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ELECTRIC COOLING OF MILK ON THE FARM
J. C. MARQUARDT AND A. C. DAHLBERG

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ELECTRIC COOLING OF MILK ON THE FARM

J. C. MARQUARDT AND A. C. DAHLBERG

In the last three years there has been a tendency for the larger dairy farms to install electric cooling units and insulated tanks, particularly in the large market milk areas. This has been due to the extensive advertising of the newer types of refrigeration units, to the value of insulation to conserve cold, and to the importance of refrigeration in assisting to secure premiums for high-quality milk by prevention of bacterial growth.

As a result, numerous questions have arisen. Are the electric refrigerators dependable? What does it cost to operate them? Is it desirable to spend money for insulating materials? How should the milk be cooled? It was in an endeavor to obtain impartial data on these questions that an electric refrigerator was installed at this Station in April, 1928, to cool the milk produced by the herd of 26 Jersey cows maintained at the Station. This publication is a report on how the equipment was installed, how it has worked, and, in certain cases, on experiments to determine why the results were secured.

There are several factors to consider in the proper cooling of milk. The cost must not be so excessive as to too greatly increase the cost of milk production. There is need for cooling the milk quickly enough to a temperature sufficiently low to reduce bacterial multiplication to negligible numbers. This temperature should be maintained throughout the time the milk is in the tank. The equipment should be simple, easily regulated, and the whole procedure of milk cooling should require as little labor as possible.

One conclusion of these experiments ought to be stated at the beginning so that the reader will bear it in mind throughout the discussion, namely, that when conditions exist comparable to those described, it is recommended that warm fresh milk of good flavor be placed immediately after milking into a well-insulated water tank at 40°F without previous cooling or subsequent agitation.
THE INSULATED COOLING TANK

There was need of a rather complete installation to make it possible to conduct certain experimental tests, hence certain features of the experimental tank are not favored for practical farm use. For example, the surface tubular cooler with an electrically driven pump has been shown by the experiments to be unnecessary, yet it is shown in the illustrations as actually used. The work will be presented as it was planned in the belief that it might be helpful to others planning on the installation of such a refrigeration unit.

Several essentials were considered in the construction of the tank. There is need of sufficient size to hold the required number of cans and still provide space to contain sufficient water and ice or refrigeration coils. The Station herd produces 500 to 600 pounds of milk per day or six to seven 10-gallon cans. As a matter of fact, the tank, constructed to hold a total of six cans, has been used to cool five cans of milk at one time. If the usual practice of cooling only night's milk can by can as milked is employed, this tank would be ample for six cans per milking, or about 500 pounds of milk. Altho the tank would hold eight or nine cans when set tightly together, such crowding is not desirable as can be readily illustrated.

The inside dimensions of the experimental tank are 35 inches wide, by 60 inches long, by 26 inches deep, with a 1½-inch pipe set in a corner to maintain a water level of 20½ inches. This allows a floor area of 17 by 20 inches per can which is satisfactory for tanks holding 6 to 10 cans, but for smaller sizes the capacity ought to be increased to about 20 by 20 inches of floor area to make room for ice or coils. Tanks ought not be constructed for less than four cans.

The Station tank contains 42,000 cubic inches to the overflow which, at 231 cubic inches per gallon, gives it a capacity of 182 gallons. When the tank is filled with cans there are 2 gallons of ice and water for each gallon of milk.

A calculation shows that with water in the tank at 40°F warm, fresh milk at 90° will be cooled by the water alone to 57° when six cans are placed in the tank and to 47° when three cans are used. Temperatures below these must be secured, however, and in electric cooling this must be done chiefly by ice frozen in the tank around the coils for the compressor itself is too small to give sufficient refrigeration to cool the milk as rapidly as is necessary. Hence, refrigeration must be stored as ice when the machine is operating between milkings. Allowing 1 B.T.U.
(British thermal unit) to cool 1 pound of milk or water 1°F and 144 B.T.U. to melt 1 pound of ice into water at 32°F, it can be calculated that 182 pounds of ice would be required to complete the cooling when six cans of milk are set in the tank. This figure is only approximate as the machine would be working as the milk was cooling, but it indicates the need for the refrigerator freezing a large block of ice in the tank, especially during the summer months.

The water-tight inside lining for the tank consists of a tank made of 14-gauge galvanized iron with a 1½-flanged outlet in the bottom so attached that the overflow pipe can be screwed into it. On the end there is one ½-inch hole near the top and one near the bottom for attaching the outlet and inlet of a surface tubular cooler. For ordinary purposes this attachment would not be needed, as will be explained later. The entire tank is painted with asphalt paint. The use of concrete instead of iron for the inner lining of the tank was considered. On account of the freezing of ice to the wall of the tank, engineers counselled against concrete; but in the last year it has been demonstrated that concrete would have been satisfactory. The iron tank has the advantage, however, of not adding 3 to 4 inches to the width of the wall of the tank, as would concrete. The iron, after nearly two years' service, shows but little rust, and this spring the tank will be cleaned out, dried, and repainted. Apparently, it should last at least 10 or 15 years.

The outside of the tank is made of 4 inches of good concrete. It should be stated that the tank could have been constructed a little cheaper if the inside had also been finished with concrete instead of iron. However, the wall would have been 11 inches thick instead of 7 if this substitution had been made, a factor to consider as cans must be lifted over the wall.

There are several important points to consider in the insulation of the cooling tank. Compressed cork board is almost universally used in dairy refrigerators and is now recommended for cooling tanks on the farm. While cork has been used in these experiments, it is probable that some other materials are more convenient for dairymen to purchase for making tanks on the farm. The following figures 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:
<table>
<thead>
<tr>
<th>Material</th>
<th>Heat loss in B.T.U. per hour*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corkboard (average density)</td>
<td>0.30</td>
</tr>
<tr>
<td>Celotex</td>
<td>0.34</td>
</tr>
<tr>
<td>Insulate</td>
<td>0.34</td>
</tr>
<tr>
<td>Flaxlinum</td>
<td>0.31</td>
</tr>
<tr>
<td>Fibrofelt</td>
<td>0.32</td>
</tr>
<tr>
<td>White pine (dry)</td>
<td>0.78</td>
</tr>
<tr>
<td>Oak (dry)</td>
<td>1.02</td>
</tr>
<tr>
<td>Brick</td>
<td>3.0 to 6.0</td>
</tr>
<tr>
<td>Concrete</td>
<td>6.0 to 9.0</td>
</tr>
</tbody>
</table>

*Figures taken from report by U. S. Bureau of Standards.

These materials are sold in varying thicknesses, but for these tests they were all built an inch thick. It will be noted that several common insulating boards are approximately equal to cork, while concrete is only 1/25 as efficient.

These data on insulation values were secured under ideal test conditions and would not hold exactly true under practical conditions. There is ground underneath and on part of the sides of most tanks. Consequently, the heat losses thru a tank insulated with 3 inches of cork and thru a non-insulated tank with 4-inch concrete walls were determined. The trial was made on several days, but that of July 25, 1928, was typical. The air temperature varied from 72° to 80° F. The water in both tanks was 42° at the start and the test lasted for 24 hours. In the non-insulated tank, 288 pounds of ice were placed and 40 pounds were left after 24 hours. The water warmed to 43°, making a total refrigeration loss of 258 pounds of ice. In the insulated tank the original 94 pounds of ice were reduced to 22 and the water in the tank was lowered to 39.5°, thus making a loss equivalent to 46 pounds of ice when the water temperature was considered. The 3 inches of cork saved 212 pounds of ice in one day, which at $5.00 per ton was worth 53 cents. If we assume similar losses for five months per year, the insulation saved $80.00, or three times its cost in one year. It should not be assumed that 3 inches were the best thickness of cork to use, but rather that thorough insulation was profitable.

Insulation value generally depends upon the presence of innumerable air cells which conduct heat slowly due to no convection currents and low specific heat. If the insulation becomes wet its value is largely destroyed on account of the high specific heat of water. The cork in the experimental tank was made water tight by hot asphalt. The cork was purchased in slabs of 2- and 1-inch thickness so that joints could
be lapped to prevent air circulation. The asphalt was heated in a broad pan large enough so that the slabs of cork could be dipped one side at a time. If this is impossible, the hot asphalt should be painted on the cork. Each piece of cork ought to be thoroly coated on all sides and edges, and when the cork is placed in position all crevices should be filled with hot asphalt. The cork coated with asphalt really ought to be a watertight job so that there is no danger of wetting. The underside of the 2-inch plank which covered the concrete and cork and which extended around the top of the tank was coated with roofing cement to prevent any water from working back into the insulation.

Fig. 1.—Tank Construction with Metal Inner Tank, Cork Insulation, and Cement Frame.

The bolts inserted in the cement hold the 2-inch plank on the top of the tank.

The construction of the tank is shown in Figs. 1 and 2, while Fig. 3 is a sketch showing a cross section of the tank. More details on the use of cement, and the details of making cement walls, tanks, etc., can be secured from the manufacturers of cement; from the manufacturers of electric refrigerators for farm use; from the Department of Rural Engineering at Cornell University, Ithaca, N. Y.; from the United States Department of Agriculture at Washington; and from others.
The refrigeration was supplied by a Frigidaire air-cooled compressor operated by a ½ horse-power motor and equipped with one cooling drum. The principles of mechanical refrigeration are simple. The heat in the milk is taken up by the water which surrounds the cans and is imparted to the refrigerating gas in the drum which is immersed in the water. The gas containing this heat and which actually is still much colder than the water is pumped out of the tank thru the compressor. The gas is compressed into a smaller volume and the heat which it contained now being in so small a space makes the gas so hot that it can be air cooled. The gas used in most small machines is sulfur dioxide. The cooled compressed gas now flows as a liquid to the expansion drum or cylinder in the water tank where the pressure is released and the gas vaporizes and expands. Both these changes require heat so that the gas becomes cold and is ready again to take heat from the cooling tank.

![Figure 2](image)

**Fig. 2.—The Tank After Two Years Service.**
The brine tank (A) is covered with a plank when the cooling tank is in use. The brine tank was added to increase the cooling capacity of the equipment. Also, the tank can be lengthened to provide a dry air space for household refrigeration.

One point which is generally overlooked in the operation of these refrigerators is that the machines are too small to cool milk with sufficient rapidity by running as needed. In other words, it is essential with this machine, and it is typical of all others now on the market, to
store refrigeration in the tank to be used as a rapid supply of refrigeration. This is done by freezing ice around the drum or coils by the automatic operation of the machine between milkings. The ice cake must be so shaped that it will readily melt when warm milk is placed in the tank. This means that the ice must not be nearly cubical in shape. Unfortunately many expansion drums are too nearly cubical.

In the case of the installation at the Experiment Station, the machine gave ample capacity, except in the summer months when the ice would not melt rapidly enough. This condition could be remedied in several ways. In the Station tank a small brine tank (Fig. 2,A) was constructed of 20-gauge iron which was wide enough to enclose the coils, deep enough to keep above the water level, and long enough to extend nearly across the tank. The brine tank, after installation, was filled with brine and the ice frozen around the tank. This gave plenty of exposed surface to handle any reasonable amount of refrigeration and gave complete satisfaction in routine milk cooling. The brine, with a specific gravity 1.2, was made by placing 30 pounds of calcium chloride in a 10-gallon can and filling with water. About \( \frac{1}{4} \) pound of air-slaked
lime was added to neutralize the brine so that the corrosion of the tank would be held to a minimum. Experiments demonstrated the value of this brine tank when an expansion drum is used.

It should be possible to construct a more satisfactory design of expansion drum. For example, if the present type could be lengthened about 50 per cent, the brine tank would be superfluous. The ideal expansion design is the expansion coil which encircles the entire tank thereby giving the maximum exposed surface in the best location.) In the future such improved types will be made available thru engineering research.

The installation of the insulated tank could be lower in the floor were it not for the necessity of slanting the return pipe away from the expansion drum to drain out the oil. In this experimental tank the top is about 16 inches off the floor which makes it necessary to lift the can a few inches too high. Some electric refrigerators now have overcome this difficulty.

COOLING MILK IN CANS

There are ample data in the literature to demonstrate that milk cools very slowly in a 10-gallon can immersed in ice water, that it cools much more rapidly when stirred, and that for best cooling the milk ought to be tubular cooled before placing the can of milk in the tank of water. There can be no doubt whatever concerning the absolute necessity of tubular cooling of milk 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 ice water may be entirely different when a well-insulated tank of ample capacity is used.

Milk freshly drawn from the udder of the cow ought not to require the rapid cooling necessary to maintain a low bacterial count such as is known 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, altho 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.

Be that as it may, Hunziker, at Cornell University, in 1901, extended the study on this subject and found that bacteria decreased in freshly
drawn milk, particularly when stored at 70°F. A few years later Stocking, also at Cornell University, verified the results, but noted an exceptional sample in which the bacteria had increased in three hours at 70°F. He cautioned that “immediate cooling” is necessary due to irregularities in the milk. It should be stated that this objection is less valid when a can of milk is cooled because it is the milk of several cows, most of which would have the germicidal action. In 1922, Macy, at Minnesota, found under practical farm conditions that the count of uncooled milk scarcely 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 the tank of water without previous cooling, the lid was tightly put in place, and the milk was 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 tubular cooler to the required temperature before placing in the tank of water. Mention should be made of the fact that the stirring rod was washed and rinsed with hot water after each usage and was steamed in a tin cabinet for 10 to 15 minutes once a day. The tubular cooler was washed with a Diversol sterilizing solution, rinsed with hot water, and then with a lukewarm Diversol solution.

Table 1.—Influence of Cooling Methods on the Bacterial Content of Milk After 24 Hours Storage.*

<table>
<thead>
<tr>
<th>Cooling Method</th>
<th>Water Held in Tank at</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35°-40°F</td>
</tr>
<tr>
<td></td>
<td>Low count</td>
</tr>
<tr>
<td>Original</td>
<td>11,700</td>
</tr>
<tr>
<td>Tubular-cooled</td>
<td>—</td>
</tr>
<tr>
<td>Can-cooled, not stirred</td>
<td>11,900</td>
</tr>
<tr>
<td>Can-cooled, stirred</td>
<td>12,700</td>
</tr>
</tbody>
</table>

*Figures represent plate counts per cc according to standard methods. First two columns based on 17 lots of milk, third column on 13 lots, and other columns on 9 lots each plated in duplicate.
†Due to one exceptionally low result, otherwise these counts would be about 16,000.

After the cans were filled with milk at the barn, the entire amount was mixed together and divided into three cans which were sampled for bacterial counts and cooled according to the three described methods. After 24 hours, samples were again taken for bacterial counts and the milk was often examined for flavor and odor. Only a limited
number of tests were made with tubular-cooled milk due to a shortage of supply and the desirability of complete data on the other cooling methods. In these studies the tank was held at various temperatures as shown in Table 1. The milk with high bacterial counts was secured by complete disregard of sterilization of the milking machines.

The data for tubular-cooled milk are incomplete, but it is well known that approximately 50°F is the critical temperature above which the bacterial count of milk increases markedly in 24 hours. In some instances not given in the table the passage of milk over the cooler gave noticeable increases in count.

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. The large, well-insulated tank with plenty of available ice enabled this easy method of cooling to give excellent results. There was no increase in bacterial count of milk placed in water below 40°F, and if these results are indicative of what might be generally expected, then the highest quality of milk can be maintained by can cooling without stirring. As a matter of fact, equally good results were secured below 50°F, but we favor 40° or less to produce grade A milk of lowest bacterial count because of the added safety against mishaps. For ordinary market milk for pasteurization the results show that a temperature under 50° for the water tank would be ample. However, in an insulated tank it is almost impossible to have ice in the tank continually without securing colder temperatures. Even in non-insulated tanks a temperature of 50° can be maintained if a tank of sufficient size is supplied with ice.

There is a popular belief, with certain supporting evidence, that the growth of bacteria in milk containing millions of organisms is more difficult to check than in milk of low bacterial content. Altho the data presented on this point are somewhat meager, they fail to show any difference in the temperature required to check bacterial growth due to total count.

Considering the failure of bacteria to develop in can-cooled milk, the rapidity of cooling is of special interest. When milk above 90°F was placed in water at 35° to 40° and was stirred after one- and two-hour periods, the temperature was around 60° in one hour and at 50° at the end of two hours. Whenever the temperature of the milk was at 70° to 80° as it was placed in the tank, it dropped to 50° within an hour.

Several thermometers were set in a fixed position at various places in
the unstirred can and the temperature was recorded at 10-minute intervals for periods of four hours. The milk was rapidly cooled at the sides of the can and in the center at a point near the handles of the can, and it is safe to assume that the milk below this point was cooled even more rapidly. The point of special interest was that at about an inch below the neck and in the center of the can. It should be stated that all cans were completely filled with milk. At this location in the can the milk cooled so slowly that the temperature was below 60° only after four hours cooling.

There are two reasons why the counts were not increased in unstirred milk in spite of the slow cooling at the surface of the milk, namely, (1) the germicidal action of the milk and (2) the small amount of milk involved. The shoulder of the can is narrow at the top and probably not over 2 or 3 quarts of milk are involved. This is clearly indicated by the slight effect this top milk has on the temperature of the whole can after stirring.

Evidence was accumulated to show whether growth did or did not occur in the cream layer. It is known that the fat globules take bacteria with them as they rise to the surface because gravity cream has a higher count than milk. An endeavor was made to avoid this error by dividing a batch of fresh milk into two cans, one of which was warmed to 98°F and the other cooled by a sterilized tubular cooler to 50°F. In the latter sample no growth should occur in a few hours. Samples were drawn hourly for five hours with a sterile pipette, the tip being inserted just below the surface of the milk. Every precaution was taken to secure accurate results and to avoid disturbance of the milk in the can.

Examination of the samples by direct microscopic method showed that leucocytes also rose with the fat, but that differences in bacterial counts were not sufficiently great to be studied by this method. The results secured by plating according to standard methods of the American Public Health Association are given in Table 2. The data demonstrate that the increase in bacterial counts for the top milk when milks at 98° and 50°F were placed in a cooling tank with water at 40°F were similar. In both cases the bacterial content was from 10 to 15 thousand times the fat content of the milk or cream. The bacterial content of the mixed milks after five hours cooling was the same in both cans, and the types of bacteria had not changed. These facts indicate the failure of bacteria to multiply in the top-milk even tho slowly cooled.
Milk must be freshly drawn from the cow to permit can cooling without stirring. For example, if cooled night's milk is warmed on the following morning to 90°F and separated, the cream and skim milk must be tubular cooled to 50°F or less to prevent bacterial growth. In fact skim milk cooled in cans without stirring actually began to sour enough to cause serious digestive disturbances in the young calves at the Experiment Station in the summer of 1928. The cream also soured too quickly to be of value as sweet unpasteurized table cream.

Stirring milk in the can during cooling increased the bacterial count to an insignificant extent. The increase was so consistently secured that there can be little doubt concerning the accuracy of the observation and the improbability of the variation in counts being due to normal discrepancies in the method of making the plate count. Had the agitation been violent, one could assume that the count was increased due to breaking up of bacterial clusters, but the agitation was gentle.

Two or three movements of the stirring rod from the top to the bottom of the can is sufficient stirring. There is a possibility that the stirring rod was not sterile, that bacteria dropped in as the lid was removed and re-inserted into the can, etc. These points illustrate the possibilities of bacterial contamination and that milk ought to be handled as little as possible. It is safe to recommend that if a dairy farmer believes that no stirring of milk in the can is too revolutionary a procedure, then he should stir the can of milk once after one or two hours in the tank. More stirring is unnecessary and may result in contamination.

Table 2.—The Bacterial Content of Milk About 1 Inch from the Top of the Can During Cooling in Water at 40°F Without Agitation.*

<table>
<thead>
<tr>
<th>Kind and Age of Milk</th>
<th>Bacterial Counts at Initial Temperatures of</th>
<th>Fat Contents at Initial Temperatures of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98°F</td>
<td>50°F</td>
</tr>
<tr>
<td>Fresh milk, mixed</td>
<td>53,000</td>
<td>53,000</td>
</tr>
<tr>
<td>Top milk, 1 hour old</td>
<td>133,000</td>
<td>108,000</td>
</tr>
<tr>
<td>Top milk, 2 hours old</td>
<td>195,000</td>
<td>167,000</td>
</tr>
<tr>
<td>Top milk, 5 hours old</td>
<td>282,000</td>
<td>262,000</td>
</tr>
<tr>
<td>Mixed milk, 6 hours old</td>
<td>52,000</td>
<td>53,000</td>
</tr>
</tbody>
</table>

*The averages are based on five lots of milk.

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 well water. Water usually must 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.

ELECTRIC REFRIGERATION

In view of the data which have demonstrated that 3 inches of cork
in a water-cooling tank paid for itself and saved about $80.00 worth
of ice at $5.00 per ton in one year, it seems unbelievable that the value
of insulation for use on the farm has not previously been given more
attention. It has remained for the manufacturers of small refrigeration
units for use on the dairy farm to promote the value of insulation.
They have been forced to do this because their machines are small,
because the refrigeration must be utilized to best advantage, and be-
cause it seems to be human nature to be willing to waste ice but to
conserve electricity. A small increase in meter readings has more effect
in bringing about economies than the wasteful use of ice.

Our data clearly demonstrate that insulation not only pays for itself
the first summer, but that it is essential for maintaining uniformly cold
temperatures. There is little information to show what ice will do in
cooling milk in insulated tanks. Such studies are now being conducted
and a report on this subject will be made in another year. Possibilities
along this line are indicated by the fact that one 70-pound cake of ice
reduced the temperature of three-fourths of a ton of water at 42°F
over a 24-hour period in the month of July to 39°F.

When the electric refrigerator was installed, data were collected on
every conceivable subject which might be of interest in studying the
value of the machine. Records were kept of the minimum and maxi-
mum temperatures of the air, the initial and final temperature of the
milk, the temperature of the water in the tank, the electricity used, etc.
Some of these data are given in Table 3, and the amount of ice that
would have been used in place of electricity has been calculated with
approximate accuracy.

The figures show that on a yearly basis 1.08 kilowatt hours of
electricity were employed to cool 100 pounds of milk, a result based
on 13 months operation. The cost depends on the electric rate in any
locality and would be 5.4 cents at the usual rate of 5 cents per kilowatt
hour. By calculation, it was shown that 29 pounds of ice would have
been needed to do the same task which, at $5.00 per ton, would be 5.8
cents. These costs are but a part of the total, for with the electric
Table 3.—Data on the Cooling of Milk in a Water Tank Cooled by a Mechanical Refrigerator.

<table>
<thead>
<tr>
<th>Month</th>
<th>NUMBER OF 10-GALLON CANS, DAILY</th>
<th>TEMPERATURE OF MILK</th>
<th>ELECTRICITY IN KILOWATT HOURS</th>
<th>ICE EQUIVALENT IN POUNDS†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial</td>
<td>Final*</td>
<td>Total</td>
</tr>
<tr>
<td>1928</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>5.8</td>
<td>60</td>
<td>39</td>
<td>138</td>
</tr>
<tr>
<td>July</td>
<td>7.3</td>
<td>64</td>
<td>41</td>
<td>265</td>
</tr>
<tr>
<td>August</td>
<td>8.1</td>
<td>65</td>
<td>41</td>
<td>233</td>
</tr>
<tr>
<td>September</td>
<td>6.8</td>
<td>65</td>
<td>39</td>
<td>321</td>
</tr>
<tr>
<td>October</td>
<td>5.3</td>
<td>60</td>
<td>39</td>
<td>200</td>
</tr>
<tr>
<td>November</td>
<td>4.7</td>
<td>59</td>
<td>38</td>
<td>139</td>
</tr>
<tr>
<td>December</td>
<td>5.2</td>
<td>70</td>
<td>38</td>
<td>105</td>
</tr>
<tr>
<td>1929</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>5.7</td>
<td>72</td>
<td>38</td>
<td>84</td>
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<tr>
<td>February</td>
<td>6.5</td>
<td>74</td>
<td>38</td>
<td>94</td>
</tr>
<tr>
<td>March</td>
<td>6.7</td>
<td>74</td>
<td>38</td>
<td>123</td>
</tr>
<tr>
<td>April</td>
<td>6.2</td>
<td>75</td>
<td>40</td>
<td>143</td>
</tr>
<tr>
<td>May</td>
<td>6.0</td>
<td>80</td>
<td>42</td>
<td>252</td>
</tr>
<tr>
<td>June</td>
<td>6.2</td>
<td>83</td>
<td>44</td>
<td>212</td>
</tr>
<tr>
<td>July</td>
<td>7.0</td>
<td>84</td>
<td>43</td>
<td>192</td>
</tr>
<tr>
<td>Average for all months (228,778 pounds total milk)</td>
<td></td>
<td></td>
<td></td>
<td>178</td>
</tr>
</tbody>
</table>

*This temperature is given as 5°F above the water temperature because part of the milk each day was tubular cooled only and never attained the coldest temperature.
†Approximate daily loss of ice for May, June, July, and August was 75 pounds; for January, February, March, April, September, October, November, and December, 25 pounds daily.
refrigerator there is the original investment, depreciation, and an annual service which we believe ought to be regular.

With ice there is the enormous shrinkage to consider, the original investment in the ice house and its lower depreciation, and the disagreeable, wet task of handling ice in the summer when time on the farm is at a premium. The electric refrigerator requires a simple temperature adjustment in the spring and fall.

It is somewhat difficult to give comparisons between the cost of cooling milk by electricity and by ice. Many factors which need to be considered have already been discussed. It may not be out of line to assume that the cost of ice on the farm is approximately $5.00 per ton. In view of the fact that ice shrinkage usually amounts to 50 per cent of the original total, this would mean that ice must be put up at a cost not exceeding $3.00 per ton. Most of the data collected on this subject indicate that this is a reasonable charge. The information which has been collected in the course of this study indicates that the cost of the ice would pay for the electricity to operate a mechanical refrigerator. The original cost of the electric unit would, of course, be in addition to this. One must realize that there are certain advantages of the electric refrigerator, such as the maintenance of a more uniform and lower temperature and its greater convenience due to the elimination of the handling of ice in the summer time, which partially counteract the greater expense of the electric cooler.

One of the unknown costs in the electric refrigerator is depreciation. There is no accurate way of estimating this item, which can be determined only thru years of actual service of the machines. This year the International Association of Ice Cream Manufacturers published depreciation rates on ice cream machinery based upon actual experience, and since electric refrigerators have been used for cooling ice cream for about five years, the Association has some basis for estimating cost. Their schedule of depreciation is 20 per cent on the iceless cabinet, which would mean that the machines should give about five years of service. This depreciation rate is excessive for farm dairy units because of the great difference in the temperature of an ice cream cabinet and a milk cooling tank. It is probably more reasonable to assume that mechanical refrigerators ought to last for periods of 10 to 15 years on the farm.

The attention which the electric refrigerator requires is meager but essential. They should be installed where there will be a minimum
of dampness. This precaution will prevent rusting and corrosion of the machine. The electric motor requires oiling twice a year, while the compressor is automatically oiled. Altho manufacturers of electric refrigerators make no mention of service, nevertheless, it seems desirable that the equipment should be examined once a year by the local representative, who should notice things which needed attention to preserve the life of the machine. He could also re-charge the outfit with refrigerating gas in case of leaks.

It is necessary for the dairyman to regulate the temperature of the machine twice each year. In the spring the regulator must be changed to make the machine operate for a longer period of time and in the fall the regulation must be reversed. Probably the best way of determining the proper regulation of the machine is to have a thermometer hanging in the water in the tank. The regulator should be so adjusted that the temperature will be below 40°F. The tests with the experimental tank have shown that the temperature of the water in the tank is constant within 2°F, irrespective of its location. In other words, there is no necessity for agitating water in the cooling tank and it makes little difference where the thermometer is hung if the tank is properly insulated.

In tank cooling with ice, the water level is held at the overflow by the constant addition of ice. No such additions to the volume of water are regularly made with electric refrigeration. Therefore, it is necessary to watch the water level and to add enough water to keep the level near the top of the overflow pipe.

The cost of the electric unit is sufficiently great to prohibit its use on very small dairy farms. It is probable that the four-can tank is the smallest size that can be economically used. In this connection mention should be made of the fact that costs of cooling milk by ice also become excessive in the case of the very small dairy farms.

Mention has been made of the fact that most of the cooling that is done by the electric refrigerator is actually done by the ice which is frozen on the cooling coils, drum, or brine tank. It is essential that ice should be stored in the tank in large amounts during the summer months, but the amount of ice required during the winter months need not be great. It is self-evident that the operation of the mechanical compressor by electricity is very reliable and convenient and that the automatic control of the temperature is especially desirable. Nevertheless, it should be recognized that these machines can be operated
satisfactorily without the electric control. It is but necessary to start the machine just before milking and to permit the machine to run for a sufficient period of time after milking to build up a cake of ice of sufficient size to maintain the temperature until the next milking period. In the case of the six-can tank this requires a cake of ice of approximately 150 pounds.

Such a method of operating the machine is not desirable where electricity is available, but it illustrates the possibility of the manufacturers of electric refrigerators constructing a machine which could be operated by a gasoline engine or which could be run directly from a line shaft. This idea is entirely practical and the manufacture of such machines would make it possible to install mechanical refrigerators on any dairy farm, even tho electricity was not available.

SUMMARY

Except for occasional sporadic udder infections and cows which normally give milk with high bacterial content, there are but two things essential to the control of the bacterial content of milk, namely, the prevention of contamination due to contact of the milk with unsterilized utensils and apparatus, and the prevention of multiplication of the bacteria by cold temperatures. Contamination from utensils is cared for by thorough sterilization and complete drying. Much has been done to reduce the bacterial contamination of milk by sterilizing utensils, but less progress has been made in the cooling of milk.

This study has demonstrated the economic value of 3 inches of some insulation such as compressed cork in milk cooling tanks for use on the farm. Insulation saves its cost the first summer and is essential in securing and maintaining low temperatures.

Milk of good flavor and low bacterial content can be produced by can cooling without stirring, providing the water in the tank is maintained at a temperature of 40°F, that the tank is of ample capacity, and kept full to the overflow, that the milk is placed in the tank as soon as drawn, and that the original milk should be of good flavor and low bacterial content.

The flavor of milk was not injured by cooling without stirring, nor was there any necessity of keeping the cans uncovered until the milk was cooled.

The electric refrigerators being sold for use on dairy farms appear to be practical. The machines require little attention, are reliable,
and afford a constant source of refrigeration which requires no special labor at any time.

The essentials of proper milk cooling as shown in these studies are very simple, and may be listed as follows:

1. The cooling tank should be large enough so that when filled with cans of milk there will be twice as much ice and water as milk. Altho this means a large tank, it is necessary for can cooling.

2. Insulation with 3 inches of cork, or its equivalent, protected against moisture, saved more than its cost in refrigeration in one summer. The insulation is essential for maintaining a low temperature, altho 3 inches may not be necessary.

3. Milk can be satisfactorily cooled by placing it immediately after the can is filled at milking time in cold water at 40°F, providing the tank is of ample size, well insulated, and a large enough source of refrigeration is available. The milk need not be stirred or surface cooled. Should stirring be thought desirable, one stirring after one or two hours in the water is ample. For milk of bad flavor, such as absorbed feed flavor, aeration may be desirable.