SOME OBSERVATIONS RELATED TO THE EFFICIENCY OF HOME FREEZER UNITS

by

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INTRODUCTION

Low temperature has long been used as a method of food preservation. Since early times people who lived in cold climates made use of low temperature and unheated sheds as a means of preserving their meats, game, and fish.

Man has always been concerned with the preservation of food. People in different regions used different methods of preserving their food, depending upon their natural resources. Probably the earliest method of preservation was that of drying. Next in line would be curing, including smoking; spicing; pickling; and fermentation. Sterilization and canning was introduced around 1810. Man finally copied a natural means of preservation, freezing, and modified it for commercial and home use. All of these methods have been changed or improved in some manner until four general methods of preservation are now recognized. These are (1) drying or dehydration, (2) curing, (3) sterilization and canning, and (4) low temperature or freezing. It is this latter method as related to home storage units that is of concern in this paper.

Although none of these methods are new, it is only within the last thirty years that particular attention has been given to freezing as a method of food preservation. The commercial freezing of meat, other than fish or poultry, was first begun in the United States in about 1875 Boren (3). The artificial freezing of fish and poultry on a commercial basis was started in the United States in 1864 Boren (3). Prior to that time fish caught in the Great Lakes were frozen by allowing the fish to remain on the ice for a few hours. This system of freezing was known as "weather freezing" and is still used in winter in the Great Lakes region.

The first artificial freezing of fish was accomplished by placing the fish in a covered pan surrounded by ice and salt. Ammonia refrigeration was begun in the United States around 1880 (29). According to Pennington, (24) 1941, A. and E. Robbins froze poultry in 1865. Egg freezing dates back to 1889, when 100 five-gallon cans of shelled eggs were frozen (29). The freezing of small fruits began in the Eastern part of the United States in 1905. The real beginning meat freezing as it is known today dates from 1923, when Clarence Birdseye introduced the method of quick freezing now known as the Birdseye Method (2). The commercial freezing of vegetable, the most recent of all, was begun by the Birdseye organization in Hillsboro, Oregon, 1929. Today, more than 7,329,000 pounds of food is frozen annually excluding ice cream, cream, eggs, wholesale cuts of meat, and poultry. To this must be added more than 2,400,000,000 pounds of food frozen in locker plants and home freezers, making an estimated total of approximately 9,729,000,000 of food frozen annually in the United States. This is a tremendous increase over the 892,000 pounds frozen in 1935 (29).

This tremendous interest in frozen foods by the public did not come about overnight, but is the result of the foresight of the pioneers of scientific food preservation. They were searching for a method of preservation that would preserve natural flavor, color, and texture; and give maximum palatability and maximum nutritional value. Freezing is the method that came closest to preserving these characteristics (20) (35).

Much work has been done on the nutritional value of frozen food and the majority of the results show that the nutritional value of frozen foods, if handled properly, is not significantly different from that of the fresh product. This is true for foods frozen commercially or at home. However, the majority of the authors recommend quick freezing as opposed to slow freezing. Just what constitutes quick freezing has been somewhat controversal, and numerous definitions have been suggested. As far as this paper is concerned, quick freezing may be defined as "freezing at -20°F. or lower." Sharp freezing may be defined as "freezing at temperatures between 0°F. and -20°F.," and slow freezing is defined as freezing at temperatures above 0°F.

There are two types of home freezers, the walk-in type and the reach-in type. While the reach-in type is sold and popular in almost every region of the country, the walk-in type seems limited to the Pacific Coast region. There are two styles of the reach-in type home freezers, the chest or horizontal style and the upright or vertical style. The first home freezer on the market was the chest style which appeared in 1938. It was not until about 1940 that the upright or vertical style made its appearance on the market, and this was primarily the results of demands by the homemaker who expressed a desire for a freezer that opened in front and was equipped with shelves, similar in design to her refrigerator. However, it was 1950 before the manufacturer was fully sold on the upright style. Between 1953 and 1954 the sale of the chest style dropped from 67 percent of the total sale to 37 percent, according to the National Association of Electrical Merchandising. This association also noted that there was a decline in the number of smaller units (4.4 to 9.0 cu. ft.) and an increase in the sales of units that ranged from 12.0 cu. ft. to 18.0 cu. ft. (22).

The size and style of box a family buys depends upon the number in the family and family income. Consideration is given to initial cost, economy and efficiency of operation. These are important points to consider when selecting a home storage unit. This study was undertaken to obtain additional information on these and other points related in home storage, or freezer units.

REVIEW OF LITERATURE

All methods of food preservation have as their primary objective, the maintainance of food in an edible state and preservation of high nutritional value for a relatively short period of time, with minimum changes in its original quality.

Many authors have studied the influence of freezing and freezing rate on the nutritional value of the product. Tressler and Evers (28) stated that freezing gives greater protection against nutritional loss than any other method of preservation. Louder and Smith (19) compared frozen evaporated milk with that taken directly from the can, using rats as the experimental animal, and found that the rats made equal gains in weight on the two. Snow (26), Dyer (9), and Nikkils and Linko (23) showed that the deterioration of fish during freezing and storage, is partly due to the denaturation of the protein.

In 1934, Fellers, et al. (11), using the bioassay method, found that frozen asparagus contained as much vitamin A as the fresh product. Stimson, et al. (27) employing both chemical and bioassay methods, reported a loss of approximately 18 percent during preparation for freezing and freezing peas. Relcher (25) stated that lean, raw pork frozen for nine months showed no loss in vitamin B_1, and no significant loss in B_2 after six months of storage. Tressler and Evers (28) stated that there was no evidence to indicate that freezing <u>per se</u> causes any destruction of thiamine in any meat.

Dubois, et al. (8), showed that low temperature inhibits the development of rancidity, and stated that under proper storage conditions, changes in fat are of little significance from a nutritional standpoint. Gortner, et al. (12), stated that fat rancidity of pork became evident after four months with storage temperatures above 0°F., but that pork can be stored up to one year at 0°F. or lower. They also stated that pears stored at 0°F. maintain all of the ascorbic acid content, while strawberries and snapbeans lost only thirty-three percent of their ascorbic acid in twelve months.

Tressler and Evers (28) stated that the loss of inorganic salts in frozen meat and poultry is negligible.

Kellogg (17) stated that freezing had a protective rather than a destructive effect on thiamine, but stated that quick freezing of the tongue showed a significant loss of thiamine.

Mackintosh, et al. (21) stated that freezing did not have a significant effect on the tenderness of pork, and that sausage seasoned prior to freezing kept better than sausage not seasoned. Dubois and Tressler (7) stated that spices, such as sage, mace, pepper, and ginger may be added before freezing, but salt seems to activate oxidation and enhances rancidity, and therefore, should not be added before freezing. Woodroof (34) stated that sausage and stuffed fowl of various kinds are the only meats that are completely seasoned before being frozen. Seasoning includes the addition of salt, black pepper, red pepper, sage, onions, smoking, or the addition of cereals. Dubosis, et al. (8) stated that pork stored below 0°F. can be stored about 10 months, and pork stored above 0°F (10-15°F.) becomes rancid in about four months.

In 1937, in a study on the "Influence of feeezing on the palatability of pork roast," U.S.D.A. Workers (29) stated that pork loins stored for seven days at 20°F. showed no important difference from their mates stored at 34°F. for the same period, nor were they different from loins stored for 29 days at 20°F., but loins stored for 180 days at 20°F. were inedible. Brady, et al. (4) observed no significant difference in the palatability of slow and quick frozen steaks. However, he observed the least cooking loss from the quick frozen steaks. Lee, et al. (18) found that rate of freezing had little effect on the flavor, odor, texture, juiciness, or appearance of beef. They also found that neither thiamine, riboflavin, niacin, pantothenic acid, nor pyridoxine were measurably altered by rate of freezing.

Westerman, et al. (32); Westerman, et al. (33) while studying the influence of freezing rate and storage temperature on the B-complex vitamin content of pork observed that the greatest loss came with loins aged three days at 30°F. before freezing, in which the losses were as follows: thiamine 33 percent after 24 weeks; riboflavin 20 percent after 32 weeks; and after one day of aging at 30°F., panthothenic acid and nicotinic showed a 24 and 18 percent loss after 16 and 32 weeks respectively. Rate of freezing seem to have no effect on the vitamin content.

Hustrilid and Winters (14) stated that fluctuating temperatures below 5°F. have no effect on the appearance and palatability of vegetables, fruits, and meat. Gortner, et al. (12) stated that the quality of foods stored at 10°F., and at a fluctuating temperature between 10 and 20°F. was definitely inferior to that stored at 0°F.

Research has established the fact that freezing is a highly satisfactory method of preservation, and for best results all products should be frozen rapidly and stored at a temperature of 0°F. or lower with a minimum of fluctuation above that temperature. In general, quick freezing methods and low temperature storage are used by industry today. In the early days of the locker plant, slow freezing was common, but most locker plants today are equipped so that the normal volume can be sharp frozen. Likewise, the first home units made no provision for rate of freezing, but today, the majority of home units are equipped with a sharp freezing compartment, or with a temperature adjustment to facilitate sharp freezing. Following the introduction of the home freezer in 1938 (34) and increasing sale in the ensuring few years, there was a demand from the housewife for information related to the economy, use freezing load, preparation for freezing, etc., of this new style household appliance. Since the early units were the chest type, the early information related to this type unit.

Woodroff (34) stated that the first requirement of a home freezer is to be able to maintain a temperature of 0°F. year-around, and it should be able to remain within five degrees of zero when loaded to 10 percent of its capacity with unfrozen food. Donnalley (6) stated that power consumption, based on a unit volume of the box, decrease slightly as the volume of the freezer increases. He also stated that the freezing rate, the rate at which the freezing zone travels from the outside of the meat toward the center, increase linearly with the lowing of the air temperature of the cabinet for still air freezing. He developed the following chart as a result of his study.

Table 1. Power consumption per 24 hours.

Freezer No.	K.W.H. per 24 hours	Capacity cu. feet	K.W.H. per 24 hours per cu. ft.
1	3.25	14.3	0.23
2	2.38	9.3	0.26
3	2.38	6.0	0.40
4	4.46	25.4	0.18
5	3.41	14.3	0.24

Ehrenkranz, et al. (10) made the following observations while freezing ground beef in home freezers (chest type):

1. The freezing zone of ground beef was between 31 and 25°F.

2. The change in temperature of ground beef was nearly zero in the freezing zone, and became rapid again below 25°F.

3. Interchanging layers during freezing decreases the time for food to reach 10°F. by 27 percent. By interchanging the layers, they found that 72 pounds of meat can be frozen in a 2.46 cu. ft. freezing compartment in 28.8 hours. When the meat was not interchanged the freezing time was 39.4 hours.

More recently with the addition of larger units and the upright style, the housewife has become more interested in size and style of freezer to buy, cost of operation, where to locate the freezer in the home, and how to use it for best result. Numerous surveys and studies have been made to gain information in response to these and other questions. Atherton and others (1) stated that the cost of freezing per pound of food would vary from ten cents to six cents or less. They also stated that freezers located in basements or cold sheds have a decreased running time and consequently a lower cost of operation. Isaacs and others (15) stated that operating cost may be cut from 11 percent to 17.5 percent by locating the freezer in unheated areas. In relating the cost of operation to freezer size, he stated that if one uses the full capacity of the freezer it is more economical to buy a large unit, but if one does not use the full capacity of the freezer one should obtain a smaller unit, since the total kilowatt consumption and initial cost of the larger unit is higher. He further stated that the kilowatt consumption of a 15 cu. ft. unit was about 4.68 K.W. per month per cu. ft. and that this figure would vary with the season of the year. Cooper (5) stated that while operating at normal conditions, chest models will show an increase in cost of operation of $ .77 per year and upright models an increase of $1.50 per year as a result of opening the door once each hour for 60 seconds, five times a day. Boren (3) stated that the electricity required for storage and maintainance is approximately 0.07 kilowatt-hours per hour, and approximately 0.17 kilowatt-hours per hour for freezing. He also stated that meat in amount up to 120 pounds can be added to units up to 11.4 cu. ft. in size without causing significant fluctuation to effect the quality of the meat already in storage, and he recommended that the control setting should be changed from storage to freezing at the beginning of the freezing operation.

How much will my freezer hold is a question frequently asked by the housewife. Greene and Later (13) stated that the quality of food stored in a given space is dependent upon the food, type of package, shape of storage space, and type of container.

METHODS AND PROCEDURE

This study was undertaken to secure additional information concerning the efficiency and economy of commercial home freezers. Four commercial freezers were used in this study. They were designated as boxes I and II (Plate I), and boxes III and IV (Plate II).

Box I was a two compartment, top-opening or chest type unit of a 15 cu. ft. inside measurement. One compartment of 2.0 cu. ft. capacity was designed as a freezing compartment. This compartment was separated from the 13 cu. ft. storage compartment by a two inch non-insulated wall. The motor and compressor was located directly under the freezing compartment. Freon-12 was used as the refrigerant and a one-fourth horse power motor operated the compressor. The coils were arranged along the bottom and the sides of the freezer compartment, and around the sides and one end of the storage compartment. The box was insulated with two inches of batt-type insulation. This box was thermostatically controlled with a thermostat designating off, normal, and cold. Normal was the setting recommended by the manufacturer for regular operation.

Box II was a side-opening or upright type unit of 15 cu. ft. capacity. It was constructed with four aluminum shelves and shelving in the door provided additional space equivalent to one shelf. Freon-12 was used as a refrigerant, a one-third horse power motor operated the compressor. Coils were arranged under all shelves and the floor of the unit. The refrigerating mechanism was located below the floor and separated from the storage space by a two-inch insulated wall. This box was controlled with a thermostat numbered from 1 to 7. The number setting was designated by the manufacturer as the setting for regular operation. This box had two-inches of insulation.

Box III was a side-opening or upright type unit having a capacity of 15 cu. ft. It had five shelves constructed of metal rods which ran parallel to the sides of the box about one and one-fourth inches apart. Coils were arranged under shelves 1, 2, 3, and 5. A removable basket was under shelf 5. Freon-12 was used as a refrigerant and the compressor was operated by a one-fourth horse power motor. This box was controlled with a thermostat that read off, normal, and cold. Normal was the setting designated by the manufacturer for operation. This box also had two inches of insulation. The refrigerating mechanism was locating directly below the removable basket, and separated from it by a two-inch insulated wall.

Box IV was also a side-opening or upright type unit with a capacity of 15 cu. ft. It had four shelves. Coils were arranged under shelves 1 and 3. These two shelves were constructed of metal rods running parallel to the sides of the box. Freon-12 was used as the refrigerant and the compressor was operated by a one-fourth horse power motor. The refrigerating mechanism was located below the floor, and was separated from the storage space by a two-inch insulated wall. There was no mechanism on this box for changing the temperature setting, but was designed by the manufacturer to operate at zero degrees.

The meat used in this study was ground beef, made in a ratio of 25 percent fat to 75 percent lean. The beef was ground three times, passing through a one-fourth, one-eighth, and three-sixteenth inch plate respectively, then packed in two pound packages, using an approved wrapping material, Watt and Mackintosh (30).

The trials in each box were as follows:

Trial I. No load, in which each box was operated for 24 hours at the storage setting designated by the manufacturer. The average temperature maintained, current used, and percent running time were recorded.

Trial II. No load, in which each box was set at its lowest setting and operated for twenty-four hours, average temperature maintained and current used were recorded.

Trial III. One hundred fifty pounds storage load, each box was operated at storage condition for twenty-four hours, average temperature and current used were recorded.

Trial IV. Two hundred fifty pounds storage load, same as trial III.

Trial V. Forty pounds freezing load in which forty pounds of unfrozen beef was placed in the box and frozen, current used, and time to freeze were recorded.

Trial VI and VII. Forty pounds of unfrozen ground beef was placed into each box with a 150 and 275 pound storage load respectively. The same data as in trial V were recorded.

All temperatures were determined by means of thermocouples connected to a Leeds-Northrup type potentiometer, as shown in Plates I and II. The thermocouples used were iron vs. constantan type. All readings were made in millivolts and a reference junction of 32°F. was used. These readings were converted to degrees Fahrenheit by means of an iron vs. constantan chart.

The terminal end of the thermocouple was inserted into the center of the package representing the load. Representative packages were picked arbitrarily. Millivolt readings as indicated by the thermocouples were taken at intervals of 15 minutes to two hours, depending upon the rapidity of the change of temperature. Readings were taken until the temperature of the meat reached 0°F.

The location of the thermocouples in box I was as follows:

1. In the center of the freezing compartment.
2. Six inches from the floor and eight inches from the wall adjacent to the freezing compartment.
3. On the bottom in direct center of the storage compartment.
4. Eight inches from the top, 10 inches from the front side, and 15 inches from the end distal to the freezer compartment.
5. On the bottom, six inches from the most distal end of the box, and on the back side.

The location of the thermocouples in boxes 2, 3, and 4 were as follows:

One thermocouple in the center of each shelf.

Location of package during each trial.

Box I. All freezing was done in the freezing compartment, and since only 40 pounds were frozen at a time there were only one and one-half layers of meat. All meat was placed in the storage compartment for storage. Boxes II, III, and IV. Meat to be frozen was placed on any two shelves designed for freezing. Meat for storage was divided among the remaining shelves.

In all trials, one thermocouple was left exposed to the air in order that the air temperature of the box while freezing and storing could be determined. Figure 1 shows the relative location of thermocouples in all boxes.

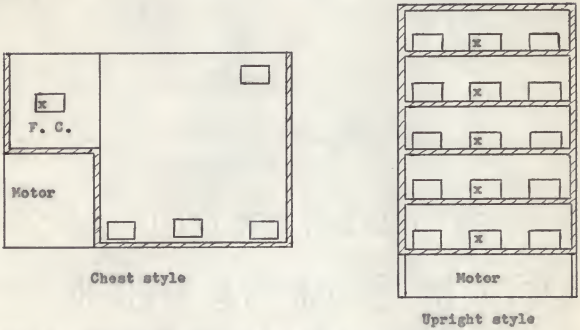


Fig. 1. Location of leads in the two styles of units.

Each box was prepared for the trial at hand, by setting the controls at the desired setting immediately before beginning the trial. A freezing time of 24 hours was selected as the maximum time allowable for any freezing operation.

Power consumption was measured during freezing and storing by a kilowatt-hour meter connected into the power line leading to each box. Kilowatt readings were made at the beginning and end of each trial.

RESULTS

Data on the power consumption of each box are presented in tabular form in tables II and III, and trials 5, 6, and 7 are presented graphically in figures 2, 3, 4, and 5.

Box I

Trial I. The total kilowatt consumption for a 24 hour period was 3.41 kilowatts. The rate of consumption was .142 kilowatts per hour, or .009 kilowatts per cu. ft. per hour. The average temperature maintained was -5.1°F.

Trial II. At a freezing setting for a period of 24 hours this box consumed a total of 4.56 kilowatts, a rate of .190 kilowatts per hour, or .013 kilowatts per cu. ft. per hour. At this setting the box averaged a temperature of -16.9°F.

Trial III. The total kilowatt consumption during this trial was 3.49 kilowatts. The box used .145 kilowatts per hour, or .009 kilowatts per cu. ft. per hour. The average air temperature maintained for the period was +3.4°F.

Trial IV. This box consumed 3.13 kilowatts during this trial, .130 kilowatts per hour, or .008 kilowatts per cu. ft. per hour, and averaged an air temperature of +3.2°F. during the period.

Trial V. During this freezing trial, this box consumed 4.71 kilowatts, .303 kilowatts per hour, or .02 kilowatts per cu. ft. per hour. The time required to cool the load to 0°F. was 15.5 hours.

Trial VI. During this trial box I consumed 3.68 kilowatts, .167 kilowatts per hour, or .018 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 14.2 hours.

Trial VII. During this trial this box consumed a total of 3.12 kilowatts of current at a rate of .167 kilowatts per hour, or .011 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 22 hours.

Box II

Trial I. The total kilowatt consumption for a 24 hour period was 3.12 kilowatts. The rate of consumption was .130 kilowatts per hour or .008 kilowatts per cu. ft. per hour. The average temperature maintained was -3.0°F.

Trial II. At a freezing setting for a period of 24 hours this box consumed a total of 4.03 kilowatts, a rate of .168 kilowatts per hour, or .011 kilowatts per cu. ft. per hour. At this setting the box averaged a temperature of -12.4°F.

Trial III. The total kilowatt consumption during this trial was 3.03 kilowatts. The box used .126 kilowatts per hour, or .008 kilowatts per cu. ft. per hour. The average air temperature maintained for the period was +1.5°F.

Trial IV. The box consumed 3.61 kilowatts during this trial, .150 kilowatts per hour, or .009 kilowatts per cu. ft. per hour, and averaged an air temperature of +.75°F. for the period.

Trial V. During this freezing trial, this box consumed 2.12 kilowatts, .326 kilowatts per hour, or .021 kilowatts per cu. ft. of space per hour. The time required to cool the freezing load to 0°F. was 6.5 hours.

Trial VI. During this trial box II consumed 2.62 kilowatts of current, .319 kilowatts per hour, or .021 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 8.3 hours.

Trial VII. During this trial this box consumed a total of 2.39 kilowatts of current at a rate of .299 kilowatts per hour, or .019 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 8.0 hours.

Box III

Trial I. The total kilowatt consumption for a 24 hour period was 3.97 kilowatts. The rate of consumption was .165 kilowatts per hour, or .011 kilowatts per cu. ft. per hour. The average temperature maintained was -5.9°F.

Trial II. At a freezing setting for a period of 24 hours this box consumed a total of 5.11 kilowatts, a rate of .210 kilowatts per hour, or .014 kilowatts per cu. ft. per hour. At this setting the box averaged a temperature of -14.7°F. for the trial.

Trial III. The total kilowatt consumption during this trial was 4.00 kilowatts. The box used .166 kilowatts per hour, or .010 kilowatts per cu. ft. per hour. The average air temperature maintained for the period was -7.9°F.

Trial IV. The box consumed 4.00 kilowatts during this trial, .166 kilowatts per hour, or .010 kilowatts per cu. ft. per hour, and averaged an air temperature of -9.3°F. for the period.

Trial V. During this freezing trial, this box consumed 3.01 kilowatts, .376 kilowatts per hour, or .024 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 8.0 hours.

Trial VI. During this trial box III consumed 3.21 kilowatts of current, .267 kilowatts per hour, or .017 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 12.0 hours.

Trial VII. During this trial this box consumed a total of 3.25 kilowatts of current at a rate of .281 kilowatts per hour, or .018 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 11.5 hours.

Box IV

Trial I. The total kilowatt consumption for a 24 hour period was 2.75 kilowatts. The rate of consumption was .115 kilowatts per hour, or .007 kilowatts per cu. ft. per hour. The average temperature maintained was -7.1°F.

Trial II. Same as trial I.

Trial III. The total kilowatt consumption during this trial was 2.88 kilowatts. The box used .120 kilowatts per hour, or .008 kilowatts per cu. ft. per hour. The average air temperature maintained for the period was -5.0°F.

Trial IV. The box consumed 3.43 kilowatts during this trial, .143 kilowatts per hour, or .009 kilowatts per cu. ft. per hour, and averaged an air temperature of -8.4°F. for the period.

Trial V. During this freezing trial, this box consumed 2.85 kilowatts of current, .231 kilowatts per hour, or .015 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 12.3 hours.

Trial VI. During this trial box IV consumed 2.40 kilowatts of current, .184 kilowatts per hour, or .012 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 13.0 hours.

Trial VII. During this trial this box consumed a total of 2.83 kilowatts of current at a rate of .248 kilowatts per hour, or .016 kilowatts per cu. ft. per hour. The time required to cool the freezing load to 0°F. was 11.6 hours.

DISCUSSION

The total kilowatt consumption for boxes I, II, III, and IV while operating empty was 3.41, 3.12, 3.97, and 2.75 respectively, for a 24 hour period. The kilowatt consumption of boxes I and II are in close agreement with those observed by Donnaley (6). The kilowatt consumption was higher for box III and lower for box IV. However, neither was significantly different from those observed by Donnaley (6). The kilowatt consumption per cu. ft. per hour was less than .010 for all units except unit III in which case the kilowatt consumption was .011 per cu. ft. per hour. In these trials box IV consumed less power per cu. ft. per hour and less total power. Box III had the highest kilowatt consumption for the period. The higher kilowatt consumption for box III was no doubt due, in part, to leakage around the door due to poor door seal. This fact can be considered for box III throughout the remaining trials in connection with power consumption. The low kilowatt consumption of box II may be accounted for as a result of its smaller motor, larger evaporator surface, and shorter running time. The low kilowatt consumption for box IV can only be accounted for by assuming greater efficiency of the box.

Table 2. Power consumption, during storage trials, for all four boxes

Trial No.	Control setting	Kilowatts per hour	Kilowatts per cu. ft. per hr	Kilowatts per 24 hours	Air Temp.
Trial I	Storage	No-load			
Box I		.142	.009	3.41	-5.1
Box II		.130	.008	3.12	-3.0
Box III		.165	.011	3.97	-5.9
Box IV		.115	.007	2.75	-7.1
Trial II		No-load			
Box I		.190	.013	4.56	-16.9
Box II		.168	.011	4.03	-12.4
Box III		.212	.014	5.11	-14.7
*Box IV		---	---	---	---
Trial III		150 pounds storage load			
Box I		.145	.009	3.49	+3.4
Box II		.126	.008	3.03	+1.5
Box III		.166	.011	4.00	-7.9
Box IV		.120	.008	2.88	-5.0
Trial IV		275 pounds storage load			
Box I		.130	.008	3.13	+3.2
Box II		.150	.009	3.61	+ .75
Box III		.166	.011	4.00	-9.3
Box IV		.143	.009	3.43	-8.4

* The control setting of this box was fixed by the manufacturer and could not be changed.

Table 3. Power consumption, during freezing trials, for all boxes.

Trial No.	Control setting	Kilowatts per hour	Kilowatts per cu. ft. per hr	Kilowatts to cool to 0°F.	Time in hours*
Trial V	Freezing		40 pounds with no-load		
Box I		.303	.020	4.71	15.5
Box II		.326	.021	2.12	6.5
Box III		.376	.024	3.01	8.0
Box IV		.231	.015	2.85	12.3
Trial VI	Freezing		40 pounds with 150 pound storage load		
Box I		.277	.018	3.94	14.2
Box II		.319	.021	2.62	8.3
Box III		.267	.017	3.21	12.0
Box IV		.184	.012	2.40	13.0
Trial VII	Freezing		40 pounds with 275 pound storage load		
Box I		.167	.011	3.68	22.0
Box II		.299	.019	2.39	8.0
Box III		.381	.018	3.25	11.5
Box IV		.248	.016	2.83	11.6

* Time required for the internal of the freezing package to reach 0°F.

All boxes maintained a temperature well below the recommended 0°F. The average air temperature maintained during trial I was -5.1, 03.0, -5.9, and -7.1°F. for boxes I, II, III, and IV respectively. Type of box had little or no effect on efficiency of operation during this trial.

When the control setting was switched to freezing for a 24 hour period it was found that 20 to 25 percent more power was required to operate the boxes. The kilowatt consumption for boxes I, II, and III was 4.56, 4.03, and 5.11 respectively, for the 24 hour period. Box IV was not included in this trial because the control setting was set by the manufacturer and could not be changed. The kilowatt consumption per cu. ft. per hour increased slightly and the total kilowatt consumption per hour was increased by .048, .038, and .048 for boxes I, II, and III respectively. This is not in agreement with Boren (3), who found that the kilowatt consumption per hour during freezing was double the kilowatt consumption per hour during storage. However, the boxes used by Boren were of much smaller size, and a great many improvements have been made in the engineering of home freezers since 1951.

The average air temperature maintained during this period was -16.9, -12.4, and -14.7 for boxes I, II, and III respectively. These temperatures were low enough to sharp freeze as defined previously. The temperature of -7.1°F. maintained by box IV during trial I was sufficiently low to sharp freeze. It was noted that the temperature in box I (chest style) varied greatly at different locations. The average temperature maintained at the various locations are presented in table 3. The temperature of the freezing compartment was not recorded during trials III and IV because this compartment presumably, will not be used for storage.

The total kilowatt consumption for boxes I, II, III, and IV for trial III was practically the same as for trial I. The total kilowatt consumption for boxes I, II, III, and IV with a 150 pound storage load was 3.49, 3.03, 4.00, and 2.88 respectively, for a 24 hour period. The kilowatt consumption per hour and the kilowatt consumption per cu. ft. per hour was practically the same as when operating empty.

Table 4. Temperature reading according to location

Box I

Position	Trial I	Trial II	Trial III	Trial IV
1	-7.77	-18.89	**	**
2	-2.49	-14.10	+2.10	- .36
3	-5.05	-21.61	+5.4	+ 4.4
4	-1.10	-13.63	+7.5	+ 7.6
5	-1.47	-16.45	*- .93	*- .98

* Thermocouple in frozen package
** Freezing compartment, not included

The average air temperature maintained for boxes I and II during trial III (150 pounds storage load) was slightly higher than 0°F., being +3.4 and +1.5°F. respectively. While this temperature is higher than recommended, it may be considered as a relatively safe storage temperature. The air temperature for boxes III and IV remained well below 0°F., -7.9 and -5.0°F. respectively.

During trial IV in which 275 pounds was stored for 24 hours, the total kilowatt consumption for all boxes were practically the same as they were in trial I. Box I decreased in total kilowatt consumption, boxes II and IV showed an increase, and box III remained the same. The total kilowatt consumption for boxes I, II, III, and IV was 3.13, 3.61, 4.00 and 3.43 kilowatts respectively, for the 24 hour period. The average air temperature was lower for all boxes in trial IV than in trial III, being +3.2, + .75, -9.3, and -8.4°F. for boxes I, II, III, and IV, respectively. The lower air temperature for boxes III and IV may account, in part, for their higher kilowatt consumption during this trial.

The closeness in total kilowatt consumption by all boxes in trial I, III, and IV substantiate previous reports stating that it cost no more to operate a home freezer when it is full than it does when the box is empty or near empty. The owner of a home storage unit saves more when he keep his unit full or nearly full than he does when his unit is operating empty. From these limited data it may be deduced that units equipped with temperature controls is less economical to operate than units with no such adjustments.

Kilowatt consumption is influenced by various factors, such as percent running time and location of the unit. The percent running time was recorded for all boxes while operating empty and is presented in Table 5. During the period of this study the room temperature ranged from 77 to 82°F., and at all times two boxes were under observation, so that room temperature should have had a minimum of influence on operating efficiency. The data in Table 5 indicate that the mechanical operation was remarkable uniform for all boxes. It may be of interest to note that box II, operating 37.3 percent of the time and equipped with a one-sixth horse power motor used 3.12 kilowatts of power for a 24 hour period which was higher than that consumed by box IV, but lower than box I and II.

Table 5. Estimated running time for all units.

	Box I	Box II	Box III	Box IV
No. of cycles per hour	2.8	2.8	3.0	2.7
Ave. length of cycle in min.	9	9	8	8.5
Percent running time/hour	42	37.3	40	38

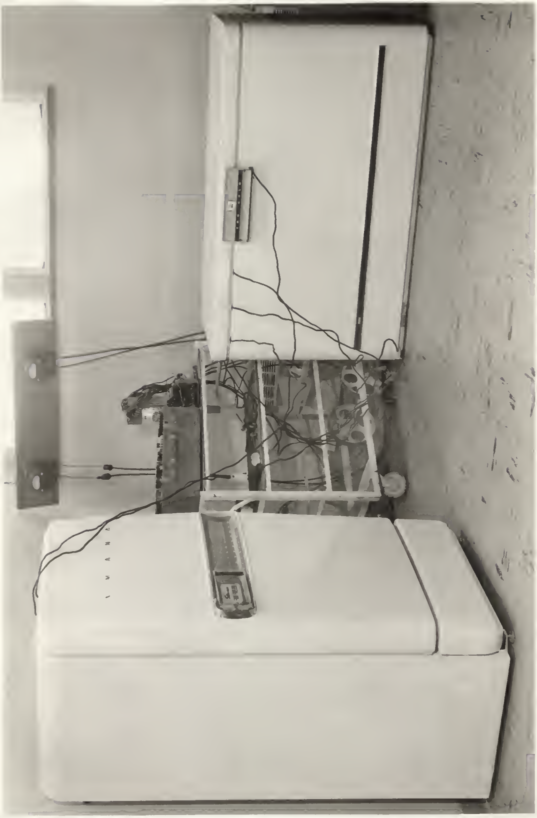
Every owner of a home storage unit is interested in the degree to which such a unit may be used as a freezer. As a result of many studies it has been deduced that rapid freezing is most desirable for protection on quality in the product. The time required to freeze a specified amount of product should offer an index of the freezing capacity of the unit. Forty pounds of ground beef packaged in two-pound packages was selected as an appropriate load for freezing. Three trials were run, trial 5, 40 pounds freezing with no-load, trial 6, 40 pounds freezing with a 150 pound storage load, and trial 7, 40 pounds freezing with 275 pound storage load. Data were collected on rate of freezing and power consumption. This data is tabulated in table III and is presented graphically in Figs. 2, 3, 4, and 5.

All boxes froze the 40 pounds of ground beef well within the requirements defined as sharp freezing, however, box I probably reached its maximum when freezing 40 pounds with a 275 pound storage load. Since the automatic switch on box IV cut out twice during trial VI and once during trial VII it might also be considered that 40 pounds would be the maximum freezing load for this unit with such storage loads as used in trial VI and VII. Each of the other two boxes probably could have frozen a larger load and still qualify under the conditions described as sharp freezing.

Box I consumed the most power during freezing and had the slowest freezing rate. The slower freezing time accounts for the higher kilowatt consumption. Box II was the superior box in all freezing operations, in freezing rate and economy of freezing. This box required 6.5, 8.3, and 8.0 hours to complete trials V, VI, and VII respectively. Box III

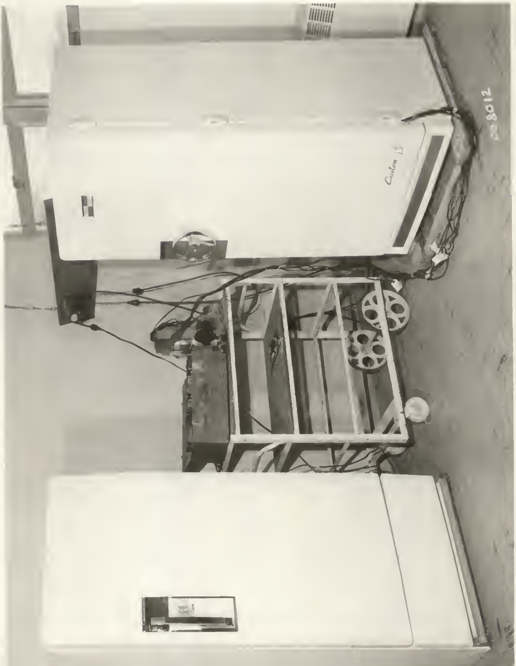
EXPLANATION OF PLATE I

Home storage units I and II used in this study. The Leeds-Northrup type potentiometer and thermocouple leads used to indicate the temperature of the meat are shown.



EXPLANATION OF PLATE II

Home storage units III and IV used in this study. The Leeds-Northrup type potentiometer and thermocouple leads used to indicate the temperature of the meat are shown.



differed little from box II in rate of freezing, but required slightly more power to complete the freezing operation. This was possibly due to the design of the freezing shelves described earlier. At the same time long freezing time and greater power consumption might be contributed to the fact that there were greater door leakage in box III than any other box. In economy of operation box IV ranked close to box II. Box III and IV have freezing curves that are practically parallel, Fig. 4 and 5.

When all observations had been completed each box was defrosted. Only one, box III required defrosting during the study. Large deposits of frost would accumulate around the door and first shelf, and required defrosting about once each month during the study. Approximately 35 pounds of frost was removed from box III at each defrosting. In general, frost is formed when warm air seeps into the unit, causing condensation which accumulates chiefly around the door. The greater amount of leakage in box III is more obvious when compared to the accumulation of only 2.0, 6.0, and 4.3 pounds of frost collected from box I, II, and IV, respectively. Box I was the superior unit so far as door leakage is concerned and this may be contributed to the style of design.

SUMMARY

All units used in this study were designed to operate at a safe storage temperature, but boxes I and II operated at a temperature slightly above 0°F.

The power consumption was not significantly changed with an

increased storage load for any unit tested. Box I, Chest style, showed a decrease in power consumption with an increased storage load.

When no temperature adjustment is installed on the box as box IV, the power consumption can be expected to increase with the storage load.

Tight fitting doors are essential to economical operation and will cause a minimum of frost to accumulate in the unit.

Air temperature will vary to a greater degree in chest style units than in upright models.

The compressor can be expected to operate from 36 to 45 percent of the time when operating under normal storage conditions.

A fifteen cu. ft. unit can be expected to use from .13 to .17 kilowatts per hour when storing load of a 150 to 275 pounds.

Fifteen cu. ft. units can be expected to use from 20 to 25 percent more power when freezing than storing.

It is recommended that for sharp freezing all units designed with temperature adjustments be set at their coldest setting.

Boxes designed as box I should not be expected to sharp freeze load greater than 40 pounds when the storage load is more than 275 pounds.

Units of all styles tested will not show a high cost of operation when operating in room temperature of 75 to 85 degrees F., and the mechanical operation of all such units will be about the same.

For storage purposes only, units designed to operate at a single setting by the manufacturer, operates more economically, but their capacity for freezing is lower than units with temperature adjustments. Units with adjustable temperature controls should be set for storage immediately after the freezing operation is completed.

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APPENDIX

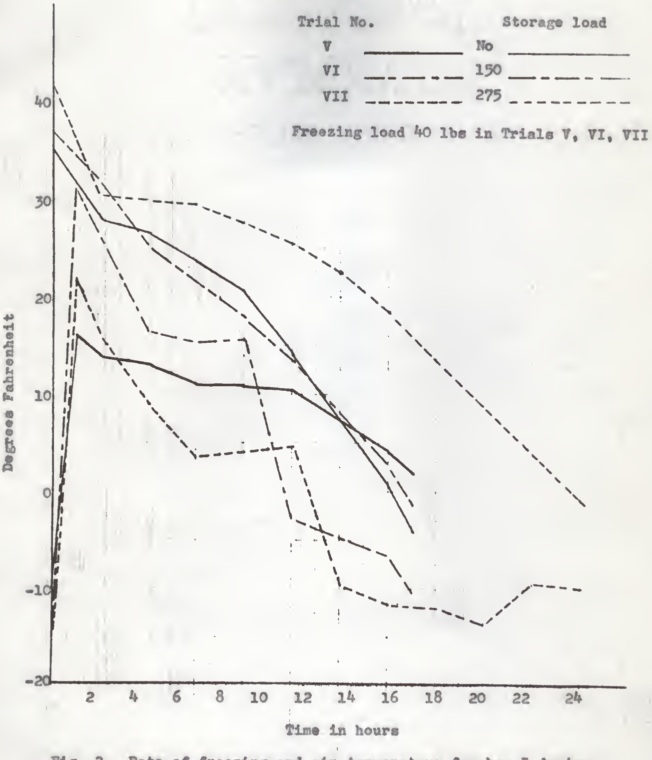

Fig. 2. Rate of freezing and air temperature for box I during trials V, VI, and VII.

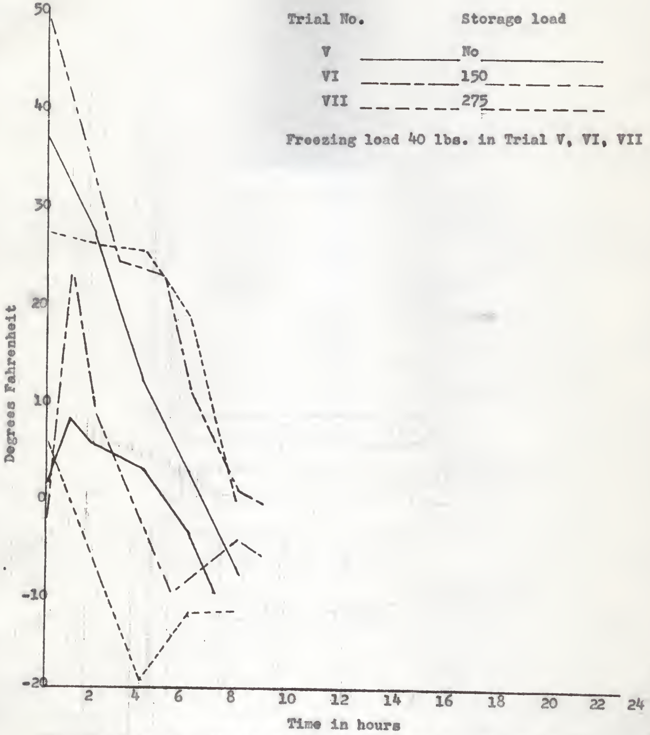

Fig. 3. Rate of freezing and air temperature for Box II during trials V, VI, and VII.

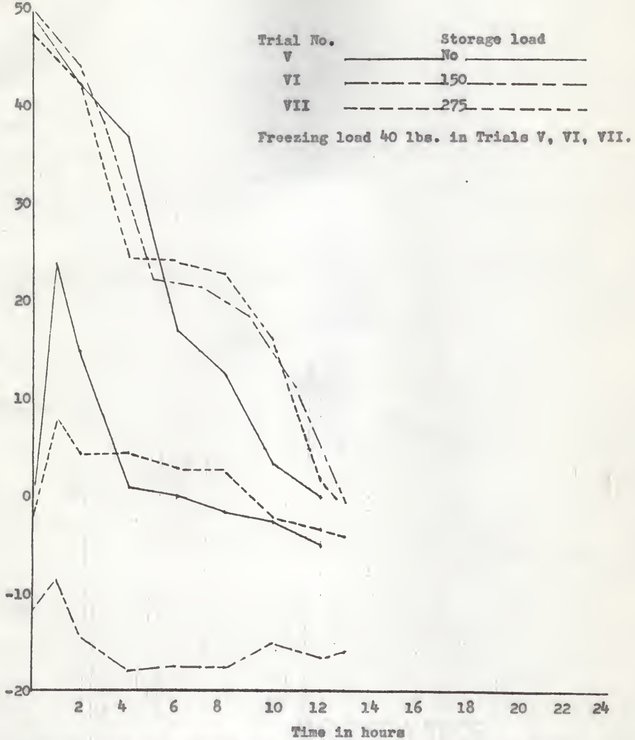

Fig. 4. Rate of freezing and air temperature for box III during trials V, VI, and VII.

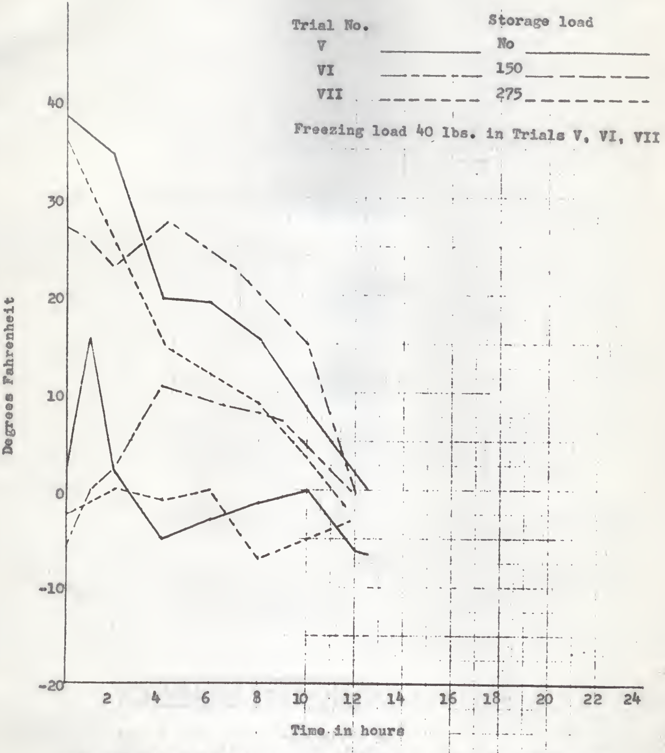

Fig. 5. Rate of freezing and air temperature of box IV during trials V, VI, and VII.

SOME OBSERVATIONS RELATED TO THE
EFFICIENCY OF HOME FREEZER UNITS

by

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B. S., Fort Valley State College
Fort Valley, Georgia, 1957

AN ABSTRACT OF A THESIS

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Since the first commercial home freezer was sold in 1938, a great many improvements have been made in the design of home storage units so as to meet the demands of the housewife, to increase their efficiency, and to lower their cost of operation. Among the many improvements made, a cabinet or upright style unit was placed on the market in 1940. However, it was not until 1950, that full scale production of this new style unit was undertaken by the manufacturers. The enormous increase in sales as well as the introduction of the cabinet style unit, gave rise to many questions from the owners, relative to cost of operation, how much can one freeze, how long does it take to freeze meat in a home freezer, as well as many other questions. Information of this type seemed to be lacking. This study was undertaken to obtain additional information on these and other points related to home storage, or home freezer units.

Four, fifteen cu. ft., commercial home freezers were used in this study, one chest and three upright models. The boxes were designated as boxes I, II, III, and IV. Seven trials were set up to collect data on the efficiency and cost of operation of each box. The trials were as follows: (1) Each box was operated at storage setting specified by the manufacturer with no storage load for a 24 hour period, (2) each box, except box IV, was operated at its coldest setting for a 24 hour period, (3) each box was operated at its storage setting for a 24 hour period with a one-hundred and fifty pound storage load, (4) each box was operated at its storage setting for a 24 hour period with a two hundred and seventy-five pound storage load. For each of the above trials the following data were recorded; percent running time (trial

I only), power consumption, and air temperature of the unit.

Trials V, VI, and VII were freezing trials in which forty pounds of ground beef were frozen with no storage load, with a one hundred and fifty pound storage load, and with a two hundred and seventy-five pound storage load. The time required to cool the product to 0°F., power consumption, and air temperature of the storage space while freezing were recorded for these trials.

All temperatures were taken by means of a Leed-Northrup type potentiometer connected to thermocouples of the iron vs. constant type. Power consumption was taken by means of a kilowatt meter connected in the power line between the wall outlet and the unit.

The conclusions drawn from the data collected were as follows:

All units were designed to operate at a safe storage temperature, but boxes I (chest style) and II (upright style) operated at a temperature slightly above 0°F.

The power consumption was not significantly changed with an increased storage load for any unit tested. Box I showed a decrease in power consumption with an increased storage load.

When a temperature adjuster is not installed on the unit, as box IV, the power consumption can be expected to increase with the storage load.

Tight fitting doors are essential to economical operation and will cause a minimum of frost to accumulate in the unit.

Air temperature throughout the box will vary to a greater degree in the chest style unit than in the upright models.

The compressor can be expected to run from 36 to 45 percent of the time when operating under normal storage conditions.

A fifteen cu. ft. unit can be expected to use from .13 to .17 kilowatts of currents per hour when storing a load of one hundred and fifty to two hundred and seventy-five pounds.

Fifteen cu. ft. units can be expected to use 20 to 25 percent more power when operating at a freezing setting than when operating at a storage setting.

For sharp freezing, all units designed with temperature adjusters should be set at the coldest setting at the beginning of the freezing operation.

Boxes designed as box I should not be expected to sharp freeze loads greater than forty pounds when the storage load is more than two hundred and seventy-five pounds.

Units of all styles tested will not show a high cost of operation when operating in a room temperature of 75 to 85 degrees F., and the mechanical operation of all such units will be about the same.

For storage purposes only, units designed to operate at a single setting by the manufacturer, operates more economically, but their freezing capacity is lower than units designed with temperature adjustments. Units with adjustable temperature controls should be set for storage operation immediately after the freezing operation is completed.

Upright model freezers can be expected to sharp freeze forty pounds with a storage load up to two hundred and seventy-five pounds in a time range between eight and fourteen hours. Chest style units can be expected to freeze under the same conditions in a time range between fifteen and twenty-three hours.