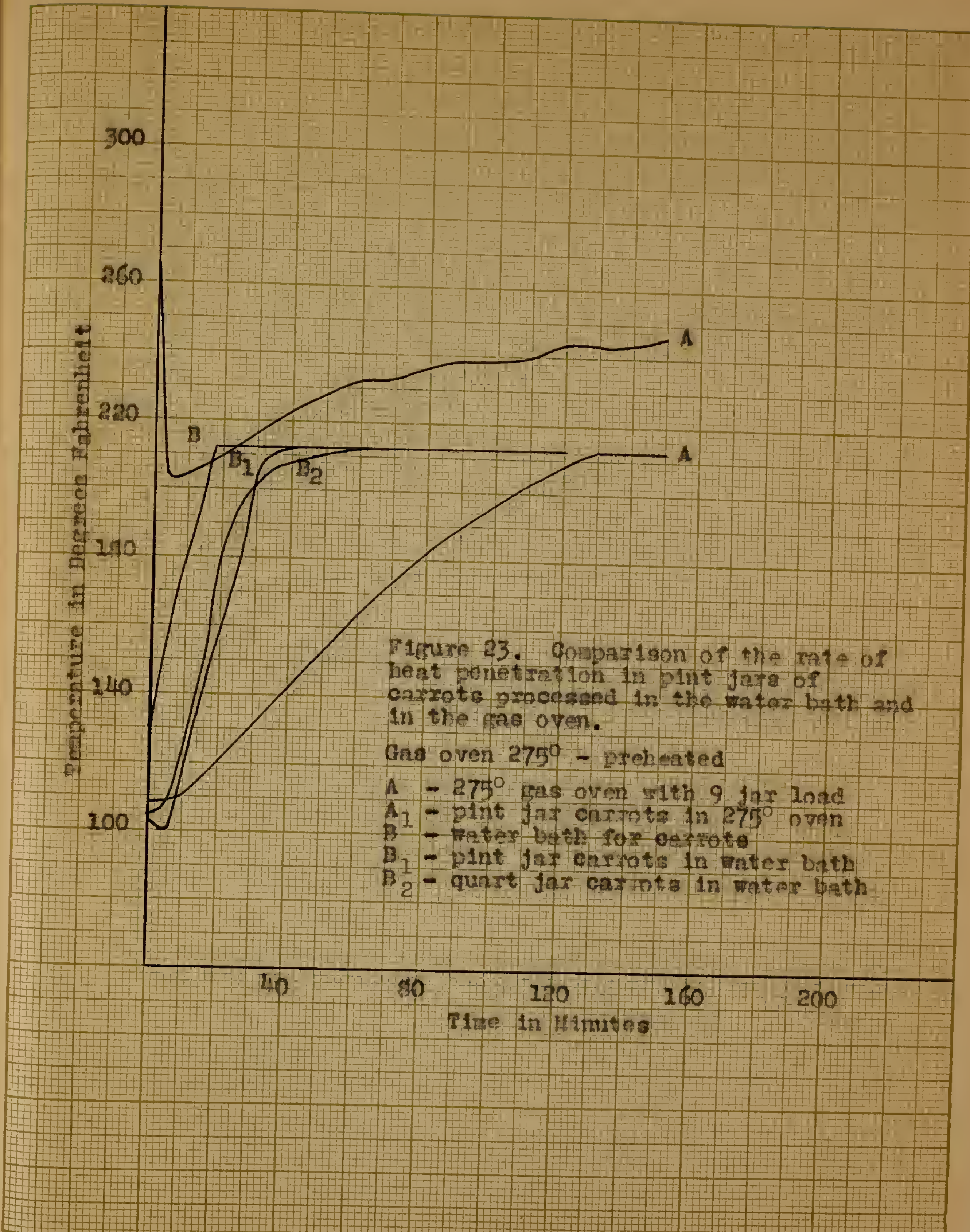


Figure 23. Comparison of the rate of heat penetration in pint jars of carrots processed in the water bath and in the gas oven.

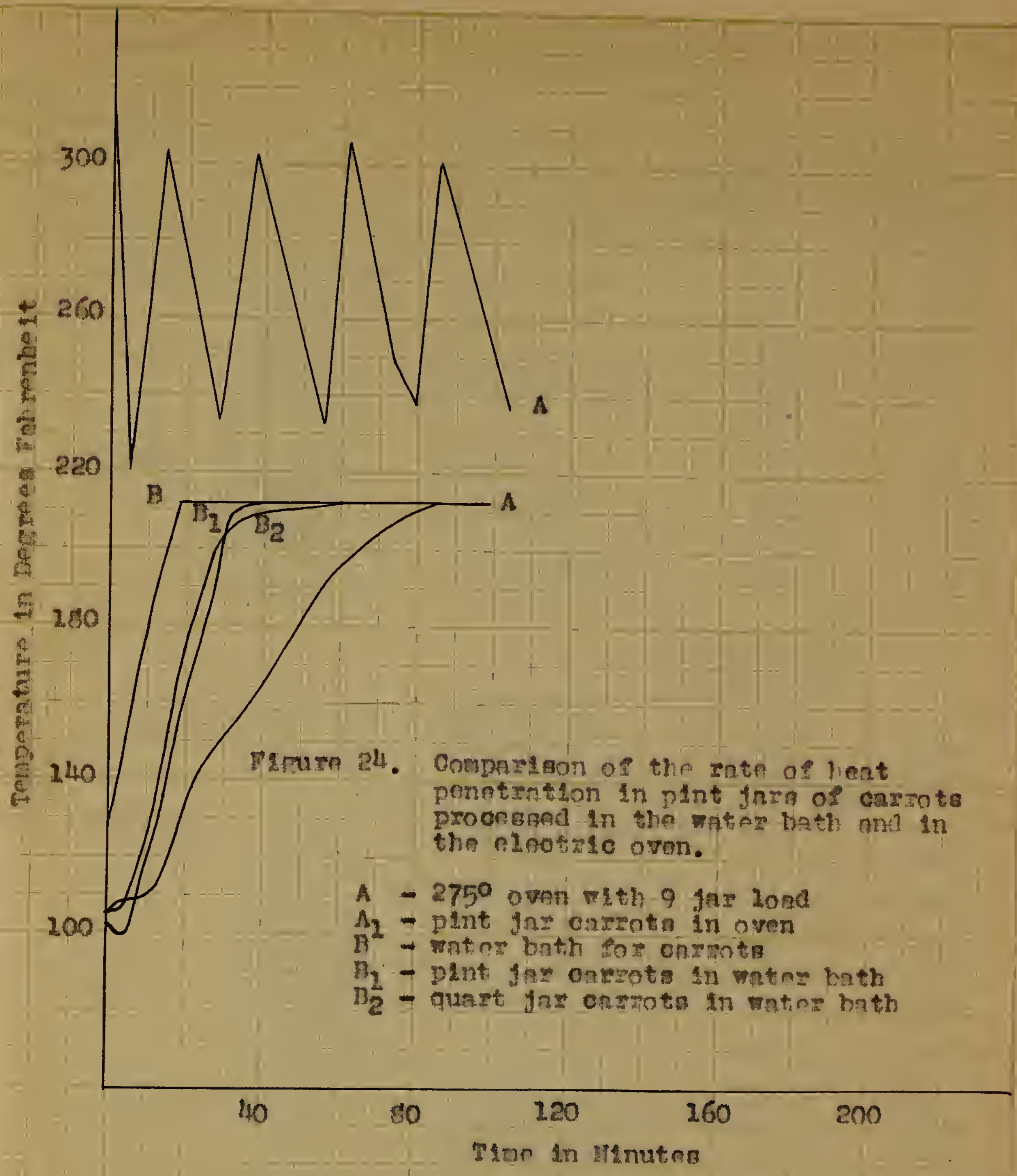


Figure 24. Comparison of the rate of heat penetration in pint jars of carrots processed in the water bath and in the electric oven.

A - 275° oven with 9 jar load
$A_1$ - pint jar carrots in oven
B - water bath for carrots
$B_1$ - pint jar carrots in water bath
$B_2$ - quart jar carrots in water bath

Table V. Water Bath Processing Equivalents for Gas and Electric Ovens

| Product | Method of Processing | Processing Time (Minutes) | Maximum Internal Temperature of Jars |
|---|---|---|---|
| Tomatoes, pint jar | Water bath | 30 | 190.8 |
| " quart " | " " | 40 | 180.4 |
| " pint " | Gas oven | 96 | 180 |
| " quart " | " " | 165 | 180 |
| " pint " | Electric oven | 82 | 180 |
| " quart " | " " | 145 | 180 |
| Peaches, pint jar | Water bath | 20 | 187.8 |
| " quart " | " " | 25 | 187.5 |
| " pint " | Gas oven | 83 | 187.5 |
| " quart " | " " | 130 | 187.5 |
| " pint " | Electric oven | 92 | 187.5 |
| " quart " | " " | 133 | 187.5 |
| | | Time required to reach 212° | |
| Carrots, pint jar | Water bath | 27 | 212 |
| " " " | Gas oven | 128 | 212 |
| " " " | Electric oven | 86 | 212 |
| Corn, " " (hot) | Water bath | 61 | 212 |
| " pint jar (hot) | Gas oven | 78 | 212 |
| " pint jar (cold) | " " | 130 | 212 |
| " pint jar (hot) | Electric oven | 63 | 212 |
| " pint jar (cold) | " " | 137 | 212 |
| Meat, pint jar | Water bath | 35 | 212 |
| " " " | Gas oven | 123 | 212 |
| " " " | Electric oven | 93 | 212 |

example the time required for quart jars to reach 180° in the water bath was about 1/3 to 1/4 as long as that required in the ovens. Similar results were obtained with the other products canned in the oven. In each case, the time required for a jar in the oven to reach the water bath temperature equivalent is much in excess of that usually recommended for oven processing. (See Table 1).

There was considerable variation between the results obtained from the two ranges and also among repeated tests made in the same oven. These and other variable factors make it almost an impossibility to work out an effective time table for oven processing.

## 12. Bacteriological Examination of Oven Processed Foods.

A comprehensive bacteriological study of oven canned foods was not feasible during the course of these investigations. However, sample jars of the various foods processed for different lengths of time and at different oven temperatures were incubated at a temperature of 90° for several weeks and then examined by organoleptic and bacteriological tests.

The organoleptic tests of spoilage included appearance, odor, and suction as described by Sunderlin, Levine, and Nelson (14). Bacterial counts were determined by incubating plates made from the canned foods three days on nutrient agar at approximately 90°. The tests for thermophilic organisms were incubated at 131°. The tests for anaerobes were made in tubes of casein digest agar sealed with petrolatum. The tomatoes and peaches were not examined for anaerobes and thermophiles because thermophilic spoilage in fruits is rarely encountered. The results of these tests are given in Tables VI, VII and VIII.

The percentage of jars showing poor seals and little or no vacuum was surprisingly high. To determine whether this was a result of oven processing or of a faulty type of jar, vacuum tests were made on jars of food processed by one of three different methods; hot water bath, steam pressure cooker, and oven processing. The porcelain was removed from the Mason jar lids so that the vacuum could be determined. The results were as follows:

Table VI. Bacteriological Examination of Oven Canned Foods

| Product | No. of jars | No. of sterile jars | Number of jars showing | | | | |
|---|---|---|---|---|---|---|---|
| | | | Poor seal & vacuum | Dark-ening | Yeast | Mold | Aerobes |
| **Tomatoes** | | | | | | | |
| Gas oven 275° | | | | | | | |
| Pts. to 190° | 3 | 3 | Seals and vacuums poor but the number was not recorded | - | - | - | - |
| " " 200° | 2 | 2 | | - | - | - | - |
| " " 212° | 3 | 3 | | - | - | - | - |
| " " 180° | 7 | 7 | | - | - | - | - |
| Qts. " 180° | 4 | 4 | | - | - | - | - |
| Gas oven 350° | | | | | | | |
| Pts. to 180° | 3 | 3 | | - | - | - | - |
| " " 190° | 2 | 2 | | - | - | - | - |
| " " 212° | 2 | 2 | | - | - | - | - |
| Electric oven 275° | | | | | | | |
| Pts. to 190° | 3 | 3 | | - | - | - | - |
| " " 200° | 2 | 2 | | - | - | - | - |
| " " 212° | 2 | 2 | | - | - | - | - |
| " " 180° | 7 | 6 | | - | - | - | 1 |
| Qts. to 180° | 5 | 5 (1 doubt-ful) | | - | - | 1 | - |
| Electric oven 350° | | | | | | | |
| Pts. to 180° | 3 | 3 | | - | - | - | - |
| " " 190° | 2 | 2 | | - | - | - | - |
| " " 212° | 2 | 2 | | - | - | - | - |

Table VII. Bacteriological Examination of Oven Canned Foods

| Product | No. of jars | No. of sterile jars | Number of jars showing: Poor seal & vacuum | Darkening | Yeast | Mold | Aerobes |
|---|---|---|---|---|---|---|---|
| <u>Peaches</u> | | | | | | | |
| Gas oven 275° | | | | | | | |
| Pts.-35 Min. | 3 | - | 3 | 3 | - | 3 | 1 |
| " to 187.5° | 2 | 2 | 1 | 1 | - | - | - |
| " -50 min. | 3 | 1 | 3 | 3 | 2 | 2 | 2 |
| " -70 min. | 5 | 3 | 5 | 4 | - | 2 | - |
| Qts. -35 min. | 3 | 0 | ? | 3 | 3 | Not tested | |
| " to 187.5° | 5 | 5 | ? | - | - | - | - |
| Gas oven 350° | | | | | | | |
| Pts. -35 min. | 3 | 3 | - | - | - | - | - |
| " to 187.5° | 5 | 5 | - | - | - | - | - |
| Gas oven 250° | | | | | | | |
| Pts. -35 min. | 3 | 0 | ? | 3 | 3 | - | 3 |
| Electric oven 275° | | | | | | | |
| Pts. -35 min. | 3 | 1 | 3 | 3 | 1 | 1 | 1 |
| " to 187.5° | 3 | 3 | 2 | 2 | - | - | - |
| " -50 min. | 3 | 3 | - | - | - | - | - |
| " -70 min. | 5 | 5 | 1 | 1 | - | - | - |
| Qts. -35 min. | 3 | 0 | ? | 3 | 3 | Not tested | |
| " to 187.5° | 5 | 5 | ? | - | - | - | - |
| Electric 350° | | | | | | | |
| Pts. -35 min. | 3 | 3 | 1 | 1 | - | - | - |
| Electric 250° | | | | | | | |
| Pts. -40 min. | 3 | 0 | ? | 3 | 3 | - | 3 |

Table VIII. Bacteriological Examination of Oven Canned Foods

| Product | No. of jars used | No. of sterile jars | Number of jars showing | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Poor seal & vacuum | Darkening | Yeast | Mold | Aerobes | Anaerobes | Thermophiles |
| **Corn** | | | | | | | | | |
| Gas 275° | | | | | | | | | |
| Pts.-3 hrs. (hot) | 3 | - | 1 | - | - | - | 3 | - | 2 |
| " -3 hrs.+ preheat (hot) | 4 | - | 3 | - | - | - | 4 | - | 1 |
| " -3 hrs. (cold) | 1 | 1 | - | - | - | - | - | - | - |
| Electric oven 275° | | | | | | | | | |
| Pts.-3 hrs. (hot) | 3 | - | 1 | - | - | - | 2 | - | 1 |
| " -3 hrs.+ preheat (hot) | 4 | - | 3 | - | - | - | 4 | - | 1 |
| " -3 hrs. (cold) | 1 | - | 1 | - | - | 1 | 1 | - | - |
| **Carrots** | | | | | | | | | |
| Gas oven 275° | | | | | | | | | |
| Pts.-2½ hrs. | 8 | 8 | 6 | - | - | - | - | - | - |
| Electric oven 275° | | | | | | | | | |
| Pts.-2½ hrs. | 7 | 6 | 5 | - | - | - | - | 1 | - |
| **Meat** | | | | | | | | | |
| Gas oven 275° | | | | | | | | | |
| Pts.-4 hrs. | 6 | 3 (1 doubt-ful) | 5 | - | - | - | 2 | 3 (1doubt-ful) | - |
| Electric oven 275° | | | | | | | | | |
| Pts.-4 hrs. | 6 | 3 (1 doubt-ful) | 2 | - | - | - | 2 | 4 (2 doubt-ful) | - |

| Product | Method of Processing | Number of Jars Tested | Number of Jars Having Little or no Vacuum |
|---|---|---|---|
| Carrots | Water bath 2 hrs. | 20 | 13 |
| Meat | " " 4 hrs. | 20 | 5 |
| Carrots | Pressure cooker (10 lbs.- 35 min.) | 4 | 2 |
| Meat | Pressure cooker (10 lbs. - 90 min.) | 6 | 1 |
| | Totals | 50 | 21 |

Slightly more than 40 per cent of the jars that were tested had very little (under 6 inches) or no vacuum. This indicates that the type of jar used does not give a satisfactory seal. Just how much this factor may influence the results of the bacteriological examinations herein reported cannot be estimated. Sunderlin, Levine, and Nelson (14), reported that of the different tests used, change in vacuum ranked lowest with respect to the detection of spoilage of canned foods. While there was a fairly high percentage of spoilage among the poorly sealed jars, there were also many with poor seals that were sterile. Microorganisms were likewise found in some jars that had high vacuums. Six of the 15 jars of spoiled corn had high vacuums and 9 had low vacuums.

Four of the spoiled jars of meat had high vacuums. Practically all of the poorly sealed jars of peaches were sterile, although they showed darkening.

Out of 52 jars of tomatoes that were incubated and examined bacteriologically only one contained viable molds and another saprophytic aerobes. The rest of them gave negative bacteriological tests. Yeasts and molds were the principal organisms found in the spoiled jars of peaches although many of the jars that were processed for only 35 to 40 minutes also contained aerobes. The darkening of the peaches was probably due to poorly sealed jars in the case of the longer processing periods and to insufficient heat to destroy oxidative enzyme action in the shorter processing periods.

The spoilage of corn was due to a variety of microorganisms including thermophiles and aerobic spore-forming organisms, 15 jars showing the presence of the former and 14 jars the presence of the latter.

Only one jar of carrots showed the presence of anaerobes; the rest were sterile. Active spoilage was not observed in the jars of meat but 4 jars contained spore-forming aerobes and 7 contained anaerobes,

all in the inactive spore state.

These data indicate that many of the common spoilage microorganisms are not destroyed in jars of food subjected to the recommended oven processing periods. However, due to the poor seals on the Mason type of jar, too far reaching conclusions cannot be drawn as a result of the bacteriological findings. It may be pointed out that spore-forming bacteria, both aerobes and anaerobes, may be present in the spore state in apparently sound canned foods without active growth or any evidence of spoilage. This finding is in accord with results reported by other investigators, i.e., that sterility tests in themselves are unreliable means of ascertaining the keeping quality or freedom from spoilage in canned foods. Incubation tests of the canned products themselves is a better criterion of their bacteriological quality. The mere presence of bacterial spores in canned foods is insufficient evidence on which to judge the fitness or wholesomeness of canned foods.

13. Liquid Content of Oven Processed Jars

One of the objectionable features of oven canning is the loss of liquid from the jars. The

amount of expelled liquid varies with the oven temperature, the particular type of oven and the length of the processing period.

Plate 10 shows the difference in liquid content of jars of tomatoes processed in 275° and 350° ovens. Plate 13 shows peaches canned in 350° ovens to 187.5°. This difference was apparent with other foods similarly processed and was more noticeable with jars of food having an internal temperature of 212° than with those reaching only an internal temperature of approximately 180°.

The loss of liquid from the jars varied with the oven used. Plates 10 and 14 show the difference between liquid levels of tomatoes and corn canned in the gas and the electric ovens. The greater loss of liquid from jars in the electric oven seemed to be due to some sort of a pumping action, the maximum loss occurred at the time maximum temperature peaks were reached in the oven.

There was less liquid in long-processed jars than in short-processed jars. Tomatoes heated to 212° lost more liquid than those heated only to 180°. Corn processed 3 hours lost more liquid than carrots

processed 2½ hours. The liquid in the jars of corn extended only 1/2 to 2/3 the height of the jar. Plate 14 shows pint jars of beef which were processed 4 hours in the oven. The liquid level in some of these jars was extremely low.

This loss of liquid from oven-canned jars of food not only spoiled the attractiveness of the jars but affected the quality of the food as well. The food above the liquid became dry, tough, and caramelized. This was especially true of the corn and meat.

## VI. Foods Used in Oven Canning Studies

### 1. Tomatoes

Pint jars of tomatoes were prepared as previously described and processed in 275° ovens, to internal temperatures of 180°, 190°, 200° and 212°. A 350° oven was used to process similar loads to 180°, 190 , and 212°. Plate 9 compares the jars of tomatoes processed at these two oven temperatures. There was an excessive loss of liquid from the jars processed at 350°. Plate 10 also shows the effect of oven temperature upon pint jars of tomatoes.


Plate 9. Effect of Oven Temperature

| 350° Ovens | | 275° Ovens | |
|---|---|---|---|
| 1. | Electric - 180° | 9. | Electric - 180° |
| 2. | " " | 10. | " " |
| 3. | Gas - 180° | 11. | Gas - 180° |
| 4. | " " | 12. | " " |
| 5. | Gas - 190° | 13. | Gas - 190° |
| 6. | " - " | 14. | " - " |
| 7. | Electric - 190° | 15. | Electric - 190° |
| 8. | " " | 16. | " " |

Plate 10. Effect of Oven Temperature

| | |
|---|---|
| 1. 350° electric oven | 5. 350° gas oven |
| 2. " " " | 6. " " " |
| 3. 275° electric oven | 7. 275° gas oven |
| 4. " " " | 8. " " " |

These jars were removed from the oven as soon as they reached an internal temperature of 212°.

There was practically no spoilage of the oven canned tomatoes. They were all processed to an internal temperature of 180° or more and this was equivalent to temperatures obtained in the hot water bath method.

Quart jars of tomatoes (Plate 11) processed to 180° were sterile with one possible exception. The pints as well as quart jars of tomatoes were unattractive in appearance, especially those processed to a high internal temperature. The best tomatoes, from the standpoint of appearance and flavor, were those processed in a 275° oven to a maximum temperature of 180°. The quality of the product decreased in proportion to increase in the oven temperature and any increase in the length of the processing period.

2. Peaches

Pint jars of peaches, prepared as previously described, were canned in 250° ovens for 40 minutes, (Figures 18 and 19), a process recommended by some companies. At the end of that time the internal temperature of the jars was only 126.5 to 127.5°. The peaches in the tops of the jars became darkened and all of the jars fermented within a week after being processed.

Plate 11. Quart jars of tomatoes processed to an internal temperature of 180°.

Top row--canned in 275° electric oven

Lower row--canned in 275° gas oven

The next process used was that of a 275° oven for 35 minutes for both pints and quarts. The pint jars at the end of the period had reached an internal temperature of 115-121° and the quart jars had reached only 93 - 95° (Figures 16 and 17). Five of the 6 pint jars (Plate 12) and all of the quart jars processed at 275° for 35 minutes were lost by spoilage. Pint jars were also processed at 350° for 35 minutes (Figure 18) and not one of the 6 jars incubated from this process spoiled. Their internal temperature was 122-127°. Plate 12 shows jars of peaches processed at 275° and 350° for 35 minutes. There is considerably more darkening in the jars processed at 275° than in those canned at 350°. In some cases the extreme darkening extended half the height of the jar.

Pint jars of peaches were canned in 275° and 350° ovens to 187.5° (Plate 13) or the water bath temperature equivalent for peaches (Figures 16 and 17). Quart jars were also processed to this temperature in 275° ovens. Plate 14 shows the appearance of quart jars of oven canned peaches. The level of the liquid in the jars should be especially noted. Not a single jar of these peaches processed to 187.5° was lost by spoilage.

Plate 12. Pint jars of peaches processed in 275° and 350° ovens for 55 minutes.

1-3. 275° electric oven
4-6. " gas oven
7-8. 350° electric oven
9-11. " gas oven

Plate 13. Pint jars of peaches processed in 350° ovens to the water bath temperature equivalent of 1[illegible]7.5°.

Top row. gas oven
Lower row. electric oven

Plate 14. Quart jars of peaches processed to the water bath temperature equivalent of 187.5°.

1-3. 275° electric oven

4-5. 275° gas oven

Pint jars of peaches canned in 275° ovens for 50 minutes reached internal temperatures of only 138 - 153°. Those canned at this temperature for 70 minutes reached 165 - 183°. Two jars out of 6 processed for 50 minutes spoiled, and 2 out of the 10 processed 70 minutes spoiled.

3. Carrots

Pint jars of carrots, prepared as previously described, reached an internal temperature of 212° in the water bath in 27 minutes. This would mean that carrots processed 2 hours in a water bath would be at or near the boiling temperature for 93 minutes. Pint jars of carrots required 86 - 128 minutes in a 275° oven to reach the boiling point (Figures 23 and 24). These carrots were at 212° for only 22 - 64 minutes out of a 2½ hour oven process.

Pint jars of carrots were processed 2½ hours in 275° ovens and only 1 out of 15 jars was lost by spoilage.

4. Corn

Corn, that was heated to boiling before packing into the jars, was processed in 275° ovens

for 3 hours only in one case and for 3 hours plus the time required for the corn to reach an internal temperature of 212° in the second trial. This hot-packed corn reached the boiling temperature in the water bath in 61 minutes and in the ovens in 63 to 78 minutes. (Figures 20 and 21). Corn packed in the jars cold and covered with boiling water required 130 to 137 minutes in a 275° oven to reach 212°. The hot-packed corn was at the boiling temperature 102 to 117 minutes and the cold-packed corn only 43 to 50 minutes during a 3 hour processing period.

Fourteen pint jars of hot-packed corn and 2 pint jars of cold-packed corn, processed in 275° ovens for 3 hours, were incubated and tested for spoilage. Only 1 jar was sterile and that was one that had been cold-packed. Most of the corn was sour and spoiled and contained thermophilic and aerobic spore-forming organisms. Some of the corn had become dry and caramelized on top.

5. Meat

Pint jars of beef, prepared as previously described, were processed for 4 hours in 275° ovens (Plate 15). They required 93 - 123 minutes to reach

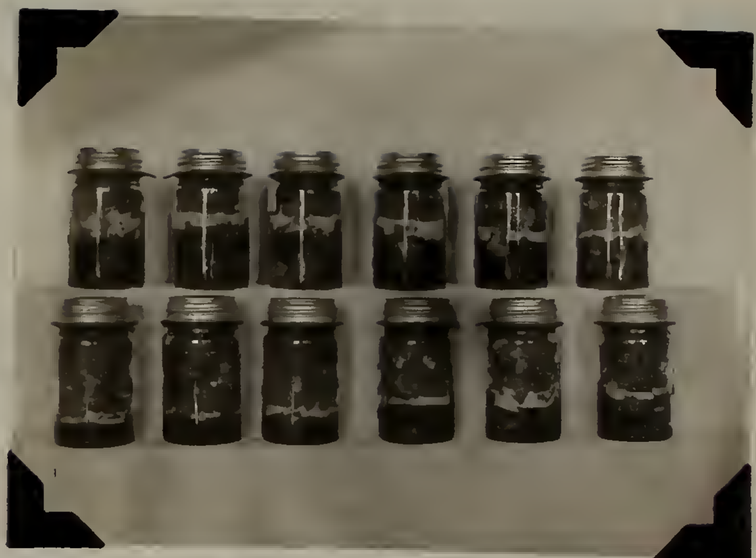

Plate 15. Pint jars of beef processed 4 hours in 275° ovens.

Top row. Gas oven

Lower row. Electric oven

212° in the ovens as compared with 35 minutes in the hot water bath (Figures 20 and 21). Six of the 12 jars of meat that were incubated showed the presence of aerobes, anaerobes or both. However, active spoilage was not observed. The liquor level in the jars was very low and the meat above it was dry, scorched, tough, and inedible.

## VII. Summary

1. All of the heat-controlled, insulated gas and electric ovens tested differed widely in their behavior. Even with the heat controls set for the same temperature, foods canned in these ovens would vary considerably in the time they required to reach a maximum or an end temperature. For this reason it is impossible to make a time table for oven canning that will be effective for all ovens.

2. The gas oven was affected considerably by the size of the oven load. An increased load meant a decreased maximum oven temperature and a decrease in the rate of heat penetration into the jars.

3. The size of oven load did not have such a noticeable effect upon the oven temperature and rate of heat penetration in the electric oven as it did

in the gas oven. Although there were variations both in the oven temperatures and in the rate of heat penetration, these could not always be correlated with the size of the oven load.

4. There was a difference of from 3 to 15 minutes in the time required by jars in the corner and in the center of the oven to reach finish temperature. The rate of heat penetration was more rapid in the center jar with a 3-jar load and in the corner jar with a 6 or 9-jar load.

5. The effect of the position of a jar in the oven was influenced by the size of the load and, in the case of the electric, by the size of the drip pan used.

6. The size of the jar used is an important factor in determining the rate of heat penetration to the center of the jar.

7. The rate of heat penetration is more rapid in a jar processed in 350° oven than in one processed in a 275° oven. It is also more rapid in a 275° oven than in a 250° oven.

8. There is a greater loss of liquid from jars processed in a 350° oven than from those in a 275° or

a 250° oven. The quality of the finished product is higher when a 275° oven is used than when a 350° oven is used.

9. The initial temperature of the jar's contents is an important factor in determining the length of time required to reach 212° or finish temperatures lower than the boiling point.

10. The maximum temperature reached in unsealed jars of food processed in an oven is approximately 212°.

11. Preheating the oven, especially for loads no greater than 6 pint jars, is probably an unnecessary waste of time and fuel and can be eliminated by a small increase in the length of the processing period.

12. There are differences in temperature in various parts of a jar of food during the processing period. Food at the center of the jar is coldest and that nearest the side is hottest. This temperature difference between the center and the exterior portion of the jar decreases as the food approaches 212°.

13. Oven processing has a greater deteriorating effect as measured by decreased elasticity upon rubber jar rings than does processing in either the hot water

bath or the steam pressure cooker. Marked quality differences were noted among several kinds of jar rubbers used in canning.

14. The fuel consumption per jar was slightly greater for jars processed in the gas oven than for those processed in a water bath heated on the gas range. The fuel consumption per jar was 1/3 to 1/2 less for those processed in the electric oven than for those processed in a water bath heated on the electric range.

15. The microorganisms present in understerilized peaches and tomatoes were largely yeasts and molds; in vegetables, spore-forming bacteria. The latter may often be present in canned foods without showing active growth.

16. Incubation of canned foods at warm temperatures is a better criterion of keeping quality than a bacteriological examination.

17. Data obtained during these studies indicate that many of the common spoilage organisms are not destroyed in jars of food subjected to the recommended oven processing periods.

18. The height of liquid was greater in the finished jars of foods canned in the gas oven than in foods canned in the electric oven.

19. The loss of liquid from jars in the electric oven seems to be due to a pumping action resulting from fluctuations in oven temperature. The maximum loss occurs at the time maximum temperature peaks occur in the oven.

20. The processing periods usually recommended for oven canning fall far short of the time required by oven canned foods to reach water bath temperature equivalents.

21. The loss of liquid from jars of oven canned food is objectionable not only from the standpoint of appearance and ease in handling but, as in the case of meat and some vegetables, from the standpoint of flavor and texture of the finished product.

22. Judged by the results obtained in this work, the Mason type of jar does not give an effective seal.

23. Oven canning is influenced by so many variable factors that it cannot be recommended as a safe method of food preservation.

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