A STUDY OF LOW COST REFRIGERATION EQUIPMENT FOR COOLING CREAM

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE

Fred Eugene Satchell

1947

This is to certify that the

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"A STUDY OF LOW COST REFRIGERATION EQUIPMENT
FOR COOLING CREAM"

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FRED E. SATCHELL

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Arthur W. Farrall
Major professor

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A STUDY OF LOW COST REFRIGERATION EQUIPMENT FOR COOLING CREAM

By

Fred Eugene Satchell

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A STUDY OF LOW COST REFRIGERATION EQUIPMENT FOR COOLING CREAM

PURPOSE OF PROBLEM

It is generally recognized that in the postwar period, considerable pressure will be brought on the butter industry to improve the quality of their product. Federal and State laws may require such improvement or it may be forced by consumer pressure.

One of the most effective ways of maintaining the high quality of farm held cream is by the use of low temperatures. This problem has been set up to design, build and test one or more basic designs for a low cost mechanical refrigerator which will prevent cream deterioration and thus make better butter possible.

HISTORY AND DEVELOPMENT OF THE BUTTER INDUSTRY [9]

Butter has been used for various purposes including food, medicinal and cosmetic purposes since before the beginning of the Christian Era. Martiny, a German dairy scientist, records the making and use of butter in 2000 A.D. For centuries the cream for this butter was separated by gravity. To be effective, gravity separation must take place on cream that has not lost the physical properties characteristic of sweet cream. Thus, since effective separation requires from 24 to 48 hours, this method is successful only when the temperature of the cream could be held low enough to prevent curdling in this length of time.

In the infancy of butter as a food, there seems to have been developed a taste for rancidity, probably from necessity. Butter was even buried and left for long periods of time. One practice was to bury the butter and then plant a tree over it to insure against its being disturbed. The Irish buried butter in the peat bogs of that country. Specimans have been recently discovered that are believed to be over eight hundred years old.

Until the middle of the 19th century the factory system of butter manufacture was practically unknown. The butter was nearly all made during the summer months on the farm. Refrigeration, pasturization and other present day quality control methods were unknown at that time and the market butter was of inferior quality. By the end of the flush season the butter was of such poor quality that it was not marketable as such. It was generally disposed of as packing stock.

Efforts to renovate packing stock butter were first successful in 1885. In this process the butter is melted, clarified and refined. This oil is mixed with skim milk, milk or cream and regranulated. About 50,000,000

pounds per year of this butter were sold during the first decade of the 19th century.

Records indicate that Manchester, Iowa started the first butter factory in 1871. This first factory gathered whole milk and skimmed the cream in the factory, however, the practice of gathering cream and processing in a central plant became popular at nearly the same time.

In 1879, Dr. Gustav Patrick DeLavel, introduced his continuous cream separator in Sweden. Factories in this country changed to his separator in the years from 1885 to 1890 and farm separation practically disappeared. During this period creameries bought whole milk and separated it at the creamery. This practice yielded a much better quality of cream than was obtained under the old system. Consumption increased rapidly and the butter industry flourished.

The farm separator was introduced in the last decade of the 19th century. Its acceptance was slow at first but was firmly established by 1920 and by 1930 was adapted on practically every farm in the dairy regions of this country.

The creameries again adopted the gathered cream system and the responsibility for cream quality was shifted again to the farm. While the farm separator undoubtedly

has helped to spread the dairy industry and thus increased the volume of dairy products, it has resulted in much of the cream being received in an advanced stage of deterioration. This has in turn had an adverse effect on the quality of American butter. Keen competition for cream volume has also aggravated the quality program. Efforts toward cream quality improvement have been nullified in many sections by the refusal of creameries to pay a premium for high quality cream.

There has resulted from this situation of poor butter quality two definite trends, one is directed toward the return to the gathered milk system with better utilization of the non-fat milk solids to pay the added transportation cost. There has been a great amount of research on better processing methods and market development for these products.

The second approach is to provide the farmer with inexpensive facilities to maintain the quality of the cream until delivered to the factory. This approach should appeal particularily to the farmer who desires the skim milk for stock feed or other home use. Perhaps it could not be justified unless there was a good use present for the skim milk, or unless the farmer was far removed from a market.

BACKGROUND FOR THE PROJECT

The butter industry has two main purposes in the American economy. The first purpose is the obvious one of providing income to thousands of farmers. These farmers are usually small producers or are isolated from a fluid milk market.

The second purpose is less apparent but not less important. The butter industry acts as a balance wheel in the fluid milk industry. There have always been periods of slack and heavy production of dairy products. Usually the farmer takes advantage of the lush spring feed supply to produce the heaviest flow of milk. Conversely, in mid-winter milk production falls off markedly. Therefore, if the fluid milk supply is to be adequate in this slack winter period, some profitable means of using the surplus spring and early summer flow must be provided. The dairy industry has traditionally used this summer surplus to produce butter.

THE QUALITY PROBLEM

The quality of the cream and butter produced from this surplus milk is good because the milk is gathered every day and separated in the collecting station or processing plant. However, the consumer also uses butter made from cream produced by the small or isolated dairyman

and here the cream quality program needs prompt and serious action. Much of this cream is a week or more old and has already suffered severe deterioration by virtue of high temperature storage or neglect of proper cleanliness procedures.

The quality of the butter made from this cream is necessarily very poor in spite of the excellent work in pasteurization and neutralization of sour cream preparatory to butter making. In view of the widespread introduction of vegetable fat substitutes during World War II, it seems very necessary to establish high standards of butter quality to meet this competition and maintain the consumer market necessary to both functions of the butter industry. The loss of the consumer market for butter would be a tremendous blow to the entire dairy industry. Butter men are becoming increasingly conscious of the adverse effect on consumer goodwill that this poor butter is producing. They are ready to back any sound program that will improve the quality of cream received. The industry technology makes good butter a simple attainment if the cream supply is of reasonable good quality.

Current Approaches to Quality Control

There are two basic approaches to the problem of maintaining the quality of farm held cream. One method would be the use of preservatives to inhibit bacterial

and enzyme activity. The use of common salt for this purpose was patented by Williams (U.S. Patent No. 2,192,864) and made available as a public service patent.[19] This method was shown to be effective by several investigators[3,6,11,17] but has never been approved by the Pure Food and Drug Administration.

It was found that butter could be held for one week at room temperature with no appreciable deterioration in quality if about 10% of salt was added. Butter from this cream in no instance contained over 2.5% of salt and scored from 2 to 5 points higher than unsalted cream held under the same temperature conditions.[6] It would be difficult to standardize the salt content of butter made from salted cream since the salt present could only be estimated without a chemical determination. Also salt is corrosive to all common dairy metals except stainless steel which would be a definite deterrent to its widespread use.

Hydrogen peroxide has also been shown to be an effective bacteriacide and has been used to preserve dairy products particularily in Italy. The advisability of recommending the use of chemical perservatives by inexperienced farmers is open to many criticisms and has not received official encouragement.

The second and perhaps the best procedure, based on present knowledge, would be to maintain the cream at a

low temperature to inhibit bacteria growth. Golding and Miller [8] found that mold in cream grew most rapidly at 77.5 degrees to 86 degrees F. While growth will occur at lower and higher temperatures, the rate of growth at temperatures approaching the freezing point of water is very slow.[2] The work of many investigators shows a rapid increase in bacteria growth rate when the temperature is raised from 45 degrees to 50 degrees F. (Fig.1)[14] The rate does not change markedly at temperatures lower than about 48 degrees. Therefore there would seem to be no advantage in maintaining lower temperatures. In fact raw sweet cream characteristically develops a bitter metallic flavor when held at temperatures below 40 degrees F.[15]

RELATIVE IMPORTANCE OF CLEANLINESS AND COOLING

It has been shown conclusively that the temperature of cream storage is the most important single factor in cream quality and therefore, in butter quality. All cream possesses some initial contamination. Milk, freshly drawn into sterile containers will usually show bacteria counts in the thousands. These bacteria multiply very rapidly at temperatures above 50 degrees F.

In an experiment conducted at Pennsylvania State College, [1] milk was plated and the bacteria counted directly after drawing from the cow and after "cooling" 12 hours. These tests were made on a farm and the milk temperature

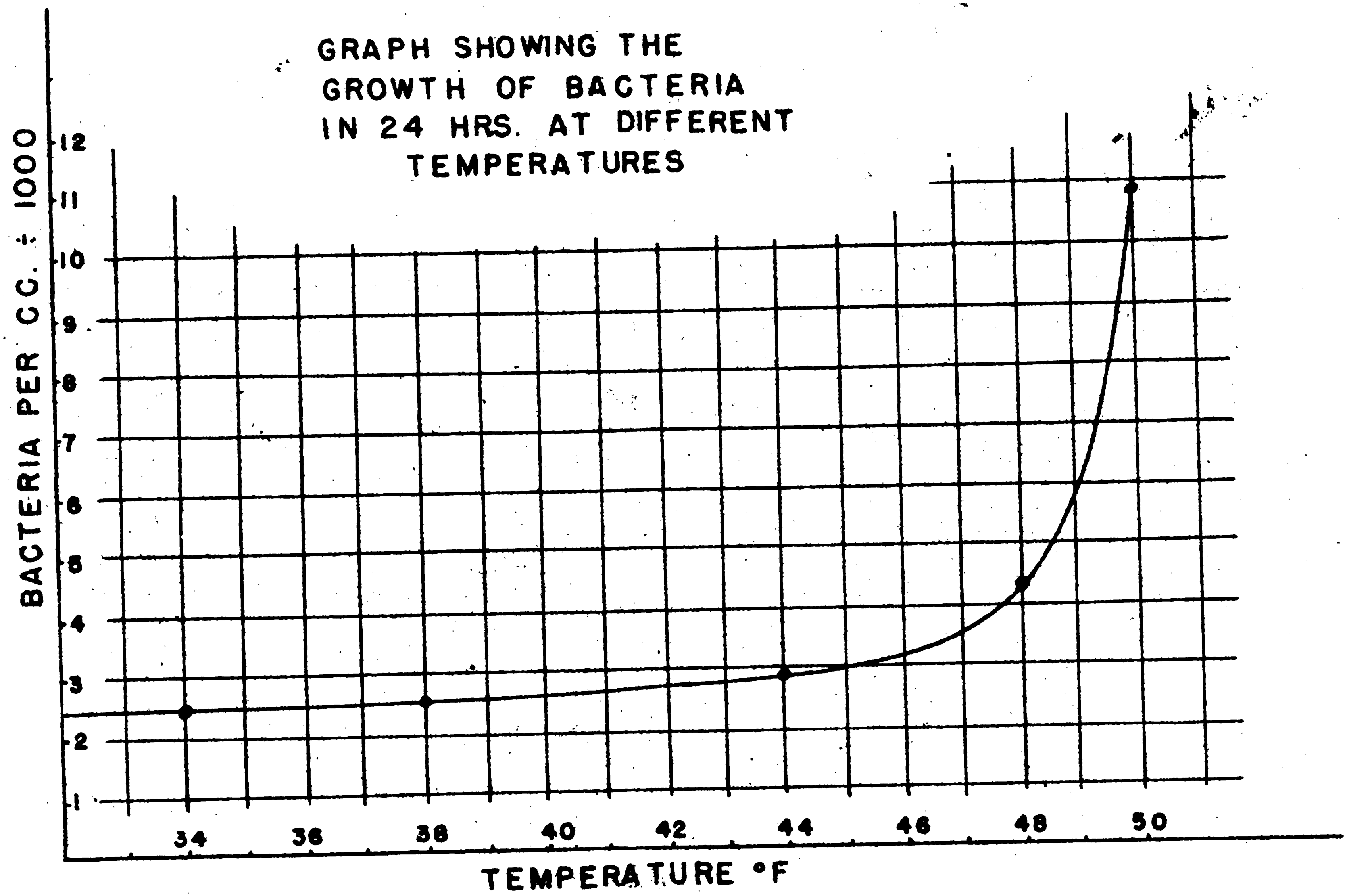

GRAPH SHOWING THE
GROWTH OF BACTERIA
IN 24 HRS. AT DIFFERENT
TEMPERATURES
BACTERIA PER CC. ÷ 1000
12
11
10
9
8
7
6
5
4
3
2
1
34
36
38
40
42
44
46
48
50
TEMPERATURE °F

Fig. No.1

after cooling was still relatively warm - 60 to 68 degrees. Under these conditions percentage increases of up to 762,400 percent were noted.

In a study by J. M. Jensen and A. L. Bortee at Michigan State College,[10] the effect of separator cleanliness and storage temperature was studied. Three storage temperatures were used, 53, 63, and 73 degrees F. Three samples were stored at each temperature making a total of nine samples. At each temperature, samples were stored which had been separated from (a) a carefully washed and sterilized separator bowl, (b) a dirty separator bowl stored at 53 degrees F. and, (c) a dirty bowl stored at 73 degrees F. The results of this test are shown in Figure 2. The overwhelming effect of temperature of storage is very apparent. Figure 3 shows work done by different investigators but also illustrates the effect of storage temperature and its relative importance compared to cleanliness.

It may be concluded that the three essential factors in the maintaining of cream quality are time of holding, temperature of storage, and good cleanliness habits. In this study, the element of temperature is given heavy stress. It appears that temperature control can minimize but not eliminate the evils of long holding and heavy contamination.

EFFECT OF CLEAN AND UNWASHED SEPARATOR BOWLS ON BACTERIA GROWTH (JENSEN AND BORTREE)

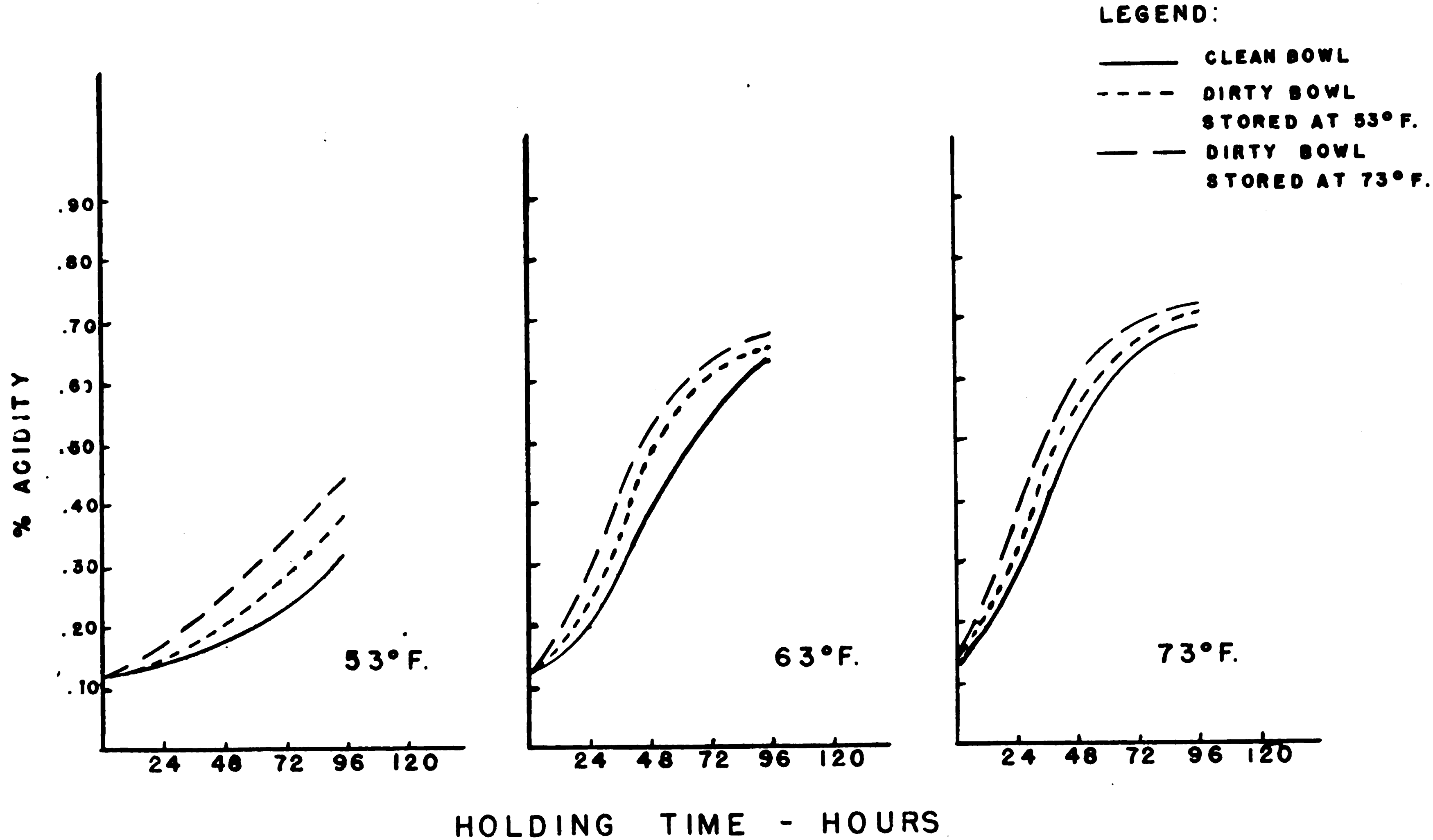


Fig. No. 2

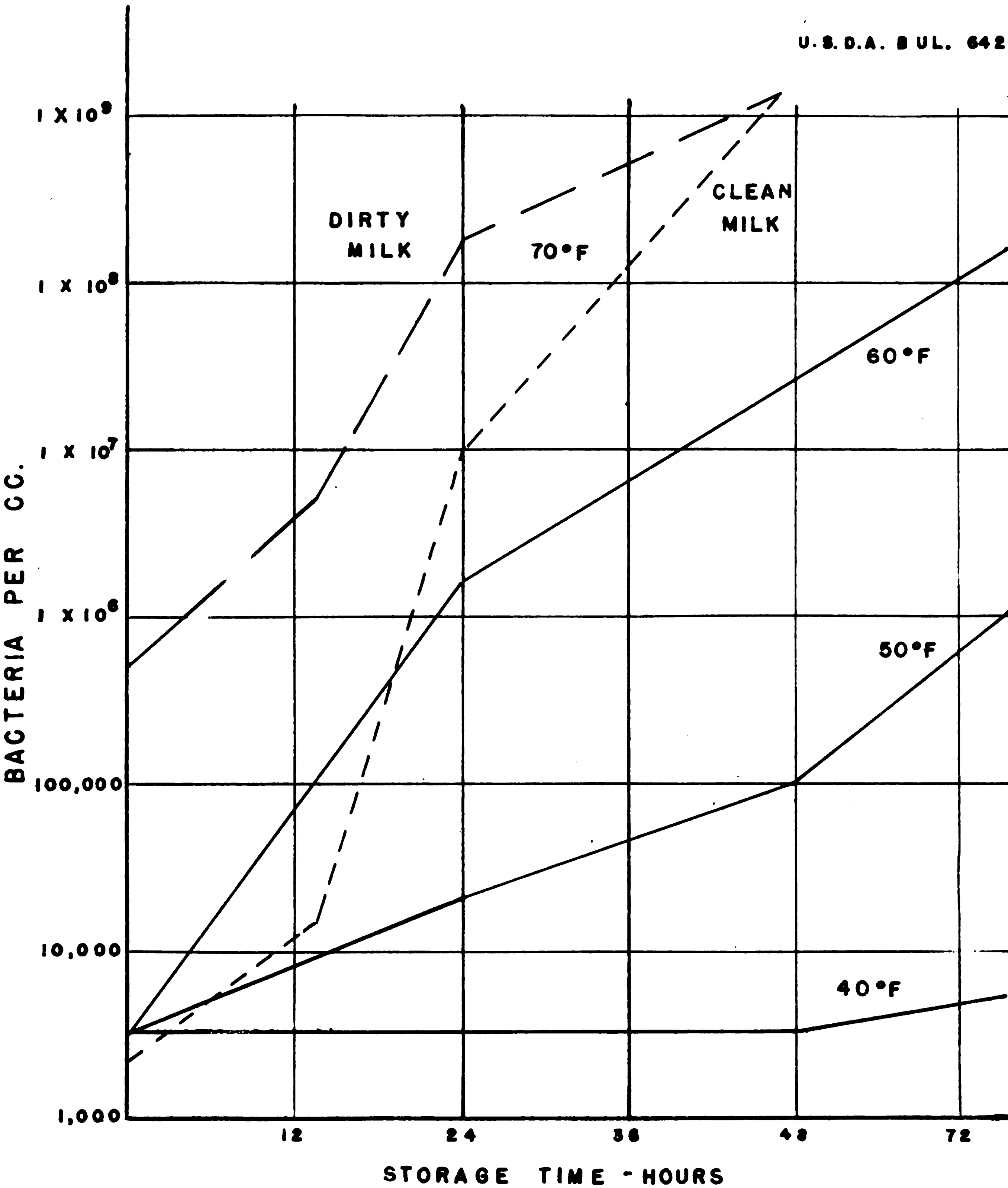
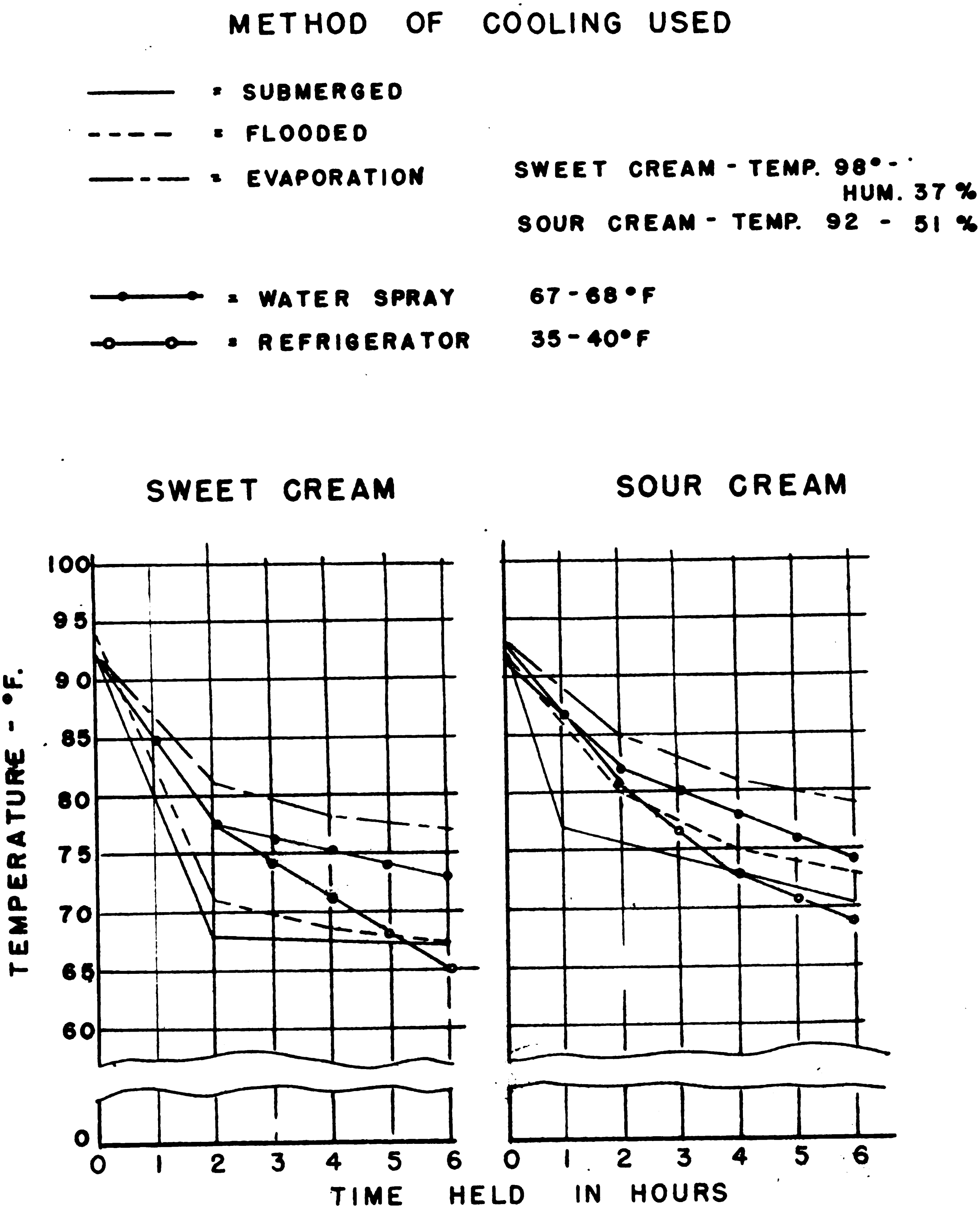

U.S.D.A. BUL. 642
DIRTY MILK
70°F
CLEAN MILK
60°F
50°F
40°F
1 X 10^9
1 X 10^8
1 X 10^7
1 X 10^6
100,000
10,000
1,000
BACTERIA PER CC.
12
24
36
48
72
STORAGE TIME - HOURS

Fig. No. 3

Method of Cooling

Caulfield and Martin [5] studied five methods of cooling cream which have practical significance. (Fig. 4) These five methods included submerging the can in cold water, flooding or allowing a heavy flow of water over the cans, evaporation of water from wetted cloth wraps, water spray and storing in a refrigerator. Not included but certainly worthy of note is mechanical refrigeration of the water bath. This would, in fact, be faster and more effective than the previous five. However, the five methods studied cooled in order of decreasing rapidity, submerged, flooded, refrigerator, water spray and evaporation. All except refrigeration are dependent on local conditions such as water temperature, humidity and air temperature.

The two most common methods used in the collecting stations were evaporation and water spray. The use of evaporative cooling is intrinsically slow and under conditions of greater than 60% relative humidity this method is ineffective. During the test, temperatures obtained varied with the room temperature and the humidity. Room temperatures ranged from 103.5 degrees to 72 degrees. Corresponding temperatures obtained in the cream were 82 degrees to 84 degrees for 103.5 degrees room and 57 degrees to 64 degrees for 72 degrees room with the



CAULFIELD & MARTIN

J. DAIRY SCIENCE

Fig. No. 4

variation at a definite room temperature due to variation in humidity conditions. Bacteria would grow rapidly even at the lowest of these temperatures. Spraying is also only effective if the water and room temperatures are low. One must conclude that the only dependable method of obtaining and maintaining consistently low temperatures is by the use of mechanical refrigeration either in a dry box or to lower the temperature of the cooling water used.

Choice of Dry Cooler for Temperature Control

The use of a water bath adds two outstanding difficulties to the problem. First, the box must be constructed more substantially to support the added weight and to eliminate danger of leaks from dents, sprung seams and corrosion. Second, the cream producers add cream in small quantities. It would be a nuisance to keep the cream container upright under the bouyant effect of the water. Another factor which would depend on the individual is the danger of the water becoming foul and imparting flavors to the cream.

A small one can milk cooler was developed by the Wilson Cabinet Company, Smyrna, Delaware at the request of T.V.A. Tests made by J. E. Nicholas, [12] Pennsylvania State College, indicated that this cooler could handle satisfactorily as much as two ten gallon cans of milk in twenty-four hours. The cans would be cooled one at a time with

about a twelve hour interval. In the state of Pennsylvania a survey showed that nearly fifty percent of the milk producers could have gotten along with this inexpensive cooler. Demand among milk producers was poor, however, and this line has been discontinued.

In view of these facts, it was decided that this investigation should try to develop and prove the effectiveness of one or more simple basic designs of mechanically cooled dry boxes that could maintain cold temperatures yet be reasonable in cost.

ECONOMICAL FEASIBILITY OF A CREAM COOLER

The introduction of a cream cooler as a necessary item of equipment for the cream producer may be very easily justified in the eyes of the researcher on quality improvement and aesthetic grounds alone. However, it will certainly never gain widespread acceptance by the cream producer unless it is possible to show a dollar benefit.

Obviously then, a farmer must receive a premium for producing sweet cream if he is to be converted. As long as the farmer receives the same pay check for sour deteriorated cream as for fine quality cream, he will never go to the added expense of installing cooling equipment. We believe in the premium system and had to assume its ultimate acceptance to justify this project.

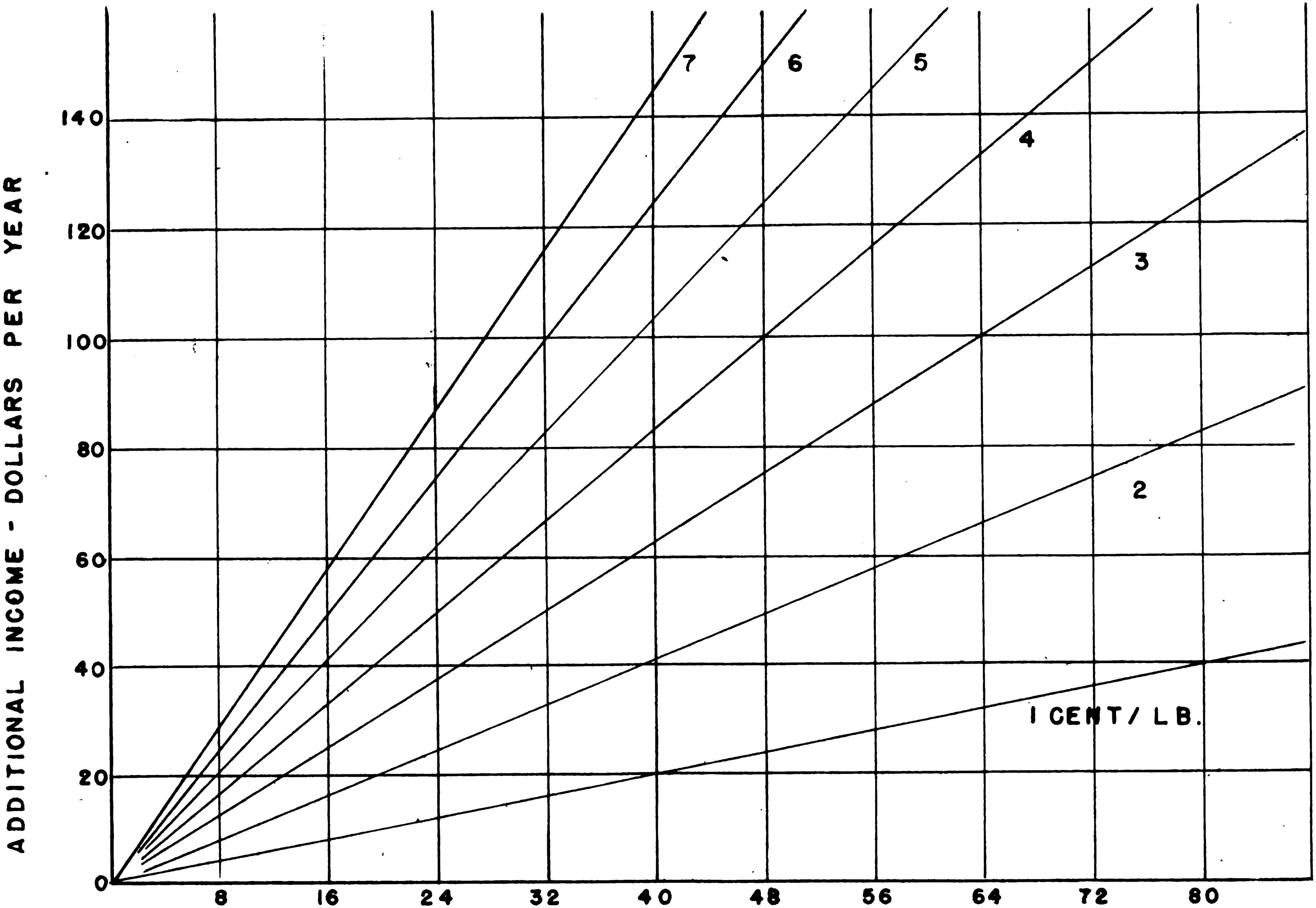
How much premium should the farmer get? Our aim was to design a cooler to sell for one hundred dollars. Under present conditions of inflated prices, a quality cooler cannot be produced for this sum if handled through the customary retail channels. However, we were able to get an estimate of manufacturing cost of approximately ninety-five dollars for one unit and one hundred and ten dollars for another of slightly different design. Therefore if the butter industry shows enough interest to handle the cooler on a non-profit basis as milk cans have been handled, our aim can be realized.

Assuming a capital cost of one hundred dollars with an estimated life of 15 years, we arrive at these cost figures:

1.	Depreciation and Maintenance at 10%	$10.00 per year
2.	Average Interest Cost at 6%	3.30 per year
3.	Cost of Operation 1/2 kw per day at 2¢	3.65 per year
	Total	$16.95

Operational cost data were taken from the average of several cooling runs with a cream load of from 16 to 25 pounds per day. This would correspond to about 45 pounds of fat per week.

Reference to Figure 5 would immediately tell how much premium a farmer should receive to finance the cooler.



GRAPH OF INCREASE IN INCOME RESULTING FROM SELLING SWEET CREAM AT PREMIUMS OF 1 TO 7 CENTS PER LB.

Fig. No. 5

For example, a farmer producing over 32 pounds of fat a week could justify a cooler with a 1¢ premium while the producer of only 8 pounds per week would have to receive a premium of 4½ per pound. The 32 pound producer on the other hand would show a net profit of nearly $50.00 every year with the 4¢ premium. These figures show that even a small premium would finance the cooler except for the very small producer.

DESIGN OF COOLER

It was decided that two fundamentally different cabinet types would be designed and built. The "R", or round unit would be designed primarily to handle cream. Most farmers would find that there was sufficient space for some storage of other foodstuffs in this unit.

Another unit "S", would be designed to handle cream plus substantial storage space for eggs foodstuff.

Tentative Requirements for Experimental Unit

1. Should maintain a cabinet temperature of not higher than 45 degrees F. at an ambient of 100 degrees F.
2. All controls automatic.
3. Capacity:
   "R" one ten gallon can or four five gallon "shot" cans. (A "shot" can is

a straight sided five gallon can $9\frac{1}{2}$ inches in diameter and 21 inches high).

4. Compressor should have a load capacity sufficient to cool two gallons of cream in about six hours from 90 degrees to 50 degrees. It should be able to do this as well as to maintain the cabinet temperature by compensating for the leakage and usage loads.

Heat Load

Total outside area:

"S" unit	37.6 sq. ft.
"R" unit	28.75 sq. ft.

Kelvinator heat loss tables [13] give a value of 3000 BTU/day for heat leakage from the "R" unit with a temperature difference of 50 degrees F. This is for an insulation thickness of three inches of cork or its equivalent with metal walls. 3000 BTU/ day is equivalent to 125 BTU/hour. If a usage factor of 5% is assumed, the total usage and leakage equals 131 BTU/hour. The usage factor attempts to compensate for heat lost when opening and closing the cabinet. Since this cabinet should only be disturbed twice daily, the usage could be expected to be small. Also the design calls for a top opening cover which reduces the heat lost in opening the cabinet.

The amount of product load is determined by the following equation:

$$Q = w\, c\, (T_1 - T_2)$$

Q - Product load - BTU/hour

w - weight of material cooled - pounds

c - Specific heat - BTU/pound $^\circ$F.

T_1 - Initial Temperature - $^\circ$ F.

T_2 - Final Temperature - $^\circ$ F.

If we desimgn to cool 16 pounds from 90 degrees to 50 degrees in six hours this becomes:

$$Q = (16)\,(.68)\,\frac{(90 - 50)}{6}$$
$$= 72.5 \text{ BTU/hour}$$

The total load on the compressor should not exceed the leakage and usage load of 131 BTU/hour plus 72.5 BTU/hour from cooling the cream, or a total of 203.5 BTU/hour. On the basis of this light heat load, a 1/8 h.p. hermetic compressor with static condenser was considerd adequate.

Specifications for this type and size compressor unit give a capacity of 1085 BTU/hour at 90 degrees ambient and 20 degrees low side temperature. Since this value represents one hundred percent operating time and we will design for a maximum of fifty percent operation, the top capacity for design purposes should be 543 BTU/hour. This is over twice the anticipated load but smaller units are not standard and so would cost more than the 1/8 h.p. standard model.

Determination of Length of Evaporator Coil

In designing the coil length (area), the engineer is given considerable latitude for the exercise of good judgment. For example, the heat transfer may be computed from coil to air and the coils placed in the space being cooled or the design may place the coils on the outside of the wall. The transfer then is computed from the wall itself and depends on the type and efficiency of the coil to wall contact and the spacing of the coils on the wall. A figure recommended by the engineers of Kold Hold Company, manufacturers of refrigeration plates, for 3/8 inch coils fastened with good thermal contacts every 2 inches on the plate is 2.25 BTU/sq. ft. ^{o} F.

With the coil mounting determined, the engineer is allowed to set a figure for temperature difference between the refrigerant and the storage space. There are power economies to be derived from operation at as high a refrigerant temperature as possible since the coefficient of performance of a compressor rises sharply as the low side pressure is raised. This economy of operation to be gained by using a large transfer surface must be balanced against the added construction cost of using extra tubing.

There are several factors which make accurate determination of coil length difficult. In most installations, design is based on the compressor operating

only a fraction of the time. The coil temperature, therefore, is not constant, varying from some low value to a temperature approximating that of the box itself. It is customary for design purposes to assume a maximum operating time of 2/3 of the elapsed time. With the static condenser which is rather limited in capacity, this value is probably too high and we have used 50 percent as a maximum operating time.

Computation of Coil requirements:

A. For the "R" unit:

Total load (leakage, usage, product) is equal to 203.5 BTU/hour. If we assume 50% operating time, the load has an effective value for design purposes of (2) (203.5) or 407 BTU/hour.

Using a figure of 2.25 BTU/sq.ft. $^{\circ}$ F. and assuming a temperature difference of 20 degrees (24.6 psi gauge)

Heat transfer	(20) (2.25)	=	45 BTU/sq.ft.
Transfer area	407/45	=	9 sq.ft. of plate

Each foot of coil represents (2)(12)/144 or 1/6 sq. ft.

(9) (6) = 54 feet of coil

If a temperature difference of 15 degrees is used:

Heat transfer	(15) (2.25)	33.7 BTU/ sq.ft.
	407/33.7	12.3 sq.ft.
		73.8 feet of coil

The specification for the round unit called for a coil length between these - 65 feet total length or an effective length of 60 feet.

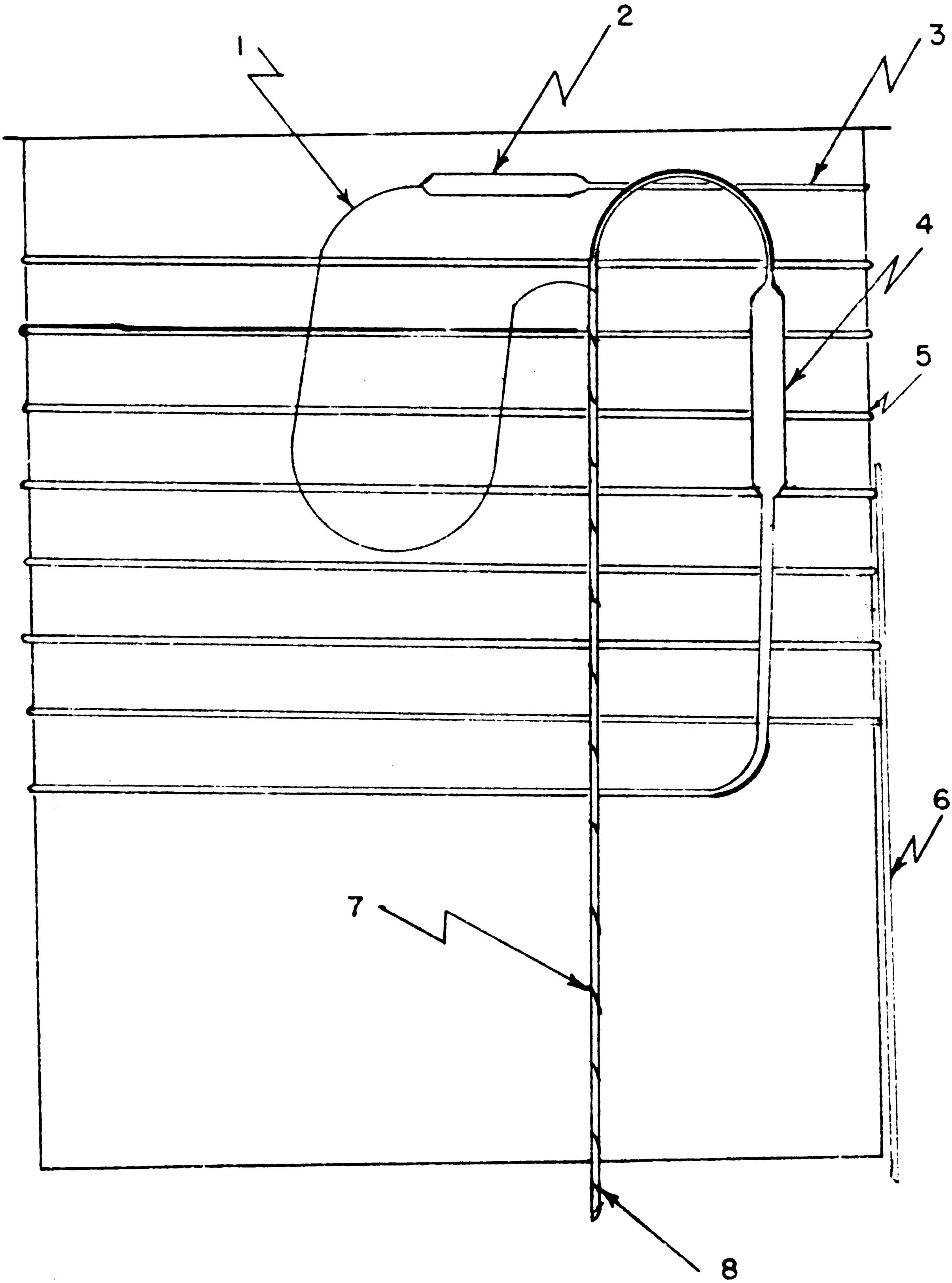
Corresponding figures for rectangular box:

Total load (leakage, usage, product load)				243.5 BTU/hr.
Basis of 50% operating time				487 BTU/hr.
Heat Transfer rate	20°	temperature	dif.	45.0 BTU/sq.ft.
" " "	15°	"	"	33.8 BTU/sq.ft.
Transfer Area	20°	"	"	10.8 sq.ft.
" "	15°	"	"	14.4 sq.ft.
Coil Length	20°	"	"	64.8 feet
" "	15°	"	"	84.4 feet

Specification calls for 75 feet of coil which should give a temperature difference of approximately 18 degrees and a low side pressure of about 28 psi gauge.

Description of Coil Mounting

Details of the coil mounting on the inner shell of the "R" unit are shown in Figure 6. Expansion of the refrigerant is accomplished by the pressure drop through the capillary tube (1). (Numbered references refer to Figure 6). Current practice favors the use of capillary tubes in small installations - 1/4 h.p. or less. They have the advantages of small expense, adaptability to heat exchange with the suction line and constancy of



INNER SHELL
WITH COIL DETAILS

Fig. No. 6

pressure drop. With the conventional type of expansion valve, a small erosion of the valve seat causes a very appreciable change in the pressure drop and flow characteristics of the valve. Also the small clearance of the conventional valve together with the very sharp drop in temperature across the valve orifice creates an ideal condition for frost formation. The capillary type of expansion system uses from 6 to 20 feet of tubing with comparitively large clearances. The system shown is .040 inches in diameter and twelve feet long. The amount of tubing used depends on the temperatures desired in the box. The longer lengths are used where low temperatures are needed. The greater resulting pressure drop across the capillary enables a lower pressure to be obtained in the expansion coil. This of course results in a lower vaporizing temperature for the refrigerant. The capillary is wound on the suction line as shown which effectively cools the liquid refrigerant in the tubing at the expense of the expanded gas leaving the coils.through the suction line.

Although great care is used to eliminate all the moisture in the system, it is considered good practice to install a drier in the low side. Such a drier is shown at (2). The drying agent commonly used is silica gel which combines physical strength, chemical inertness, and great moisture hold capacity.

The expansion coil (3) was top fed although in small coolers using freon the choice of top or bottom feeding is largely a matter of personal preference. However, top feeding is felt to give better heat transfer coefficients by virtue of more complete wetting of the coil. With refrigerants which are immisible with oil, top feeding helps in returning the oil to the compressor. This is not a factor with freon, which is miscible with oil and carries the oil back in its vapors. Proponents of bottom feed coils point out that the chances of getting liquid refrigerant back in the suction line are lessened by introducing the liquid at the bottom and letting the dry vapor boil off. To avoid drawing liquid refrigerant back into the compressor when using top feeding, the suction line is supplied with an accumulator (4) and the coil is bent up and down as shown.

In mounting the coils on the outside of the refrigerated space and using the cold wall system, it is essential that good thermal contact between the coils and the metal shell be obtained. A common practice in the past has been to solder the coils to the shell. This method is very effective but adds considerably to the labor cost. The thermal bond was obtained in this unit by bridging between the shell and coil with thermomastic #446 manufactured by Prestite Company of St. Louis, Missouri. There are several members of this group which

differ only in the conducting filler. The base is a non-hardening asphaltic material similar to the material used to vapor seal the box. Into this base a metallic powder is incorporated (aluminum, carbon, etc.) to increase the thermal conductivity.

Relative heat transfer value for metallic Permagum and thermal Mastic as compared to air and asphalt are as follows:

Air	1.00
Asphalt	1.57
#440 Metallic Permagum	3.24
#446 Thermal Mastic	3.80
#447 Thermal Mastic	3.50

These units are only comparative and do not give an absolute figure for conductivity.

The method of heat exchange is shown at point 7. The capillary expansion system is wrapped around the suction line. Both the suction line and the capillary extend about four feet beyond point 8 to give sufficient tubing to make the compressor connections.

Also shown in Figure 6 at point 6 is the thermal well into which the control bulb is inserted. The well is bent so that the control bulb exerts a pressure on the sides and so will stay in place. Control in this unit is

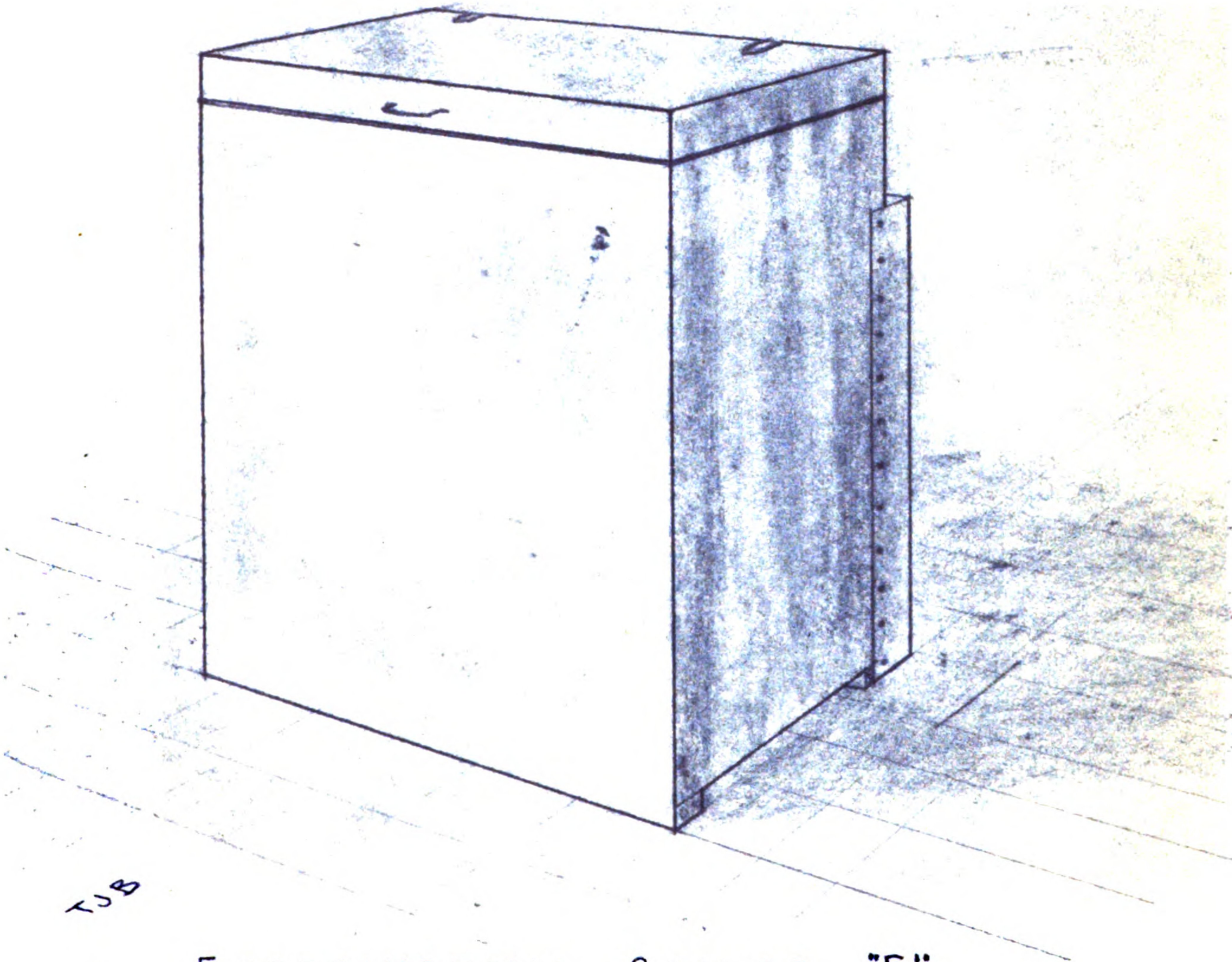
from the coil temperature rather than the box temperature. This is less expensive than trying to place the control in the box but has the disadvantage of allowing the box temperature to rise when heavily loaded. As an example, the box temperature rose to 56 degrees F. when loaded with ten gallons of water at 100 degrees. This temperature is 18 degrees above the no-load cabinet temperature. Naturally this decreases the speed of cooling. If subsequent experience indicates that more rapid cooling is desirable, changing the control to the box itself would be a logical move.

Insulation

The amount of insulation to use is determined by consideration of the factors of installation cost and operation cost. It is usually desirable to use enough to preclude the possibility of moisture condensation forming on the surface. Tables have been compiled which consider these factors and make recommendation based on experience and theory.

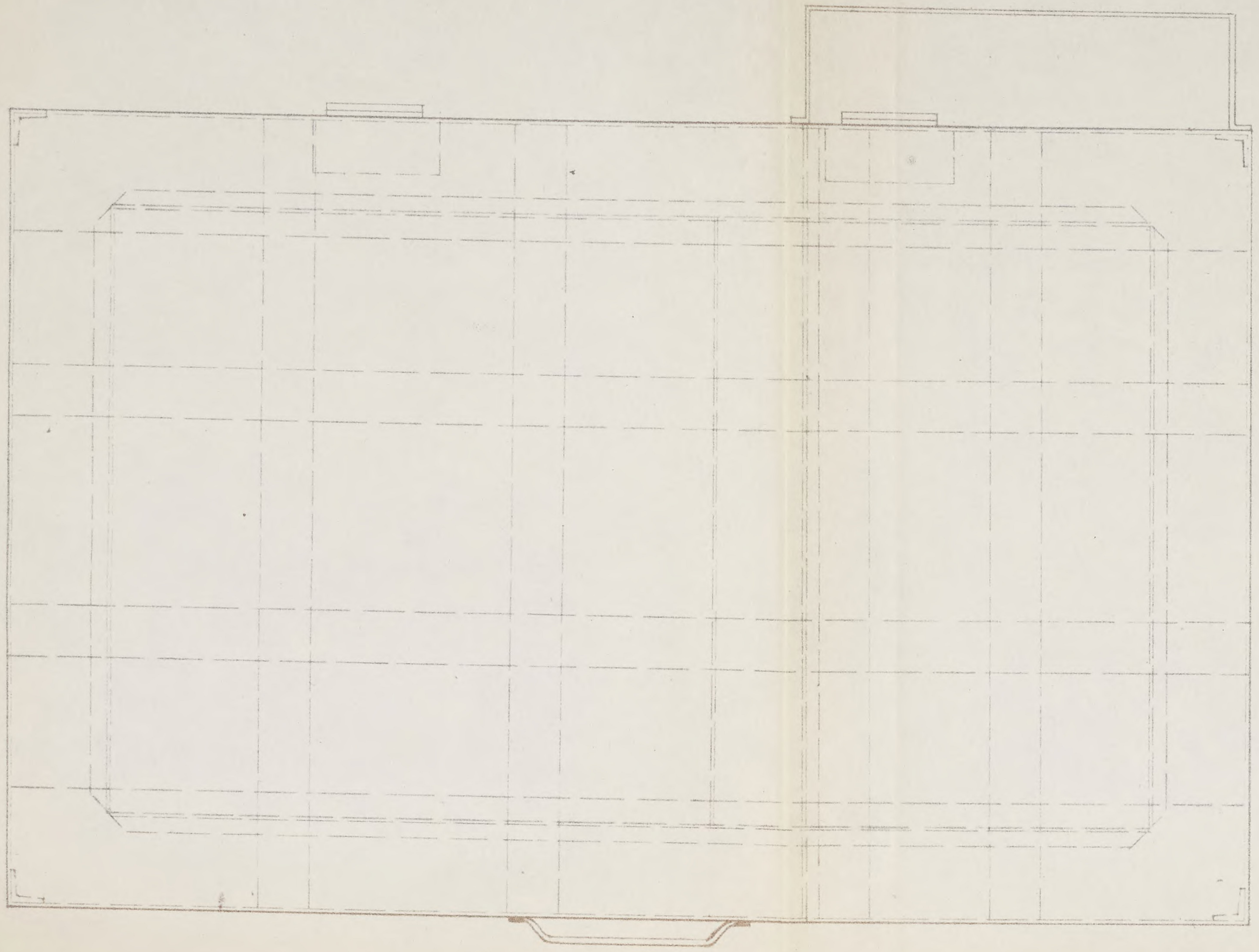
Three inches of insulation was used on these boxes. This is adequate for preventing large heat losses and to prevent condensation.[7,20] Fibre glass was used except as indicated on Drawing No. 1 of the type "R" unit. Here temlock rigid insulation was used as part of the bottom to supply support for the inner container.

FIG 7



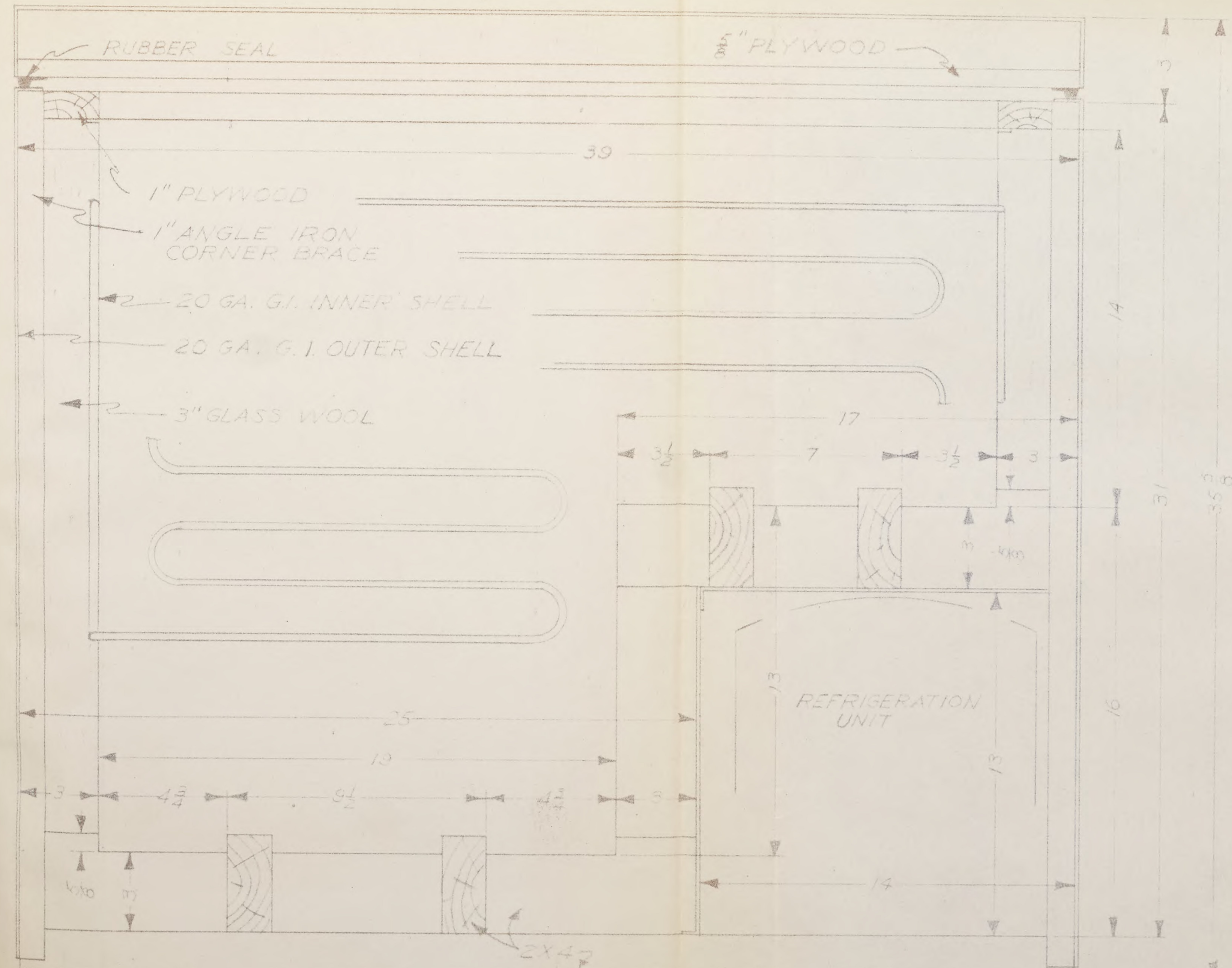
TJB

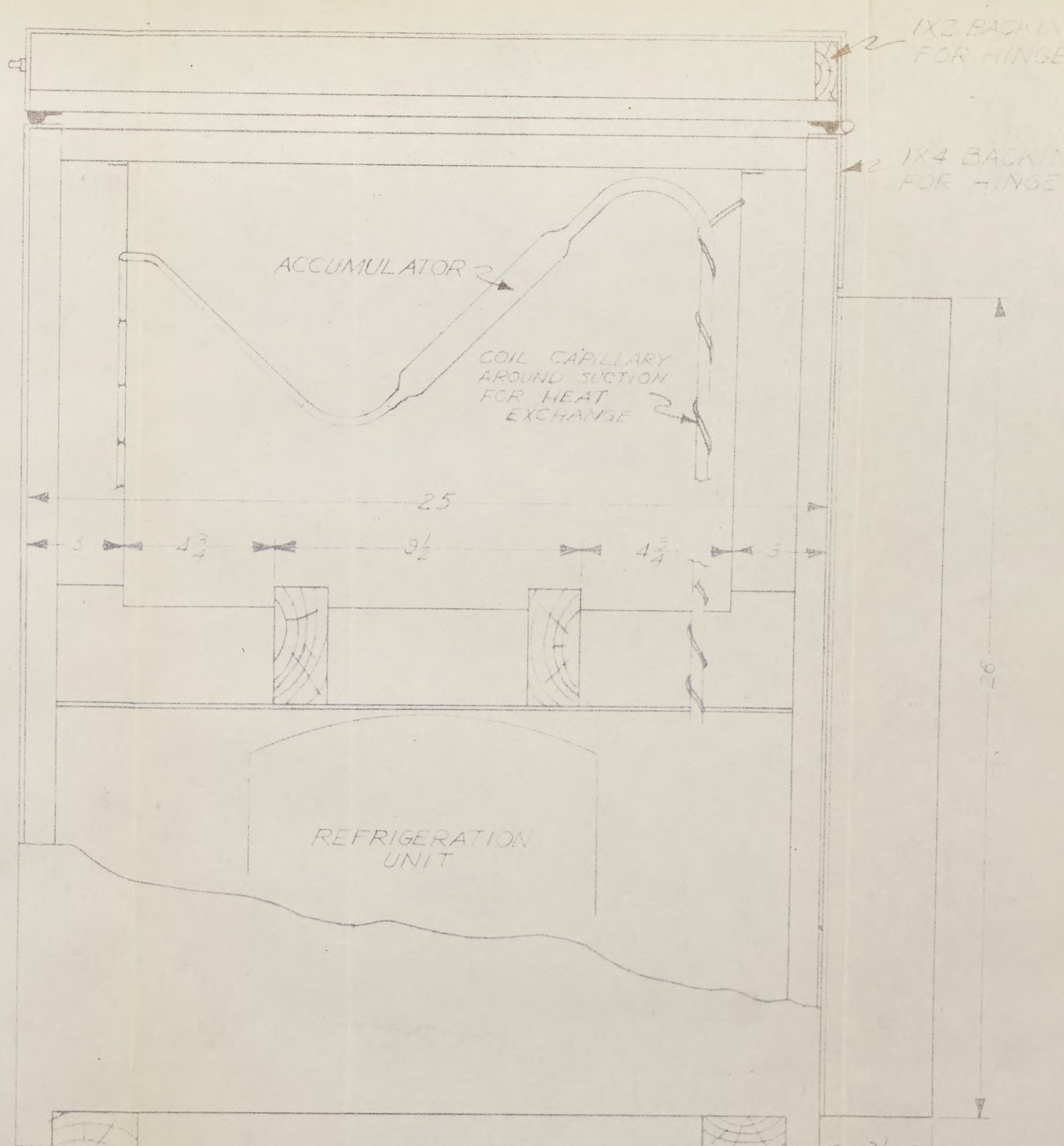
EXPERIMENTAL COOLER "S"



SAMPLE CREAM COOLER
#2

NOTES
1. FINISH ALL OVER WITH AL. PAINT
2. PERMAGUM SEAL ALL JOINTS
3. COIL CEMENTED TO SHELL WITH "PRESSITE" #446 THERM. MASTIC





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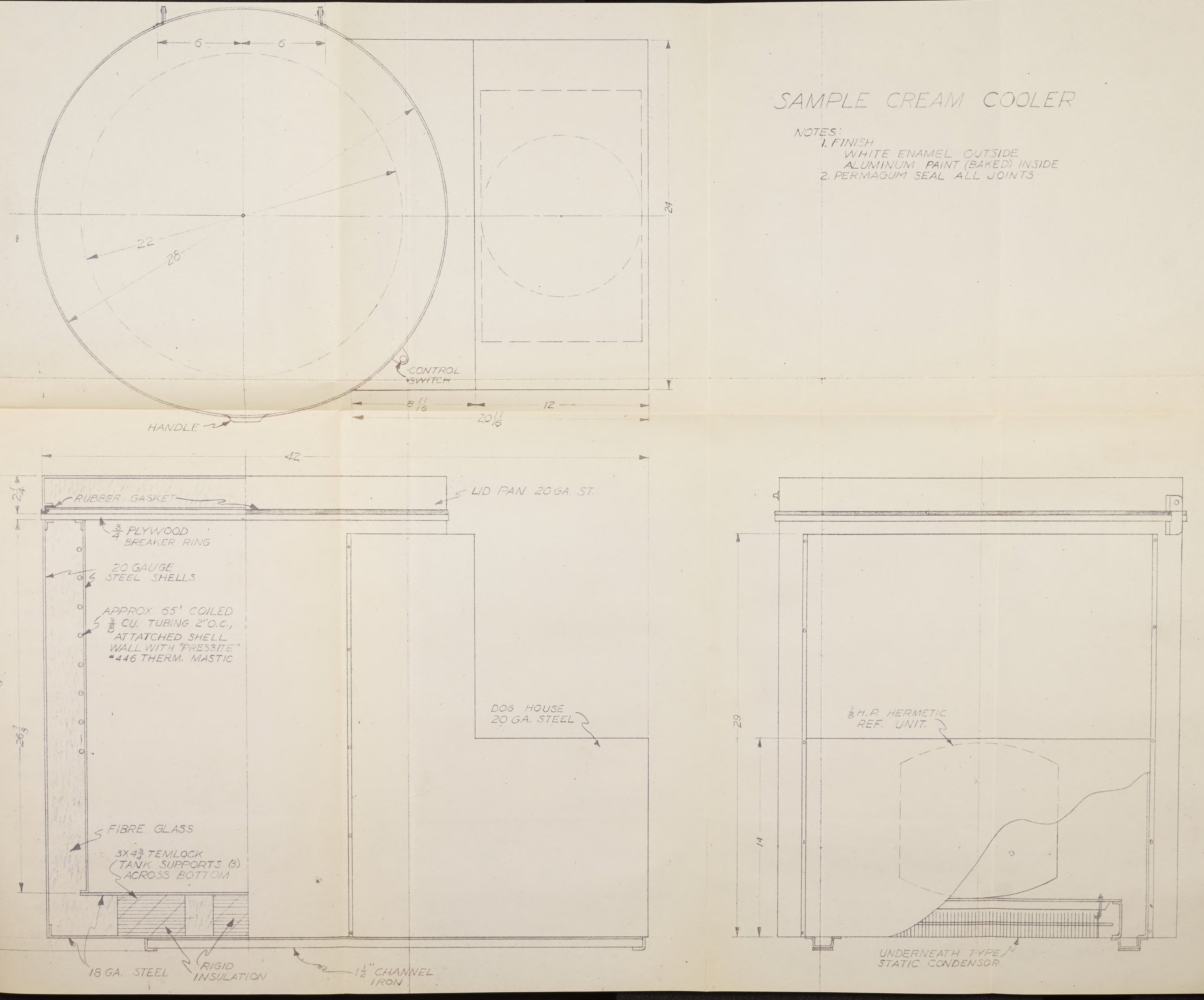

SAMPLE CREAM COOLER
NOTES:
1. FINISH
WHITE ENAMEL OUTSIDE
ALUMINUM PAINT (BAKED) INSIDE
2. PERMAGUM SEAL ALL JOINTS
6
6
22
28
24
CONTROL SWITCH
HANDLE
8 11/16
12
20 11/16
42
2 1/4
33 1/3
26 1/3
RUBBER GASKET
LID PAN 20 GA. ST.
3/4 PLYWOOD BREAKER RING
20 GAUGE STEEL SHELLS
APPROX. 55' COILED 3/8 CU. TUBING 2" O.C., ATTATCHED SHELL WALL WITH "PRESSITE" #446 THERM. MASTIC
DOG HOUSE 20 GA. STEEL
FIBRE GLASS
3X4 3/4 TEMLOCK TANK SUPPORTS (3) ACROSS BOTTOM
18 GA. STEEL
RIGID INSULATION
1 1/2" CHANNEL IRON
29
14
1/8 H.P. HERMETIC REF. UNIT.
UNDERNEATH TYPE STATIC CONDENSOR

On the "S" unit, this support is obtained by using crossed wooden 2 by 4's. These were used because it is necessary in this unit to space the inner container away from the wall. This spacing is accomplished by dressing the 4" dimension down to 3" except for 3" on the end which is left 4". The inner box then is held by the end projection as shown in Drawing No. 2.

It will be necessary to pack insulation into the vertical section beside the compressor before mounting the back panel. Insulation should also be packed into the spaces around the wooden supports before the inner shell is put in place.

Plywood breaker strips are used on the top of the inner shell of both boxes to prevent the flow of heat from the outer to the inner shell. It is not uncommon to see coolers built without this precaution but merely feeling how cold the outer shell is at this point will indicate the rapid flow of heat into the box.

This breaker ring is mounted differently in the two boxes. Close inspection will show that the mounting on the "S" unit has two outstanding advantages over the top mounted ring in the "R" unit.

First, in the "S" unit the rubber cover gasket seals on the outer jacket. This eliminates all danger of

moisture infiltration at this point. Also, bringing the outer shell up over the breaker strip gives a metal ring on top to take the abuse of setting cans on it.

Plywood was used on the underside of the covers to give them rigidity. They also act in the same manner as the breaker strip discussed above in preventing heat flowing along a metal path into the box. All outside joints were sealed with permagum to prevent infiltration of moisture vapor.

AIR CIRCULATION SYSTEM

Both compressors were specified with static condensers. This means that air circulation over the condenser is by natural draft. The use of this type condenser eliminates fans and other external moving parts. They are justified on small capacity units such as this if some means of encouraging natural draft is used.

Both cabinets contain built-in stacks that increase the flow of air through the condenser. Air is drawn from the floor through the condenser where it picks up heat and becomes lighter. This creates an updraft which draws in more cool air to continue the process.

We were unable to find design procedures for stack area or height. The dimensions used are adapted from current industrial practive.

Finish

Both units were finished with aluminum paint on the inside. Th "R" unit was built according to our plans by the Revco Company, Inc., Deerfield, Michigan. It received a baked white enamel outer finish. Since we have no baking ovens in our department, the "S" unit was specified with aluminum finish. It may be enameled white if desired.

PUTTING UNIT IN OPERATION

After the cabinet is finished the coils are throughly dehydrated before being connected to the compressor. Revco, Inc. heats the coils four hours at 280 degrees and then draws a vacuum of from 15-18 microns. Slightly lower vacuum may be used with 50 microns the recommended limit.

Freon is introduced into the evacuated coil until a positive pressure is assured. Connection is made to the compressor, connecting first the high side and then the low side. Back seat the low side and then the high side valves. Dehydrate by heating the freon charging line and connect to the low side valve. Start the compressor and allow freon to enter the low side valve by loosening the valve periodically. (Valve is closed when front seated - open when back seated and vented to the atmosphere when in an intermediate position) Charge should be introduced slowly. The right amount has been charged when the frost line appears just out of the box with the compressor running full time. Freon should be purged if the frost line moves near the compressor.

The "R" unit was put into operation in the above manner. The box temperature reached - 14 degrees with a coil temperature of - 19 degrees with the compressor running full time. The control was then hooked in and the unit run at about 45 degrees for one week before undergoing further testing.

TESTING PROGRAM

In evaluating the cooler performance, tests were set up to provide the following information:

1. No-load current consumption.
2. Cooling rates on water in different amounts and in different containers.
3. Cooling rates and quality studies on cream.
4. Performance under conditions as they exist on an average farm.

No-Load Current Consumption

The no-load current consumption test is run on new units to obtain cost of operation figures and to check the design heat loss figures.

The unit was set up in a room of the Department of Agricultural Engineering. The test set up was as shown in Fig. 8. The circuit is controlled by a thermal control. The sensitive bulb of this control is therefore by the coil proper. Control is of coil temperature. A wattmeter was placed in the circuit to record the current consumption. Hooked in parallel with the compressor was a self starting electric clock which will show the total operating time of the compressor. This same general setup was used in all subsequent tests.

After the unit had come to equilibrium, the test was started. Following are the results of three no-load tests.

NO-LOAD TEST

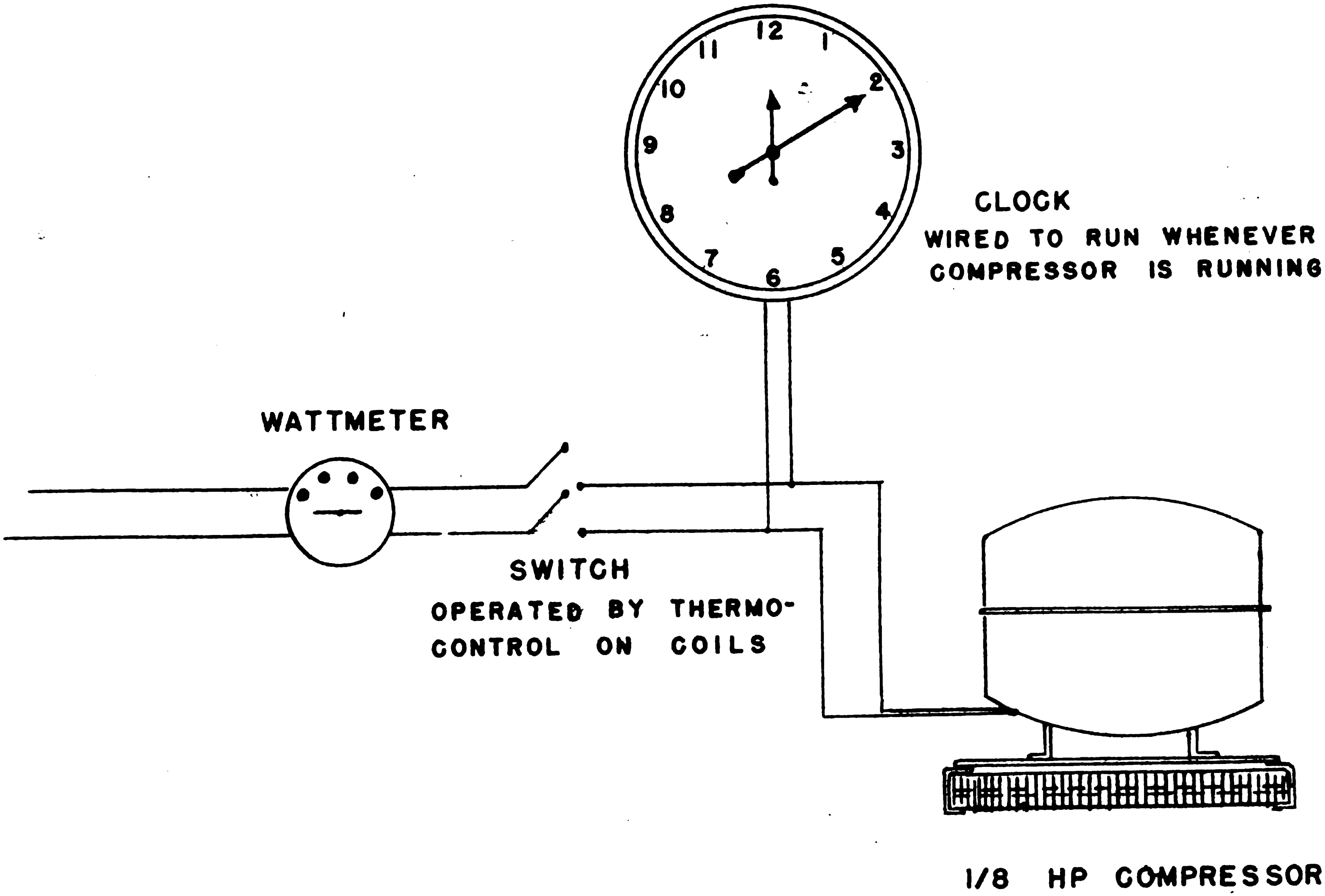
Table No. 1

Test No.	Time Hr.	KWH used	Ave. Room Temp	Ave. Cab. Temp.	KWH Used/24 Hrs. °F.
1	44	.60	68	44	.01365
11	136	3.0	76	37.5	.01375
12	96	1.9	75	41	.0139
				Average	.0137

The above results show good agreement despite the widely different ambient and cabinet temperatures used. The unit of current consumption used does not conform to any recognized standards but it does put the data in a form that is easily used in further computations.

Cooling Rates on Water

Cooling rates were run on water to indicate something of the speed of cooling that could be expected with cream. Copper-constantin thermocouples were used for temperature measurement. The readings were made with a Leeds and Northrup potentiometer. Examination of Figs. 9



DIAGRAMATIC SKETCH OF TEST SETUP USED

Fig. No. 8

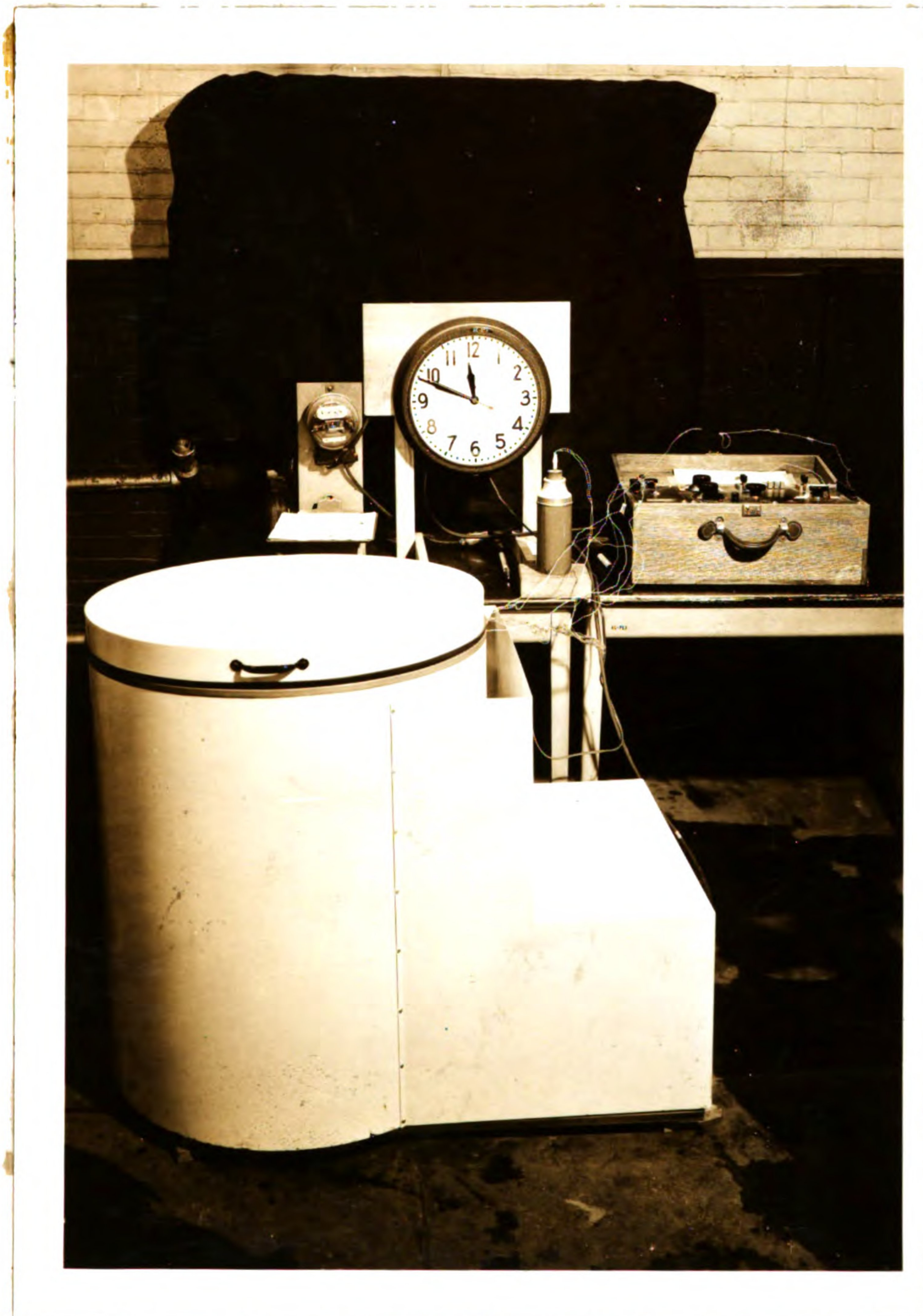


Fig. No. 9

Fig. No. 10

Fig. No. 11

and 11 will give the reader the general test setup. The thermocouples were shielded in five millimeter glass tubing which had been drawn to a capillary at the end and then sealed. The capillary was drawn small enough so that the thermocouple junction just fit. The thin glass walls and good physical contact made the thermocouples rapidly responsive to temperature changes.

The combination thermocouple holder and container cover was drilled for seven tubes. It was made from two different thicknesses of plywood. The thicker piece was of a smaller diameter then the mouth of the can. A thin piece was cut with a larger diameter and fastened as shown to form the cover. The couples are adjustable in depth so that a good cross sectional picture of temperature conditions can be obtained.

A summary of the results obtained with water are given in the following table.

Table No. 2

Test No.	Size can	Lbs. water	initial Temp.	Final Temp.	Time Hr.	Initial Rate of Cooling °F/Hr.
2	10 Gal.	72	98	74	8.5	2.56
3	5 Gal.	33.5	91	66	8.5	2.94
4	5 Gal.	16.5	86	57.5	8.5	3.40
5	5 Gal.	16.5	87	54	8.5	3.80
6	10 Gal.	72	89.5	87	1.0	2.50
7	5 Gal. (3)	72	81	61	7.5	2.67

Typical cooling curves are shown in Fig. 12. These test show that the rate of cooling was relatively slow in all cases. The rate is affected by both the amount of water to be cooled and the container used. The difference caused by the containers is due to the larger area for heat transfer when using smaller containers.

Determination of Compressor Performance

The coefficient of performance of a refrigeration machine is defined as the ratio of refrigeration obtained to the heat equivalent of the power supplied.[18]

$$\text{Coefficient of Perf.} = \frac{\text{Heat removed - BTU's}}{(\text{KWH})\ (3412)}$$

A refrigeration unit is not considered to have an efficiency in the same sense as a power plant since it does no useful physical work. Its function is rather to pump heat from a low temperature T_2 to a higher temperature T_1. Thermodynamic consideration of the carnot or ideal refrigeration plant leads to the following treatment.

The coefficient of performance in a carnot refrigeration plant is equal to:

$$\frac{Q_2}{Q_1 - Q_2} = \frac{wT_2\ (s_2 - s_1)}{w(T_1 - T_2)\ (s_2 - s_1)} = \frac{T_2}{T_1 - T_2}$$

Q_2 = Heat absorbed in evaporator

Q_1 = Heat rejected by the condenser

w = weight of refrigerant circulated

T_2 = Absolute temperature in evaporator

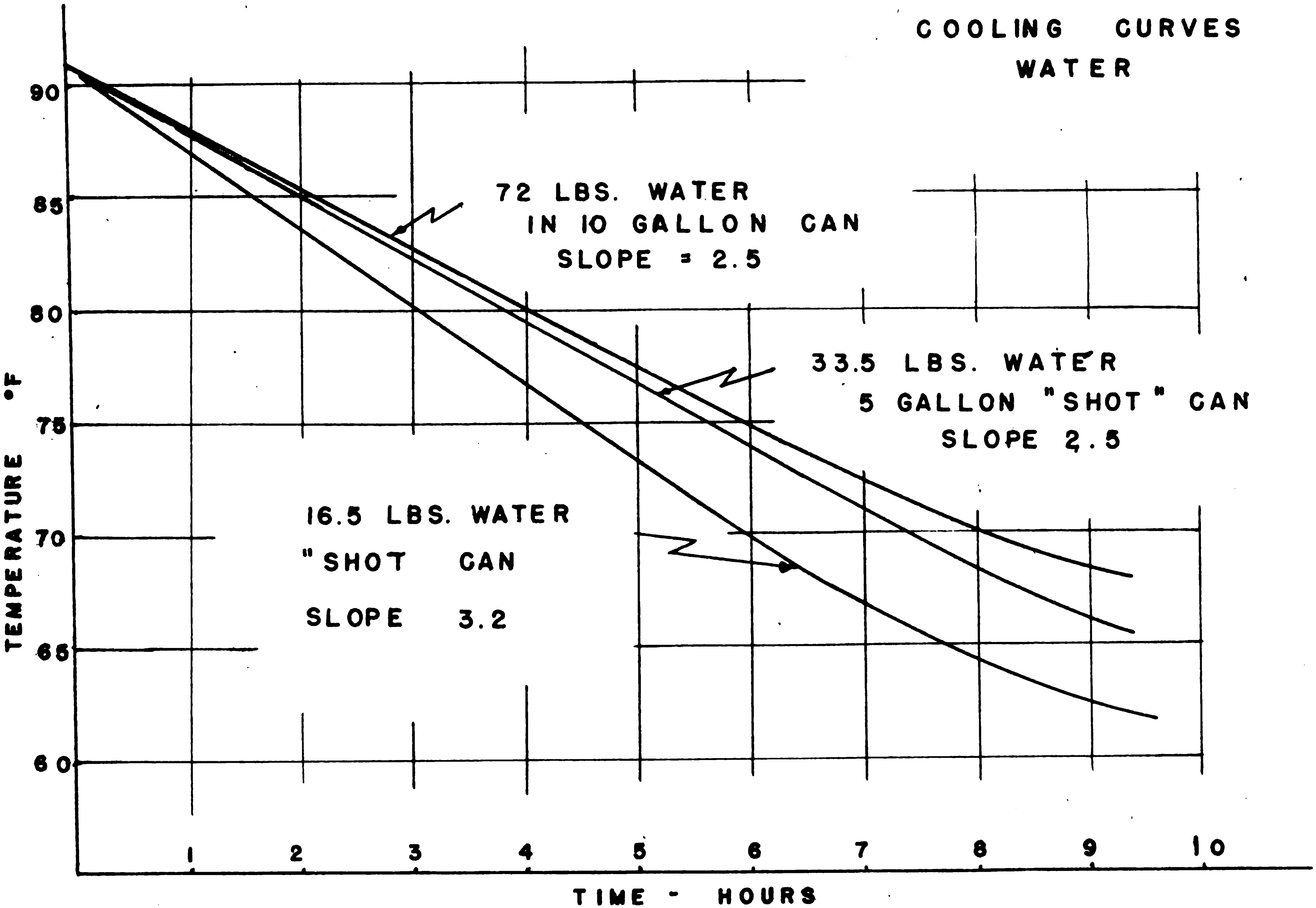

COOLING CURVES
WATER
72 LBS. WATER
IN 10 GALLON CAN
SLOPE = 2.5
33.5 LBS. WATER
5 GALLON "SHOT" CAN
SLOPE 2.5
16.5 LBS. WATER
"SHOT CAN
SLOPE 3.2
TEMPERATURE °F
90
85
80
75
70
65
60
1
2
3
4
5
6
7
8
9
10
TIME - HOURS

Fig. No. 12

T_1 = Absolute temperature in condenser

s_2 = entropy of vapor

s_1 = entropy of liquid

Inspection of this equation shows that the efficiency of performance is a function of the absolute temperature and that the efficiency rises as the difference between T_2 and T_1 becomes less.

Inserting values obtained in testing the "R" unit with the control setting at the lowest temperature, we have the following:

Evaporator temperature	22° F.	482° R
Condenser temperature	112° F.	572° R

Carnot coefficient of performance $\dfrac{482}{572 - 482} = 5.35$

In cooling a load of 5,212 BTU's over a period of 162 hours, ambient temperature 75 degrees and cabinet temperature 43 degrees, the unit used 3.4 KWH. Using the previously determined figure of .0137 BTU/24 hours $^{\circ}$ F. for heat leakage with a temperature difference of 32°:

$$\frac{(.0137)(162 \text{ hrs.})(32)}{(24 \text{ hrs.})} = 2.97 \text{ KWH}$$

This leaves 3.4 - 2.97 or .43 KWH to handle the load of 5,212 BTU or a coefficient of performance

$$\text{C. of P.} = \frac{5,212}{(.43)(3412)} = 3.58$$

This value for the coefficient of performance is higher than might be expected for a small unit. Expressed as

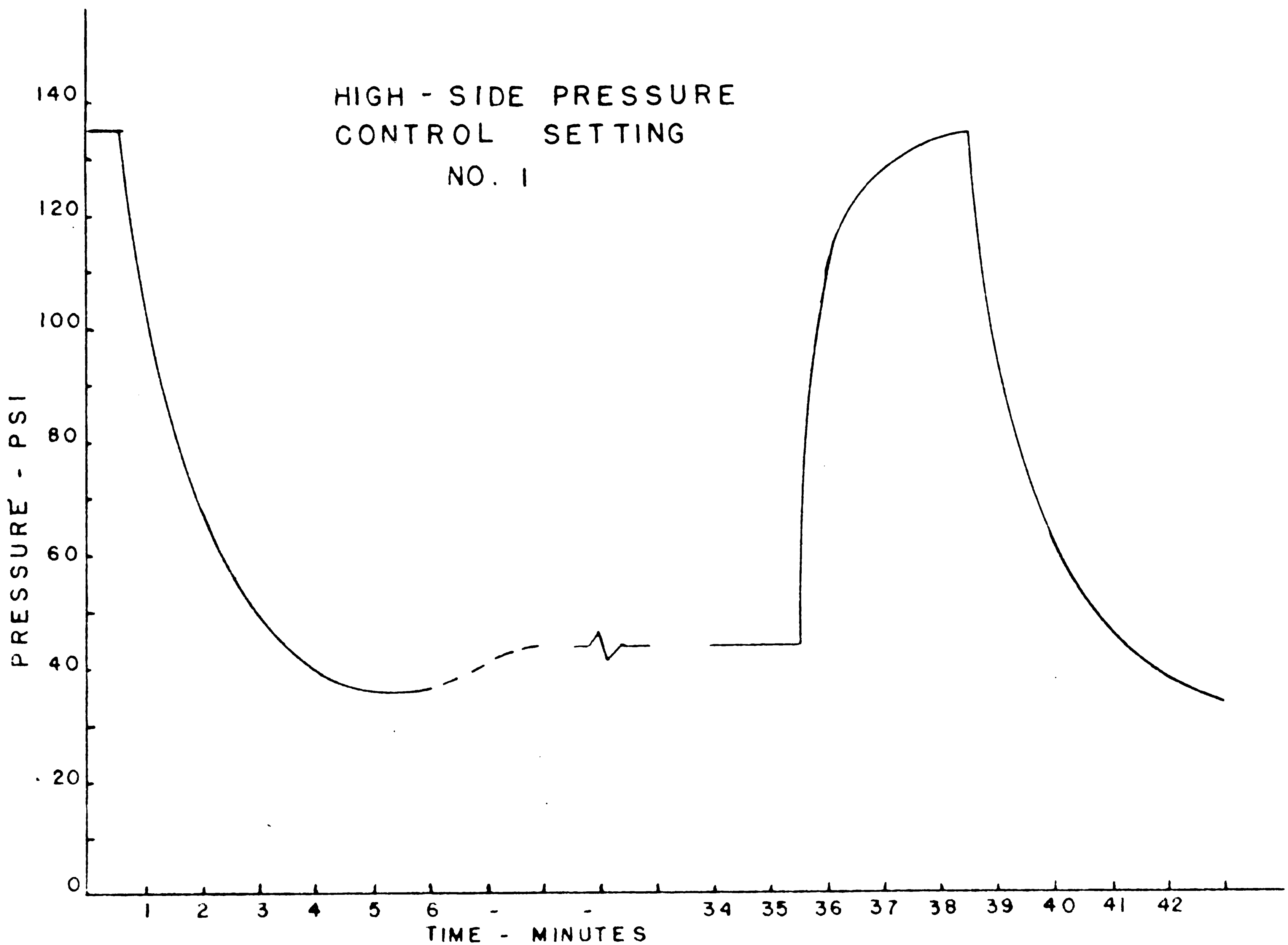

HIGH - SIDE PRESSURE
CONTROL SETTING
NO. 1
PRESSURE - PSI
140
120
100
80
60
40
20
0
1
2
3
4
5
6
34
35
36
37
38
39
40
41
42
TIME - MINUTES

Fig. No. 13

percent, this becomes 66.7% of the theoretical. The difference between this value and 100 represents the inefficiencies in the compressor and motor.

EFFECT OF HOLDING CREAM AT LOW TEMPERATURE

Since these coolers were designed to maintain high quality in farm held cream, much stress was given to the following series of tests which were set up to closely simulate farm conditions.

Many investigators have found that adding warm milk to cold milk has a tendency to stimulate the activity of the enzyme lipase. However, there is no doubt that the farmer would be very happy to be able to add his cream to the previously accumulated cream with no further treatment. We decided that this point should be explored so in each test twenty gallons of milk were divided into two equal ten gallon portions before separating. When ten gallons had been separated, the cream was placed in a cold water bath and the temperature was lowered rapidly twenty or more degrees before placing in the cooler. The results of this treatment are given in the series of samples lettered "A". The remaining milk was separated and the cream was placed in the cooler at the separating temperature. This series was lettered "B".

This procedure was repeated for four consecutive

days with the cream added to the previously accumulated cream. Four series of runs were made with "A" and "B" treatment in each series. Thus a total of eight batches were cooled and tested. Only in run No. 2 was the cream stirred into the older cream. In runs 1, 3, and 4, the cream was merely poured into the older cream.

In runs 1, 2, and 3, the milk to be separated was taken from the delivery truck at the college receiving station. Run No. 4 was made from college herd milk. A relatively high bacteria count was obtained on this milk due to the fact that it stood for some time before separating. (See Table No. 3) There was no way of telling whether the milk taken from the delivery route was morning or night milk. The milk was sampled immediately for bacteria count and then warmed to approximately 95 degrees before separation.

An effort was made to choose milk with an average to poor quality since it is recognized that the quality of milk produced by the farmer that markets cream is generally of lower quality than the whole milk producer. That we did get highly contaminated or poorly handled milk is apparent from both the bacteria counts and the flavor criticisms. In no case was there acid development in the cream to a degree sufficient to impair the flavor of butter made from it.

Table No. 3

DATA ON MILK SEPARATED

	RUN NO.	DATE STARTED	FIRST DAY	SECOND DAY	THIRD DAY	FOURTH DAY
BACTERIA COUNT	1	4/15/47	250,000	210,000	95,000	650,000
	2	4/28/47	215,000	150,000	900,000	58,000
	3	6/23/47	28,000,000	3,900,000	2,800,000	3,700,000
	4	7/8/47	90,000	30,000	650,000	770,000
TEMP. MILK RECEIVED °F	1		71	60	55	60
	2		62	63	69	58
	3		72	70	69	70
	4		78	79	80	76
TEMP. SEPARATED °F	1		100	90	86	88
	2		86	92	95	100
	3		96	95	97	100
	4		96	98	98	97

MILK WAS RECEIVED COLD AT THE COLLEGE RE-CEIVING STATION. IT WAS WARMED TO 90-100° BEFORE SEPARATING. THE MILK WAS SAMPLED FOR BACTERIA BEFORE WARMING.

The butter was all hand made and in many cases the score could have been raised a point if more buttermilk had been removed.

Effectiveness in Cooling Cream

The cooling rate was faster than had been expected considering the rather slow rate with water. Figure No. 15 shows a representative curve made from data obtained in run No. 1. This shows a cooling rate on the "B" sample of 25 degrees in the first four hours or 6.25 degrees per hour. This may be explained by the smaller volume of cream per can and by the lower specific heat of cream.

Each subsequent day after the first shows a lower peak temperature due to the mixing of the cold cream with the warm.

Table No. 4 tabulates the weight and temperature of the cream used in the tests. The weight varied from 6 to 10.5 pounds depending on the richness of the milk used in the test. The separator was set to deliver cream testing 40% fat.

It can be seen that the cream in the "A" series averages about 20 degrees lower in temperature than the "B" series.

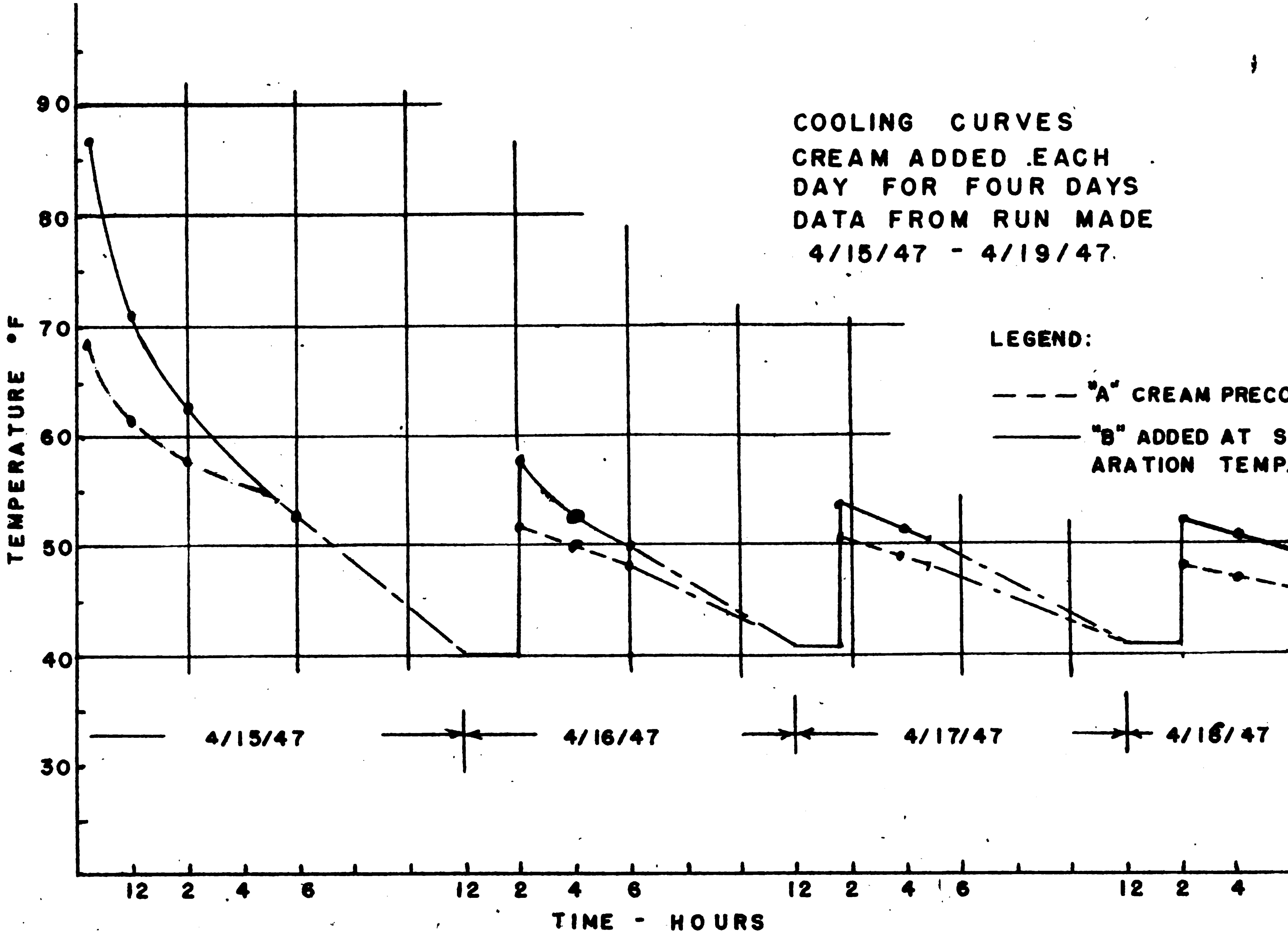

COOLING CURVES
CREAM ADDED EACH
DAY FOR FOUR DAYS
DATA FROM RUN MADE
4/15/47 - 4/19/47
LEGEND:
"A" CREAM PRECOOLED
"B" ADDED AT SEPARATION TEMP.
TEMPERATURE °F
90
80
70
60
50
40
30
4/15/47
4/16/47
4/17/47
4/18/47
12
2
4
6
TIME - HOURS

Fig. No. 15

Table No. 4

WEIGHT AND TEMPERATURE OF CREAM COOLED

TIME HOURS	WEIGHT OF CREAM ADDED TO COOLER								TEMP. OF CREAM WHEN ADDED °F.							
	1		2		3		4		1		2		3		4	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0	10 LBS.	9 LBS.	6 LBS.	6 LBS.	8.25 LBS.	8 LBS.	6 LBS.	7 LBS.	69	87	60	80	69	88	67	79
24	6.5	6.5	7	6	8.75	7.5	6.25	6	65	80	62	86	70	90	65	75
48	7	7	7.75	7.75	7	8.5	7	6.75	61	80	65	85	68	82	69	80
72	10.5	8.5	8.25	8.25	6	6	7.5	7	61	79	66	92	68	80	69	80
96																

IN EACH SERIES 20 GALLONS OF MILK WAS MIXED THEN DIVIDED INTO 10 GALLON PORTIONS. ONE 10 GALLON PORTION WAS SEPARATED AND THE CREAM RAPIDLY COOLED ABOUT 20° BELOW THE SEPARATION TEMPERATURE. THIS SAMPLE WAS LABELED "A". THE OTHER WAS SEPARATED BUT NOT COOLED. THIS WAS LABELED "B". BOTH SAMPLES WERE PUT IN THE COOLER.

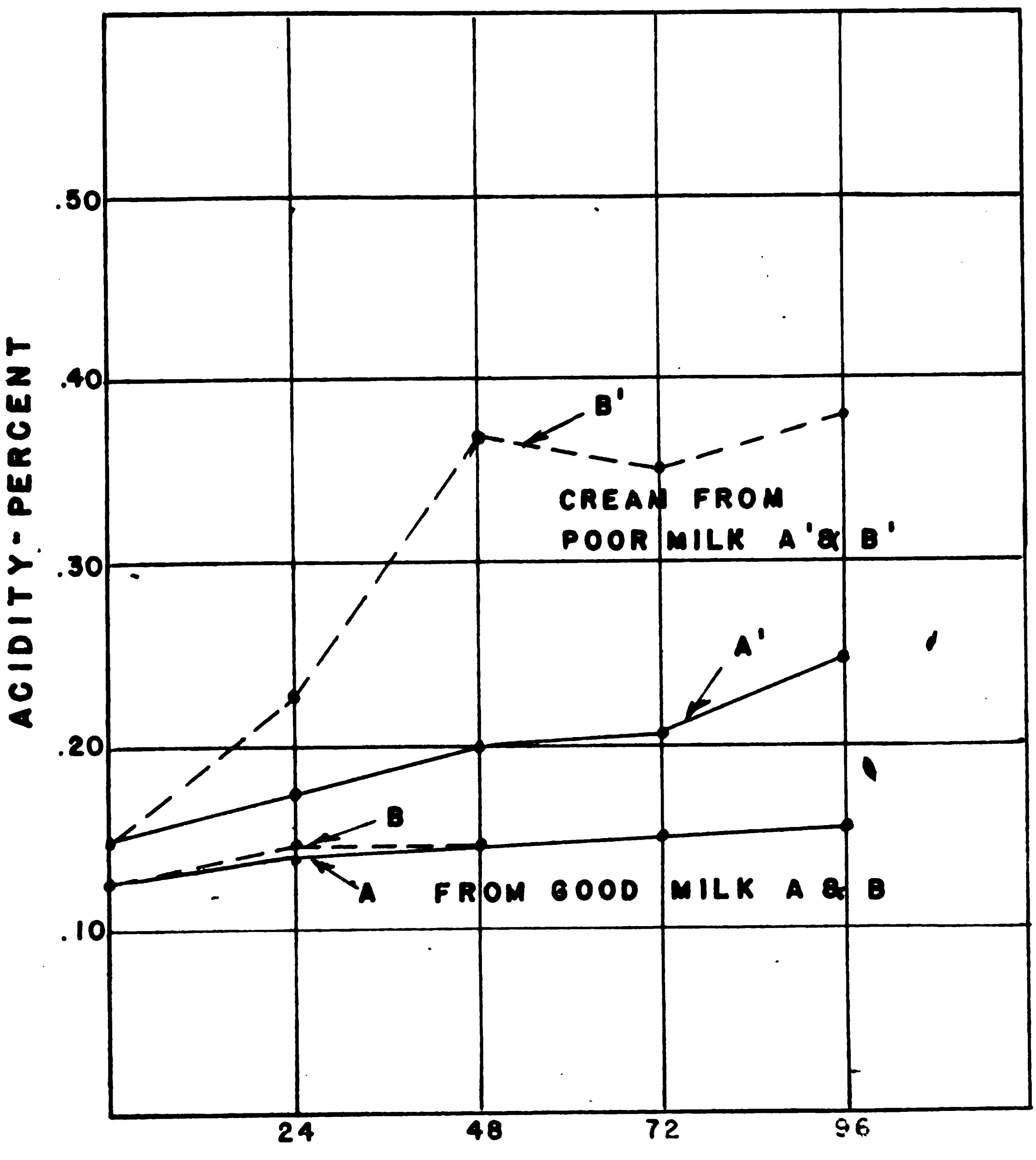
Development of Acidity

It is interesting to note that the difference in developed acidity is significantly larger in the "B" series than in the "A" series only if milk of high initial bacteria is used.

Figure No. 16 shows this development for the poorest batch and for the best. The "B" series was noticeably more acid when the initial bacteria load is very high but when milk of relatively good quality was used, neither series showed much acid development. This indicates that cream from freshly produced milk can safely be added to the cooler at separation temperature with no criticism on an acid development basis. Further study of enzyme activity or of other considerations may alter this viewpoint.

Flavor of Stored Cream

The tabulated data of Table No. 5 gives both the acidity development and a flavor score of the quality of butter that could be reasonably expected from the cream. The observer is presented with the fact that acidity development is not the only criteria of deterioration in quality. Three samples scored 93 after 96 hours holding and these samples had acidities of .180, .185 and .155. However we have a sample with the lowest acidity, .155, which graded 92 and made butter grading 91. This sample



GRAPH SHOWING DEVELOPED ACIDITY WITH GOOD MILK (AVE. BACTERIA, 380,000 PER CC.) AND WITH POOR MILK (AVE. COUNT 9,850,000)

Fig. No. 16

Table No. 5

ACIDITY AND FLAVOR DEFECTS DEVELOPED IN THE CREAM

TIME HOURS	CREAM ACIDITY %								FLAVOR SCORE							
	1		2		3		4		1		2		3		4	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0	.125	.125	.120	.120	.150	.150	.125	.125	93	93	93	93	93	93	93	93
24	.155	.180	.155	.160	.175	.225	.140	.145	93	93	93	93	93	92	93	93
48	.155	.170	.165	.172	.200	.370	.145	.145	93	93	93	93	93	91	93	93
72	.155	.165	.170	.185	.205	.350	.150	.150	93	93	92	92	92	91	93	93
96	.180	.185	.190	.225	.250	.380	.155	.155	93	93	91[1]	92[2]	92[3]	91[4]	92[5]	93

FLAVOR CRITICISM:

1- SLIGHTLY RANCID-FEED

2- SLIGHTLY ACID

3- LIGHT FEED

4- HIGH FEED

5 - SLIGHTLY OXIDIZED - METALLIC

(series "A", run No. 4) developed a slight utensil flavor during holding. The "A" series of run No. 2 was also criticised for a similar defect. It may be dangerous to draw conclusions from such meager data, but the impression is received that maintaining too low an acidity may inhance the chances of metal catalyzed oxidation.

Acidity development can be controlled by controlling temperature. Perhaps a small amount of acidity should be developed to exhaust the dissolved oxygen in the cream and thus slow the development of oxidized and metallic flavors. An indication that a small amount of acidity may be beneficial if cream is to be held for three or more days is shown in the "B" series run No. 2. This is the only sample of cream that made 93 score butter yet it had an acidity of .225%. There were five other samples with lower acidity which graded no better than 92.

Treatment of Cream After Holding

After holding the cream the prescribed 96 hours, it was neutralized with Wyandotte C. A. S. if the acidity of either "A" or "B" was in excess of .20%. The cream was then pasteurized by setting the can in hot water. A pasteurizing temperature of 156 degrees F. was chosen. When the cream temperature reached this value it was held ten minutes and then cooled rapidly in cold water. The cream was held overnight at 54 degrees, heated to churning temperature and churned in a small laboratory churn. See Table No. 6.

The butter was worked by hand and about 2.5% of salt was added. The butter was stored at 40 degrees overnight and then graded. The grading was done by Mr. G. M. Trout and Mr. J. M. Jensen of the Dairy Department of Michigan State College.

Butter from runs one and two were given storage stability tests of ten days at 70 degrees. All samples received the same score after this test as they had received previously. Flavor scores are shown in Table No. 7.

PERFORMANCE UNDER FARM CONDITIONS

The cooler was placed on the farm of Austin Cunningham to test its performance under actual conditions. Mr. Cunningham was recommended by the Dairy Department as being cooperative in spirit and a producer of considerable cream. At the time of the test he was delivering about 130 pounds of 40% cream every week.

The cooler was placed in the basement of Mr. Cunningham's home and set up with a meter and a clock as in the laboratory. (Figure No. 17) Four new "shot" cans were used for storage of the cream. The cream was added with no cooling or agitation filling each five gallon can in turn before starting on the next one. This represents

Table No. 6

TREATMENT OF CREAM AFTER HOLDING 4 DAYS IN COOLER

RUN NO.	DATE STARTED	PASTEURIZING TEMP. °F	ACIDITY OF CREAM		NEUTRALIZED C.AS	ACIDITY AT CHURNING		CHURNING TEMP. °F	CHURNING TIME		BUTTER SCORE	
			A	B		A	B		A	B	A	B
1	4/15/47	156	.180	.185	NO	.180	.185	63	15 MIN.	35 MIN.	92	91
2	4/28/47	156	.190	.225	YES	.130	.130	62	80	75	92	93
3	6/23/47	156	.250	.380	YES	.160	.160	58	27	22	92	91
4	7/8/ 47	160	.155	.155	NO	.155	.155	62	37	23	90	92

CREAM WAS PASTEURIZED BY SETTING A FIVE GALLON "SHOT" CAN CONTAINING THE CREAM IN A VAT OF HOT WATER. WHEN THE PASTEURIZING TEMPERATURE WAS REACHED, THE CAN WAS REMOVED AND ALLOWED TO STAND FOR TEN MINUTES. THE CREAM WAS COOLED RAPIDLY IN COLD WATER AND ALLOWED TO STAND OVERNIGHT AT 54°F. BEFORE CHURNING.

Table No. 7

CREAM AND BUTTER FLAVOR

	CREAM								FRESH BUTTER								BUTTER STORED 10 DAYS AT 70°							
RUN NO.	1		2		3		4		1		2		3		4		1		2		3		4	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
SCORE	93	93	91	92	92	91	92	93	92	91	92	93	92	91	90	92	92	91	92	93				
CRITICISM (SEE BELOW)			1	2	3	4	5		3	2,3	3	-	3	4	6	7	7	8 9	7	-				

FLAVOR CRITICISMS:

1 - SL. RANCID - FEED
2 - SL. ACID
3 - SL. FEED
4 - HIGH FEED
5 - SL. OXID. - METALLIC
6 - METALLIC
7 - SL. COARSE
8 - COARSE
9 - BUTTERMILK

Fig. No. 17

the minimum effort on his part and the worst conditions that could be expected.

His practice in the past has been to cool the freshly separated cream immediately to about 65 - 70 degrees. This was then added to the old cream in a ten gallon can. No further cooling was provided so that the storage temperature became the temperature of his basement where the cream was held. The cream was delivered once every week.

TABLE NO. 8

DATA ON THREE WEEKS PRODUCTION

Cream Produced	Cooler Used	Can No.	Temp. Recd.	Acidity	Ave. Acid.	Score	Current Used KWH
7-12-47		1	73	.835		89	
to	No				.778		
7-19-47		2	73	.720		89	
7-26-47		1	43	.42		90	
to	Yes	2	43	.34	.295	92	4.7
8-2-47		3	43	.25		92	
		4	62	.17		92	
8-2-47	Yes	1	42	.33		91	
to		2	42	.34	.265	92	4.5
8-9-47		3	42	.24		92	
		4	64	.14		93	

None of the cream showed any trace of metal or bitter flavor. The oldest cream had been held seven days and had an old flavor in both batches. As the cooler is set, acid develops to an appreciable degree in seven days. It was felt that the combined cream could be used to produce

92 score butter both weeks. We do not know the optimum temperature for storage at this time. Evidence points to danger in too cold temperatures as well as too warm. It seems that this optimum temperature would vary with the producer depending on the condition of the cream that is placed in the cooler.

The tests on Mr. Cunningham's farm are going forward. During the week ending August 16, 1947, he is filling all four cans simultaneously. This should provide more rapid cooling and may lower the average acidity.

On the assumption that 92 score butter could be made from the cream delivered on August 2, 1947, average acidity .295%, and that his regular delivery without the cooler would produce 89 score butter, Mr. Cunningham would market a product worth $3.05 more for this weeks period by the use of the cooler. Added to this would be a saving in time and water since he previously cooled the cream down before placing in the storage can.

Mr. Cunningham's personal reaction to the cooler has been extremely favorable. He would be very interested in operating under the premium system and would be willing to purchase a cooler to maintain high quality in his product. Present plans call for leaving the cooler on his farm for a period of several months. We believe much valuable information can be obtained by a careful inspection

of the cooler after a prolonged period of unsupervised usage. Typical information would be points of physical weakness and something of how dirty the cooler will become after long usage.

DISCUSSION

Most of the work in refrigerating dairy products has been centered about milk. While the use of a dry box has not been successful in cooling milk, we believe that it has shown great promise as a means of holding cream.

Several observations were made in the course of the project. First, very little is known about the physical behavior of cream. There is room for research on such basic properties as specific heats, coefficients of heat transfer and viscosity studies. We observed that cream will become extremely viscous, almost plastic, when cooled if it is separated from milk which has been held cold and rewarmed to about 85 degrees before separating. This plasticity does not occur in cream separated from fresh, warm milk or from cold milk which is warmed to 95 - 100 degrees and held for a few minutes. This must be caused by incomplete melting of the fat and agglomeration into larger particles to cause the high viscosity. Such thickening might improve the customer appeal of whipping cream and thus be of commercial value.

Cooling rates on cream were more rapid than was predicted from the values given with water. This seems to indicate that the characteristic formation of a thick layer of cream on the inside container wall observed when cooling with cold water does not occur with cold air. This eliminates some of the speed advantage expected with water.

The quality of the cream held in the cooler was all that could be expected. Many of the experiments were run in the spring and feed flavors were observed more often than any other defect. The "shot" cans and the separator bowl both had some exposed iron and metallic flavors were observed in two samples. The acid development could be kept below .20% very easily. The butter was hand churned and contained considerable buttermilk. This caused some lowering in score but all samples had good aging qualities.

Points particularily worth further investigation include: (1) Finding the optimum temperature of storage. (2) The method of adding cream, whether it should be added warm or cold. (3) Should the cream be thoroughly stirred into the older cold cream or added carefully with as little mixing as possible. (4) What acidity should be allowed to develop in stored cream.

The use of vacuum in conjunction with evaporative cooling might show interesting results. It is possible

that low pressure could be maintained more easily than refrigeration. Use of a vacuum chamber might also improve quality by removing dissolved oxygen from the cream.

CONCLUSIONS

(1) A dry box type of refrigeration unit effectively maintains the quality of farm held cream for about five days. This cream should score 92 or better. Longer storage is not recommended for best quality.

(2) The use of this refrigerator will show a good profit to the farmer providing a reasonable premium is given for producing quality cream.

(3) These units may be designed to provide cold storage for eggs or other perishables.

(4) To keep the investment cost low, they should be retailed at cost by the creamery.

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