CONSTRUCTION AND MANAGEMENT OF QUICK-FREEZING UNIT FOR PRESERVING HOME PRODUCED FOODS

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CONSTRUCTION AND MANAGEMENT
OF
QUICK-FREEZING UNIT
FOR
PRESERVING HOME PRODUCED FOODS

by

Paul Boyd Thompson

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TABLE OF CONTENTS

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CONSTRUCTION AND MANAGEMENT OF QUICK-FREEZING UNIT FOR HOME-PRODUCED FOODS

PURPOSE OF PROBLEM

The purpose of this problem was to make a study of the possibility and practicability of freezing and storing the family food supply at home in a home-constructed quick-freeze and storage plant.

INTRODUCTION

Freezing of fruits, vegetables and meats is rapidly becoming a universal means of preserving the home food supply. Cold storage locker plants are generally accepted as a modern and practical means of food storage. However, at the present time, lockers are available to a limited number of people. Most people are familiar with the advantages of locker storages and frozen foods and many have used this service, but the inconvenience of going to the locker plant instead of the cellar for the food has raised the question, "Why not freeze and store fruits, vegetables and meats at home?"

Why Freeze Foods?

For years people have been devising new methods of preserving perishable foods. Drying and smoking were used in the days of the early settlers. Then came the process of pickling and canning meats, fruits and vegetables. Efforts to find better methods of food preservation brought about the cold-pack process and later the hot-pack process. With the introduction of modern refrigeration, freezing became popular. Canning and freezing eliminate the dangers of food spoilage, but usually produce a marked change in the quality of fruits and vegetables as compared with that of the fresh product. With canning, the change is due to the high temperature required for sterilization. With freezing it is related to ice formation within the tissues.

Tressler (1) reports that, in general, freezing preserves the food color, flavor and palatability of fresh fruits and vegetables better than canning or any other method known to date.

Freezing also eliminates much of the drudgery and expense of home canning, including long hours over a hot stove. Preserving food products, such as meats, fruits and vegetables, by freezing is easier, simpler and in practically every case results in a great saving of time. For example, a 200-pound dressed hog can be cut and wrapped into family sized packages and made ready for freezing in about three hours. Compare this time with the day and a half or two days the housewife usually spends canning meat with a pressure cooker or other methods. When properly prepared, frozen and stored, meats, fruits and vegetables are superior to home-canned products.

Rapid Freezing Desirable

When water freezes, it tends to freeze as pure water and other elements in the water are pushed aside. All foods contain water; when they are frozen, the elements that give color, flavor and food value to the juice are also pushed aside. Some of the changes are not reversible.

Both Woolrich (2) and Warner (3) report that when a product is frozen rapidly the colloidal gel or solution sets before much of the water can separate from it.

Some investigators believe there is less damage to cell structure when the product is frozen quickly.

Woolrich (2) reports the size of crystal depends upon the length of time it takes the food product to pass through the crystallization zone which is 31°F. - 23°F. The smaller the ice crystal, the less damage to cell structure.

Warner (3) reports that quick-frozen meat, after thawing, more nearly resenbles fresh meat.

The length of time required to freeze a given product depends on the following factors:

a. Temperature of the freezer.

b. Size and shape of the container - that is, a thin package will freeze more quickly than a thick one, because heat is conducted from a thin package to the freezing plates much quicker than the heat from a thick package.

c. Material from which the container is made. Various properties exhibit different values of heat conduction. For example, a metal container will conduct heat more rapidly than a container made of paper or some other fibrous product.

d. Nature of food being frozen. No two foods contain the same amount of water, therefore, will require different length of time for freezing.

e. The amount of food being frozen. A 4-pound package will freeze faster than a 20-pound package.

As a result of rapid freezing, fresh meats, fruits, and vegetables retain their original cell structure, natural flavor and vitamin content. In many instances, the flavor and texture is improved; some investigators report that meat, especially, tastes better and is more tender after freezing.

Freezing and Storage Temperature

The temperature maintained in a freezer-storage cabinet determines to a great extent the quality of food products when removed from freezer. The length of time a product can be kept in a frozen condition depends upon the temperature and its uniformity. An excellent product can be spoiled by improper temperature.

Diehl and Birdseye (4) report that freezing at or below and maintaining a temperature of 0°F. is of great importance. The best and most recent practice is to freeze in an air temperature of about -10°F. They also report that vegetables in particular deteriorate if held much above 0°F. or several degrees lower and storage at 0°F. or higher.

Wiegand (6) also reports that temperatures ranging from -5°F. to $+5^{\circ}$F. are satisfactory freezing and storage temperatures for fruits and vegetables. He found that alternate thawing and freezing is conducive to mold growth and development of unpleasant flavors and should be guarded against.

Berry (7) has found that some yeast grow at 0°F., which indicates that care must be exercised even at low temperatures.

Taylor (8) reports that products should be frozen as quickly as possible after harvesting. He also recommends 0°F. as best for rapid freezing. Above 0°F. results in inefficiency, slower freezing and larger ice crystals.

The committee on Foods (except milk) in the Food and Nutrition

Section, American Public Health Association of which Donald K. Tressler, Chairman (9) reports that pork becomes rancid sooner than beef. Frozen pork can be kept in good condition at 15°F. for only 2 months, at 10°F. it keeps free from rancidity for about 3 months and becomes very rancid thereafter. At 0°F. pork will keep free from rancidity for at least 8 months.

They also reported that fluctuating temperatures in cold storage where meat and poultry are stored cause a rapid deterioration of the quality of the products because the fluctuations in temperature speed up dessication and also accelerate crystal growth in the product and consequently increase leakage when the product is thawed. The recommendation of the committee is that frozen products be kept at a uniform temperature not higher than 5°F. and preferably at 0°F. at all times. At such temperatures practically all foods can be kept in excellent condition for at least 8 months if they have been properly prepared before packaging.

D. L. Augustine (10) reports that raw pork in commercial quantities may be rendered safe so far as trichinosis is concerned by either rapidly lowering the temperature to -0.4°F. (-18°C.) and holding the meat for at least 24 hours at that temperature.

Effect of Freezing on Vitamins

Lease, Lease, Webber, and Steenbock (11) have shown that vitamin A is very rapidly lost from rancid meats; thus it seems that frozen liver stored at higher temperatures, than from 10°F. to 15°F. will slowly lose vitamin A.

The committee on Foods of the Food and Nutrition Section, American Public Health Association (9) reports that frozen foods stored at temperatures of 10°F. to 15°F. show a slow loss of quality (color, flavor and vitamin C) but after a year's storage the product will still be edible, provided it was packaged with sirup or sugar. Properly blanched vegetables gradually lose their vitamin C content at temperatures above 30°F.

According to Jenkins, Tressler, and Fitzgerald (12) snap beans and spinach require even lower temperatures than 0°F. if they are to maintain a high vitamin C potency longer than four months.

Dunker (13) working with fresh sweet corn found that no loss of vitamin C occurred in 34 days of storage at -23.5°F.

Fitzgerald (14) also found that freezing had little effect upon vitamin C. Vitamin C is an index of quality; most every factor that detracts from quality also lessens vitamin C content of vegetables.

In a review of studies Plagge (5) reports that according to Fellers there is no apparent loss of vitamin C content in the freezing of peaches, blueberries, cranberries, blackberries, peas, lima beans, sweet corn and asparagus, although losses were noted in grapes and cherries.

Effects of Freezing on Bacteria, Molds and Yeasts

It should be remembered that frozen foods are not sterile. However, microbial action is slowed down considerably and many organisms are killed at sub-zero temperatures.

Smart (15), in her experiments on frozen vegetables stored from 5 to 7 months at -.04°F., reported an average reduction of micro-organisms of 97.5%.

Diehl and Birdseye (4) report that fresh fruits and vegetables normally carry many thousands of spores of yeasts, molds and bacteria that cause loss of quality and decay if the product is kept at temperatures favorable to the organisms' growth. Cold retards the growth of the organisms. Neither blanching nor freezing actually sterilize the product. Some organisms survive freezing and some spoilage organisms exhibit slow growth at low temperatures; therefore, it is important that frozen foods be stored at low temperatures and the product be used very promptly after thawing.

Tressler (1) reports that growth of bacteria, yeasts, and molds becomes negligible at about 15°F. on fruits and at about 10°F. on vegetables.

Warner (3) reports that at a temperature of 15°F. there appears to be no microbial action.

Products Need Protection from Oxidation

According to Warner (3), oxidation is very rapid at high or normal room temperatures, is slow at 33°F. to 40°F., and still slower at 0. However, there may be oxidation at 0°F. and, therefore, some protection from the air must be provided for the product being stored.

Waxed papers, waxed cartons, cellophane bags, are most commonly used as wrappers and containers to keep products from coming in contact with the air.

Freezing and Storing at Home

Until recently most of the work with frozen foods has been of a commercial nature. However, many of the commercial principles can be applied to home freezing - especially those of handling and

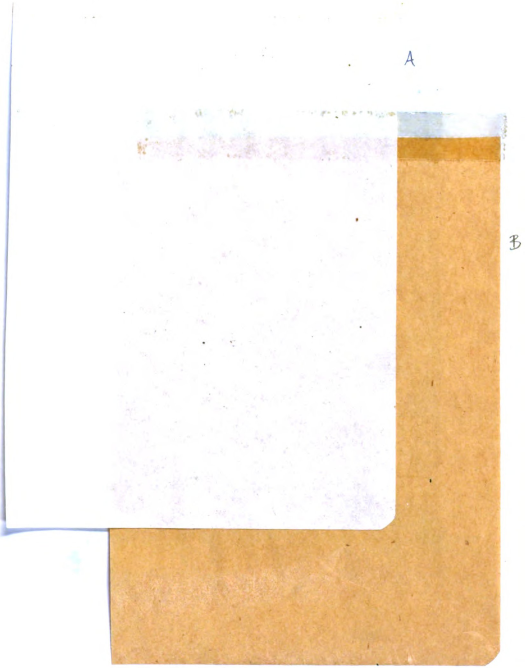

Fig. 1. Samples of paper commonly used for wrapping meats for freezer storage.

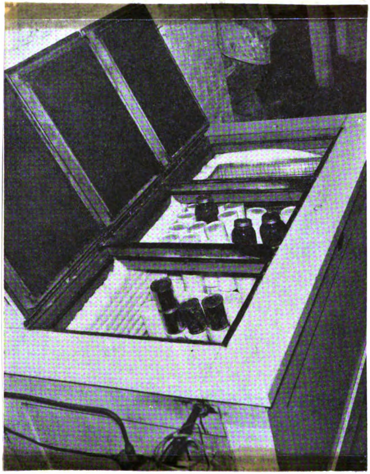

Fig. 2. The home freezing and storage cabinet of F. W. Knowles, manager of Northwest Baker Ice Machine Co., Seattle, Washington. Picture courtesy of State College of Wash.

Feg. 3. Experimental freezer cabinet built by the State College of Washington.

processing the food products. Owing to the expansion of rural electrification and the improvement in mechanical refrigerating equipment, even fast freezing can be done at home very easily.

Knowles (16), manager of the Northwest Baker Ice Machine Company of Seattle, Washington, in 1937 tells of his experiment in home freezing. He constructed an "ice cream type" cabinet, using plywood and 4" cork insulation with a galvanized iron lining. He used direct expansion coils with methyl chloride as a refrigerant and lowered the temperature to -20°F. (Fig. 2). The freezing of meats, fish, fruits, and vegetables was successfully accomplished. The products frozen were prepared by Mrs. Knowles without any special equipment, not even a thermometer for checking the blanching temperature which indicates ordinary home methods prevailed. The economic possibilities were exemplified in that butter was purchased at 20¢ a pound, stored in the freezer and used when the price was 40¢ a pound.

Danna and Miller (17) of Pullman, Washington, in 1937 built an experimental 0°F. locker for farm use. In 1938 they exhibited at the local fairs an "open-top" type of cabinet (Fig. 3). In July 1938, they constructed on the Cox farm, an experimental 35°F. cold room and 0°F. locker box within. The cold room was 8 x 7 feet and 6 feet 6 inches inside measurements. The 0°F. box was built along one side and had a capacity of 42 cubic feet. Twelve inches of wood shavings provided insulation in the walls and an additional six inches were used around the "zero" box. For evaporators the "zero" box was lined with a copper pipe coil, the cold room had a fin-type of coil. A 1/2 H.P. air-cooled condensing unit provided refrigeration for both evaporators.

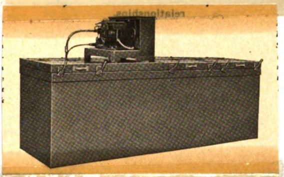

Fig. 4. A commercial built freezer cabinet.

Power consumption on the Cox plant was computed to be from 36 - 78 K.W.H. per month. The equipment, excluding labor, cost approximately $325.

At the present time there is being introduced to the public, a few commercially built home freezers and storage cabinets and in all probability most will be successful.

The home constructed freezing plant offers many possibilities as to the different arrangements of installation. For example - farmers or others who plan to construct a walk-in cooler could very easily include a freezer-storage compartment. Again there are others who would prefer to have a cabinet in their basement. A family in New York State had their freezer-storage cabinet built so that the door opened into their kitchen. A most convenient place, but probably not the most economical from an operating standpoint because most kitchens are usually warmer than some other parts of the house.

<u>Equipment and Procedure</u>

The cabinet used in the test was made at the Michigan State College Agricultural Engineering Laboratory during the late summer and fall of 1939. The cabinet stand and the plate supports were also made in the Agricultural Engineering Laboratory.

The mechanical equipment consisted of:

3 - Kold-Hold hold-over plates 22" x 52"

1 - Low Temperature Thermostatic expansion valve

1 - No. 2780-E Kold-Hold Heat Exchanger - Accumulator

7 lb. Freon 12

- Copper tubing and fittings

1 - 1/2 H.P. "Chieftan" compression unit with low pressure switch.

Fig. 5. Recording instruments used on freezer-storage cabinet at Michigan State College.

A Bristol recording thermometer was used to record the temperature within the cabinet. This instrument was mounted on the right end of the cabinet. The small tube was inserted into the cabinet through a half-inch hole drilled in the end (Fig. 5). The position of the hole was such that the thermometer tube came midway between the top and bottom and about 2 inches from the rear of the cabinet.

Room temperature was recorded on a Taylor thermograph. This instrument was placed on top of the cabinet.

A watt-hour meter was used to measure the amount of electricity used. The original plan was to place the freezing unit in a walk-in refrigerator on a dairy, farm, but this was not possible and the unit was set up in the Agricultural Engineering Laboratory and has been operating continuously since January 27, 1940.

The principal products that have been frozen and stored have been beef, pork, poultry, mutton and veal.

PART I

CONSTRUCTION OF FREEZER-STORAGE UNIT

Cabinet Type

Two principal styles of cabinets predominate. First, the top-door type of cabinet. This cabinet is simpler and probably easier to construct. It has the advantage of being operated more efficiently because there is no tendency for cold air to leak out when the cabinet lids are opened. However, the top-door type of cabinet has the disadvantage of inconvenience. That is, products stored within this type of cabinet are likely to be piled on top of each other and when one wants a definite article from the cabinet, it is necessary to take out many more products than the one desired. Products could be sorted and placed in wire baskets for storage which would probably simplify locating the food desired.

The second type of cabinet is the side-door or vertical door type. However, it may be well to point out two disadvantages as listed by Danna and Miller (17).

First, when the door is opened, cold air spills out and is replaced by warm, moist air. The moisture collects as frost on the evaporator.

Second, it is difficult to maintain door gaskets so as to prevent air leakage. Sometimes frost will accumulate between the gaskets and cabinet, causing the door to freeze shut.

These disadvantages are not so serious as they may seem. In regard to opening of doors, a freezer cabinet for home-use ordinarily would not be opened more than once a day. As to gaskets, there are available moisture-proof gaskets made and treated especially for sub-zero conditions. This type of gasket was used on the cabinet under test and during the four months it has been in operation it has not caused any trouble from freezing.

The advantages of the side-door were enough to decide to use that type of cabinet. The advantages were:

a. Convenience - a very desirable factor. Products stored on shelves are more easily arranged in a systematic order and it is much easier to find the product one is looking for. Neither does the housewife have to "stand on her head" to remove packages from the bottom of the freezer as is usually the case with a top-door type of cabinet.

b. The side-door cabinet can utilize to the greatest extent the many advantages of the plate type of evaporator which is discussed later in detail.

Size of the Cabinet

There are many things that have a part in determining the size of the cabinet, some of which are:

The primary requisites are to have a cabinet that will adequately and economically serve the needs of the family. A family of five persons requires enough storage capacity for about 250 pints of vegetables, 250 quarts of fruit, and 800 pounds of meat.

Table 1. Capacity of Freezer-Storage for Family of Five

Quantity*- Kind	Cubic feet required
250 pt. vegetables	4.33
250 qt. fruit	8.66
800 lb. meat	12.30
Total cubic feet	25.29

*Amounts recommended as an adequate diet for active people by Bureau of Home Economics.

Table 1 shows that 25 cubic feet would be adequate for the average family. Then it is probable that the freezer would not be filled to maximum capacity at all times, and therefore, the cabinet could be of about 20-25 cubic feet capacity. This size can be operated by a 1/3 H.P. condensing unit under favorable conditions. A cabinet larger than 25 cubic feet would probably require a $\frac{1}{2}$ H.P. condensing unit and this increases the cost.

Second, materials such as ply wood are made in standard sizes and it is more economical to buy in these sizes. Therefore, the cabinet dimensions were such that standard sizes could be used.

Third, it was decided to use the plate type of evaporator of a standard size of 22 x 48 inches because it costs less accordingly to buy a standard size plate. This places a minimum limit on the inside cabinet dimension. However, plates do not necessarily limit dimensions except when using standard sizes, as they can be purchased in almost any size at an additional cost.

Fourth, to expedite moving the cabinet, the outside dimensions were kept within usual doorway limits.

Considering the various factors the cabinet was made $30\frac{1}{2}$ x 36 x 72 inches over all, which gave a capacity of 20.5 cubic feet. See drawing 1 for detailed dimensions.

Properties of Insulating Materials

From a previous discussion it was found that a temperature of 0°F. to -10°F. should be maintained within the cabinet. To do this it is necessary to provide adequate insulation and refrigeration. Insulation is one of the principal parts of any refrigerating plant and its economic choice is important. Originally the cabinet was constructed to use in a walk-in cooler on a retail dairy farm. The temperature of the walk-in refrigerator was maintained at 40°F. This makes a temperature difference of 40°F., and according to the American Society Refrigerating Engineers data book, about four inches of cork is an economical thickness; therefore, four inches of cork was used in the construction of the cabinet.

There are three types of insulating materials, (a) the rigid type as cork or Celotex; (b) the blanket type as Balsam Wool and (c) the fill type as sawdust, Rock Wool and Zonolite. All types have good insulating properties, but their use is determined by the type of structure in which they are to be used.

When selecting an insulating material for a freezer cabinet one should consider the following properties:

a. Low conductivity. Conductivity as is practically interpreted includes the heat that will pass through the insulating material whether by conduction, radiation or convection. Conductivity is expressed in the number of British Thermal units (B.t.u.'s) that will pass through one square foot of one inch of insulating material in one hour for each degree F. The symbol commonly used is U or k.

b. Durable. Once insulation is in place, it should remain there and resist decay, deterioration, and other forms of breakdown.

c. Odorless. This is especially important in a case where food products are to be stored.

d. Moisture-resistant. Efficiency of insulation decreases as the moisture content increases. For low temperature conditions, it is especially important that the insulation be at its best. Some types of insulation, such as sawdust and shavings, are not so resistant to moisture and may prove troublesome when used under sub-zero conditions.

e. Good handling characteristics. The insulation should be one that can be easily applied to a particular job.

f. Structural strength. The rigid insulating materials add to the structural strength, whereas the other types do not.

g. Resistant to settling. Fill types of insulation, unless installed with care, may settle and result in air spaces, which are a source of heat leakage and increase operating expense.

h. Light in weight.

i. Fire resistant.

Cork was selected for use in the wall of the cabinet because it has the above mentioned properties in that it has a low conductivity value, good handling characteristics and most important, it is odorless, offers structural strength and rigidity and is resistant to moisture. Any rigid insulation, such as cork, can be depended upon not to settle.

Because moisture is harmful to all kinds of insulation, a moisture-vapor seal was made in the wall of the cabinet. This was an asphalt sealer and binder recommended by the Armstrong Cork Company. Two coats of this paint were applied to the interior of the outside wall. Besides providing a seal, it acted as a binder to hold the cork after it was coated with an erection asphalt. A good rule to follow is: "Seal the warm side of the insulation and ventilate the cold side."

Choice of Refrigerant

The function of the refrigerant is to act as a carrier of heat. The gaseous refrigerant is compressed, cooled and condensed to a liquid. This high pressure liquid, less much of its original heat, is passed through an expansion valve. The high pressure liquid passing to a low pressure, minus heat left in the condenser, vaporizes, absorbs heat and changes to a vapor form, then is ready to repeat the cycle.

Of the more common kinds of refrigerants, such as ammonia (NH_3), sulphur dioxide (SO_2), methyl chloride (CH_3Cl) and dichlorodifluromethane (CCl_2F_2), commonly known as Freon-12 (others are Freon 11 and Freon 21 and Freon 113) the latter was selected because

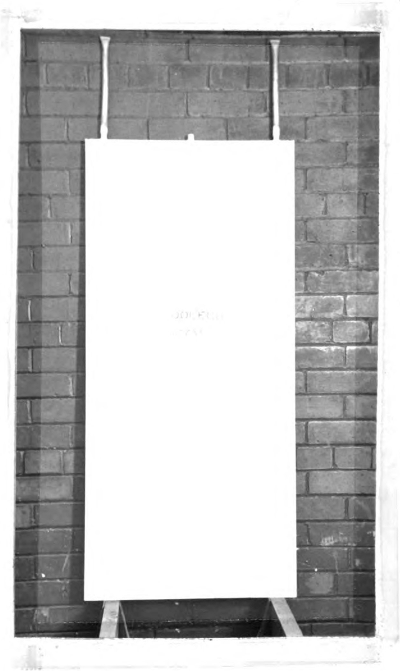

Fig. 6. A typical freezing plate evaporator.

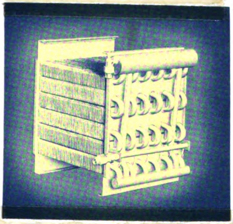

Fig. 7. A typical fin type of evaporator.

of its non-toxic properties. Freon liquid or vapor is not absorbed by, and has no effect on, any materials being refrigerated, and the vapor has no effect upon the odor, taste, color or structure of dairy products, meats, or vegetables.

Freon refrigerants, as such, are the least toxic refrigerants that have been discovered, according to the Underwriters' Laboratories Reports MH-2256, MH-2375 and MH-2630. Freon is classed as being non-combustible and non-inflammable.

Choice of Evaporator

An evaporator is a device which holds the liquid refrigerant while it is boiling and thus absorbing heat from its surroundings.

Evaporators usually are of two forms—a plain surface or a finned surface. The finned surface types are usually limited to air cooling conditions above 34^{o}F. except in special cases where they are fitted with automatic heating devices for defrosting. For sub-zero conditions the plain type of evaporators are usually used. Plain evaporators may be in the form of bare pipe coils or a plate. Figures 6 and 7 illustrate the difference in the various types of evaporators.

The plain coil evaporator is the cheaper, but for a quick freezing and storage cabinet the plate evaporator has enough advantages in that this type was preferred over the coils. Essentially the plate is a coil arrangement enclosed within a flat, rectangular metal case about 1 inch thick, 22 inches wide and 48 inches long. The width and length are variable.

Plates are obtainable with or without a hold-over solution. Figure 8 shows a section of an ice cream cabinet using plates

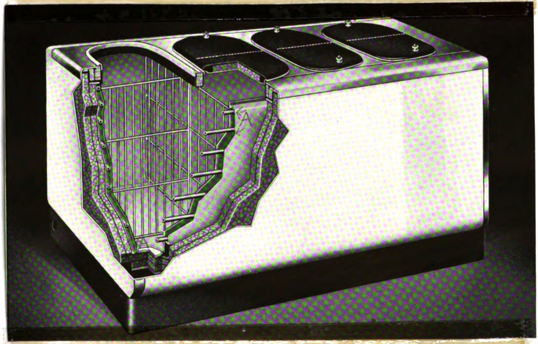

Fig. 8. Cutaway view - green portion indicates hold-over solution in freezing plates. (A)

with a hold-over solution. The hold-over solution is a solution that provides refrigeration similar to water ice, but, where ice melts at $32^{o}F.$, the hold-over or eutetic solution freezes and melts at a lower temperature, previously determined in the manufacture of the solution. $-8^{o}F.$ is the freezing and melting temperature of the colution for protection of frozen products. Because of this property of providing additional refrigeration in case of power failure, the hold-over type of plate was desirable for frozen food storage.

Other advantages of plates are:

a. Ease of installation; this simplifies construction of a home freezing plant.

b. Economical use of space; the plates are thin, take up little space and can be used as shelves and therefore adapted to the side-door type of cabinet.

c. Faster freezing is accomplished because the plate provides more surface contact for the conduction of heat, whereas coils provide only line contact. The more evaporator area that can be brought in contact with the package, the faster the product will become frozen. As previously brought out, rapid freezing is very desirable.

d. Ease and quickness of defrosting; to defrost the plates it is a simple matter to take a wire brush or a wide-blade putty knife and brush or scrape the frost from the plates. This can be done in a very few minutes, and in so doing the temperature of the cabinet will need not vary more than a few degrees. As pointed out previously, fluctuation in temperatures or variations is undesirable, and the refrigerating unit does not have to be shut down or stopped.

e. More sanitary; the flat surface can be easily cleaned.

f. Excellent appearance.

PROCEDURE - CABINET CONSTRUCTION

Bill of Material for Cabinet

Lumber

12	pieces	2 x 4 x 6 Fir
2	"	5/4 x 4 x 8 W. Pine
2	"	3/4 x 6 x 8 "
1	"	3/8 x 24 x 60 Fir plywood
3	"	1/4 x 30 x 72 " "
1	"	1/4 x 30 x 48 " "
5	"	3/4 x 36 x 72 " "

Hardware

2	pieces	3/4 x 3/4 x 1/8 x 6' - 4" angle iron
1	"	3/4 x 3/4 x 1/8 x 8' -4" " "
4	"	2 x 2 x 1/4 x 2' -6" " "
2	"	2 x 2 x 1/4 x 3' -2" " "
2	"	2 x 2 x 1/4 x 6' -2" " "

6 refrigerator hinges

2 " latches

1 Double strike

1 Gross 1-3/4 -12 F.H. screws

12 Stove bolts 1/4 x 1 R.H.

Insulation, paint, etc.

36 feet of gasket material

1 gal. asphalt binder and sealer

40 lbs. erection asphalt

41 pieces corkboard 2" x 12" x 36"

1 qt. Valdura aluminum paint

1 qt. Gray paint

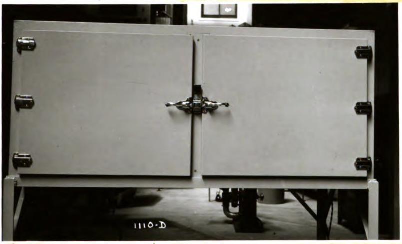

Fig. 9. Completed experimental freezer-storage cabinet - front view.

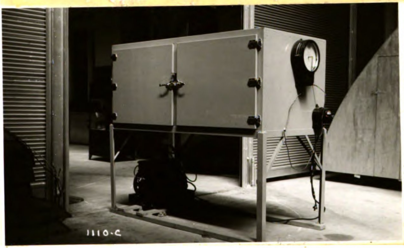

Fig. 10. View of cabinet and condensing unit.

The first step was to construct the frame, the details of which are shown on drawing No. 1. The frame was built of standard two by fours. The center section, between the doores, is made as a separate piece and is removable to facilitate installation or removal of freezing plates.

The next step was to glue and nail the 3/4 plywood back in place. Then the sides and ends were fastened in place with glue and flat head screws. The 3/4 x $3\frac{1}{2}$ trim was glued and nailed in place on the front of the cabinet. At this stage of construction the center section was made and fitted in place. It was important that this part be located in the exact center of the cabinet opening to avoid making the doors of different sizes. Making and fitting the doors was next in order, but they were not hung until after all the insulation had been put in place and two coats of paint had been applied.

For protection against the harmful effects of air infiltration, the interior of the cabinet and doors were covered with two coats of an asphalt primer and sealer recommended by the Armstrong Cork Company. The asphalt primer and sealer also provide a bond to which the hot erection asphalt stuck.

The cork slabs were fitted to the walls in such a manner that no two joints would overlap. The fitting was done first so that when the job of permanently fastening the cork insulation was begun it could be completed while the asphalt was hot. Each slab of cork was thoroughly coated with a special odorless erection asphalt and pressed in position. When the installation of the cork was completed, it was given a coat of hot asphalt to seal the joints and pores.

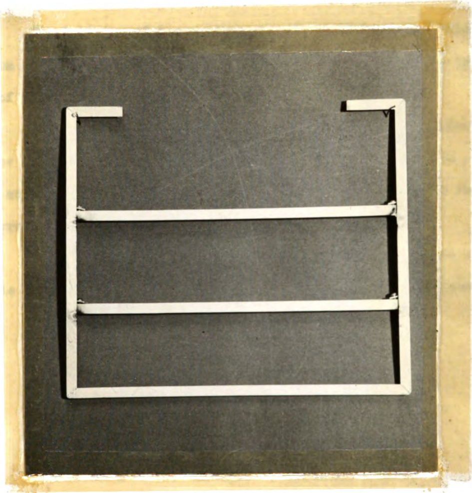

Fig. 11. Freezing plate supports.

Next the 1/4 inch plywood liner was fitted and held in place by L-shaped metal strips between the cork and frame. The back liner was fitted last; this held the back edge of the sides and ends in place. The metal strip was held in position by screws through the door jamb.

The interior of the cabinet was given two coats of Valdura Aluminum paint; the exterior was first given a sealer coat and two coats of gray paint.

The final work on the cabinet was to install the hardware and door gaskets and hang the doors. A specially prepared type of gasket material for low-temperature was used. It was obtained from the Jarrow Products Company of Chicago.

The freezer plate supports and the cabinet stand were made of angle iron. See Fig. 11 and drawing No. 2 for further explanation.

Table 2. Thermal Conductivity of Insulating Materials
(k - B.t.u. /in/ft^2/hr/^{o}F)

Material	Density lb/ft^3	K
Alfol, flat	3.0 - 4.1	.25
Alfol, crumpled	.24	.284
Balsam wool	2.2 - 3.8	.246 - .270
Cabots Quilt	3.4 - 4.6	.25 - .26
Celotex	13.2 - 14.8	.30 - .34
Cork	8.32	.283
Dry zero	1.0 - 2.0	.24 - .25
Masonite	15.0	.33
NuWood	15.0	.32
Palco (Redwood) Wool	5.0	.255
Redwood Fibre	6.72	.33
Rock Cork	15.6	.33
Temlock	15.0	.33
Kapok	.875	.24
Shavings	8.74	.40
Sawdust	1.56 - 3.62	.57 - .60
Thermofelt	7.8	.28
Thermofill	26.0	.52
U. S. Mineral Wool	12.0	.26
WOOD		
Virginia pine, across grain	34.3	.96
White pine, across grain	31.2	.78
Pitch pine, across grain	-	1.05
Fir, across grain	34.1	.97

A.S.R.E. Ref. Data Book 1939-40

Computation of Heat Loss Through Walls

For all practical purposes, the heat losses through the wall of the type of cabinet described in this report can be calculated from the following equation:

$$K = \frac{1}{.5 + \frac{x_1}{k_1} + \frac{x_2}{k_2} + .5}$$

K = B.t.u. per square foot per hour per 1^{o}F.

X, X_2, etc. = Thickness of different materials in wall section

K, K_2, etc. = Transmission coefficient of insulating materials

.5 = Commonly used as surface resistance value

Known values.

a. Inside area of the cabinet = 46.8 square feet

b. Wall section, 3/4 & 1/4 plywood & 4" cork

c. Transmission coefficient - See Table 3

d. Temperature difference, maximum average

Cabinet temperature 0^{o}F.

Outside temperature (The average maximum July temperature is 81^{o})*

1. $K = \frac{1}{.5 + \frac{1}{1} + \frac{4}{.28} + .5} = \frac{1}{16.28} = .061$ B.t.u.

2. B.t.u. per square foot per degree per 24 hours.

   = .061 x 24 = 1.464 B.t.u.

3. Total B.t.u. per degree = 1.464 x Area
   = 1.464 x 47
   = 68.8 or 69 B.t.u.

4. Maximum average outside = 81^{o}
   Maximum average inside = 0^{o}
   Temperature difference = 81^{o}

*A.S.R.E. Data Book - 1939-40 p. 184

Table 3. Specific and latent heat of various food products

Article	Composition		Specific Heat		Latent Heat
	Water	Solid	Above Freezing	Below Freezing	of Freezing
Fruit					
Berries (fresh)	86.5	13.5	.892	.46	124.5
Cantaloupes (whole)	45.0	55.0	.560	.335	65.0
Peaches (whole)	73.5	26.5	.788	.420	106.0
Pears, Watermelons	76.0	24.0	.808	.428	109.0
Meats					
Beef (fresh)	68.0	32.0	.744	.404	98.0
Beef (fat)	51.0	49.0	.608	.353	73.5
Beef (lean)	72.0	28.0	.776	.416	102.0
Hams, Ribs (not brined)	60.0	40.0	.680	.380	86.5
Shoulders " "	76.0	24.0	.808	.428	109.0
Livers	65.5	34.5	.724	.396	93.5
Lamb	58.0	42.0	.664	.374	83.5
Pork (edible portion)	60.0	40.0	.680	.380	86.5
Tenderloins, Butts, etc	67.0	33.0	.736	.401	96.5
Veal	63.0	37.0	.704	.390	91.0
Fish					
Fresh fish	70.0	30.0	.760	.410	101.0
Poultry					
Poultry, dry picked	65.0	35.0	.720	.395	93.5
Poultry, scalded	75.0	25.0	.800	.425	108.0
Vegetables					
Asparagus	94.0	6.0	.952	.482	134.0
Carrots	83.0	17.0	.864	.449	119.5
Green beans	89.0	11.0	.91	—	—
Broccoli	90.0	10.0	.93	—	—

Trade Literature - Dole Refrigerating Company, Chicago

Table 4. Approximate heat absorbed in lowering the temperature of the water content of food products from +60°F. to -5°F.

Product	Percentage of water	Heat absorbed per lb. of product B.t.u.
Fish fillets	65 - 83	123 - 157
Shellfish, edible portion	79 - 87	149 - 165
Meat, edible portions	40 - 75	76 - 142
Poultry (dressed)	39 - 47	74 - 89
Vegetables, edible portion	67 - 93	130 - 174
Berries & fruit, edible portions	83 - 90	153 - 170

A.S.R.E. Reference Data Book, 1939-40

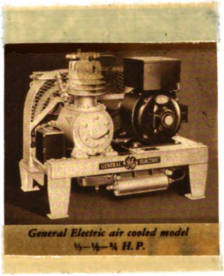

Fig. 12. Typical condensing unit.

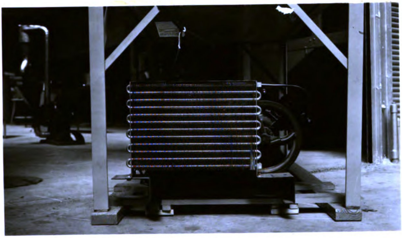

Fig. 13. Condensing unit used on freezer cabinet - end view.

5. Normal heat leakage for 24 hours = 69 x 81° = 5,508 B.t.u.

6. Adding 10% for service load then the total load would be (5508 x .10) + 5508 = 6,058 B.t.u.

Product Load

Computation of heat to be removed from product during the process of freezing. Calculations are based on the assumption that 100 pounds of beef is placed in the freezer and all heat removed in 24 hours.

1. By Table 4 the specific heat and latent heat of beef are:

   Specific heat above freezing = .744

   Specific heat below freezing = .404

   Latent heat of freezing = 98.0

2. Heat to remove above freezing, assuming the meat will be pre-cooled to about 60°F. 28°F. is used as the freezing point of beef.

   B.t.u. = lb. product x sp. heat x temperature difference
   = 100 x .744 x (60 - 28) = 2380 B.t.u.

   Latent heat = 100 x 98.0 = 9800 B.t.u.

   Heat removed from 28° to 0°
   = 100 x .404 x 28 = 1131 B.t.u.

   Total B.t.u. for 100 lb. beef 13,311 B.t.u.

Determining the Size of Condensing Unit

The capacity of a condensing unit depends upon the amount of refrigerant condensed per unit of time and therefore is dependent upon such things as the piston displacement, speed, efficiency, suction pressure, condensing temperature, and super heat.

Condensing units are manufactured in standard motor horse power size and manufacture B.t.u. per hour rating depending upon the refrigerant being used.

Then for all practical purposes if the operating temperatures, refrigerant and the amount of B.t.u. to remove per hour is known, the size of condensing unit in horsepower can be determined from manufacturers specifications.

Table 5 is typical of that found in manufacturers literature.

Referring to the previous calculations it was found that -

Normal load	=	6,058
Product load	=	13,311
Total		19,369 B.t.u. per 24 hrs.

Compressors are usually figured on a basis of 16 hours of operation out of 24; therefore, the condensing will have to remove $\frac{19,369}{16}$ or 1,210 B.t.u. per hour

Referring to Table 5, a 1/3 H.P. compressor would be required.

Note that over half of the 19,369 B.t.u. is product load and the 1/3 H.P. condensing unit is necessary only when the calculated load of products is being frozen. Certain management practices can lighten this product load and these are discussed in Part II - Management.

Computation of Plate Area

1. For low temperature conditions it is common practice to assume an air temperature and plate temperature difference of 16^{o} and a K. factor for freezing plates of 2, which means that for each square foot of plate surface as measured on both sides will absorb 2 B.t.u. per degree per hour.

2. At 16^{o} temperature difference the B.t.u. absorbed per sq. ft. = 16^{o} x 2 or 32 B.t.u. per sq. ft. per hour, one side.

3. Square foot of plates $= \frac{\text{Hourly load}}{32 \times 2 \text{ sides}}$

$$\frac{1210}{2 \times 32} = 18.9 \text{ sq. ft.}$$

4. Each plate was 22" x 52" which equals 7.95 sq. ft. one side

5. 18.9 ÷ 7.95 = 2.38 or 3 plates required

The above mentioned calculations were based on the cabinet described operating under average maximum room temperature of 81°F. conditions instead of in a walk-in cooler for which it was designed.

By adding one more inch of cork the service load would be reduced from 6,058 B.t.u. to 5,181 B.t.u. per 24 hours, a reduction of 877 B.t.u. per 24 hr. or 36.6 B.t.u. per hour.

Operating under these conditions the extra inch of insulation would be advisable, but the following factors should be considered. First, the cost, which would be about $4.50 for material provided the cabinet dimensions remain the same. This cost is not excessive and probably could easily be afforded. The other factor to consider is the reduction of storage capacity of cabinet. Forty-eight square feet is equal to approximately 4 cubic feet or a reduction of about 20% of the cabinet capacity. This is quite an item and in all probability would be worth more to the user than what could be saved in operating expense. The cabinet could be made larger, which in this case, would have to be done to accommodate the standard size freezing plates. Then the cost would be more than $4.50 or approximately $12.

Table 5. Typical makers' specification of condensing units*

Method of Cooling	Mfgr's ratings Btu/hr	Motor size H.P.	Com-pressor speed R.P.M.	No. of cylin-ders	Bore inches	Stroke inches	Capacity of Re-ceiver pounds	Width inches	Depth inches	Height inches
Air	450	1/8	1725	1	1	7/8	4	$18\frac{1}{2}$	$18\frac{1}{2}$	$11\frac{1}{2}$
Air	780	1/6	1725	1	1	7/8	4	$18\frac{1}{2}$	$18\frac{1}{2}$	$11\frac{1}{2}$
Air	885	1/4	1725	2	1	7/8	6	24	$18\frac{1}{2}$	11-7/8
Air	1,660	1/3	1725	2	1	7/8	6	24	$18\frac{1}{2}$	11-7/8
Air	1,665	1/2	1725	4	1	7/8	15	30	$18\frac{1}{2}$	24-11/16
Water	1,950	1/3	1725	2	1	7/8	6	24	$18\frac{1}{2}$	11-3/8
Water	1,875	1/2	1725	4	1	7/8	15	30	$18\frac{1}{2}$	24-11/16
Water	3,520	3/4	1725	4	1	7/8	15	30	$18\frac{1}{2}$	19-15/16
Air	4,635	1	410	2	$2\frac{1}{4}$	2	30	$31\frac{15}{16}$	$26\frac{1}{2}$	26-9/16
Air	6,970	$1\frac{1}{2}$	350	2	$2\frac{1}{4}$	3	30	$32\frac{9}{16}$	31-3/8	$29\frac{1}{4}$
Air	11,340	2	450	2	$2\frac{1}{2}$	3	27	$32\frac{9}{16}$	$24\frac{1}{4}$	$28\frac{1}{2}$
Water	1,870	$\frac{1}{2}$	1725	4	1	7/8	15	30	$18\frac{1}{2}$	24-11/16
Water	5,080	1	410	2	$2\frac{1}{4}$	2	27	$32\frac{1}{4}$	18-7/8	26-9/16
Water	8,550	$1\frac{1}{2}$	400	2	$2\frac{1}{4}$	3	27	$32\frac{9}{16}$	$24\frac{1}{4}$	$29\frac{1}{4}$
Water	10,320	2	450	2	$2\frac{1}{2}$	3	27	32-9/16	$24\frac{1}{4}$	$28\frac{1}{2}$
Water	18,070	3	460	3	$2\frac{1}{2}$	3	29	36-3/4	26-1/16	29-9/16

*A.S.R.E. Data Book 1939-40 p. 338

PART II

MANAGEMENT

The success of any home freezing and storage plant, whether commercially built or a properly constructed home-built plant will depend very largely upon the management. The introduction of frozen foods is a wonderful achievement, but unless the public learns how to select properly, process, freeze, store, and use frozen meats, fruits and vegetables an inferior product will result and freezing preservation will be retarded from which it will take some time to recover.

Location of Home Freezing Unit

For efficient operation, a freezer-storage plant should be located in a cool, well-ventilated, and convenient place. The function of a refrigerating machine is to remove heat from the refrigerated space and dissipate this heat in the surrounding air around the condenser. The warmer the outside air becomes, the more difficult it is for the refrigerating machine to give up the heat removed from the cabinet and the machine becomes less efficient. Good ventilation or air circulation aids the machine in getting rid of the heat. Too often one sees condensing units covered with some poorly ventilated cabinet. This adds to the appearance, but decreases the circulation of air.

A convenient place of location of the plant is important because of economical reasons. The more the plant is used, the more profitable it becomes to the user. A simple example will illustrate this point. Suppose it costs $20 a year to operate the plant, and 100 pounds of products pass in and out of the cabinet per year. The cost in this case is 20 cents a pound for storage. Suppose an average sized family used 1,500 pounds of frozen products a year; then the cost would be 1.3 cents per pound.

To use a freezer-storage cabinet efficiently one should plan to take advantage of placing products in the cabinet when they are at the peak of the season, when they are more delicious, most plentiful and less expensive. During the year different products are used, making room for those in season.

A suggested plan is shown in the calendar below.

January, February, March and April:

Beef, pork and other meats.

May:

Rhubarb, asparagus, and other early vegetables and fruits.

June - July:

Early fruits and vegetables.

August:

Sweet corn, lima beans, snap beans, cherries, raspberries and other fruits and vegetables - chickens.

September, October:

Peaches, apricots and other fruits.

November, December:

Pork, beef, lamb and other meats.

<u>Operation - Simple and Dependable</u>

The actual operation of a home freezing plant is relatively simple once it is installed.

The most important thing is to be sure that the cabinet temperature does not vary more than 5^{o}F. for any length of time. Keeping a thermometer in the cabinet is a good plan. Of course, the ideal arrangement, but expensive, would be to have a recording thermometer.

A plant properly installed can be depended upon to give satisfactory operation. Power line failures are not a serious problem because the utility companies are constructing better lines and giving better service. Very seldom is electrical power interrupted for any length of time in the rural areas.

Defrosting of the home freezer is simple when freezing plates are used. A wire brush or a wide blade putty knife makes a very useful tool to do the job. All that need be done is to give the plates a good brushing or scraping. Ordinarily defrosting needs to be done about once every two months. Of course this depends upon the amount of moist air that enters the cabinet. Usually one can tell from observation when the frost needs to be removed.

It is well to remember that the accumulation of frost on any freezing unit lowers the efficiency because frost is a rather poor conductor of heat and therefore, it is desirable to defrost the unit when needed.

The home freezing plant will give the same dependable service the household refrigerator has been giving.

Differences in Kinds of Product and Methods of Handling

Some kinds and varieties of fruit, and vegetables are better adapted for freezing preservation than others.

Strawberries, cherries, blueberries, raspberries and peaches are a few of the more common kinds of fruits that have proven suitable for freezing.

Of the vegetables, peas, lima beans, snap beans, asparagus, spinach, broccoli, Swiss chard, cauliflower, and corn cut off the cob have been most satisfactory kinds for freezing.

There appears to be a difference in the freezing quality of different varieties within the same kind of product. Tressler (1) rates the Eclipse peach, excellent; J. H. Hall, good; Late Alberta, fair and the Carmen, very poor.

Tressler (1) also reports that a variety in one locality may be desirable for freezing, while the same variety in another locality may be undesirable for freezing. A possible explanation may be the lack of uniformity in soil and climatic conditions.

Much work is being done by investigators in determining what varieties of fruits and vegetables are suitable for freezing in different localities. Timely information regarding varieties adaptable for freezing is best obtained from the Horticultural or Home Economics Department of the State Agricultural College.

For best results it is essential to select fruit and vegetables that are in their prime condition for immediate consumption. Freezing does not improve the quality and texture of over-mature or under-mature products.

Freezing fruits and vegetables within a few hours after gathering is necessary if the original quality is to be maintained. Harvesting the products in the morning and freezing them in the afternoon or sooner is desirable. At ordinary summer temperatures vegetables change rapidly after harvesting. Sugar and moisture are lost rapidly and vitamin C may be partially destroyed by delay after harvesting.

If products must be held over to the next day they should be placed under some form of refrigeration. Temperatures of 32°F. to 40°F. greatly slows up the respiration and enzymatic changes.

Freezing preservation is reasonably new to most people and the method of processing vegetables and handling fruits differs somewhat from home canning methods. Usually freezing is much simpler and quicker. Even though freezing is simple and quick the processing procedure must not be neglected. Very often the tendency is for people to blame the equipment rather than the preparation or processing the food product.

In brief, the method of handling vegetables is as follows: After sorting, grading and washing the most important step is the scalding or blanching. Blanching intensifies or brightens the color, destroys many molds, yeasts and bacteria, makes packing easier by softening the tissue and inactivates enzymatic activity. The last is very important. After the blanching the vegetables are dipped into a cold water bath to stop cooking action and cool the product. Vegetables can be packed "straight" or in a weak salt brine.

Fruits require a different treatment. They are usually sorted, graded and washed the same as the vegetables. Fruits do not require blanching. Fruits are usually packed in a sirup solution or plain sugar and some kinds of fruits can be successfully frozen without either sugar or sirup.

Containers for fruits and vegetables that are to be stored at $0^{o}F$. should be as air-tight, moisture-proof and vapor-proof as economically possible. Glass and tin cans satisfy the requirements in regard to moisture proofness and air-tightness. With glass there is a breakage problem unless care is exercised in filling the can. Tin cans have been very satisfactory except carelessness may result because people may confuse them with ordinary canned goods and they are liable to be left out in an open room to thaw, then spoilage starts very soon. The rectangular shaped, waxed carton with a moisture-vapor proof liner has proven dependable and also utilizes the locker space better than cylindrical containers. Containers having small openings at the top or taper towards the top should be avoided because of the difficulty in removing the products.

Meats are the simplest of the products to handle because about all that needs to be done is to cut the meat in a family sized piece and wrap it in a moisture-vapor proof paper. See sample, Figure 1. It is well to label the package as to content, weight and date.

Freezing of Products

Good management practices are - pre-cool the product, freeze in small quantities and in small, flat, rectangular packages. Each package being frozen should be in direct contact with the freezing plates in order that freezing will be as rapid as possible.

The household refrigerator is suitable for pre-cooling small amounts of product, whenever one is available, or in some cases, cold water or ice may be used. Although it would not be necessary to obtain ice especially for this purpose.

Refrigerating plants are designed to cool and freeze a pre-determined load in a certain length of time; therefore, it would

be better to distribute the load over a period of time other than to introduce a large quantity of goods at one time. The introduction of large quantity of warm product at one time is liable to cause the temperature of the cabinet to rise more than it should. The temperature ought not to vary more than $4^{o}F.$ or $5^{o}F.$ Thirty to fifty pounds would be considered a reasonable amount to freeze at a time. Sixty-five pounds of meat was placed in the freezer cabinet being tested and the temperature did not vary more than $4^{o}F.$

The smaller the package the faster it will freeze and for practical purposes the package ought to be of a size that one package would be enough for a meal. With the smaller, family size package, there will be less waste because the product will be consumed and none need be left over for other meals. This is important because frozen foods tend to spoil after thawing quicker than fresh foods. However, frozen foods can be kept for a few days under good refrigeration.

Vegetables deteriorate very rapidly after harvesting; therefore, to have a high quality product vegetables should be harvested, cleaned, processed, and frozen as quickly as possible. Consequently small quantities can be handled much easier and quicker. The same would also hold true for fruits.

For best results, products should be spread over the freezing plates in a single layer if possible. After the products have frozen the packages can be piled to make room for freezing additional products.

Length of Storage Time

For practical purposes there are no advantages in extremely long storage periods, such as more than a year. The primary purpose of a freezer storage is to carry products over to a time when they cannot be obtained fresh. For example, vegetables and fruits could be frozen in July or August and used during the winter months.

Most fruits and vegetables can be stored successfully for a year. Most meats with few exceptions can be kept for about one year, provided it is well wrapped and stored at a uniform temperature of 0^{o}F. or below. Pork turns rancid quicker than beef; fat pork turns rancid quicker than lean pork, and it is advisable to keep pork not longer than 8 months at 0^{o}F.

Care in Handling Frozen Foods

Frozen foods should be regarded as perishable foods. Because of the blanching and freezing treatment frozen foods are more perishable than fresh foods. Although there has been a great reduction in microorganisms, there are enough left to start spoilage if and when the optimum temperature is reached for the organisms growth. A general rule is to cook and consume frozen vegetables just as soon as they have thawed - cook all vegetables before eating. Left-overs when cooked immediately will keep for a short time under refrigeration.

Fruits are considered satisfactory for consumption in the raw state. They may be eaten partially thawed or completely thawed. A rule similar to the one used for vegetables could apply for fruits - consume frozen fruits as soon as they have thawed.

Frozen meats may be cooked as soon as they have thawed or cuts such as steaks and chops may be cooked in the frozen state by starting the cooking at a low temperature. With larger pieces it may be preferable to thaw before cooking. The method to use will depend on personal likes and dislikes.

Cleanliness is Necessary

Cleanliness about and in the freezing cabinet is just as important as cleanliness in the preparation and processing of food products. Keeping the freezer clean and in a sanitary condition is a very good form of insurance of preventing the development of any off-odors within the freezer storage. Food from a clean and sanitary place is much more appetizing than that from a less attractive place.

Tressler (18) says: "As yet, too little consideration has been given to sanitation of locker plants, and, even in some instances, to sanitary precautions in commercial food freezing plants. Unless strict sanitary precautions are maintained in food plants, both during the preparation of the food and its subsequent refrigeration, freezing preservation will get a black eye from which it will take years to recover. Spoiled frozen food is certain to make those who eat it ill, and a few deaths from so-called "ptomaine" or botulinus poison will come close to wrecking the grand and glorious prospects of the general use of freezing preservation."

This statement should emphasize the importance of using sanitary methods in the preparation of food products for the home freezing plant.

Results

The freezer-storage unit has been in operation since January 29, 1940. It has been operating in the Agricultural Engineering laboratory at Michigan State College. The results are as follows:

Investment in Equipment

The cost of the freezing plant at retail prices would be:

a.	Cabinet, complete	$66.67
b.	Cabinet stand	6.06
c.	Freezing plates	105.00
d.	Condensing Unit 1/2 H.P. (Includes pressure switch)	200.00*
e.	Expansion valve, low temperature	15.00
f.	Heat exchanger	20.00
g.	Freon-12	7.00
h.	Fittings, tubing, etc.	5.00
	Total cost at retail prices	$ 434.73

Operating Costs

A kilowatt-hour meter was installed on February 8, 1940. During the period from February 8 to February 16 the temperature of the cabinet was -20°F. to -22°F. February 16 the temperature of the cabinet was adjusted to -10°F. and has been maintained at that temperature since.

The power consumption record is shown in Table 6.

Table 6 shows that it requires 1.12 kw-hr. less to operate the cabinet at -10°F. than at -20 or -22°F.

Operating at -10°F. the average consumption of electricity was 3.25 kilowatt hours per day.

The cost of electricity varies within the state, depending

*Approximate cost of 1/2 H.P. condensing unit.

Table 6. Kilowatt-hours required to operate home freezer storage cabinet February 8, 1940 to May 15, 1940.

Date	Meter Reading	Kw-hr. used	Av.Kw-hr. per day	Temperature of cabinet	Remarks
Feb. 8	7,972			-20°F.	Meter installed
16	8,007	35	4.37	-22°	Temperature adjusted to -10°F.
21	8,023	16	3.20	-10°	
29	8,050	27	3.37	-10°	Recording thermometer installed Feb. 29.
Mar. 4	8,063	13	3.25	-10°	
11	8,084	21	3.00	-10°	
19	8,106	22	2.74	-10°	
27	8,128	22	2.74	-10°	
Apr. 6	8,162	34	3.40	-10°	
22	8,214	52	3.25	-10°	
May 6	8,267	47	3.35	-10°	

Av. Kw-hr./day Feb. 16 to May 6 = 3.25 Kw-hr.

on the amount of electricity used. Studies made by the Consumers Power Company show that on three demonstration electrical farms, 1937-38, the average yearly cost of electricity was 1.49, 2.105 and 2.648 cents per kw-hr.

Using a value of 2 cents per kw-hr. the cost of operating the freezer-storage cabinet would average approximately 6.5 cents per day. At the 1.5 cent rate, the approximate daily cost would be 4.87 cents. The operating cost could also be decreased by raising the cabinet temperature to 0°F., but it would not be advisable to raise the temperature above this point.

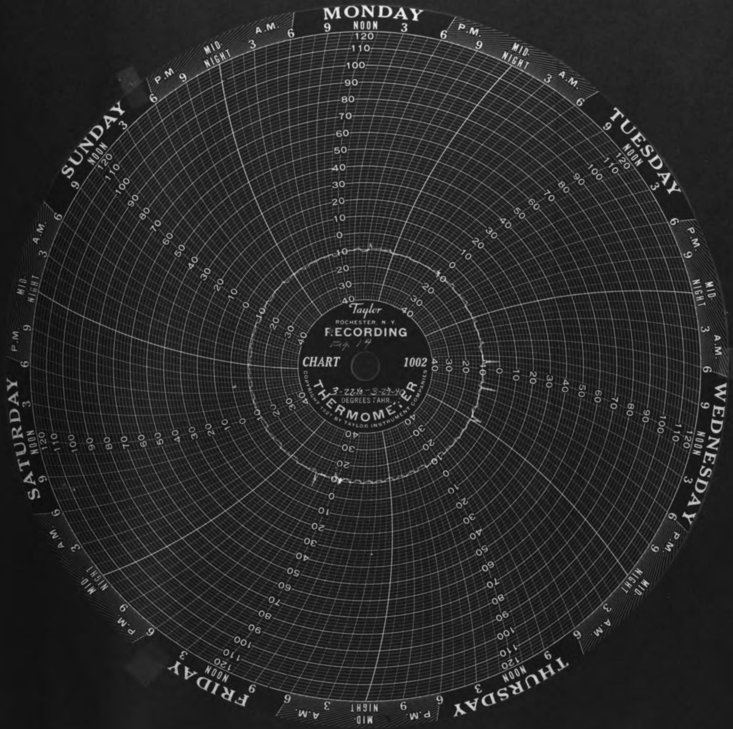

Figure 14. Typical charts showing the temperature inside of Freezer-Storage Cabinet

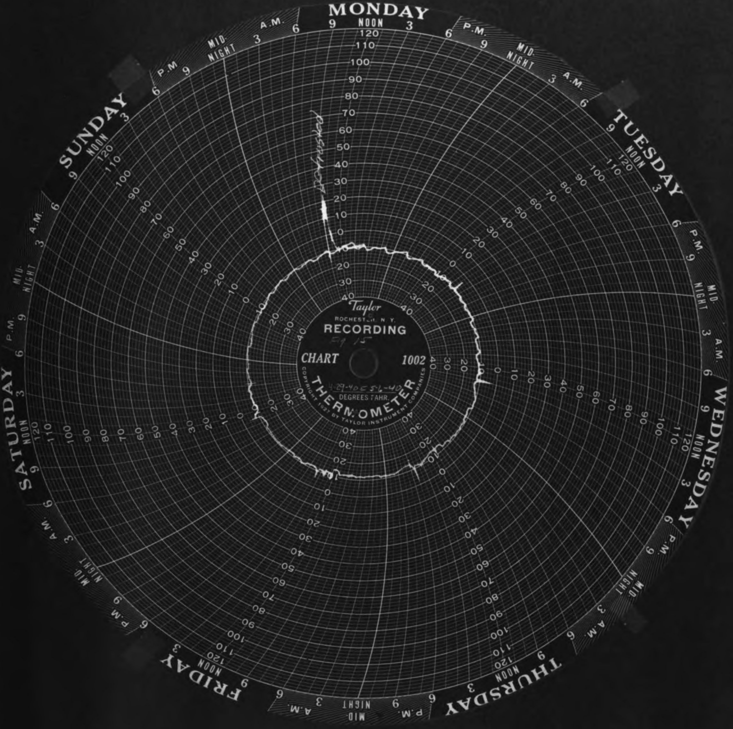

Figure 15. Typical charts showing the temperature inside of Freezer-Storage Cabinet

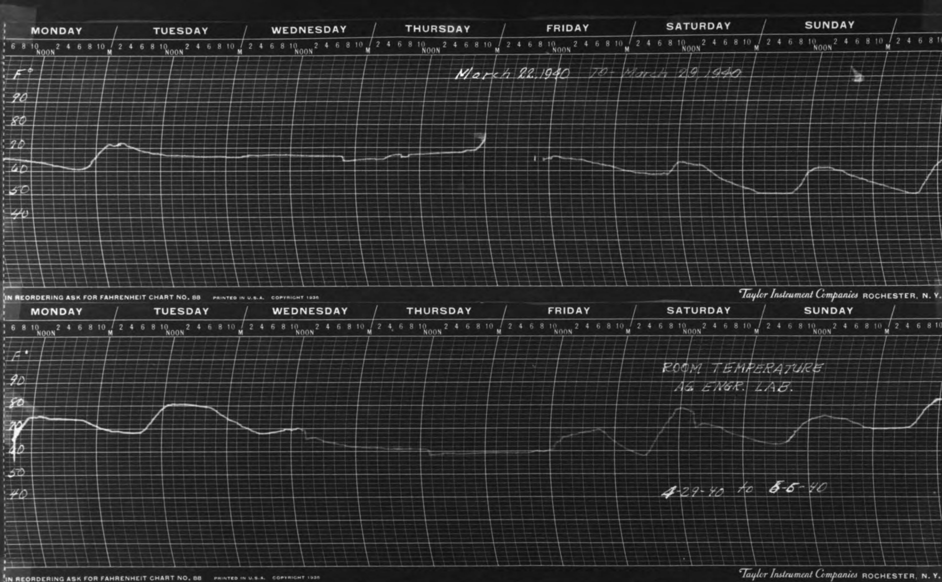

Figure 16. Charts showing the room temperature of Agricultural Engineering Laboratory

Total Yearly Costs

Total yearly cost includes depreciation, interest, taxes, insurance, repairs and operating expenses. For equipment of this kind 15% of the investment is considered as overhead expense. Therefore, 15% of $434 would be $65.10 (Table 7).

Table 7. Estimated total yearly cost of freezer-storage unit

Item	Amount (dollars)
Overhead (15% of $434) includes depreciation, interest taxes, insurance, repairs and miscellaneous	$65.10
Operating @ 6.5 cents per day	23.72
Total	$88.82

Operating Performance

Maintenance of a uniform temperature of 0°F. or below in the freezer-storage compartment is of primary importance in freezing preservation of foods. The temperature in the cabinet has been maintained very satisfactorily. Variations in temperature have not exceeded a plus or minus two degrees except when the doors were opened for placement or removal of products and when power was off. Figures 14 and 15 illustrate typical records of the cabinet temperature. Figure 16 illustrates the corresponding temperature records of the room temperature.

For some unknown reason the electricity was disconnected from 3:00 p.m. Wednesday, April 10 to 9:00 a.m. Friday, April 12, a period of 42 hours. After the first 6 hours the temperature was -5°F., after the next 6 hours the temperature was 0°F. and during the next 30 hours the temperature rose only 10° resulting in a temperature of +10°F.

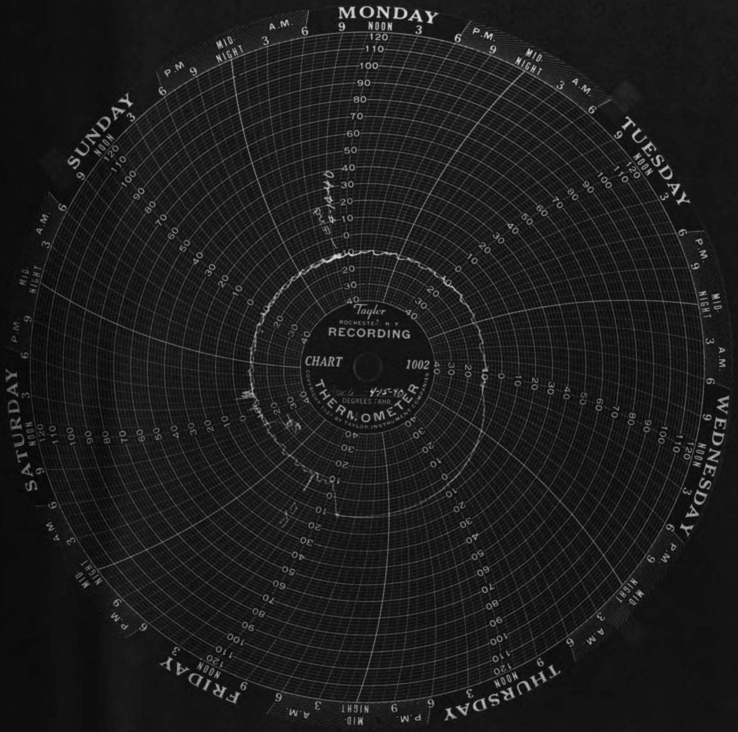

Figure 17. Chart showing the temperature of the freezer cabinet during the time the power supply was disconnected

During the first 6 hours the temperature rose only 5° which indicates there would be no particular harm done to product during short periods of power failure (Figure 17).

After the freezing unit had been in operation for about 8 weeks some frost accumulation was noticed on the front center of the top plate. Frost accumulation could have been caused by leaky door jackets, opening and closing of the doors and leaving the doors ajar. Because of the type of locking arrangement it was possible for anyone attempting to open the cabinet door to release the catch just enough to leave the door ajar. One shim was removed from the door strike and a notice posted on the door requesting that the doors be kept tightly closed. Since then the frost accumulation has been reduced considerably.

Products Frozen and Stored

Poultry, pork and beef have been frozen and stored in the freezer-storage cabinet. Only a few hours are required to freeze meat. Sixty-five pounds of beef varying in weight from $1\frac{1}{2}$ pound to 5 and 8 pound packages were completely frozen in about 8 or 9 hours. This time was determined by observation of the place on the temperature chart when the temperature leveled off to normal -10°F. With the introduction of this 65 pounds of meat the temperature did not vary more than 4°. An average sized steak laid flat on the plates will freeze solid in about one hour and twenty minutes. One hundred twenty-five pounds of choice cuts of pork was the first amount of meat frozen. Unfortunately the recording thermometer was not available when this meat was frozen.

Five chickens have been frozen, three were frozen whole and two were cut into pieces for freezing.

Fig. 18. Products stored in freezer-storage cabinet.

The quality of the pork, beef and chickens at the time of consumption was excellent. Freezing seems to improve the flavor and tenderness of meat. Chicken in particular appeared to be more tender than when eaten fresh.

Conclusions

This study shows that home produced foods can be frozen and stored in a home-built cabinet.

Meats frozen and stored at $0^{\circ}F.$ or below are more palatable than those canned by pressure cooker or preserved by other methods. Investigations have shown that frozen fruits and vegetables are of better quality and more nearly resemble the fresh fruit or vegetable than canned products. Imagine being able to invite your friends in for fresh strawberry shortcake at Christmas. Blueberries, cherries and peaches are other delicious fruits that can be enjoyed out of season. This is but one example of the services derived from a home freezing unit.

Labor saving is am important factor. The home freezing unit can contribute greatly to lightening the duties of the homemaker. Meats especially can be preserved so much easier and quicker by freezing than by canning. From experience it was found that a 200-pound hog could be cut into family sized servings, wrapped, labeled and ready for freezing in about three hours. Compare this time with one and one-half or two days the housewife usually spends canning meat by ordinary methods. This time did not include the rendering of the lard or making sausage.

The total cost of owning a home freezing unit including depreciation, interest, repairs and operation would be approximately $88 per year. Rental of the equivalent space, 20.5 cubic feet, from a commercial locker plant would cost $39.40.* Assuming 1,500 pounds of food products stored per year, the locker plant processing charges would be approximately $23.25. Add this to $39.40 and the total is $62.65. Comparing the two kinds of storage the cost per pound (for 1,500 pounds) would be 5.8 cents for the home freezer and 4.2 cents for the commercial locker. The home freezer-storage is at the source of supply and consumption thereby eliminating the inconvenience and the expense of travel to and from the locker plant.

Home produced meat is much cheaper than that purchased from the local market. By freezing his own meat the farmer has a quality of meat equal to or better than that he would purchase from the local market. For example a saving of $12.46 may be made by freezing one hog (See Table 8).

On that basis, the savings on two hogs would pay for the operating costs of a home freezing unit. The savings that could be realized on a beef would be about $60 to $75.

The total yearly cost as calculated is higher than necessary because the price of the 1/2 H.P. condensing unit was used in calculating the yearly cost. A 1/3 H.P. condensing unit could be used and this would decrease the amount of investment and interest. The cost of operating the 1/3 H.P. unit would be less than that of operating the 1/2 H.P. unit.

The economy of a home freezing plant will depend upon the use

*Based on locker size 18 x 20 x 30 inches at the rate of $12 per year.

Table 8. Savings realized by preserving home produced pork

Cut of meat	Dressed yield per hog* (pounds)	Retail price per pound**	Purchase price
Hams	33.1	$ .19	$ 6.30
Loins	26.7	.21	5.35
Bacon strip	21.4	.20	4.28
Picnic shoulder	20.4	.11	2.24
Boston butt	8.8	.19	1.67
Spare ribs	8.8	.12	1.06
Sausage trim	17.3	.08	1.38
Lard	24.0	.07	1.68
Hocks	3.7	.10	.37
Head & feet	18.3	.01	.18
TOTAL	182.5		$24.51
Av. live weight	234	$5.15/cwt***	12.05
SAVINGS			$12.46

* Brown, Geo. A. and Westveld, Amy. The Home Meat Supply Michigan State College Ext. Bulletin 151, Nov. 1935, p. 13

** Prices obtained at local market April 16, 1940

*** Prices on Detroit Livestock Market April 16, 1940 made of it. For example, if 1,500 pounds of product can be frozen and stored for 5.8 cents per pound, to freeze and store 500 pounds of products the cost would be 17 cents per pound.

Additional farm income may be had by marketing frozen farm products. For example, frozen poultry could be a specialty.

Home freezer-storage units can be adapted to various installations to accommodate different situations and individual requirements. The freezer fits in especially well with a walk-in cooler, thus offering storage under controlled conditions throughout the year. No longer would the farmer have to depend upon freezing weather to preserve his fresh meat supply.

Although the present freezer-storage unit has performed satisfactorily, it is believed that following suggestions or changes would be advisable.

a. Simplification of cabinet by re-designing, making it adaptable to either a rigid, blanket or fill insulation. See drawing 3.

b. One door is recommended, simplifies construction and in addition decreases the amount of heat leakage, amount of gasket material and expensive hardware.

c. Suggested that the interior door stop be adjustable to provide a positive seal against the inside gasket.

d. Using one door the whole front section should be demountable to facilitate installation of plates. This suggests that a front section and door assembly could be commercially built and marketed to farmers or others contemplating building a home freezer-storage unit.

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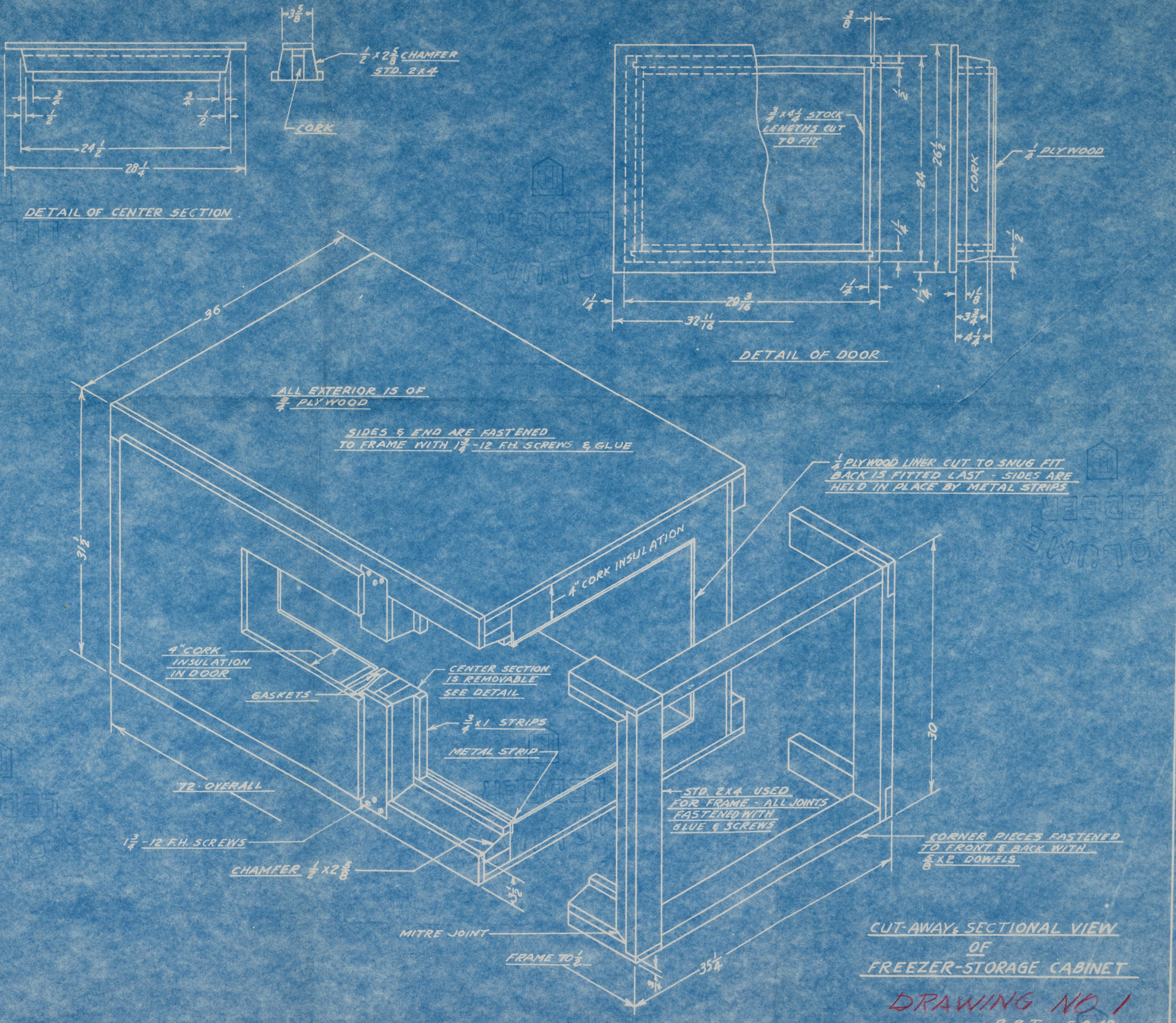
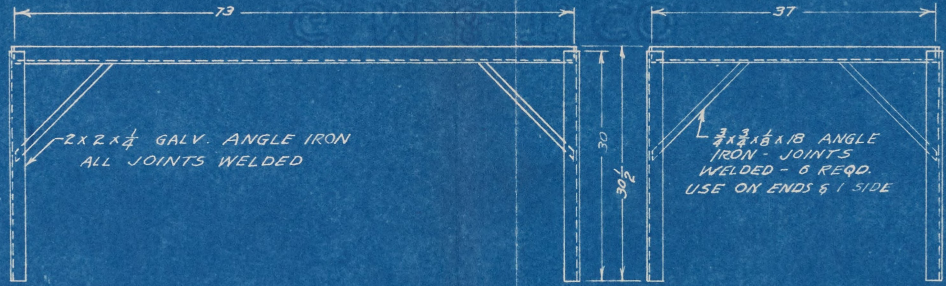


CUT-AWAY & SECTIONAL VIEW OF FREEZER-STORAGE CABINET

DRAWING NO 1

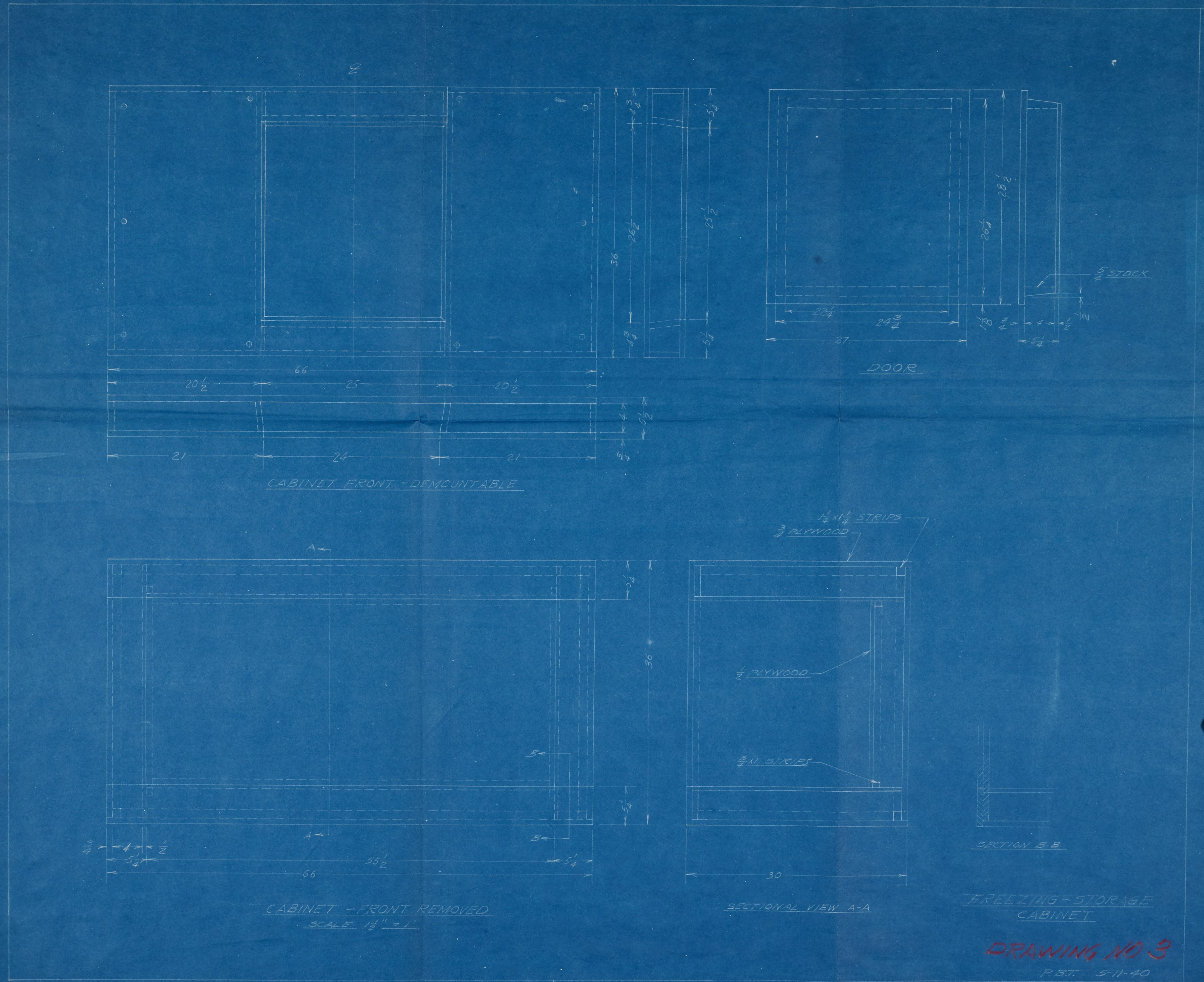
P.B.T. 5-9-40



STAND FOR FREEZER CHEST

SCALE 1" = 1'

P. B. T. 11-39


CABINET FRONT - DEMOUNTABLE
DOOR
5/4 STOCK
CABINET - FRONT REMOVED
SCALE 1½" = 1'
1¼ x 1½ STRIPS
3/4 PLYWOOD
1/2 PLYWOOD
3/4 x 1 STRIPS
SECTIONAL VIEW A-A
SECTION B-B
FREEZING - STORAGE CABINET
DRAWING NO 3
P.B.T. 5-11-40