8-1935

Milk cooling

Harold Walter Henry

To the Graduate Council:

I am submitting herewith a thesis written by Harold Walter Henry entitled "Milk cooling." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Extension.

C. E. Wylie, Major Professor

We have read this thesis and recommend its acceptance:

S. A. Hinton, Paul W. Allen

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

July 15, 1935.

To the Committee on Graduate Study:

I submit herewith a thesis written by Mr. H. W. Henry and entitled "Milk Cooling", and recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science in Agriculture, with a major in Dairy Husbandry.

C. E. Wylie
Major Professor

At the request of the Committee on Graduate Study, we have read this thesis, and recommend its acceptance.

S. A. Hinton

Paul W. Allen
per G. M. C.

Accepted by the Committee

J. S. Ament
Chairman

MILK COOLING

A THESIS

Submitted to the Graduate Committee
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science
in
Agriculture

by

H. W. Henry

August, 1935.

PREFACE

Milk and other dairy products are among our most important foods. The growing population in the larger towns and the increase in the use of milk means that new problems will always arise in the production and handling of milk.

This thesis is intended as a study in the problem of milk cooling. In preparing this thesis, references have been made to the latest investigations along the lines of milk cooling and in each case credit has been given to the writers and investigators whose material has been used.

The author is greatly indebted to Professor C. E. Wylie, and Mr. S. A. Hinton, of the University Dairy Department, for their helpful suggestions in the research work and also the actual writing of this thesis.

H. W. Henry.

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INTRODUCTION

Milk is man's most important food. It is the first food given to the new-born babe. It strengthens the growing child, the youth, and the adult. It is the perfect food for the invalid and the a ged.

The production and marketing of milk and its products is one of America's largest industries. The people of the United States consume nearly six billion gallons of milk annually as fluid milk, besides the millions of gallons which go into butter, cheese, ice cream, etc.

Milk, as it leaves a normal healthy cow is practically free from bacteria. It is free from the pathogenic, or disease-causing type. Immediately after the milk is drawn from the cow it begins to absorb bacteria from the air and from the surface of the containers in which it is handled.

All spoilage of food, as it is known, is caused by the action of minute organisms(bacteria). Their harmful effect is from three sources. First, they consume the valuable food elements to nourish their own bodies. Second, their excretion of waste matter creates chemical changes in the product, reducing its food value and creating bad tastes and odors. Third, the life span of the organisms is short and their dead bodies create chemical toxins that are injurious to human beings.

Since warm milk is nearly an ideal medium for the propagation of bacteria of certain types, they grow very rapidly in it. The rate at which these bacteria multiply varies as to the temperature of milk.

At a low temperature between 40° and 50° F. the bacteria become practically inert, but as the temperature rises above 50° F. the multiplication begins. Freezing, also has a harmful effect on milk. It causes a separation of the solids and the precipation of a part of the protein and mineral constituents. Freezing may also reduce the cream line and thus give the milk a watery appearance.

Many factors, concerning milk cooling will be discussed later in this thesis. Among them are, time required to cool, materials used for cooling, temperature, bacteria, quality of milk, cost, and others.

Experimental data are given on the different devices used in cooling milk. The important systems studied are, the Frigidaire, the Daniels cooler, and the home made box. These systems cool milk by the direct immersion method. The results, measured by the efficiency and cost are compared with other types of coolers, such as the tybular and the conical types, which cool milk by aeriation.

By the direct immersion method, we mean cooling milk by placing the cans directly in water, or some other cooling media, such as brine, and allowing it to cool. Either ten or five gallon cans may be used, and in a few cases the bottles have been cooled by this method. By the aeriation method, we mean allowing the milk to flow over a cooler, (either conical or tubular) and thus cool as it is being exposed to the air. The direct immersion and the aeriation methods are compared as to the quality of milk, judged by the flavor and the number of bacteria per cubic centimeter.

The insulation value of different materials are compared, and the practical value of each, as measured by time and temperature is given. The materials studied are air, shavings, and ground corn cobs.

Special attention is given the home made type of cabinet, with the idea of finding whether it will be practical or economical, as compared with the popular commercial machines.

DEFINITION OF TERMS

Tank. A cooling box. It may be made of concrete or other material. If made of concrete they are usually built partly in the ground and therefore, not movable. Commercial tanks are generally cork insulated metal boxes and are easily moved. These are called cabinets.

Cooler. It may be either the tank or the cabinet. The tank and the cabinet are referred to as the wet type of coolers. The wet type coolers are filled with water. The cans of milk are immersed directly in this water. This process of milk cooling is termed "Direct Immersion".

Storage Box. The dry type of cooler. When milk is cooled over the aerator it must be stored in a dry type of cooler or in the "storage box" to keep it cold. The air in the storage box is cooled either by the cooling coils which are exposed to the air of the dry box or by the brine tank, in which case, the cooling coils are located in the brine tank.

Double Transfer. When a brine tank is used in the storage box, the heat is removed in two steps. The heat is first absorbed from the warmer air by the brine, and from the brine by the cooling coils. This is called double transfer. A double transfer of heat takes place in a wet type of cooler if a brine tank is used to cool the water.

British Thermal Unit. The unit of quantity of heat is the British thermal unit, which is generally abbreviated and written "B.t.u.". One B.t.u. is the amount of heat necessary to raise the temperature of one pound of water one degree fahrenheit. For example, the heat required to change one pound of water at 32° F. (freezing point) to 212° F. (boiling point) is 180 B.t.u. To change one pound of ice at 32° F. to one pound of water at 32 F., 144 B.t.u. must be supplied. Conversely it requires the extraction of 144 B.t.u. from one pound of water at 32 F to freeze it into ice at the same temperature.

Kilowatt-hour. (K wh) The most commonly used unit of electrical energy. One killowatt-hour is equivalent to 3415 B.t.u.

Specific heat. The amount of heat, expressed in B.t.u., required to raise or lower the temperature of a pound of the substance one degree. The specific heat of water is one. The reason that the heat required to raise one pound of water one degree F. is taken as the unit, is because water is one of the most difficult of all substances to heat. Practically all other substances require less heat to raise to a unit quantity 1 F. For example, the heat necessary to raise one pound of iron 1°F. is only 1 x 0.113 x 1 or .113 B.t.u. In other words, while it takes one B.t.u. to raise one pound of water one degree F., it only takes .113 B.t.u. to raise one pound of iron one degree F. The specific heat of a substance, therefore, is its ability or capacity, compared with water to absorb heat.

PART I. REVIEW OF THE LITERATURE

Water as a Cooling Agent.

Water, perhaps is the most common milk cooling agent. It has been used for this purpose for centuries. When a can of warm milk is placed in cold water the heat passes into the water until the temperature of the two is about the same. According to Gamble(1), the final temperature of both milk and water depends largely upon the relative volume and the initial temperature of each. If a ten gallon can of milk at a temperature of 85° F. is placed in a cooling tank containing 30 gallons of water at 37° F., the final temperature of both will be about 50° F. It is evident, therefore, that in cooling milk with water alone to below 50° F., it is necessary to have a large volume of water compared to that of milk.

When a substance is said to cool, it gives up its heat to the surrounding medium. If this medium is a poor conductor of heat, such as air, the rate of cooling will be extremely slow. According to Johns(2) a can of warm milk placed in a refrigerator where the air is below freezing, requires approximately twelve hours to cool to below 50° F. Consequently the attempts to cool milk in snow banks or exposed to outdoor temperatures in winter are never satisfactory. Water, on the other hand, is a good conductor, and will cool down the milk over twenty times as fast as cold air at the same temperature.

According to Trout, (3) the most general practice of cooling milk in Michigan is by placing the cans of milk in a tank of cold water. He states that for efficient cooling by this method, at least six or seven gallons of water at a temperature of 48° -- 50° F., are required for each gallon of milk cooled. A certain amount of time is required

1.2:5
2.3:4
3.4:7

as well. As a general rule, from 30 to 60 minutes, depending upon the amount of stirring, are required with this method to reduce the temperature of the milk to a safe temprature for storage, and transportation to market.

The time element in the tank method of cooling is a problem on some farms located at the beginning of the hauling route, where the milk hauler begins early in the morning to gather his load. Frequently in such locations, the morning's milk is either uncooled, or insufficiently cooled; and it often arrives at the receiving station at a high temperature, or is in an off-flavored condition and is, therefore rejected.

The surface cooler is a quick method of reducing the milk's temperature. Where the milk house and cooler are located near the stables, and each cow's milk is immediately placed in the cooler, practically all of the milk is cooled when the milking is completed. The time element is thereby reduced to a minimum.

The question has been raised repeatedly as to the water requirements of a surface type cooler. Water with a pressure must be used with this method of cooling. To determine the water requirements of a surface cooler, tests were made at the Michigan Experiment Station(4) on five different coolers. Ten gallons of milk were cooled in each test over each cooler. A water meter was attached so that the amount of water, used by each type of cooler, could be determined accurately. The results of the waterrequirements of the different coolers are presented in Table 1.

An examination of Table 1 shows that, of the five coolers used, three yielded a milk with a final temperature below 60° F. These three coolers were numbers 2, 4, and 5; the spiral tubular, the large horizontal tube open, and the small horizontal tube closed. The average water requirement per gallon of milk necessary to secure a temperature of 60° F., was 7.1 gallons. In these three systems the counter flow water system is used, and the water entering under pressure at the bottom and passing out at the top of the cooler, while the milk flows by gravity down over the surface. The milk, on leaving the cooler comes in contact with the coldest water. In the other two systems the counter flow system is not in use, and consequently, a low temperature of cooling could not be obtained.

A milk cooling experiment was conducted in 1929 by Price, Hurd and Copson(5), at the Oregon State Experiment Station. The purpose of the experiment was to find just what results could be obtained when using mechanical refrigeration. They found that milk at 95° F. could be cooled to 59° F. in one hour, when the cans were kept in still water (55° - 45° F.), and to 46° F. in one hour when the water was circulated around the cans. They also found that when the milk was pre-cooled by a tubular, tap-water cooler to 66° F. before being placed in refrigerated water, it cooled to 45° F. in one hour when the cooling water was circulated and to 55° F. when the water was not circulated.

Nicholas(6) shows, from his work on milk cooling, that with the same water to milk ratio, milk cools more rapidly with agitation of the cooling water. With a water to milk ratio of 7, when three ten gallon cans are cooled, it requires 45 minutes to reach 50° F. with agitation of 1 hour and 30 minutes, or twice as long to reach the same temperature without agitation. He summarizes his work as follows: "(a) A large water to milk ratio is of prime importance for rapid cooling of

5.5:11-20
6.6:35

milk; hence a large tank or cabinet for cooling several cans is desirable; (b) Low Temperature cooling, while requiring more kilowatt hours, is essential for low temperature of milk; (c) agitation of the water is advantageous if the water milk ratio is not less than 10 for 40° F.; and 8 for 36° F; and 6 for 33° F. cooling water, provided no ice exists on the cooling coils; and (d) if milk is to be cooled to only 50° F., the cooling water should not be less than 40° F." This means that heat leakage and, consequently, power consumption will be low, hence more milk can be cooled per kilowatt hour than when low temperatures are required.

Table I. AMOUNT OF WATER REQUIRED BY VARIOUS SURFACE TYPE COOLERS TO BRING ABOUT DEFINITE COOLING.

No.	Distinguishing Characteristics	Initial Water Temperature	Initial Milk Temperature	Gallons of Milk	Gallons of Water	Final Temperature of Milk	Gallons of Water per Gallon of Milk
1.	Conical straight sided	58	93	10	50	65	5 : 1
		58	93	10	15	64	1.5: 1
		58	93	10	37.9	76	3.79: 1
2.	Spiral tubular	52	93	10	85	58	8.5 : 1
		52	93	10	50	59	5 : 1
		52	93	10	23	62	2.3 : 1
3.	Submerged hollow cylinder	52	93	10	200	68	20 : 1
		52	93	10	100	75	10 : 1
		52	93	10	50	78	5 : 1
		52	93	10	25	86	2.5: 1
4.	Large horizontal tubes open	52	93	10	102	57	10.2: 1
		52	93	10	50.8	59	5.08:1
		52	93	10	30	62	3 : 1
5.	Small horizontal tubes closed	52	93	10	97	56	9.7: 1
		52	93	10	44	58	4.4: 1
		52	93	10	27.9	60	2.79:1

<u>Cost of Cooling Milk</u>

"What does it cost to cool milk with electric cooling equipment? How does the cost of electric cooling compare with the cost of cooling with ice?"

These questions have been asked many times by dairymen, who are anxious to make a high quality product, but are keenly interested in costs since the margin of profit, on so many dairy farms, is small.

Bucknam(7), in New York found that if electricity could be purchased at four cents per kilowatt hour, the total cost of cooling milk was 11.4 cents per 40 quart can, or 13.2 cents per 100 pounds of milk. On the other hand, when milk was cooled by ice, Bucknam reports that the cost varied from 7 to 39 cents, with an average of 13.7 cents for each 40 quart can of milk. For each 100 pounds of milk this would be 15.9 cents. The study in New York showed that it was cheaper by 2,7 cents to cool 100 pounds of milk with electricity.

From Corbett's(8) survey in Rhode Island, made in 1929, the average cost of cooling 100 pounds of milk with ice was 10 cents. When cooling milk with electricity using wet boxes the cost was 13 cents for each 100 pounds of milk, and with dry boxes the cost was 14 cents for each 100 pounds of milk.

Ackerman(9) in New Hampshire found that the average cost of cooling 100 quarts of milk was 30 cents when ice was used, and 15 cents when the cooling was done by electricity. For each 100 pounds of milk this would be 13.9 cents, when ice was used compared with 6.9 cents

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7.7:8
8.8:11
9.9:14

when electricity was used. The equipment used on the farms studied by Ackerman was of the dry room type, consisting of an insulated room large enough to admit a person, and chilled through the medium of cold dry air.

Ellenberger(10), in Vermont found that it cost 22.1 cents per 100 pounds of milk when cooled with ice, as compared with 16.7 cents with electricity. The ice was valued at $3.00 to $4.00 per ton.

Andersen(11) states that when a base rate of three cents per kilowatt hour is used the average cost of cooling milk is 10.8 cents per 100 pounds. When the power charge is three cents per kilowatt hour, the power charge for cooling 100 pounds of milk is only 2.72 cents. See Table No. II.

Table II. COST OF COOLING MILK BY ELECTRICITY

Cost Item	Average annual cost	Average cost for each 100 pounds milk	Percent of Total
Power	$23.29	$00.0272	25.0
Depreciation Unit	$34.34	$00.0401	37.0
Depreciation Tank	$12.54	$00.0147	14.0
Interest	$22.07	$00.0258	24.0
Repairs	$00.00	$00.0000	00.0
Total	$92.33	$00.1078	100.0

10.10:9
11.11:8

Moses and Travernetti [12] state that from their work, the electric power consumption for the operation of a farm milk cooling plant depends upon the method of handling the milk, the time of the year, the type of plant or system, and the construction and operation of the plnt.

When the milk is cooled and stored in 10 gallon cans with the brine system used, about .12 kilowatt hours is consumed per gallon of milk. Using the base rate of three cents per kilowatt hour this would mean the cost of 4.2 cents for power for 100 pounds of milk.

When the milk is cooled and stored in bottles, the brine system being used, about .17 kilowatt hours is consumed per gallon of milk. This means that if electricity is worth 3 cents per kilowatt hour, the cost of 100 pounds of milk handled under these conditions would be 6 cents for the power.

When milk is cooled only, and is not stored, the brine system being used, about .03 kilowatt hours is consumed per gallon of milk. This means that the power cost per 100 pounds of milk would be 1.05 cents.

When cooled and stored, or not stored, the direct expansion system being used, about .05 kilowatt hours is consumed per gallon of milk, this means .06 cents per 100 pounds of milk, if 3 cents per kilowatt hour is charged for the power.

Price, Hurd and Copsen [13] found that it required 45.6 pounds of ice per 100 pounds of milk to lower the temperature of the milk from 95° F. to 35° F., but only 28.4 pounds, if the milk was first tubular cooled to 70° F., and then tank cooled to 35° F. With ice at 50 cents

12.12:33
13. 5:22

per hundred the respective costs were 22.8 and 14.2 cents. They state that, "Under average conditions, a kilowatt hour was required to cool 100 pounds of milk with electric refrigeration equipment (immersion tanks insulated with three inches corkboard). This would cost 3 cents at the usual power rate. A liberal allowance for interest, depreciation and repairs on an electric refrigerator of sufficient capacity to cool 80 gallons of milk per day should not exceed 20 cents per day which would be about 3 cents per 100 pounds of milk, making a total cost of 6 cents per 100 pounds of milk. The electric refrigeration equipment is less expensive and more convenient." The dry storage method was not approved because cooling proceeded at a slow rate. Water agitation greatly hastened the cooling process.

Brackett and Lewis(14) studied the cost of mechanical cooling on four Nebraska farms, using a dry room type of refrigeration. The warm fresh milk was passed over a two-part tubular aerator, in the upper half of which was water, and in the lower part brine circulated. The milk on the upper part of the aerator ranged in temperature from 50° F. to 56° F. The cooled milk after passing over the brine section of the aerator, ranged in temperature from 38° F. to 42° F. The average amount cooled daily on the four farms were 40, 120, 100, and 235 gallons. The kilowatt hours used per 100 pounds of milk were 1.80, .58, 1.03, and .85.

Krepp (15) used five different immersion type coolers, four of them insulated on the side with three, and one with two inch cork board. The kilowatt hours of electricity used in cooling milk from 95° to 45° F. ranged from .1023 to .0586 for each B.t.u. of heat removed.

14.13:17
15.14:38

Allowing an average of 4,000 B.t.u. to be removed from each can, (85 pounds of milk) the kilowatt hours required to cool 100 pounds of milk ranged from .58 to 2.74. Much more electricity is used in cooling milk to 35° F. than to 45° F., as was evident in trials with one of the tanks where 1.76 kilowatt hours were required to cool 100 pounds of milk to 45° F., and 2.44 kilowatt hours was required in cooling the milk to 35° F.; a 40 per cent increase. Stirring the water around the cans with an agitator decidely increased the rate of cooling. The cooling medium being at 38° F., it took about four hours to lower the temperature from 95° F. to 45° F., but when the water was agitated, it took slightly over two hours.

Riley [16] calculated the cost of cooling milk with ice in a medium sized insulated tank, with three inches of corkboard, to be 10.1 cents per 100 pounds of milk, ice being rated at 28.5 per 100 pounds in the cooling tank, which price allows for shrinkage and labor of removal from ice house to the tank. In a similar tank where electricity was used, its cost at five cents a kilowatt hour varied from 3.47 to 8.65 cents per 100 pounds of milk. This variation depended on the efficiency of the different mechanisms, which in turn is affected by the conditions of temperature and pressure under which they work, as well as by their design.

Hoards Dairyman [17] collected data during eight months on the cost of cooling milk with electricity on several Wisconsin farms. Special meters were installed on four farms and definite figures thus became available as to the current actually used for cooling milk to about 40° F. The average records appear in Table III.

16.15:1
17.16:632-3

Table III. KILOWATT HOURS PER 100 POUNDS MILK

Month	Total milk Cooled	Total Electricity Used	Electricity per 100 Pounds of milk
		K.w.h.	k.w.h.
April	84,965	430	.51
May	91463	706	.77
June	94,804	710	.75
July	86,323	997	1.16
August	80,695	1,052	1.30
Sept	80,900	747	.92
October	75,422	685	.91
November	68,136	296	.43
Total	662,710	5,623	
Average			.85

Weekly bacterial counts were made and only twice did their number exceed 25,000 per cubic centimeter. It was the general opinion of these Wisconsin dairymen that electricity really cost no more than ice. The total investment was slightly more, but the yearly cost of the energy was somewhat less than the annual cost of filling the ice house. They found electricity to be more efficient and that the disagreeable tasks connected with cooling milk with ice were eliminated.

Frandsen(18) found that in the immersion type of tank 40 pounds of ice or 1.20 kilowatt hours of electricity were required to cool 100 pounds of milk from 90° F. to 45° F., and it took about two hours time to cool milk from 90° to 50° F., the cooling water being at 40° F.

Newlander(19) states that practically no difference was found in the cost of cooling milk by mechanical (wet storage type) refrigeration, and by the use of ice, viz., 15 and 14.5 cents per 100 pounds. They found that the average cost of cooling 100 pounds of milk by mechanical (wet storage type) refrigeration over a year's time was 12.75 cents and that approximately one kilowatt hour of electricity or 35 to 40 pounds of ice were used on the average, in cooling 100 pounds of milk.

18.17:3
19.18:7

Effect of Cooling on Bacteria

The number of bacteria present in milk is generally accepted as one of the most important factors in determining the quality of milk. As the temperature of the milk is reduced from the body temperature after milking, the rate of bacterial growth is decreased. According to Price, Hurd, and Copson(20), when the milk is cooled to below 50° F., the bacterial increase is practically stopped for a period of from 12 to 24 hours. However, if a longer period of time in storage is desired the temperature of the milk must be maintained at 32° F. to prevent bacterial increase.

From the results of their experiment, in cooling milk from 95° F. in ten gallon cans in non-circulated water at 35° F. to 45° F., they conclude that the increase in the number of bacteria per cubic centimeter at the end of 14 hours storage was only 450, which is of little or no significance. The rate of cooling by this method, as given in the trials, shows that a temperature of approximately 60° F. can be reached in one hour, 55° F. in two hours, and 50° F. in four hours. This is offered as evidence that it is not necessary to cool milk immediately to below 50° F. in order to maintain a low bacterial count.

Marquardt and Dahlberg(21) report similar facts, in regard to the time and temperature of cooling milk. They found that the bacterial content of can-cooled milk did not increase in 24 hours when the water in the tank was below 42° F., and that stirring was of no value. However, they state that this is true only of freshly drawn milk. The milk which is older will increase in number of bacteria per cubic centimeter if cooled by this slow process.

20.5:18-19
21.19:12

In this investigation the milk was cooled in three ways, namely (1) a can of freshly drawn milk immersed in a tank of water without previous cooling, the milk not agitated in any way; (2) the milk was treated as in (1) except that it was stirred after one and two hour periods; and (3) the milk was cooled by a surface cooler to the required temperature before being placed in the tank. The data for the tubular-cooled milk are incomplete, but the results of the other two methods of cooling are shown in Table No. IV.

Table IV. INFLUENCE OF COOLING METHODS ON THE BACTERIAL CONTENT OF MILK AFTER 24 HOURS STORAGE.

Cooling Method	Water held at		
	35°-40°F	45°-50°F.	55°-60°F.
Original	11,700	15,700	10,000
Can-Cooled not stirred	11,900	16,000	67,000
Can-Cooled stirred	12,700	17,000	86,400

The results of real significance are that the bacterial content of can-cooled milk did not increase in 24 hours when the water in the tank was below 42° F., and that stirring was of no value.

According to Johns[22], milk should be cooled as promptly as possible. He states that freshly drawn milk contains a substance known as lactenin, which is able to restrain bacterial growth for a certain period of time. If cooling id delayed, this effect soon passes off, and on the other hand, if the milk is cooled immediately, the lactenic effect may be extended, even to 24 hours or longer.

22.3:4

Experiments carried on by Johns have shown that when a flask of freshly drawn milk was immediately placed in a refrigerator at 50° F. to 55° F. the bacterial count after 24 hours shows only a moderate incfease. Another portion of the same milk, allowed to remain in the laboratory for three hours before placing in the refrigerator, showed a marked increase in the bacteria count during the same period of storage.

Results from this experiment are shown in Table V.

Table V. VALUE OF IMMEDIATE COOLING IN RETARDING BACTERIAL GROWTH IN MILK
(Refrigerator temperature 50°-54°F.)

Houss in Refrigerator	Milk cooled at once	Milk cooled after 3 hours
	Bacteria per Cubic centimeter	
0	18,700	17,700
6	14,900	19,800
12	17,900	37,300

In this experiment the storage temperature was not low enough to prevent bacterial growth but where the lactenic effect was conserved through prompt cooling, the increase, in the bacterial count, was very small compared with that in the sample of milk which was not promptly cooled.

Bowen[23] states that since milk coming from the cow at approximately 100 degrees F. contains bacteria, immediate cooling is necessary for preserving the quality. Freezing of the milk, however, should be avoided. In order to maintain low bacteria count, not only

23.20:14

is it necessary to cool the milk, but precautions should be taken to prevent the entrance of bacteria during the handling operations. Table No. VI shows the results of Bowen's experiment.

Table VI. THE EFFECT OF TIME AND TEMPERATURE UPON BACTERIAL INCREASE IN MILK.

Temp. of Milk	Number of bacteria per cc at the end of			
	24 hours	48 hours	96 hours	168 hours
32	30,000	27,000	24,000	19,000
36	38,000	56,000	4,300,000	38,000,000
42	43,000	310,000	5,760,000	----
50	89,000	1,940,000	----	----
55	187,000	38,000,000	----	----
60	900,000	168,000,000	----	----
68	4,000,000	25,000,000,000	----	----
86	14,000,000,000	----	----	----
94	25,000,000,000	----	----	----

Each sample contained 30,000 bacteria per cc at the start.

The effect of temperature upon the growth of bacteria in milk is shown by the following experiment conducted by the Alabama State Board of Health.[21] Two pint bottles of milk were taken, immediately after milking, from the same pail at one of the best dairies in the Mobile district. One of these samples cooled immediately below 50° F., and the other left uncooled. At the end of a three hour period (the average time for delivery) both samples were placed in the refrigerator of the Health Department Laboratory, which varied in temperature from

24.21:3

50° to 60° F. In order to imitate conditions in the household after delivery. The uncooled milk soured 80 hours before the chilled milk. Table No. VII shows the marked effect of the chilling on the bacterial count.

Table VII. BACTERIAL COUNTS ON COOLED AND UNCOOLED MILK.

	Number of bacteria per cubic centimeter	
	Cooled milk	Uncooled milk
Plate count when milked 3 P.M.	5,000	5,000
Plate count when milked 10 A.M. next day	3,000	40,000
Plate count when milked 2 P.M. next day	6,000	85,000
Plate count when milked 10 A.M. second day	45,000	1,000,000
Plate count when milked 2 P.M. second day	170,000	14,000,000

Gamble[25] conducted an experiment in an effort to determine the effect of temperature on the development of bacteria. Two samples of milk, one containing 280,000 and the other 16,400 bacteria per cubic centimeter, were divided into four equal parts. These parts were held at four different temperatures until they soured. The high bacteria part held at 100° F. soured in 12 hours; the low bacteria part, held at the same temperature, soured in 36 hours. At 40° F. the high-bacteria part soured in 180 hours and the low-bacteria part in 396 hours. The actual results are shown in Figure 1.

Bottle No. 1 low bacteria -- No. 2 high bacteria

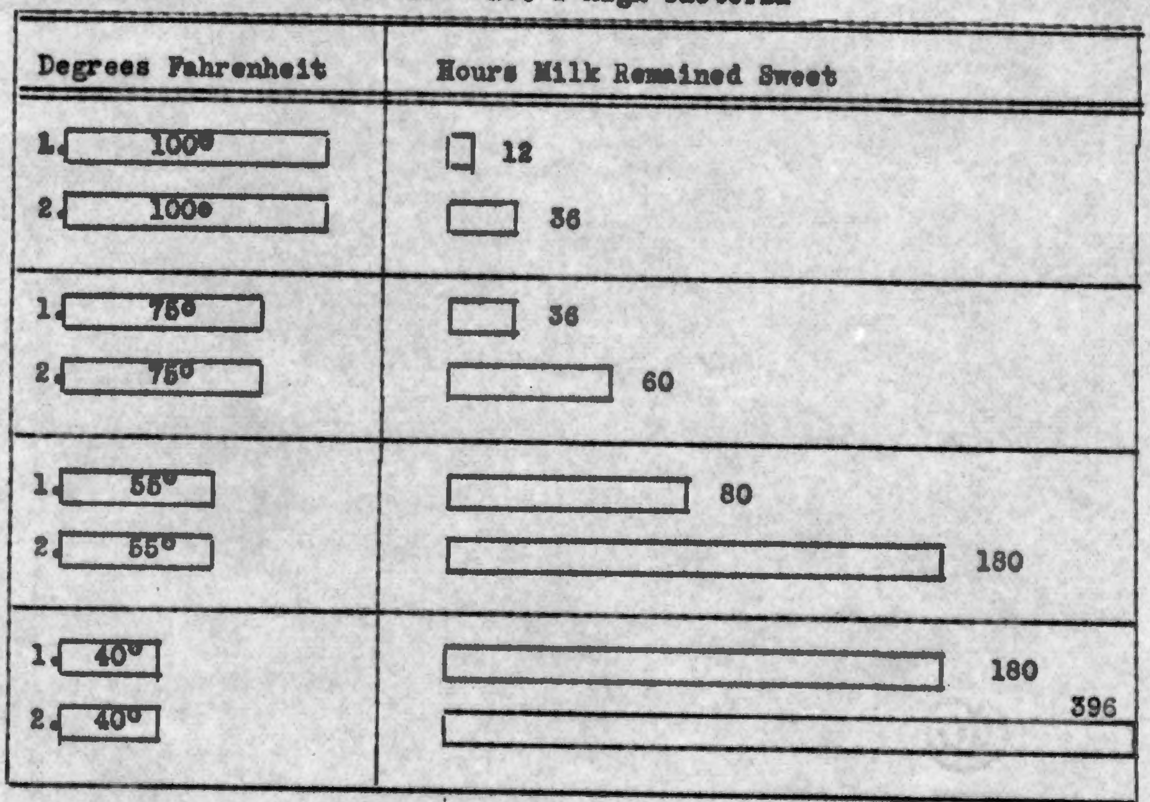

Figure 1.

25. 2:2

Methods of Cooling Milk

There are, of course, several ways in which the temperature of the milk can be reduced after milking, and under proper conditions each of these may be appropriate.(26)

There are very few sections of the country where water with a temperature below 50° F. can be found throughout the year. However, where this condition can be found, and if the water is plentiful and clean, a dairy man may obtain fairly satisfactory results by submerging his cans in tanks of this water kept moving by a steady gravity flow.

In most sections, however, the water temperature will be about 50° F. in mid-summer, and in case this is true, it will be necessary for the dairy man to resort to either ice or mechanical refrigeration to properly cool his milk. Ice, when properly used and in sufficient quantities will do a very satisfactory job on the submersion type coolers, or even supplying cold brine for circulation through aerators. A mechanical refrigerating machine, driven by either an electric motor or a gasoline engine, is a dependable as well as economical method of cooling milk.

Studies made and reported at the New Hampshire Experiment Station(27) point to the superiority of the dry room, or cabinet type of electric refrigeration over the wet type of storage. Under the former method surface coolers are used for pre-cooling the milk before it is placed in storage; under the wet type, there is no pre-cooling, as the pre-cooling and storage are combined into one process by immersing the cans of warm milk in refrigerated water.

Conclusions made from this experiment are listed as follows:

26. 22:8
27. 23:11

"The rate of cooling in the dry process is almost instantaneous as compared to the several hours for the wet tank. The final bacteria count of milk is invariably higher in the wet-tank method, due to the slow cooling process, which allows rapid multiplication of the original bacterial content.

The contamination factor of surface coolers is no greater, and generally not so great, as that of many other utensils used in the milk-handling process. This, after all, is a matter of cleaning and sterilization of the utensils, rather than a factor of refrigeration equipment; and a good percentage of the coolers tested under actual farm conditions have shown a high degree of cleanliness."

Moses and Tavernetti[28] state that the "wet" type of cooling is used but little in California, and that in some cases an aerator is also used for pre-cooling the milk.

The wet type of cooling has several advantages, among them are: (1) low in first cost, (2) easy to build, (3) easily accessible for making small quantities of ice, (4) able to store refrigeration. It has the disadvantages of: (1) being limited to storage cans, (2) being slow in cooling, (3) requiring occasional stirring of the milk unless an aerator is used, (4) being messy, and (5) making it necessary to lift the cans in and out of the tank.

Price, Hurd, and Copson[29] made a study of the two methods of cooling milk, the "wet" type of cooling was divided into two parts; pre-cooling over a tubular cooler, and then placing the milk in the refrigerated water; and not pre-cooled.

28. 12:6
29. 5:11-13

The milk was poured into 10 gallon cans at 90° F., and cooled in circulated or uncirculated water. The cans were usually filled as they floated in the refrigerated water, this allowing the can to sink as it was being filled. The results of this trial are shown in Table VIII.

The milk stored in the dry storage was first pre-cooled with a tubular cooler with tap water at 65° F. to 67° F. and then placed in dry storage. The results are shown in the following table.

Table VIII. COOLING MILK IN TEN GALLON CANS IN REFRIGERATED WATER

	Milk pre-cooled over tubular cooler 65°-67°F.				Milk not pre-cooled received at 90°-95°F.			
	Water circulated in refrigerator		Water not circulated		Water circulated		Water Not circulated	
	Degrees Fahrenheit							
Time	Milk	Water	Milk	Water	Milk	Water	Milk	Water
0	66	34	67.5	36	80	32	80	37
15 Min.	55	35	64	37	64.5	25.5	70	41
30 Min.	49	36	61	39	54	36	64	45
45 Min.	46	36	58	39	48	36	--	45
1 hr.	44	36	55	38	46	35	59	45
2 hrs.	41	34.5	52	38	42	34	56	43
3 hrs.	40	34	50	38	40	33.5	53	42
4 hrs.	38	34	48	36	38.5	33	50	40

Ellenberger[30] reports that, from his trials with methods of cooling milk, the results thus far indicate that the wet storage type of refrigeration is more economical to operate and more practical for use under conditions existing on most dairy farms than is the dry-storage type.

Table IX shows a condensed summary of the records on the mechanical unit for the months of June, July, and August. Similar data for the ice and water methods are shown in Table X.

During these months 42,725 pounds of milk were cooled with the mechanical unit. The initial temperature varied from 81° to 94° F., usually about 90° F. Temperature ranges as it left the cooler were from 36° F. to 40° F., and usually about 40° F. When removed for delivery the milk temperature ranged from 30° to 40° F. The compresser used 768 kilowatt hours of electricity and 3,219 cubic feet of water during this time. The bacterial count of the milk averaged 19,900 per cubic centimeter.

The ice and water tank was operated at as near full capacity as was the mechanical unit. It handled 28,479 pounds of milk. The initial temperature of the milk was the same as that cooled by the electrically operated unit. When removed for delivery the temperature ranged from 38° to 46° F. The tank water was changed about once a week, often enough to keep it fresh and clean. The total water usage was 517 cubic feet and 19,538 pounds of ice were used. The labor requirement was 31 hours for the three months. The average bacterial count was 22,000 but not appreciably higher than that of the milk cooled by the mechanical unit. The quality of the milk was unaffected by the method of cooling.

30. 10:11

Table IX. RECORD OF ELECTRICALLY OPERATED MILK COOLER, JUNE-AUGUST, 1928

	Milk	Temperature of Milk			Temperature of Brine			Water Usage	Elec. Usage	Average Bacteria Count
		Before Cooling	After Cooling	Ready for Delivery	Entering Cooler	Leaving Cooler	Storage Room			
	Lbs.	°F.	°F.	°F.	°F.	°F.	°F.	Cu.ft.	Kwhs.	per c.c
June	15,051	86-93	38-44	36-42	7-30	16-37	32.42	631	209	37,900
July	15,166	86-94	38-46	37-44	7-29	14-46	33-43	1,096	246	12,000
August	12,508	81-94	36-42	34-43	7-34	12-50	32-38	1,492	313	9,800
Three Months*..	42,725	81-94	36-46	34-44	7-34	12-50	32-43	3,219	768	19,900

Table X. RECORD OF THE ICE AND WATER COOLER, JUNE-AUGUST, 1928

	Milk	Temperature of Milk					Temperature of Water		Water Usage	Ice Usage	Average Bacterial Count	Labor
		Entering Tank	Stirred after 15 Min.	Stirred after 30 Min.	Stirred after 45 Min.	Ready for Delivery	When Cooling Started	When Milk was Removed				
	Lbs.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	cu.ft.	Lbs.	Per c.c.	hours
June	10,079	86-93	68-78	59-66	52-68	38-43	32-48	36-43	300	5,882	41,700	10
July	9,881	86-94	68-75	58-68	53-61	40-46	38-50	39-44	215	6,772	15,500	11¼
August	8,519	81-94	66-76	56-66	48-58	38-43	32-44	36-42	200	6,884	8,900	11
Three Months	28,479	81-94	66-78	56-68	48-61	38-46	32-46	32-50	715	19,538	22,000	31¼

*To remove ice from storage, to wash same and place in cooling tank.

since both methods were efficient in reducing the milk to the desired temperature.

The cost of cooling milk, as computed from data given in Tables IX and X, is shown in Table XI. The water cost is based on a charge of 20 cents per 100 cubic feet (748 gallons); electric power is figured at 5¢ per kilowatt-hour; the labor, having to do with the wet type of storage, is rated at 30 cents per hour; and the ice is valued at $4.00 per ton of usable ice.

Table XI. COMPARATIVE COST OF COOLING 100 LBS. OF MILK BY MEANS OF ICE AND ELECTRICITY.

	Water Usage		Ice Usage		Elec. Usage	Fixed Charges		Cost per 100 lbs.	
	Ice	Elec.	Ice	Labor		Ice	Elec.	Ice	Elec.
	Cu. Ft.		Lbs.		Kwh.	Cents.		Cents	
June	2.2	4.2	58	6	1.39	4.1	5.9	19.3	13.7
July	2.3	7.2	68	6.8	1.62	4.2	5.8	21.6	15.4
Aug.	2.5	11.9	81	7.7	2.50	4.8	7.1	25.4	22.0
3 Mos.	2.5	7.5	69	7.8	1.80	4.4	6.2	22.1	16.7

Hotis[31] states that, from his work with wet-tank storage as compared with dry-box storage, it is apparent that dry storage costs slightly more. The average power consumption per gallon of milk cooled was 5.8 watt hours with dry storage and 4.6 watt hours with wet storage.

A comparison of mechanical refrigeration with ice was made by Hotis[32] with the results reported in Table XII. These figures show that it took 4.8 watt-hours of electricity or .123 pounds of ice to cool 1 gallon through 1° F. and to hold the average storage temperature. If the cost of ice to the farmers was 40 cents per 100 pounds, the cost

31. 24:18
32. 24:21

of electricity was 3.5 cents per kilowatt hour, and their period of warm weather was 7 months, the average cost of electricity on each of the farms studied would be $110.00 less than the cost of ice. This amount should be more than sufficient to take care of interest, depreciation, and repairs on the mechanical unit.

Value of Insulating Materials

There are several important points to consider in the insulating of the cooling tank. Cork board is almost universally used in dairy fefrigerators, and is recommended for cooling tanks on the farm. While cork board is most generally used, it is probable that some other materials are more convenient for the dairyman to purchase, if he is making the tank on the farm. The following figures, taken from the report by the United States Bureau of Standards, give the heat losses in B.t.u. per hour, per square foot of different materials, per 1°F. gradient in temperature, and per 1 inch of thickness:

Material	Heat loss in B.T.U. per hour
Corkboard	.30
Celotex	.34
Insulate	.34
Flaxinum	.31
Fibrofelt	.32
White Pine (dry)	.78
Oak (dry)	1.02
Brick	3.0 to 6.0
Concrete	6.0 to 9.0

These materials may be secured in varying thicknesses, but for these tests they were all built one inch thick.

Marquardt and Dahlberg[33] studied the value of different insulating materials in connection with their study of the cost of cooling milk. The heat losses, through a tank insulated with 3 inches of cork and through a non-insulated tank with 4 inches of concrete wall, were determined. The water in both tanks was at 42°F. at the start and the test lasted for 24 hours. In the non-insulated tank, 288 pounds of ice were places, and after the 24 hour period, only 40 pounds were left. The temperature of the water at the end of the trial was 43°F., making a total refrigeration loss of 258 pounds of ice. In the insulated tank 94 pounds of ice were placed, and after the 24 hour period there were 22 pounds of ice left and the water in the tank was lowered to 39.5°F., making a loss equivalent to 46 pounds of ice. The three inch cork board saved 212 pounds of ice in one day, which at a cost of $5.00 per ton would be 53 cents. If a similar loss for a five month period could be assumed, the insulation saved $80.00, or three times its cost in one year.

Tavernetti[34] states that there are many different kinds of insulations made from various materials. (See Table No. XIII). Some of these materials are available in sheet form, the material being pressed into sheets, quilts, or felts. Also some of these materials are sold in loose form, the individual fibers being loose or the material coarsely ground. The first forms are shown as sheet insulation, and the latter as fill insulation. The sheet insulation has the advantages of being more easily made moisture-proof, of not

33. 19:6
34. 25:6

settling, and of usually having a low heat transfer factor. They have the disadvantages of being relativdly high in first cost, and of being harder to install. The fill insulations have the advantage of being low in first cost, of being easy to install, and of fitting into any space. They have the disadvantages of not being easily made moisture-proof and of tending to settle.

Table XIII. VARIOUS INSULATING MATERIALS AND THE THICKNESS EQUIVALENT TO ONE INCH OF CORKBOARD

Trade Name	Description	Thickness in inches equivalent to one inch corkboard
Balsa Wood	Bark from Balsa tree	1.11
Balsam Wool	Chemically treated wood fibers	1.00
Cabo's Quilt	Eel grass between kraft paper	1.00
Celotex	Matted cane fibers	1.05
Concrete		20.00
Corkboard	Compressed bark of cork trees	1.00
Fiborfelt	Felted vegetable fibers	1.09
Flaximum	Felted vegetable fibers	1.06
Ground cork	Granulated bark of cork tree	1.33
Hair-felt	Felted cattle hair	1.00
Insulex	Aerated cellular gypsum	2.00
Insulite	Prssed wood pulp	1.10
Kapok	Confined vegetable fiber	1.00
Linofelt	Confined vegetable fiber	1.00
Lithboard	Mineral vegetable fiber	1.25
Masonite	Expanded wood fiber	1.05
Mineral wool	Fibers blown from slag	1.00
Rock Cork	Fibers blown from limestone	1.00
Redwood fiber	Shredded redwood bark	1.00
Wood		3.00

Table XII. COMPARISONS OF ICE WITH MACHINES ON SAME FARMS

Farm No.	Average air Temperatures When using		Average daily Storage tank Temperature		M I L K								Power Used Per Gal. degree	Ice Used Per Gal. degree	Power Used Per Gal. cooled	Ice Used per Gal. cooled
					Average Temperature to which cooled		Average Degrees Cooled		Average Gallons Cooled per day		Average Refrigeration per day					
	Machine	Ice	Machine	Ice	Machine	Ice	Mach.	Ice	Machine	Ice	Machine	Ice				
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	No.	No.	Gal. Degr.	Gal. Degr.	Watt hrs.	Lbs.	Watt hrs.	Lbs.
4	80	80	40	37	44	46	15	15	102	101	1530	1515	5.8	.098	87.7	1.5
6	77	76	36	40	38	40	24	23	75	69	1800	1587	5.7	.124	138.	2.9
13	78	69	41	38	42	42	21	20	74	68	1554	1360	5.1	.137	106.	2.8
18	79	81	39	40	40	41	22	24	32	38	704	912	6.8	.135	150.0	3.2
19	63	64	41	44	44	44	55	52	68	70	3740	3640	1.8	.088	98.0	4.1
21	80	85	37	38	37	38	21	20	46	45	966	900	3.7	.166	77.6	3.3
Average	76	76	39	39.5	40.8	41.8	26.3	25.7	66.2	65.2	1716	1652	4.8	.123	109.6	3.0

SUMMARY OF REVIEW OF LITERATURE

1. Water is the most common milk cooling agent.
2. A large water to milk ratio is of prime importance for rapid cooling of milk.
3. Agitation of the water is advantageous if the water milk ratio is not less than 10 for 40°F. cooling water.
4. The studies, on the cost of cooling milk, showed that it was cheaper to cool 100 pounds of milk with electricity than with ice.
5. When milk is cooled and stored in 10 gallon cans with the brine system used, about .12 kilowatt hours is consumed per gallon of milk.
6. When milk is cooled and stored, the direct expansion system being used. about .05 kilowatt hours is consumed per gallon of milk.
7. In cooling milk in the direct immersion type of tank, 40 pounds of ice will do the work of 1.20 kilowatt hours of electricity.
8. When milk is cooled immediately to below 50°F., the bacterial increase is practically stopped for a period of from 12 to 24 hours.
9. There are several ways in which the temperature of the milk can be reduced after milking, and under proper conditions each of these may be appropriate.
10. The rate of cooling in the dry process is almost instantaneous as compared to the several hours for the wet tank.
11. The average power consumption is slightly higher with the "dry" type of cooling, than with the "wet" type.

12. There are many different kinds of insulation materials, and some of them are as efficient as cork board.

PART 11. ORIGINAL INVESTIGATION

Plan of Investigation.

Even though milk may be produced under particularly clean conditions, and exhibit a low bacterial count as it comes from the cows, it must be properly and promptly cooled, if it is to remain a high grade milk until such time as it is delivered to the processing plant, or to the consumer. The best of fresh milk may become an unsatisfactory product in a comparatively short time if not properly cooled. Brew[1] is reported to have said, "I think that as milk is delivered from the average farm from day to day, about 85 per cent of the high counts are the result of failure to properly and promptly cool the milk". It is clear that proper cooling is a most important step in the production of high quality milk, and of vital concern to every producer.

The general plan of this investigation is, to compare the different cooling systems, and to find out some vital factors which have to do with cooling. Accurate data was collected from each method studied. The operation of the coolers was under the direct supervision of the author and the cooling trials were made by him. Special meters were attached to all electrically driven coolers, and a daily check on the kilowatt hours made. A recording thermometer was placed in the water bath of each tank and daily charts will be kept. Factors, such as number of bacteria, cost, time, temperature and flavor were studied and compared as they are affected by different methods of cooling.

1.1:1

Object of the Investigations.

1. To study the various methods of cooling milk.
2. To compare these methods as to cost, efficiency, and adaptations.
3. To study the effect of cooling on the bacterial content of milk.
4. To make a study of the rate of cooling milk, under different conditions.
5. To study the insulating value of different materials which may be used in a home-made cooling tank.

General Procedure in Handling the Milk.

In carrying out these trials in milk cooling the milk production of the thirty-cow herd of the Dairy Husbandry Department was cooled in the milk room adjacent to the milking barn. The daily production during the period of these tests was 400-600 pounds of milk; or 2 to 3 ten-gallon cans each milking, since the cows were milked three times each day.

The morning milking was completed by ten o'clock and the milk placed in the cooling tank until five o'clock the following morning. The afternoon milking was completed by six o'clock, and the milk placed in the tank along with that produced in the morning. The night milking was completed by two o'clock, a.m. and that milk also was placed in the tank, along with that produced the two previous milkings.

The milk was removed from the tank only once a day, that being at five o'clock in the morning. In this way, one third of each day's milk production remained in the cooling tank for as much as 19 hours; one third for 11 hours, and one third for only 3 hours.

This procedure was followed for the first five months of the test period. After that time, the Frigidaire was removed from the barn, and the capacity of the cooler put in its place, was not large enough to take care of all the milk, consequently the milk had to be removed from the barn twice each day. These removals were then made at 5 a.m. and 5 p.m.

Types of Cooling and Storing Plants.

There are, of course, several ways in which the temperature of the milk can be reduced after milking, and under proper circumstances each of these methods may be appropriate.

Two general types of milk cooling and storing plants are in use, the "wet" and the "dry". The "wet" type, which is used almost exclusively in this investigation consists of an insulated tank or chest, made of wood, metal or concrete. This tank contains brine or water, cooled by a refrigerating machine. Cans of freshly-drawn milk are set into this water and cooled by conduction through the metal can. When first set into the tank the milk is much warmer than the water so that the heat transfer is rapid and the temperature of the milk drops rather quickly. Ordinarily it will drop from 90° F. to 55° F. in one hour if the temperature of the water bath is 38° F. or less. Agitating the water and the milk either by hand or mechanical means will shorten the cooling time, and cannot contaminate the milk unless, of course, a stirring rod is used in the milk. In some cases an aerator (milk cooler) and a small pump for circulating the brine or water through the aerator are used. When an aerator is used, the milk is first cooled over the aerator by well water, brine, or water from the tank, or by a combination of these, and then placed in cans and stored until shipped.

This type of plant has the advantages of being low in first cost, easy to build and install, and able to store refrigeration. It has the disadvantages of being limited to storage cans, and being somewhat slow in cooling.

This plain submersion "wet" type system of cooling and storing is recommended for dairymen who seàl their raw milk, wholesale, in cans and who are able to leave the milk in the cooler for not less than two hours after milking.

With the "dry" type of cooling and storing plant, the milk is always first cooled over an aerator. The milk is then placed in cans or bottles and stored in a dry storage box. With this type of plant, two systems of cooling may be used, the brine and the direct expansion. With the brine system, the refrigerating machine cools a tank of brine, and this in turn cools the milk and storage box. With the direct expansion system, the refrigerating machine cools the milk and storage box directly.

The advantages of the brine system are: (1) the compressor may be smaller; (2) refrigeration can be stored in the brine tank, and (3) a fairly uniform storage box temperature is always maintained. The advantages of the direct expansion system are; (1) less equipment is needed; (2) only two heat transfers are rsquired, milk to refrigerant and refrigerant to compressor cooling medium; and the operating cost is usually lower.

In comparing the "wet" and "dry" types of storage plant, one fact to keep in mind is that it is possible to cool to lower temperatures with dry storage, because the brine is held at a temperature below freezing, whereas storage water if held below freezing would form ice and could not be circulated through the milk cooler.

Cost of Cooling Milk.

The Frigidaire.

The Frigidaire used was the A-6 Model, which has a storage capacity for six 40 quart cans. The outside dimensions are 60 3/8 inches long, 41 1/4 inches wide, and 34 inches high. The cabinet is divided into two compartments, four cans to be placed in one and two in the other. The cold water is circulated, by a pump from the right-hand to the left-hand compartment. The left-hand compartment is always kept full of water. When cans are placed in the left-hand compartment, the displaced water flows over the self-leveler into the right-hand compartment. In this way the cold water always surrounds the cans above the milk line. The agitation of the cooling water is brought about by an electrically driven pump which pumps the water from the right-hand compartment into the left-hand compartment. A time-switch controls the pump and will automatically cut it off after a certain length of time. This type of cooler allows for agitation of the cooling water but no agitation of the milk.

Trials were started on this cooler the 1st of October, 1934. The total amount of milk cooled and stored during that month was 9,845 pounds; an average of 317 pounds per day. The amount of electricity consumed in cooling and storing this milk was 187 kilowatt hours, or an average of 6 kilowatt hours per day. Assuming that this power costs 3 cents per kilowatt hour, then the cost for power used in cooling for the month would be $5.61, or 5.7 cents per 100 pounds of milk cooled.

These figures are a little high, when compared with other work along this line. However, this may be due to the fact that the compressor used was running low in gas, as a very definite decrease in kilowatt hours consumed per day, was noted immediately after more gas was added to the compressor.

For the month of November, 9,944 pounds of milk was cooled by the same method. The number of kilowatt hours consumed was 115, at a cost of $3.45, or 3.47 cents per 100 pounds of milk cooled and stored. Converted into gallons, it would mean a consumption of .10 kilowatt hours per gallon of milk cooled and stored, as compared with .16 kilowatt hours consumed per gallon for the month of October.

During the month of December, there were 10,694 pounds of milk cooled and stored in the Frigidaire. This required 131 kilowatt hours of electricity, at a cost of $3.93. This would mean a cost of 3.69 cents per 100 pounds of milk, or .105 kilowatt hours per gallon. Practically the same as that for the month of November.

For January, 13,134 pounds of milk were cooled and stored, consuming 165 kilowatt hours, at a cost of $4.95. This means a cost of 3.77 cents per 100 pounds, or .108 kilowatt hours per gallon.

February was the coldest month in the year, and the volume of milk was larger than the previous months. Only 150 kilowatt hours of electricity were required to cool and store 15,732 pounds of milk. The total cost for the power was only $4.50, which means it cost 2.86 cents per 100 pounds of milk, or .082 kilowatt hours per gallon. See

Table No. XIV for complete figures on this trial.

Table XIV. COST OF COOLING MILK IN FRIGIDAIRE FOR THE MONTHS OF OCTOBER, NOVEMBER, DECEMBER, JANUARY AND FEBRUARY.

Month	Pounds of Milk Cooled	K W H Consumed	Power Cost at 3¢ per K W H	Cost per 100 lbs at 3¢ per K W H	K W H per Gal.
October	9,845	187*	$5.61	5.7¢	.16
November	9,944	115	3.45	3.47¢	.10
December	10,694	131	3.93	3.69¢	.105
January	13,134	165	4.95	3.77¢	.108
February	15,732	150	4.50	2.86¢	.082

* Gas was running low, which overworked the compressor.

The Daniels Cooler.

After collecting data on the Frigidaire for the four months period, the Frigidaire was removed from the milk room and the Daniels box put in its place. This box was only a four can unit, and consequently all of the milk could not be stored, as was with the Frigidaire. However, it was all cooled and a good part of it stored. While the Frigidaire was in use, the milk was removed only once a day, but it was necessary to remove it twice while using the Daniels cabinet.

The Daniels box was built with a movable floor. The cans of milk were placed on this floor which could be moved by an electric motor. It was in this way that the water and the milk were agitated, while with the Frigidaire only the water was agitated.

The Frigidaire

Figure 2. "Flowing Cold" Milk Cabinet, used in these Experiments.

During the month of March, 19,870 pounds of milk were produced at the dairy and cooled in the Daniels box. 279 kilowatt hours of electricity were consumed, at a cost of $8.37. This means a cost of 4.21 cents per 100 pounds of milk produced, or .12 kilowatt hours per gallon. For April, 16,120 pounds were produced, which required 234 kilowatt hours to cool. This electricity cost $7.02, which means 4.35 cents per 100 pounds, or .124 kilowatt hours per gallon. For May, 16,066 pounds were cooled which required 233 kilowatt hours, at a cost of $6.99, which means 4.35 cents per 100 pounds, or .125 kilowatt hours per gallon.

It will be noticed that the number of kilowatt hours of electricity consumed during the month of May is somewhat lower than that of the two previous months. This may be partly due to the fact that during May part of the milk was first tubular cooled with tap water and then placed in the Daniels box. This would bring the cost down considerably, as it was noted that on the days the milk was pre-cooled the compressor would require from two to three kilowatt hours less. The results of the three months trial will be found in Table XV. and these figures may be compared with those of Table XIV.

Table XV. COST OF COOLING MILK IN DANIELS BOX FOR THE MONTHS OF MARCH, APRIL AND MAY

Month	Pounds of Milk Cooled	K W H Consumed	Power Cost @3¢ per K W H	Cost per 100 lbs. @3¢ per K W H	K W H per Gallon
March	19,870	279	$8.37	3.21¢	.12
April	16,120	234	7.02	4.35¢	.124
May*	16,066	233	6.99	4.35¢	.125

* For 8 days in this month the milk was first pre-cooled over a tubular cooler using tap-water.

A comparison of Tables XIV and XV shows that there is very little difference in the two units as far as the cost of the power is concerned. For the whole five months period the Frigidaire averaged a cost of .127 cents per gallon of milk, as compared with .123 cents for the Daniels box. The average outside temperature was about the same. Since the Frigidaire was operated during the fall months, and the Daniels in the spring.

Figure 4 shows graphically, the actual pounds of milk produced during the eight months period, and also the power charge for cooling this milk by mechanical refrigeration. It will be noted that during the month of October the production was the lowest of the entire period. Also the cost per 100 pounds cooled was the highest. The Frigidaire did not have near its capacity and therefore, the actual cost per 100 pounds cooled was much higher than for those months when the machine was running at full capacity. Other factors enter also and among them is the fact that October was the warmest month of the

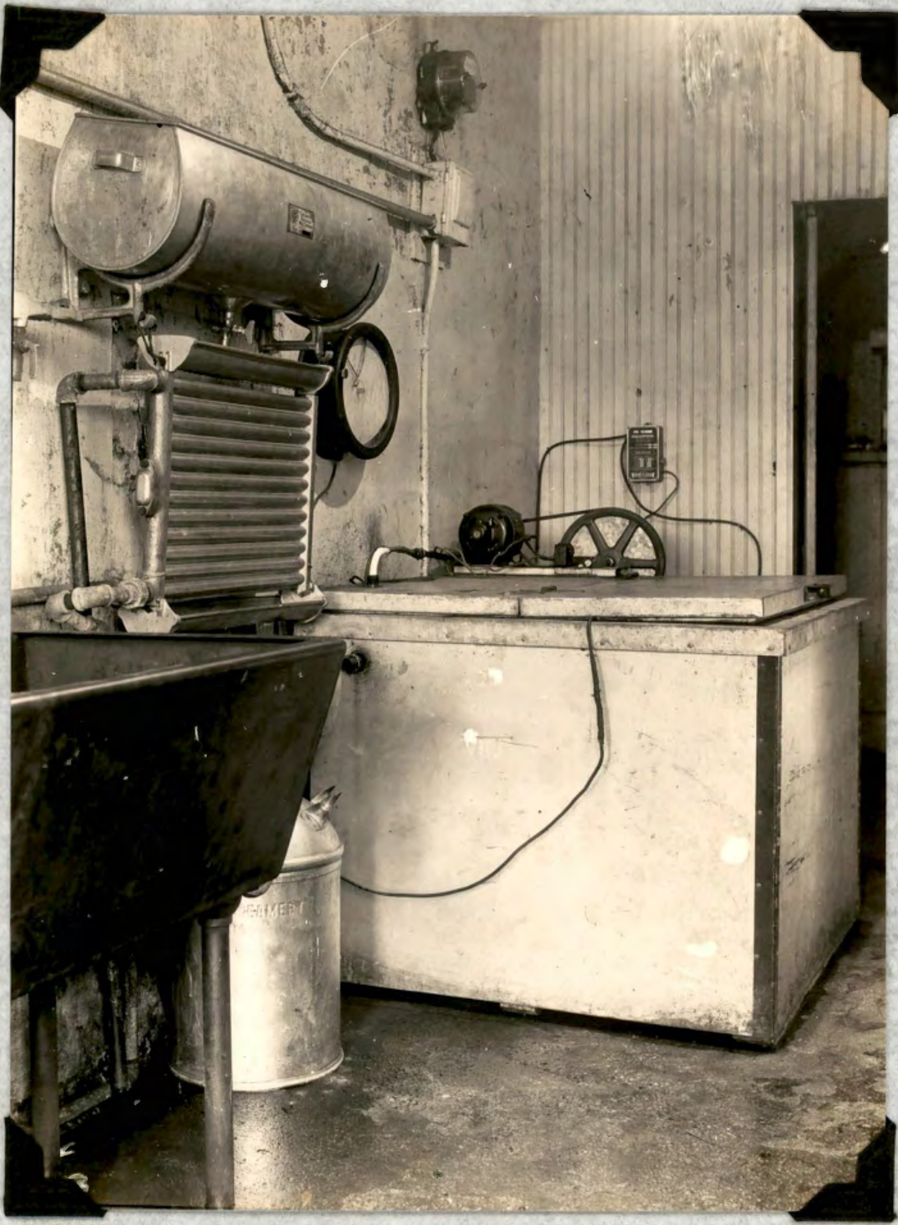

Figure 3. The Daniels Cooler, also showing the tubular cooler used in these trials.

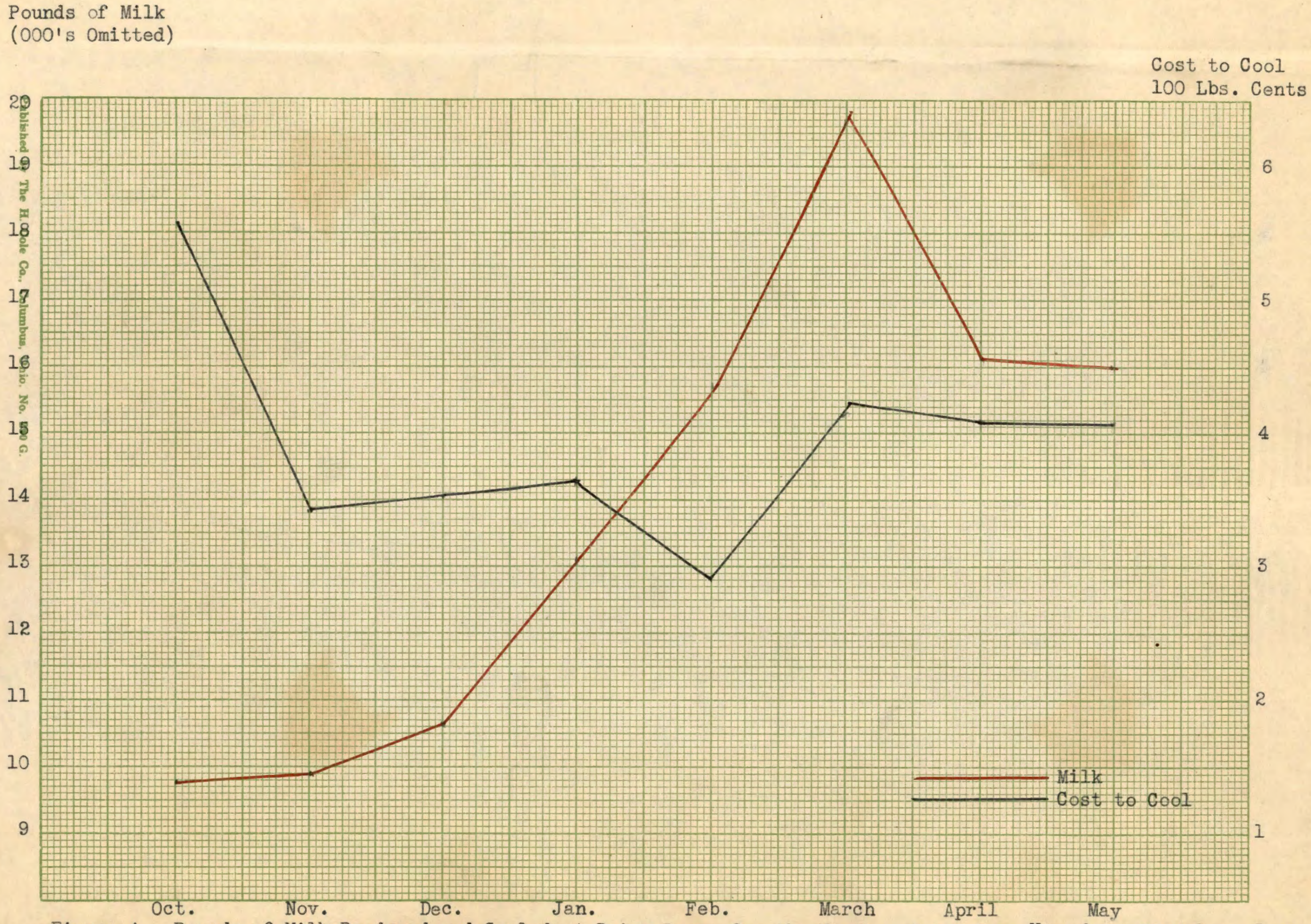

Figure 4. Pounds of Milk Produced and Cooled at Dairy Barns for the Months of October, November, December, January February, March, April and May.

fall period, and consequently the cooling unit had a much heavier load than it did during the cold month of February.

Cooling With Ice.

It was found that the average power cost for cooling for the entire eight months period was 4 cents per 100 pounds of milk cooled. A liberal allowance for interest, depreciation, and repairs on an electric refrigerator of sufficient capacity to cool 80 gallons of milk per day should not exceed 20¢ per day, which would be about 3 cents per 100 pounds of milk, making a total of 7 cents per 100 pounds of milk.

From the review of literature we find that the number of pounds of ice required to cool 100 pounds of milk is 28.4. Ice at 1/2 cent per pound would cost 14.2¢ to cool 100 pounds of milk as shown above. Under these conditions one can easily see that the electric refrigeration equipment is must less expensive. Not only is it less expensive, but it is also more convenient. With the mechanical refrigerator the expense and labor of actual operation is reduced to a minimum, whereas with ice the cost of labor alone is a big item in milk cooling.

The cost of an adequate supply of ice, however, often places this cooling means out of the reach of the dairyman who has to figure his cost closely. If artificial ice is used, it must usually be trucked several miles in summer and the less through melting is a considerable amount. If natural ice is available, the dairyman must have a generous ice house, which means a substantial investment, and the daily labor cost as well as the seasonal cost of harvesting and storing the ice, makes this procedure expensive. In addition to these facts, there are few regions in the United States that can be absolutely positive of a satisfactory ice harvest every winter, and if the ice crop is short or of poor quality, the dairyman may lose a large amount of his dairy profit when his short supply of ice becomes exhausted in summer.

Rate of Cooling. The Frigidaire

Much work has been done on the rate of cooling. It is an important factor since the growth and multiplication of bacteria are so closely connected with it. Many investigators believe that it is absolutely necessary to bring the temperature of milk down to 50° F. or below, within an hour after it is milked. They have found that unless the milk is cooled immediately, the bacteria growth is very rapid.

Trials were run with the Frigidaire in order to find out the exact time required to cool a 40 quart can of freshly drawn milk to 50° F. The milk was at a temperature of 86° F. at the start. After the end of a ten minute period the temperature had gone down to 76° F. In 20 minutes the temperature was 69° F., and after thirty minutes had expired the temperature was down to 64° F. The temperature was read every 10 minutes and it was found that one hour and fifty minutes were required to bring the temperature down to 50° F.

The temperature of the water was 38° F., but the pump was not working. Consequently neither the milk nor water was agitated. It was interesting to note that the temperature of the milk near the edge of the can was brought down much more rapidly than was the milk in the center of the can. In fact, the milk next to the edge of the can was brought below 50° F. in less than one hour.

A similar trial was run with the Frigidaire. The pump was working, which circulated the water around the cans. The temperature of the milk was 88° F., and after 10 minutes of cooling the temperature had gone down to 74° F. After 20 minutes the temperature was 65° F., and after 30 minutes of cooling the temperature had gone down to 58° F. It was found that by cooling milk with the Frigidaire, (temperature of water bath at 38° F.) it required one hour and 10 minutes to cool to below 50° F. A summary of these trials is shown in Figure 5.

A summary of Figure 5 shows that the can of milk cooled while the water was being agitated, reached 50° F. in 40 minutes less time than did the can which was cooled in still water. This shows the value of circulating the cooling water as the milk is being cooled.

Table XVI shows the rate of cooling 10 gallon cans of milk in circulated water at 40° F. as compared with non-circulated water. The increase in temperature of the water bath is also given. This trial was made with the Frigidaire.

Table XVI. COOLING MILK IN 10 GALLON CANS IN ELECTRICALLY REFRIGERATED WATER.

Temperature of water 40° F. at start
Temperature of milk 81° F. - 83° F. start

Time	Water Circulated		Water not Circulated	
	Milk	Water	Milk	Water
	°F	°F	°F	°F
Start	81	40	83	40
15 Min.	64	41	73	41
30 Min.	56	43	66	42
45 Min.	52	42	63	45
60 Min.	51	41	60	45
75 Min.	50	40	57	43
90 Min.	--	--	54	42
105 Min.	--	--	52	41
120 Min.	--	--	50	41

Milk can be cooled as efficiently with ice as with mechanical refrigeration. A trial was made in order to determine the rate of cooling milk with ice water. The Daniels box was filled with water and enough ice added to bring the temperature of the water down to 40° F. When this temperature was reached the ice remaining in the water was removed and a 10 gallon can of milk at a temperature of 82° F. was immersed in this water. The temperature of both the milk and water was taken at the end of each fifteen minute period. The results from this trial are shown in Table XVII. These results when compared with those in Table XVI show that the rate of cooling in water at 40° F. is just the same no matter whether ice or mechanical means are used to supply the refrigeration. In the trial with ice the water was circulated around the can by means of stirring the water.

Table XVII. COOLING MILK IN 10 GALLON CANS IN WATER REFRIGERATED WITH ICE.

Temperature of water 40° F. Temperature of milk, start 82° F.		
Time	Milk	Water
Start	82	40
15 Minutes	70	44
30 Minutes	60	47
45 Minutes	55	48
60 Minutes	52	48
75 Minutes	50	48

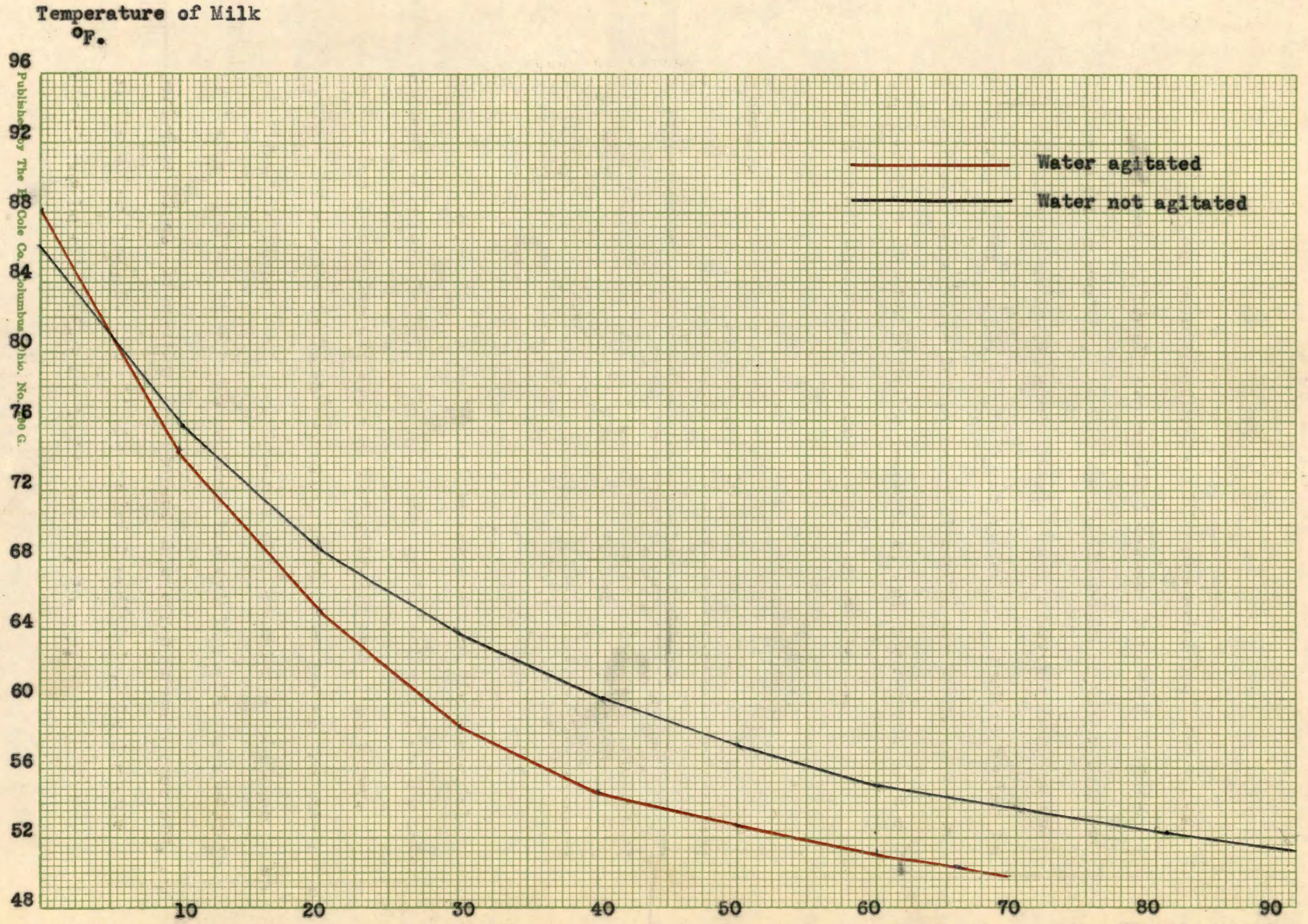

Figure 5. Rate of Cooling in Frigidaire.

<u>The Daniels Cooler.</u>

Studies were made on the rate of cooling milk in the Daniels box. Two trials were made, one with the agitator working and one with it off. The results are shown in Figure 6.

A can of warm milk (92° F.) was placed in the cooling water (38° F). The agitator was not in use, and consequently neither the milk nor the water were agitated. The temperature of the milk (in the center of the can) was read after each 10 minute period. After the 1st period the temperature had gone down to 77° F., to 69° F. in twenty minutes, and to 56° F. in one hour. It required one hour and 55 minutes to bring the temperature of the milk to 50° F.

A second trial was run with the Daniels box. This time the agitator was in use. Both the milk and the water were agitated. It was found that after 10 minutes the temperature of a can of milk was brought from 88° F. to 72° F. After 20 minutes the temperature had reached 62° F. and it required only 50 minutes to bring the temperature of the milk down to 50° F.

An examination of Figure 4 shows the advantage of agitation of both water and milk. It required 65 minutes longer to cool the milk without agitation. Figure 7 shows a comparison of milk, being cooled without agitation, with milk as it is cooled with agitation of just the cooling water and also the agitation of both the milk and the water. The figure shows that a ten gallon can of freshly drawn milk can be brought to 50° F. in 40 minutes less time by the agitation of just the cooling water. By the agitation of both the cooling water and the milk, the temperature of the milk can be brought to 50° F. in 65 minutes less time than by cooling milk in still water.

There are ample data in the literature to demonstrate that milk cools very slowly in a 10-gallon can immersed in water, that it cools much more rapidly when stirred or agitated, and that for most rapid cooling the milk should be tubular cooled before placing the can of milk in the tank of water. There can be no doubt whatever concerning the necessity of tubular cooling the milk which is to be set in a cold air room, because air cools milk so slowly. However, the necessity of rapid tubular cooling of fresh milk before placing it in water may be entirely different when the tank is of ample capacity, well-insulated and the cooling water at a low enough temperature.

Figure 8 shows exactly what happens to the temperature of a can of milk when first cooled without agitation and the agitator started before the cooling is completed. The milk in the still water cooled along a definite line, but when the agitation was started, the cooling line began to drop at a much greater rate.

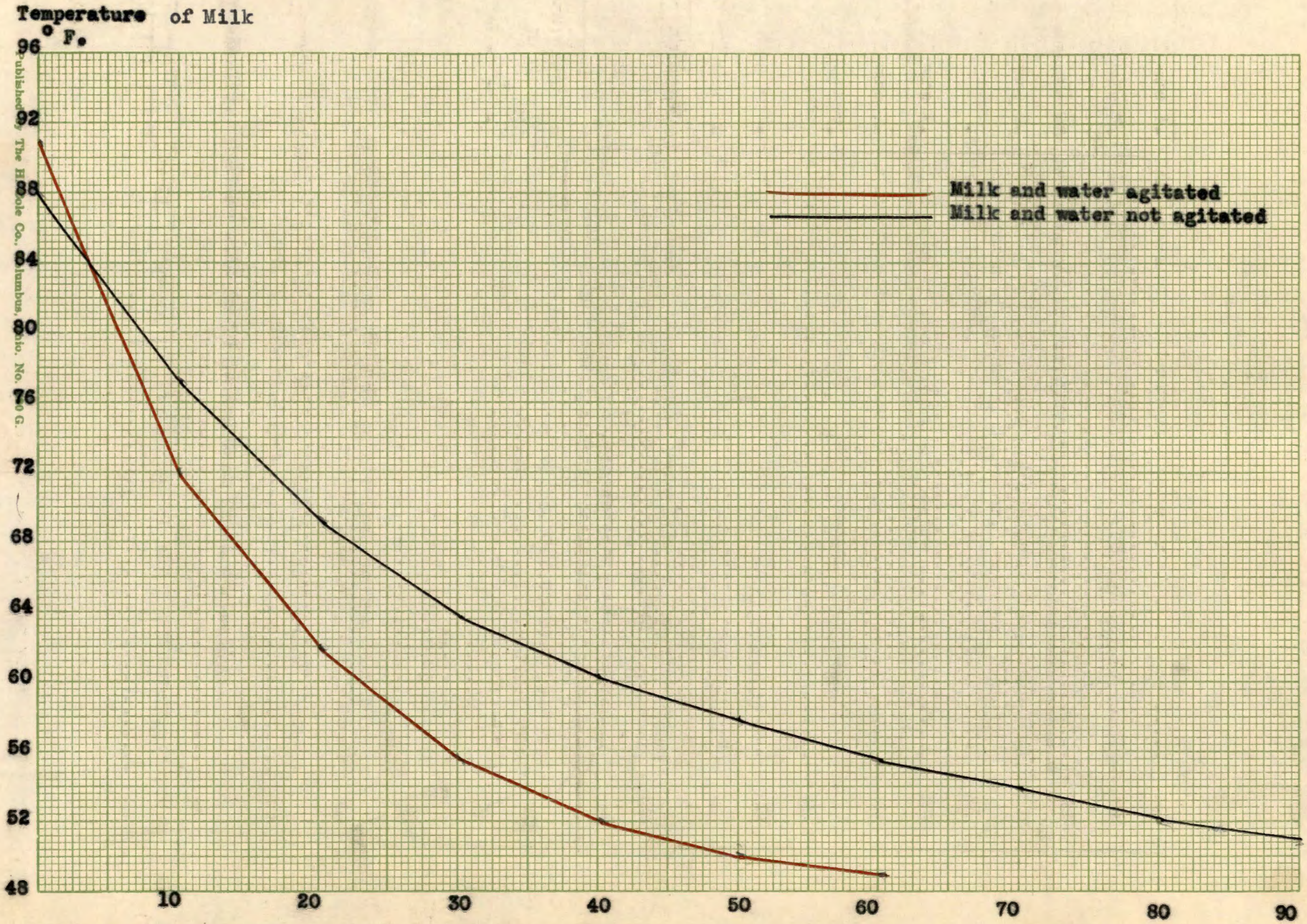

Figure 6. Rate of Cooling in Daniels Box.

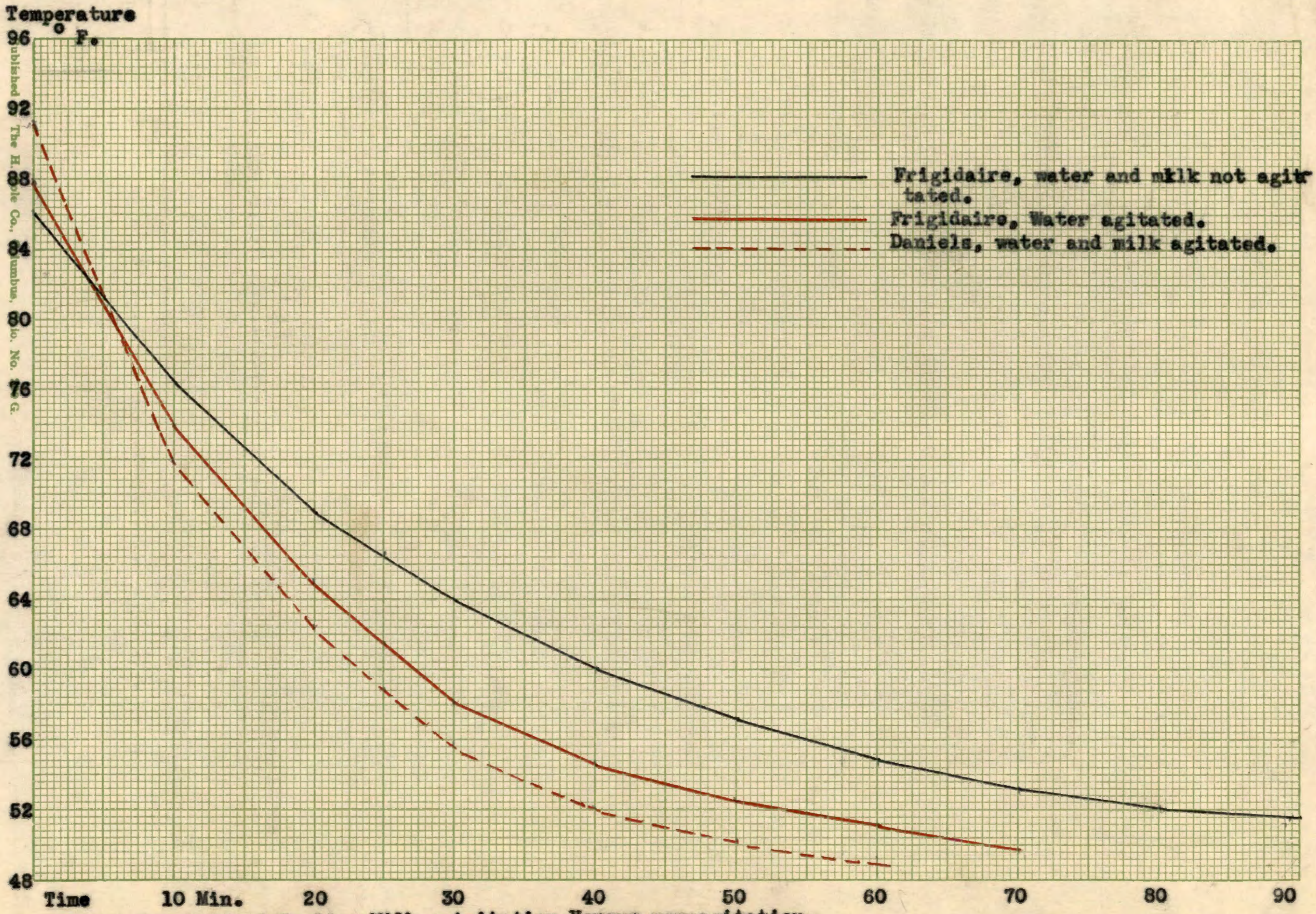

Figure 7. Rate of Cooling Milk - Agitation Versus non-agitation.

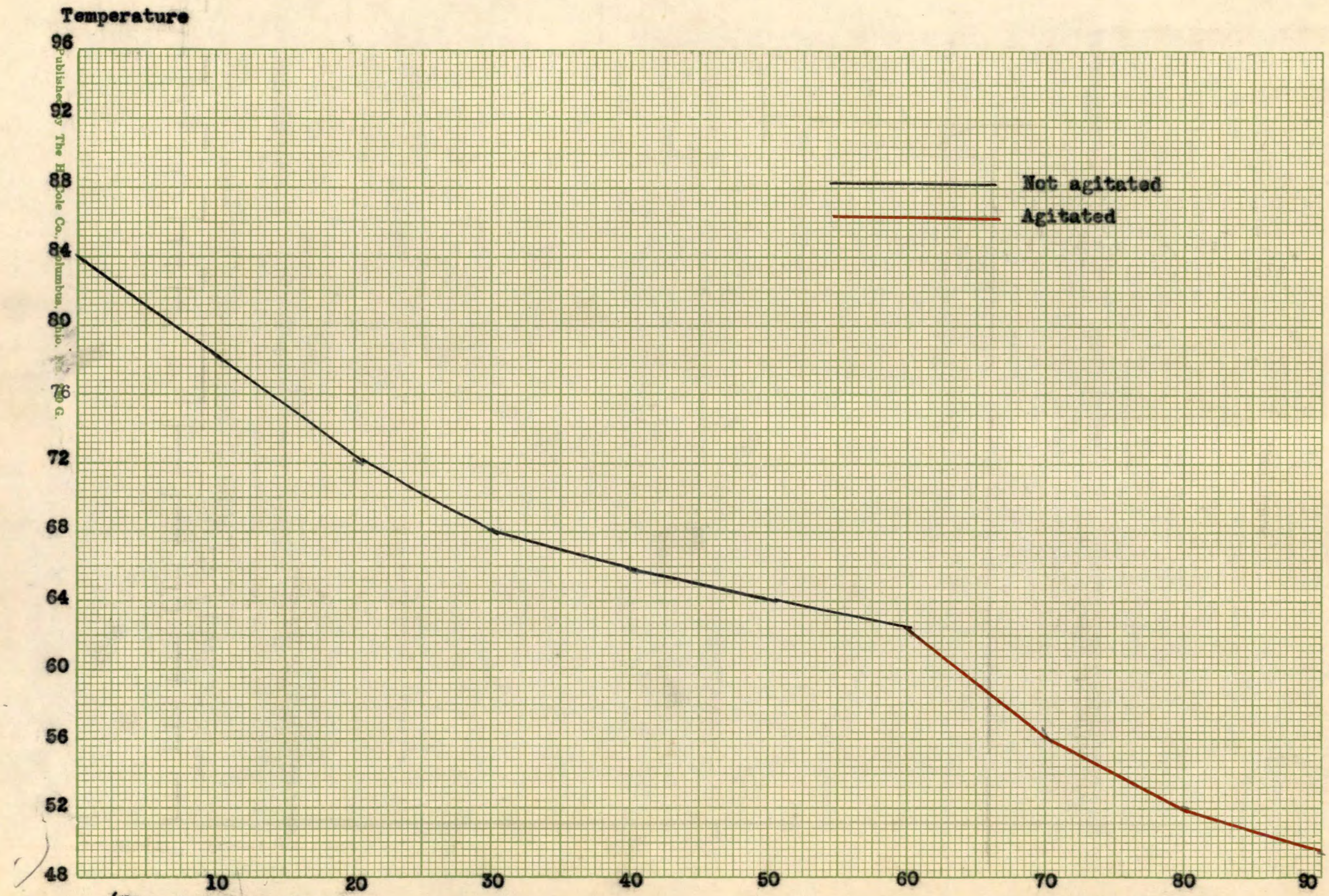

Figure 8. Rate of Cooling Milk.

The Tubular Cooler.

The tubular cooler, or aerator, usually consists of a series of horizontal tubes placed one above the other. The cooling is accomplished by allowing the milk to run in a thin sheet over the outside of the tubes, while the cooling medium runs through the inside. The cooling medium enters the aerator through the bottom tube and leaves through the top tube. When plenty of water is available, the aerator is usually made in two sections, the milk being cooled by water over the upper portion and by brine or refrigerant on the lower portion. Care should be taken to see that the milk runs in a thin sheet over the aerator and not in s treaks. This can best be accomplished by collecting the first milk passing over the cooler in a clean bottle or dipper and pouring it rapidly over the top pipes of the cooler. This wets the entire surface of the cooler with milk, and permits the remainder of the milk to spread more uniformly over the surface.

Cost and convenience, as well as milk quality must be balanced against each other in considering can cooling. If a surface cooler is used, about 20 to 30 per cent of the total cooling can be done with ordinary water. Water usually has to be pumped for the cattle, so it is not a direct expense to be charged against cooling. The use of the surface cooler saves some refrigeration expense, but it increases labor, equipment, and danger of bacterial contamination.

Trials were run with milk, pre-cooled with tap-water, over a tubular cooler. The temperature of this tap-water was 74° F. and it was found that freshly drawn milk with a temperature of 95° F. could be reduced to 78° F. by this water. This milk was then immersed in a tank of water at 38° F. and brought down to 50° F., within one hour and without either the milk or the water being agitated. The value of tubular cooling is thus evident as far as the rate of cooling is concerned. Figure 9 shows the rate of cooling milk under these conditions.

It was found from this trial that under average conditions, with a surface cooler and running water, from 10 to 15 gallons of water should be sufficiant to lower the temperature of each gallon of warm milk to within 3° of the initial temperature of the water. This means that during the winter months, when the temprature of the water is 47° F. or below, the milk can be efficiently cooled by the water alone, if a tubular cooler is used.

The exact purpose of the tubular-surface cooler for milk has not yet been closely established. According to some authorities, the only reason for using a tubular cooler is to cool the milk. Others content that it is necessary to allow the milk to flow over a surface cooler to aerate the milk for the purpose of improving its flavor in addition to the cooling. A study on the effect of cooling on the quality of milk is reported later in this thesis.

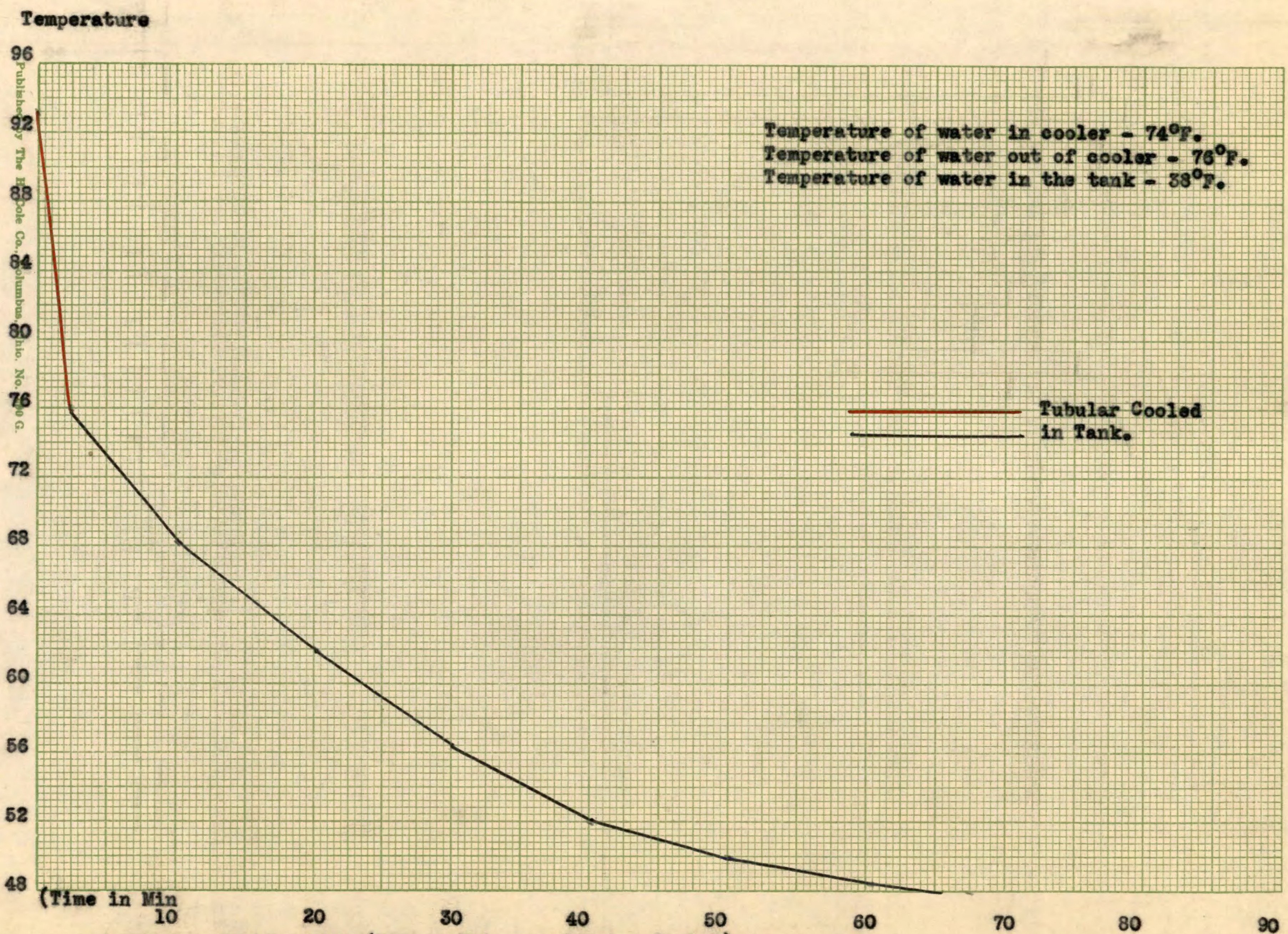

Figure 9. Cooling Milk (Pre-cooled over Tubular Cooler)

Bacterial Increase in Milk During Cooling.

Bacterial content is a big factor in determining the quality of the milk. As the temperature of the milk is reduced from body temperature after milking, the rate of bacterial growth is decreased. When milk is cooled below 50° F. bacterial increase is practically stopped for a period of from 12 to 24 hours, but for a longer storage period a much lower temperature must be maintained to prevent bacterial increase.

Milk freshly drawn from the udder of the cow should not require the rapid cooling necessary to maintain a low bacterial count, such as is know to be the case for aged milk. That bacteria fail to develop and multiply in most samples of freshly drawn milk has been well established, although there may be some doubt concerning the proper explanation of this phenomenon. At the beginning of this Century freshly drawn milk was found to have a germicidal action, but recently there has developed a belief that the effect is partly due to the changed environmental conditions of the bacteria or to the lag in bacterial multiplication preceding growth.

Hunziker, at Cornell University, in 1901, found that bacteria decreased in freshly drawn milk, particulady when stored at 70° F. I n 1922, Macy, at Minnesota, found under practical farm conditions that the count of uncooled milk rarely changed in an hour, but after two hours some samples began to give higher counts.

In this investigation the milk was cooled in three ways, namely; (1) the can of freshly drawn milk was set into a tank of water without previous cooling, and the milk was not agitated in any way; (2) the milk was treated as in (1), except that the cooling water was circulated around the can; and (3) the milk was cooled as in (1) except both the milk and water were agitated by the moving of a false bottom in the cooling tank, which shook the cans somewhat, also keeping the cooling water in motion. A sample of the milk was tested for bacteria at the beginning of the trial, and again after 12 hours. The results of this study are found in Table XVIII.

Table XVIII. INFLUENCE OF COOLING METHODS ON THE BACTERIAL CONTENT OF MILK.*

Cooling Method	Count at Beginning	Count After 12 hrs.	Time Required to Cool 50°F.	Temp. of Water	Increase in Bacteria
No agitation	6,500	7,300	1 Hr. 50 Min.	38° F.	pl 800
Water Only Agitated	13,900	10,000	1 hr. 10 min.	38° F.	M 3,900
Water & Milk Agitated	36,000	38,600	50 Min.	38° F.	pl 2,600

* Counts made by plate count.

The results of real significance are that the bacterial content of can cooled milk did not increase in 12 hours when the water in the tank was below 40° F. and that the agitation of the milk and water was of no value as far as the bacterial count was concerned. If these results are indicative of what might be generally expected, then the highest quality of milk can be maintained by can cooling without agitation of either the milk or the cooling unit.

A study of the bacteria-count data may be confusing to anyone not familiar with the usual variations in bacterial counts of milk. One group of samples of milk actually showed a decrease in the number of bacteria present in the milk during the first twelve hours. All of these increases or decreases were so slight that all of the methods of cooling and holding the milk for the first 12 hours may be considmred satisfactory in preventing increase in the number of bacteria in the milk.

In order to maintain a low bacterial count by direct immersion cooling, it is absolutely necessary to have the cooling water at a high level. This water must be up to, or above the level of the milk in the cans. Unless the water is at this level the milk near the top of the can will be insufficiently cooled. It was found that after four hours in the tank the milk near the top of the can had not reached 50° F.

A study of the bacterial count was made under these cooling conditions. A sample of milk was taken from a can immediately after milking, and before cooling. A plate count was made, and the sample of milk was found to contain 3,800 bacteria per cubic centimeter. This can was then immersed in a tank of water, (the water line was about three inches below the milk level). After 14 hours of storage another sample of the milk was taken and the count found to be 17,000, an increase of 13,200 or four times the number at the start.

The cooling water did not come up to the top of the can, and neither the milk nor the water was agitated. It is reasonable to believe, therefore, that this increase in bacteria took place at the top of the can, where the milk was at a higher temperature than that at the bottom of the can.

From this trial with especially good quality milk, one would conclude that by this method of cooling the increase in bacteria would not be an important factor. However, very little of the milk produced under average farm conditions will have a count as low as this and as a result the poor quality milk cooled under these conditions would be a very unsatisfactory product after 14 hours of storage.

Standard laboratory methods have been developed for determining the number of bacteria present in one cubic centimeter of milk, and this is generally referred to as the bacterial count of the milk. All bacterial counts in the foregoing study were made by the plate-count method.

Another series of experiments, on the bacterial increase in milk during cooling, were made, and the microscopic colony-count method used. These counts were made according to "Standard Methods of Milk Analysis", of the American Public Health Association.

In this investigation the milk was cooled and handled exactly in the same manner as that reported in Table XVIII. The milk was cooled by the same three methods: i.e., (1) no agitation; (2) water only agitated; and (3) both the water and milk agitated. The results of this trial are found in Table XIX.

Table XIX. INFLUENCE OF COOLING METHODS ON THE BACTERIAL CONTENT OF MILK.*

Cooling Method	Count at Beginning	Count After 12 hrs.	Time Required to cool to 50° F.	Temperature of water	Increase in Bacteria
No Agitation	12,000	12,700	1 hr. & 15 minutes	38°-40°F.	pl 700
Water only Agitated	47,000	40,000	1 hr. & 10 Minutes	38°-40°F.	- 7,000
Water & Milk Agitated	15,000	13,200	55 Minutes	38°-40°F.	- 1,800

* Counts made by the microscopic colony-count method.

A study of Table XIX shows a picture very similar to that of Table XVIII. The only difference in the two trials was that the milk in the latter trial had a slightly higher count than did the milk in Table XIX. This may be partly due to the fact that the microscopic count will usually show slightly higher than the plate-count method of determining the number of bacteria per cubic centimeter in milk. According to authorities on the subject this is due to the fact that a colony of bacteria may show up as a single bacterium on the agar plate, but under the microscope one is able to see each individual organism. Both methods, however, are in accordance with the "Standard Methods of Milk Analysis", of the American Public Health Association.

A study was made in order to compare the bacterial content of milk pre-cooled over a tubular cooler, with milk which was cooled by direct immersion. A can of freshly drawn milk was divided into two parts. The first part was run over a tubular cooler and then placed into the cooling tank of the "Daniels" cooler. The second part of the milk was placed directly into the "Daniels" cooler and allowed to cool without agitation in any way. After cooling and being stored for 12 hours a count was made on a sample from each part of the milk. That milk which was first pre-cooled had a count of 20,600 as compared to 18,750 for the milk which was cooled by direct immersion.

The results of this trial, while not absolutely conclusive, will serve to give some idea of the number of bacteria in milk, cooled by the two different methods.

It may be well to state here that special precaution was taken in cleaning the tubular cooler before the milk was allowed to pass over it. The cooler was washed and scrubbed with washing powder and then rinsed with a chemical sterilizing solution. The cans containing the milk were sterilized in an electric sterilizer for two hours before using. After all, the contaminating factor of the surface coolers is a matter of cleaning and sterilizing the utensils rather than a factor in cooling. If special care is taken with the aerator, or tubular cooler, the milk coming from it should be just as free from bacteria as it was before going over the cooler.

The Effect of Cooling on the Quality of Milk.

It appears that milk of low bacterial content can be produced either by tubular-surface cooling with tap water followed by can cooling in 35°-40° F. water, or by can cooling only, in 35°-40° F. water. The choice between the two methods appears to be one of economics and convenience depending on the cost of the necessary amount of cool water as compared to the additional investment in the larger refrigeration unit required and the additional power required for operation for can cooling. When a surface cooler is used it adds to the amount of equipment to be washed and sterilized and it offers an additional opportunity for contamination of the milk.

The purpose of cooling milk by the aerator or tubular cooler is two-fold, to expose the milk to the air and to quickly cool the milk to a low temperature immediately after it comes from the cow.

There are many people who believe that the most important purpose of the aerator is to expose the milk to the air, and thus improve its flavor. In other words, they believed that to place the milk directly into the cans, and to place the lid tightly on the can, was sealing the bad taste and odors in the milk. It was with this thought in mind that the following study was made.

From a can of freshly drawn warm milk, two samples were taken. The first sample was cooled, over an aerator, to 50° F., bottled and placed in storage. The second sample was sealed tightly in the bottle and cooled by direct immersion. After 18 hours the bottles were removed from the storage and submitted to fifteen judges in order to tell, if possible, if there actually was a difference in the flavor and odor of the milk. The results are somewhat surprising, as shown by Table XX.

Table XX. INFLUENCE OF COOLING ON QUALITY OF MILK

Number of Judges	Number preferring Milk cooled by Aeriation	Number preferring Milk cooled by Direct immersion	No Difference
15	3	5	7

Four samples of this milk were submitted to each judge, two of the samples were cooled by aeration, and two by direct immersion. The judges were required to tell which two of the four samples were duplicates. If this was not done correctly, that particular judge who made the error was listed in the "no difference" column. The samples were from high quality milk and most of the judges reported both samples good, with very little difference between the two samples.

The difference reported was that the sample cooled by direct immersion was slightly stronger in flavor. This may indicate, somewhat that milk cooled by aeration may lose some of the flavor, due to the fact that it is exposed to more air. It would also indicate that if the milk is of a poor quality to start with, it may be slightly improved by aeration, but if the milk is of high quality, the good flavor and odor may be kept in by direct immersion cooling rather than by exposing the milk to the air.

Practically all of the certified milk on the market today is produced, cooled, and bottled without being exposed to the air in any way. Certified milk is the only raw milk sold in some of our larger cities. New York, for example, will allow only certified milk to be sold without pasteurization. This fact, in itself, speaks well for milk which is produced without being exposed to the air.

Insulating Value of Different Materials.

Insulation value generally depends upon the presence of innumerable air cells which conduct heat slowly. This slow conduction of heat is due to no convection currents and low specific heat. Materials having poor heat conductivity are termed heat insulaters. The use of insulaters, or insulation is necessary for the construction or refrigerators and cold rooms. The amount and kind of insulating material used is a question of economies.

Many different kinds of material have been used for insulating purposes as well as special constructions involving the use of so-called dead air spaces. Tests have shown that air spaces are good insulators if some means can be found to cónfine the air and prevent the heat transmission. Insulating materials such as cork board, rock cork, etc., really contains countless numbers of tiny cells of confined air and it is only in this form that air truly acts as an insulator.

Cork is usually considered, by the authorities on the subject, to be one of the most efficient insulating materials on the market. It is used more extensively than any other material. Cork is the outer layer of the bark of an evergreen species of oak tree. The bark is dried, broken up, and pressed in metal molds. It is then baked at a moderate temperature during which process the natural gum or rosin of the bark flows and binds the whole mass together. This mass is then trimmed into boards of varying thicknesses. The ability of cork board to resist heat is easily understood when its structure is examined. It is a homogeneous mass of small air cells separated by walls. Cork because of its natural binder, is resistant to moisture and can be made practically waterproof by surfacing with asphalt.

Since the first cost of high quality insulating material is so high, and the price of a commercial cooling tank is out of the reach of some farmers, a study was made of cooling milk in a homemade box, using rough farm material for insulation. Many farmers cool their milk by using an old barrel or some other non-insulated tank. If ice is used in cooling by this method a great loss of refrigeration takes place due to heat leakage through the walls of the tank.

It is possible and may be practical for some farmers to build their own cooling tank and insulate it with materials found on the farm.

Figure 9 shows the box used in these trials. The tank is made of galvanized iron and a 4 inch space, for insulation is left between the iron tank and the outside walls. The dimensions of the iron cooling tank were 36" x 36" x 36", or a capacity of about 124 gallons of water.

This tank was filled with water and cooled to 40° F. No insulation of any kind was used, and it was found that the temperature of the water rose from 40° F. to 54° F. in 96 hours.

This trial was made in a room where the temperature was 65° F. See Figure 11.

A similiar trial was made with this same box using ground corn cobs as insulating material. The temperature of the room was the same, 65° F., and 124 gallons of 40° F. water was used. It was found that after 96 hours under these conditions the temperature of the water was only 51° F., an increase of 11° F. in 96 hours. See Figure 10.

After the trials with ground corn cobs were completed, the corn cobs were removed and dry shavings put in its place. The results from the shavings are also shown in Figure 11 and Table XXI. It was found that by using shavings for an insulator, the water temperature went from 40° F. to 48° F. in 96 hours.

Table XXI. INFLUENCE OF INSULATING MATERIAL ON INCREASE IN TEMPERATURE.

Material	Temperature of Water		Room Temperature
	Start	After 96 hrs.	
Air	40°F.	54°F.	65°F.
Ground Corn Cobs.	40°F.	51°F.	65°F.
Shavings	40°F.	48°F.	65°F.

If the insulation becomes wet its value is largely destroyed on account of the high specific heat of water. The insulating materials used in this trial were not made water tight and, consequently it was expected that the material would depreciate rapidly as it was being used. Contrary to expectations, however, the materials held up remarkably well. Check trials were made on the shavings, and the second and third trial with the same shavings showed just as good results as did trial No. 1. After 288 hours, being used as insulation, the shavings felt just as dry to the hand as they did when first put in the cooling box. Accurate moisture tests, however, were not made.

From these trials with insulating materials, it would seem that it may be practical in some cases for a farmer to build his own box, insulate it with home grown material, using either ice or mechanical refrigeration.

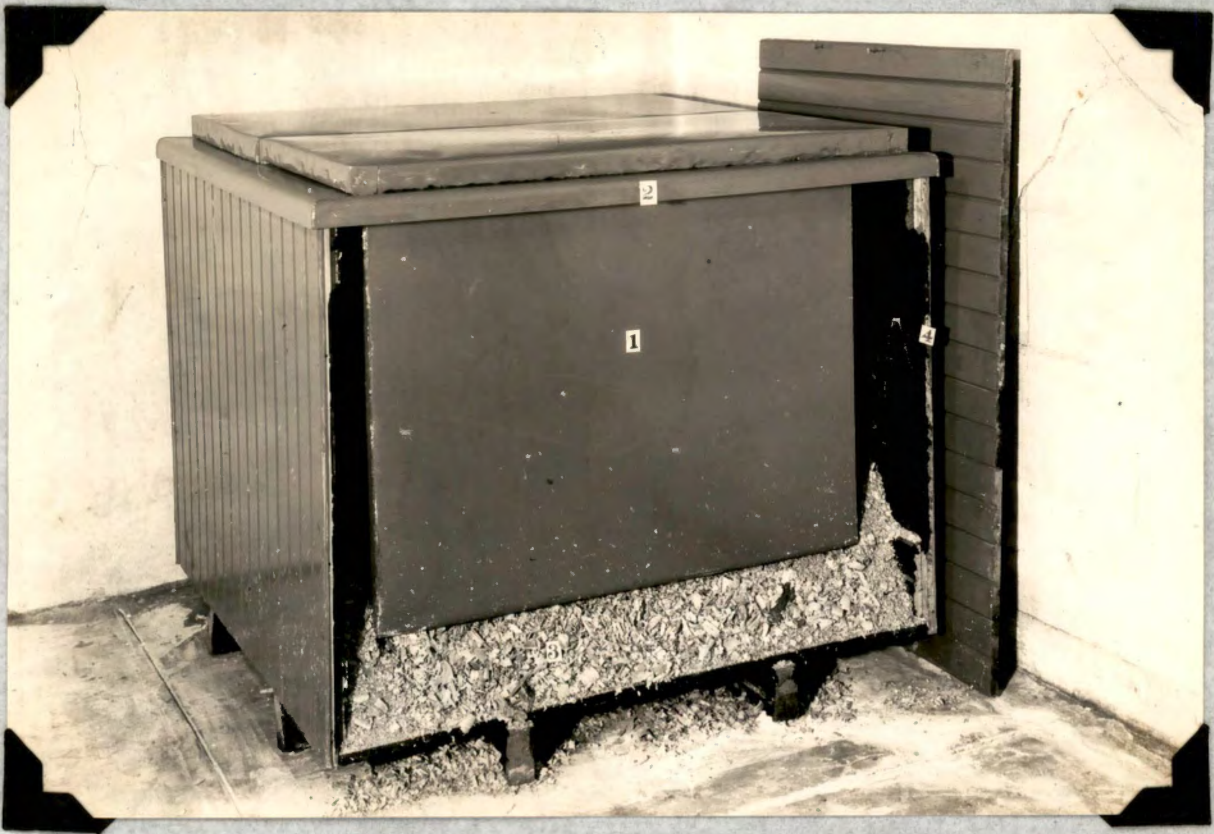

Figure 10. The Home-made Box used in the Insulation Trials.

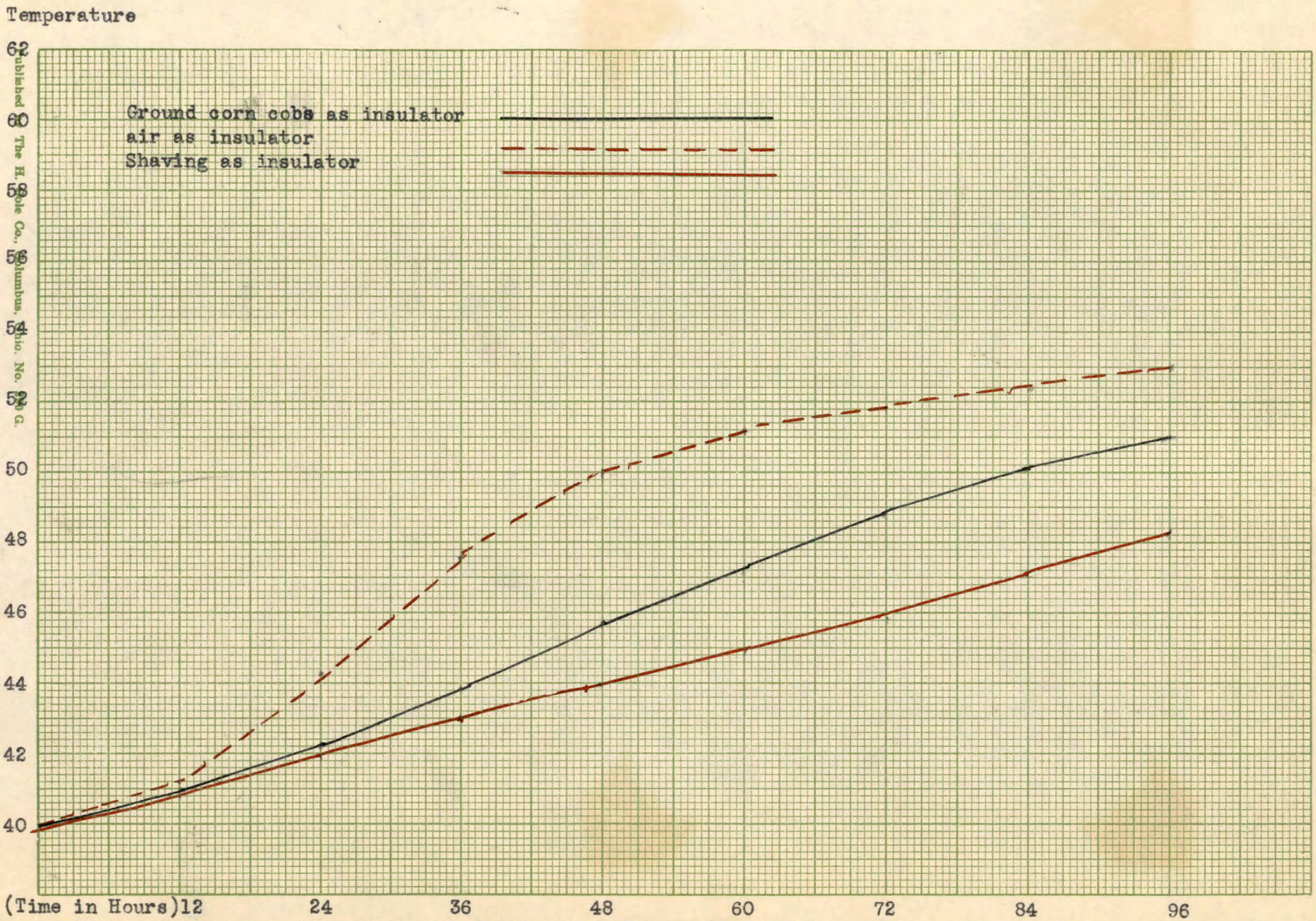

Figure 10. Influence of Insulating Materials on Temperature of Water Bath.

Problems in Milk Cooling.

Any work on cooling is essentially a study of heat. Theoretically there is no such thing as "cold" but merely the absence of heat. There are two kinds of heat to be considered, latent heat and sensible heat. According to physics, latent heat or hidden heat as it is sometimes called, is a result of work done on a body in changing its state. Sensible heat can be felt by the sense of touch and can be measured by means of a thermometer.

The unit of heat used by the physicist is the calorie, which is defined as the amount of heat required to raise 1 gram of water 1° C. The unit of heat used by the engineer is the British thermal unit, which is the amount of heat required to raise 1 pound of water 1° F. One B.t.u. is equivalent to 252 calories.

In order to find accurately the amount of refrigeration necessary to cool a substance, it is first necessary to know the ability of that substance to absorb heat, as compared with some standard. This is known as the specific heat of that substance. The specific heat of water is taken as 1, and the specific heat of milk is slightly less than 1. The specific heat of milk is usually given between .92 and .95, although it changes with the composition of milk. This means that the given amount of milk would require from .92 to .95 as much heat, to raise the temperature a certain number of degrees as would be required for the same amount of water under the same conditions. From a refrigeration standpoint a given volume of milk would require .92 - .95 as much ice to cool it a certain number of degrees as would be required by the same volume of water under similar conditions.

On the ordinary dairy farm a cold storage room is not necessary. If the milk is the only dairy product held, it can be poured in cans and set in the tank. If the milk is bottled and held for any considerable time, a cold storage room of some kind is necessary. The size of the cold storage room will depend upon the size of the business. One of the main efforts in building a cold storage room is to prevent the entrance of heat and the escape of cold from the room.

In building a cold storage room, it should, if possible, be built in the form of a cube or as near that shaped figure as possible. It is known as a geometric fact that a cube-shaped figure offers less exposed surface than any other figure of the same cubical content. Take for example a room 10' X 10' X 10'. This room contains 1,000 cubic feet and has 600 square feet of surface. Compare these figures with a room 5' X 8' X 25', which contains the same number of cubic feet, but has 730 square feet of surface. A saving of 130 square feet of surface, which means a saving in construction material, insulating material and a saving in the heat leakage which would take place in the 130 square feet of surface when the average dairyman, not familiar with mechanical refrigeration, wishes to determine his refrigeration needs, he is confronted with many trade names or terms used by those who are familiar with refrigeration. Among these terms are; melting ice equivalent, pound of refrigeration, ton of refrigeration, and pounds of ice melting in 24 hours. These terms can be easily compared by the use of simple arithmetic.

When ice melts, heat is absorbed. This absorption of heat has been given a unit of measure and a name. A pound of refrigeration is equal to that produced by melting one pound of ice. One pound of ice in melting absorbs 144 British thermal units or "144 B.t.u.". A ton of refrigeration adds the time factor with the cooling rate equivalent to the cooling effect of 2,000 pounds of ice melting in 24 hours, or 1,200 B.t.u. per hour, or 288,000 B.t.u. in 24 hours. When a ton of ice melts it absorbs 288,000 B.t.u.

CONCLUSIONS

From investigations made in this research work, the following conclusions are made.

1. When cooling milk in cans by mechanical refrigeration and with electricity at three cents per kilowatt hour, approximately four cents would be the power cost for each 100 pounds of milk cooled and stored.
2. Under average farm conditions cooling milk by electricity is much less expensive than by cooling with ice.
3. If the cooling water is agitated, it requires one hour and ten minutes to cool a ten gallon can of milk from body temperature to 50° F. in water at 38° F.
4. If the cooling water is notagitated, it requires one hour and fifty minutes to cool a ten gallon can of milk from body temperature to 50° F. in water at 38° F.
5. If both the water and milk are agitated, it requires fifty minutes to cool a ten gallon can of milk from body temperature to 50° F. in water at 38° F.
6. With 10-15 gallons of water for each gallon of milk the temperature of the milk can be brought to within 3° of the water temperature by the use of a surface cooler.
7. The bacterial content of can cooled milk will not increase within 12 hours providing the water to milk ratio is as much as 10 and the temperature of the cooling water as low as 40° F.

8. Agitation of the milk and water is of no value in checking the bacterial development, providing that the temperature of the cooling water is as low as 40° F., and that the water level is high enough to cover the milk in the can.

9. Cooling by direct immersion will have no ill effect on the taste and odor of good quality milk.

10. Shavings are more efficient as insulating material than are ground corn cobs.

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