JUNE, 1941 BULLETIN 295

AGRICULTURAL EXPERIMENT STATION

KANSAS STATE COLLEGE OF AGRICULTURE
AND APPLIED SCIENCE
MANHATTAN, KANSAS

IN COÖPERATION WITH

KANSAS COMMITTEE ON THE RELATION OF
ELECTRICITY TO AGRICULTURE

MILK COOLING ON KANSAS FARMS

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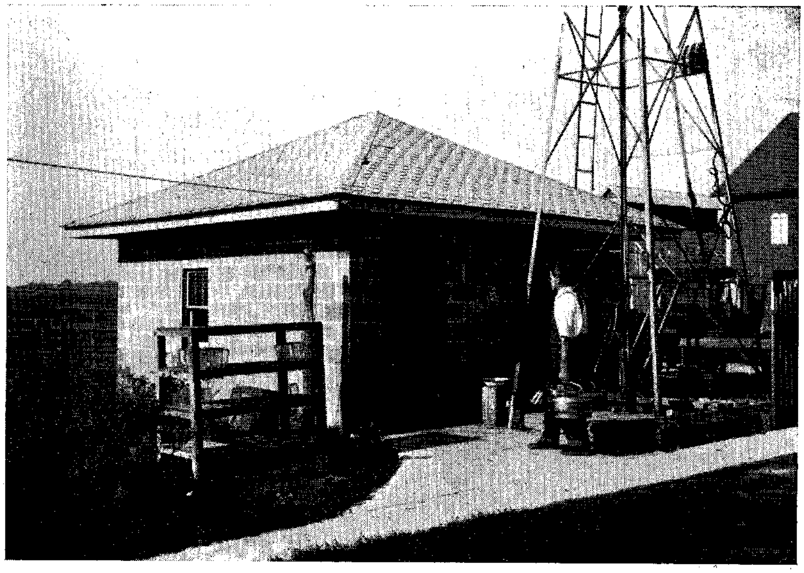

FIG. 1.—A good milk house properly located is essential for cooling and handling milk.

ACKNOWLEDGMENTS

The authors wish to extend their sincere thanks for the help and coöperation of W. H. Martin and other members of the Department of Dairy Husbandry; to the dairy farmers and milk sanitarians who assisted; to H. S. Hinrichs of the Kansas Power and Light Company for assisting and furnishing electric meters; to the manufacturers of milk cooling equipment who loaned equipment for testing; and to the Kansas Committee on the Relation of Electricity to Agriculture which sponsored the project and supplied the funds to carry on the work.

MILK COOLING ON KANSAS FARMS[1]

BY JUNE ROBERTS AND GEORGE H. LARSON[2]

There are many factors in the production and marketing of high-quality milk. They may be divided into three general phases: first, disease-free dairy cows; second, prevention of contamination from external sources; and third, prevention of bacterial growth by proper refrigeration. It should be emphasized that cooling milk does not improve its quality but merely tends to maintain the milk at the initial quality. It is essential that the dairyman use the best practices of all three phases in the production and marketing of milk.

A survey made during the summer of 1939 of the milksheds in Kansas showed that practically all were operating under the United States Public Health Service Standard Milk Ordinance, approved by the Kansas State Board of Health.[3] According to this ordinance, the cooling requirements for grade "A" milk are as follows: "Milk must be cooled within 1 hour after completion of milking to 50° or less, and maintained at that average temperature until delivery.[4] If milk is delivered to a milk plant or receiving station for pastuerization or separation, it must be delivered within two hours after completion of milking or cooled to 50° or less and maintained at that average temperature until delivered." For grade "B" milk, "The temperature requirement of retail raw milk shall be 60° and of milk for pastuerization or separation 70°."

The producer is confronted with the problem of meeting these cooling requirements of the various ordinances. Water is scarce in some localities, and in others its temperature is not low enough for proper cooling of the milk. The dairyman must then use ice or mechanical refrigeration to meet these requirements. It is the purpose of this bulletin to give pertinent information on the rates and costs of cooling milk by the important methods now used in general practice.

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1. Contribution No. 74, from the Department of Agricultural Engineering.
2. Formerly Instructor in Agricultural Engineering and Graduate Research Assistant in Agricultural Engineering, respectively.
3. Public Health Bulletin No. 220, 1939 edition, may be obtained by writing to the U. S. Treasury Department, Public Health Service, Washington, D. C.
4. The requirements for cooling milk have been changed since these studies were made and in the current milk ordinance of the U. S. Public Health Service the requirements for cooling are stated as follows: "Milk must be cooled immediately after completion of milking to 50° F. or less, and maintained at that average temperature, as defined in section 1 (S) until delivery. If milk is delivered to a milk plant or receiving station for pasteurization or separation, it must be delivered within 2 hours after completion of milking or cooled to 70° F. or less and maintained at that average temperature until delivered." This means that all raw milk must be cooled to 50° F. and milk to be pasteurized must be cooled to 70° F."

PURPOSE OF COOLING MILK

The fundamental purpose of cooling milk is to retard the growth of bacteria. The rate of bacterial growth in milk is determined by temperature and time. The general effect of temperature and time upon bacterial growth is shown in Figure 2. The numbers of bacteria plotted on a logarithmic scale in Figure 2 show that the growth of bacteria is rapid at high

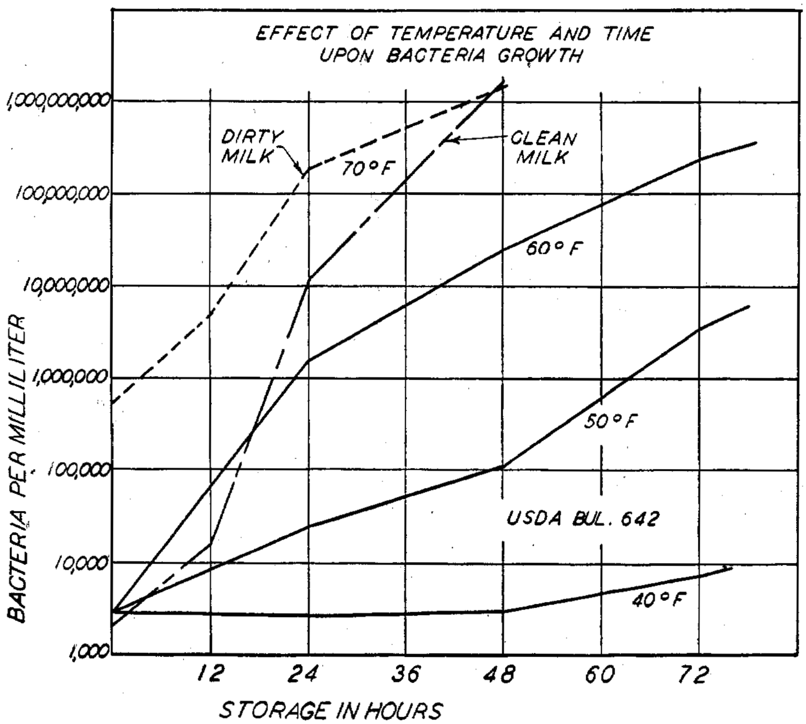

FIG. 2.—The effect of temperature and time upon bacteria growth in milk. (From U. S. D. A. bulletin No. 642.)

temperatures and there is practically no growth at 40°. Milk held at 50° shows slow bacterial growth for the first 24 hours. The effect of the delay in cooling milk is shown in Figure 3. The importance of refrigeration to control bacteria is clearly shown in Figures 2 and 3.

OBJECT AND NATURE OF STUDY

A project was started July 1, 1939 by the Department of Agricultural Engineering, cooperating with the Department of Dairy Husbandry and the Kansas Committee on the Relation of Electricty to Agriculture with the following objectives: To determine the present practices in several milksheds in Kansas, and to determine the cost, efficiency, and convenience of cooling milk by the more important methods now used.

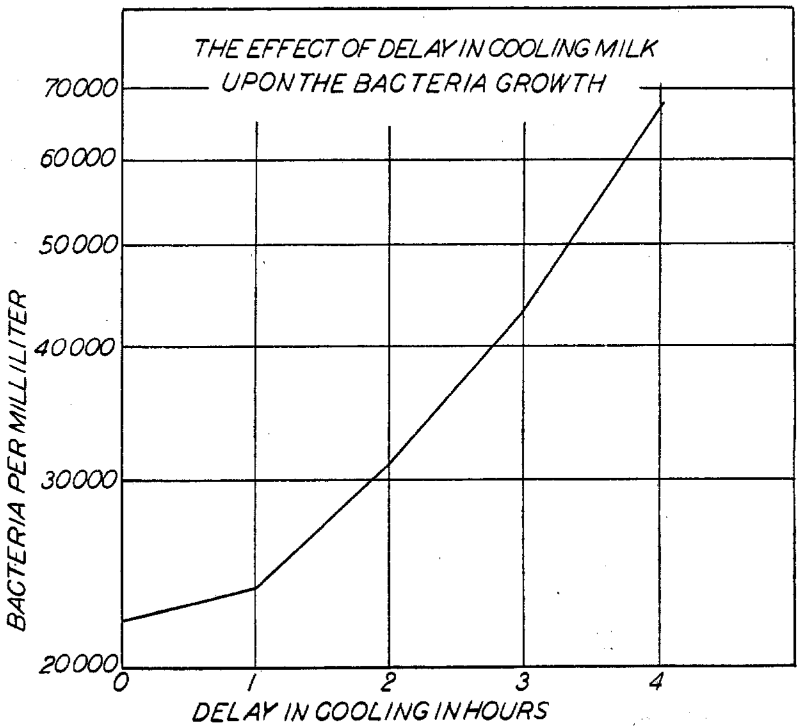

FIG. 3.—The effect of delay in cooling milk upon the growth of bacteria.

The information used in this study was obtained as follows:

1. A preliminary survey was conducted to determine the present practices of milk cooling and the equipment now used. The milk sanitarians or inspectors at Kansas City, Lawrence, Topeka, Emporia, Wichita, and Manhattan cooperated to furnish data on 1,444 individual producers.
2. A more detailed study was made of the costs and present practices from 60 individual dairymen. Records from 30 producers were obtained by mail and from 30 additional producers by personal interview.
3. Meters were installed on 28 farms and a complete record was obtained on electricity consumed, amount of milk cooled, and bacterial count of the milk.
4. Laboratory tests were made on four well-known mechanical milk coolers to check the field data and to study other factors which did not lend themselves readily to field study.

Survey Data. From the data obtained from the 1,144 graded producers it was found that 25 percent produced grade "A", 74 percent grade "B", and 1percent grades "C" and "D" milk. Of these 1,144 producers, 67 percent had electricity available, but only 24 percent used mechanical coolers. The survey shows that 24 percent of the 1,144 producers did not cool their milk, 40 percent used well water, 12 percent used ice, and 24 percent used mechanical coolers. Of the 24 percent who had mechanical coolers, 28 percent employed wet storage, 48 percent the dry box, and 24 percent the dry walk-in box. The mean well water temperature varied from 56 to 64 degrees, and the mean cost of ice was 29.9 cents per hundred pounds.

Results from Detailed Study. Data obtained from 60 dairymen showed that 36 were grade "A" milk producers and 24 were grade "B" producers. Forty-two of these dairymen had electricity available and used an average of 564 kw.-hrs. monthly. Forty-five percent used mechanical milkers and 66 percent mechanical coolers, of which 44 percent were wet storage, 26 percentwalk-in, and 30 percent dry box. Twenty-one percent of the 60 dairymen cooled milk by well water, and 13 percent with ice.

The average ice consumption for July and August, 1939, for four grade "A" producers was 107 pounds of ice per 100 pounds of milk cooled and the average for the grade "B" producers for the same period was 41 pounds per 100 pounds of milk.

METHODS OF COOLING MILK

Water. Milk and cream on Kansas farms are cooled most extensively by water. There are two methods in common use. First, and most common, is to place a can of milk in a tank and pump cold water into the tank. Many producers use a small tank for cooling the milk and then let the water from the cooling tank overflow into a larger stock tank. The effectiveness of this method depends upon the quantity of milk to be cooled and the temperature of the water. The advantage of this method is its low cost. The water is most cases must be pumped to supply the livestock; hence the cost of pumping the water need not be charged to the milk cooling. The disadvantages of this method are that there are only a few localities in Kansas ,where the water temperature is low enough for effective cooling. There is a scarcity of water in some parts of Kansas and there must also be a dependable power source so that the water may be pumped when it is needed to cool the milk.

A second method of using water is by means of surface coolers of which there are two general types, the conical and tubular. The conical or cone-shaped surface cooler is filled with water and the milk drips from a supply at the top, running slowly over the outside surface of the cone and is collected at the bottom to drain into a can. The tubular type consists of a series of tubes connected at the ends. Cold water enters at the bottom, flowing through the tubes and out of the top. Milk is permitted to run over the tubes slowly and is caught at the bottom where it is drained into a can.

Ice. Cooling with ice is similar to cooling with water except that ice is added to the water to facilitate cooling to lower temperatures. Ice may be added to the cooling tank and the milk cooled in cans or the ice may be added to the water which is used in the surface coolers. After the milk is cooled it is usually stored in an ice box until delivery. When producing grade "A" milk the tubular surface cooler is generally used, a pump and a power source being required to circulate the ice water through the surface cooler.

Mechanical. Mechanical coolers are divided into two general types, the wet-box and the dry-box. The wet-box type consists essentially of a source of power, refrigerator unit, and a storage box filled with water. The expansion coils of the refrigerating unit are placed in the water and the refrigerating unit freezes an ice bank on the expansion coils. When the milk is placed in the water, the ice melts and the compressor operates, cooling the milk. When the milk has been cooled, the refrigeration unit builds up another ice bank to be used for the next load in the cooler. Agitators in the cooling water circulate the water over the ice bank and over the cans of milk, resulting in a faster cooling. There are two general types of agitators: mechanical and pneumatic.

The dry-box type consists essentially of a source of power, refrigerating unit, brine tank, and storage box. The expansion coils of this type of cooler are placed in a brine solution (calcium chloride and water). The brine is then circulated in pipes through the dry box and the surface cooler. Many manufacturers place the brine tank in the dry box, thereby eliminating the brine pipes in the storage box. The addition of the calcium chloride to the water lowers its freezing point. In most such milk coolers the brine temperature is kept at from 23° to 28°. When the size of the dry box is large enough for a man to walk into the box it is known as a walk-in dry box type refrigerator. When using a dry-box cooler it is necessary to use a surface cooler because heat is lost very slowly from a can of milk stored in cold air.

Common Practices. Most producers who sell their milk to pasteurizing plants deliver the milk once per day, cooling the evening milk and storing it (in the box) until morning. The morning's milk is either cooled and delivered or, in some cases, it is not cooled but hauled at once to the pasteurizing plant. Some milk ordinances permit the producer to deliver the

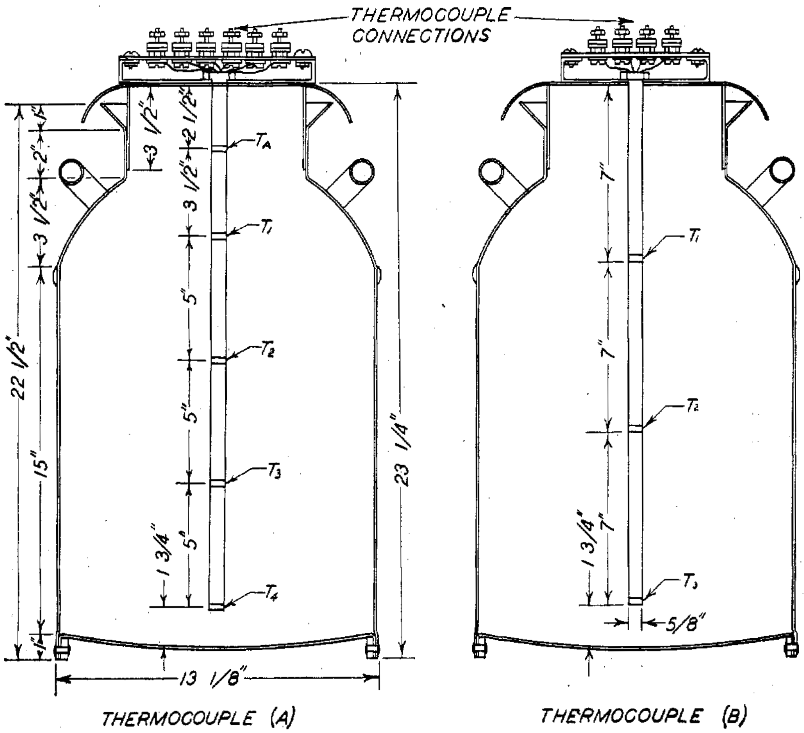

FIG. 4A.—Cross-section of milk cans showing the location of the thermocouples used to record temperatures of the milk at different depths in the can.

morning's milk without cooling if it reaches the pasteurizing plant within two hours after milking. Since most milk ordinances require this milk to be cooled to 70° within two hours, it is possible to use well water for cooling. Grade "A" producers, however, must cool their milk to 50° within one hour after milking, hence they must cool both evening's and morning's milk. Most grade "A" producers deliver only once a day. The common practice is to cool and bottle evening's milk and store it until the morning delivery. The morning's milk is cooled, bottled, and delivered. In addition to cooling the milk, the grade "A" producers cool the crates and bottles and must use some ice on the bottles while being delivered, since the milk must be delivered at 50° or below. Grade "A" producers often use the dry-box method because it provides facilities for storing the bottled milk and cooling the bottles, while those producers who sell to the pasteurizing plants may cool by either the wet storage or dry storage method.

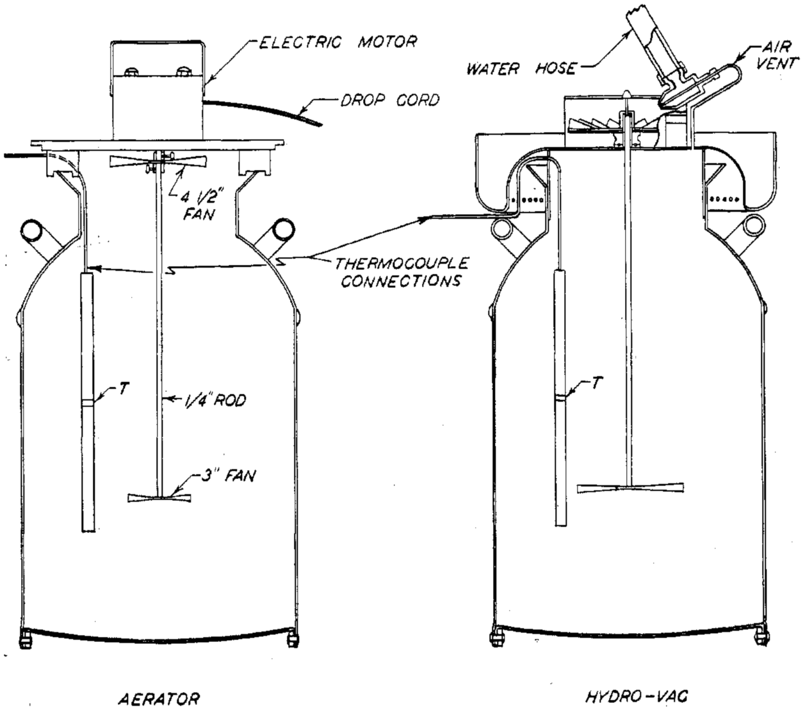

FIG. 4B.—Cross-sections of milk cans showing the mounting of the electric-motor-driven and water-motor driven stirring devices for stirring the milk while cooling.

Equipment Used for the Investigation. In the field and laboratory study, temperatures were measured by dairy thermometers, recording thermometers, and by thermocouples. Figure 4 shows a diagram of the thermocouple locations for studying the rate of cooling in ten-gallon cans. Thermocouple "A" was used in the laboratory study and thermocouple "B" was used in the field study. The letters T_1, T_2, T_3, and T_4 indicate the locations in the can at which temperature of milk was taken. The electric aerator shown in Figure 4B was an electric motor driving a stirring fan and air fan on the same shaft. A water-driven agitator is also shown. Temperature readings were obtained by means of the thermocouple "T" near the center of the can.

A total of 83 watt-hour meters were installed to measure the energy requirement of the cooling equipment. The time of

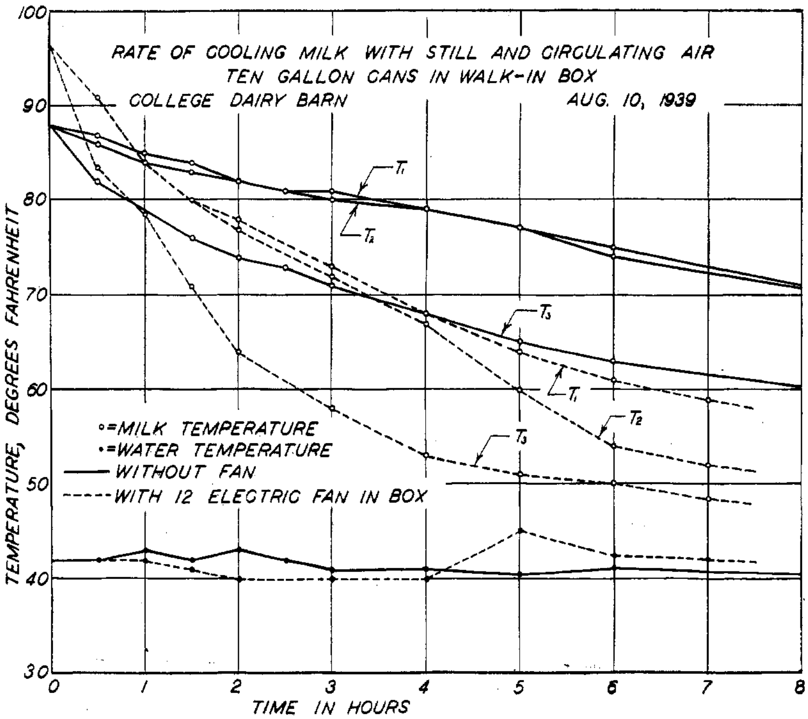

FIG. 5.—Curves showing the rate of cooling milk in 10-gallon cans set in a walk-in refrigerator.

operation of the compressors was determined by recording ammeters, Servis recorders, and self-starting electric clocks. Weights of milk production were obtained from the individual dairymen and from the pasteurizing plants to which the milk was sold. Bacterial counts were obtained from the milk inspector at the pasteurizing plants and the dairy inspector or milk sanitarian. Temperatures were taken by recording thermometers and mean temperatures were obtained from the United States Department of Agriculture Weather Bureau offices at Topeka and Manhattan.

RESULTS OF FARM STUDIES ON RATES OF COOLING MILK

Air-Cooling Milk in 10-Gallon Cans. Milk cannot be air-cooled rapidly enough to meet the requirements of the U. S. Public Health Service milk ordinance. The rate of air-cooling milk in 10-gallon cans is shown graphically in Figure 5. After 8 hours in a dry-box cooler at a temperature of 41° milk in the top of the 10-gallon cans was above 70°.

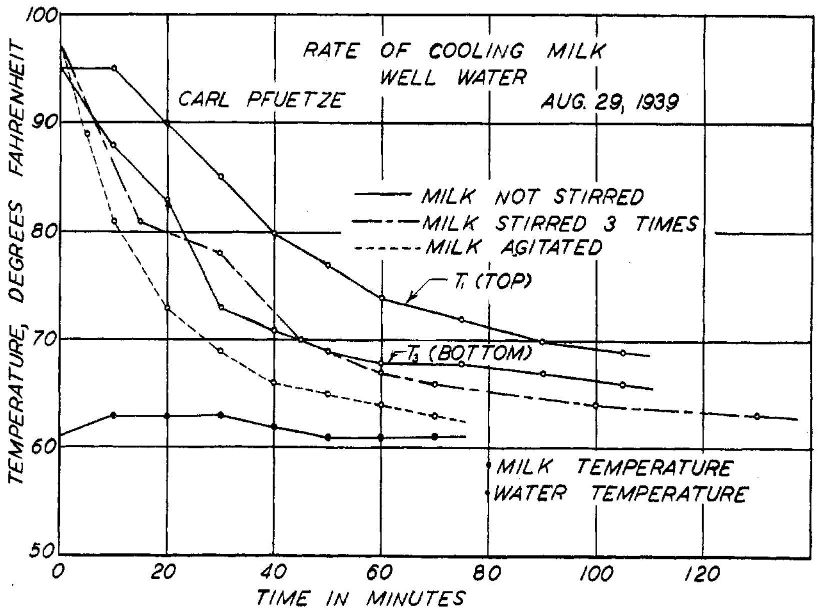

FIG. 6.—The rate of cooling milk in 10-gallon cans set in a water tank through which well water was pumped.

Cooling Milk with Well Water. Cold well water is one of the cheapest methods of cooling milk on the farm. The effectiveness of well water cooling depends upon the temperature of the water and the methods of handling the milk. Well water in Kansas has an average temperature of around 60°, therefore milk usually cannot be cooled below the 60° point without some other cooling medium. Common practice in cooling with well water is to immerse the 10-gallon cans of milk in a tank of cold water. The curves shown in Figure 6 indicate the rate of cooling in well water at 62°. In this tank, well water was being pumped into the tank continuously at the rate of 5 gallons per minute. Continuous pumping prevented any appreciable rise in the water temperature and created some agitation in the water which increased the rate of cooling. When the milk within the cans was left undisturbed, the rate of cooling was somewhat slower than when the milk was agitated. Milk

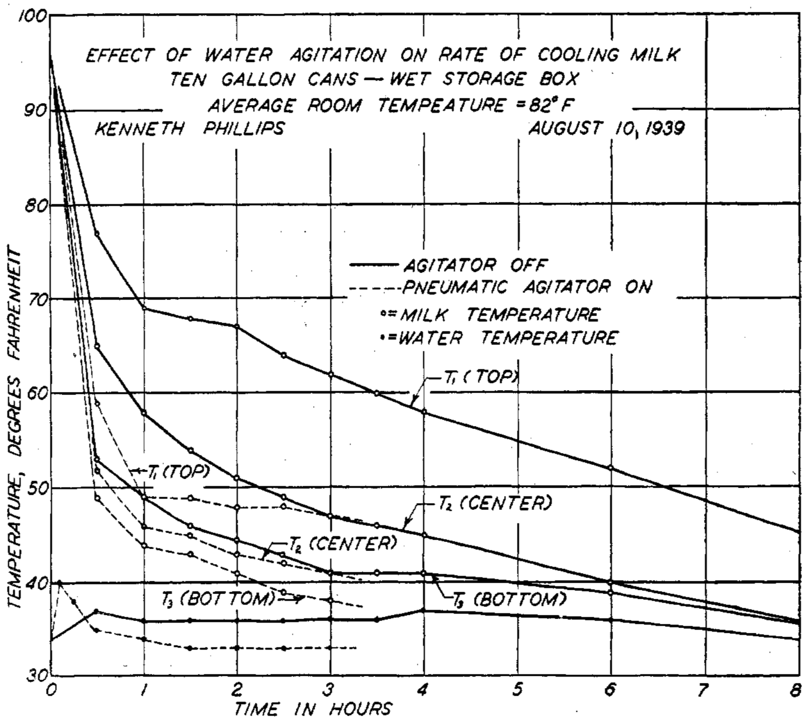

FIG. 7.—The effect of agitating the cooling water in a wet storage mechanical cooler upon the rate of cooling milk in 10-gallon cans.

was cooled to about 71° in one hour. By continuous agitation of the milk within the can, the rate of cooling is increased so much' that the milk temperature was within 2° of the water temperature after 1 hour. While this is effective cooling, it does not meet the requirements for grade "A" milk. In the northern sections of the country where ground water temperatures are as low as 50°, well-water cooling is quite successful.

Cooling Milk with the Mechanical Cooler. A series of tests were made on farm dairies to determine the rates of cooling milk in 10-gallon cans set in wet-storage boxes. In the curves in Figure 7 are shown the comparison of rates of cooling when the water in the tank was agitated by a small motor-driven pump and when the pump was not operated. The water temperature within the tank was about 35° throughout the test. When the water was not agitated, the bottom of the can was

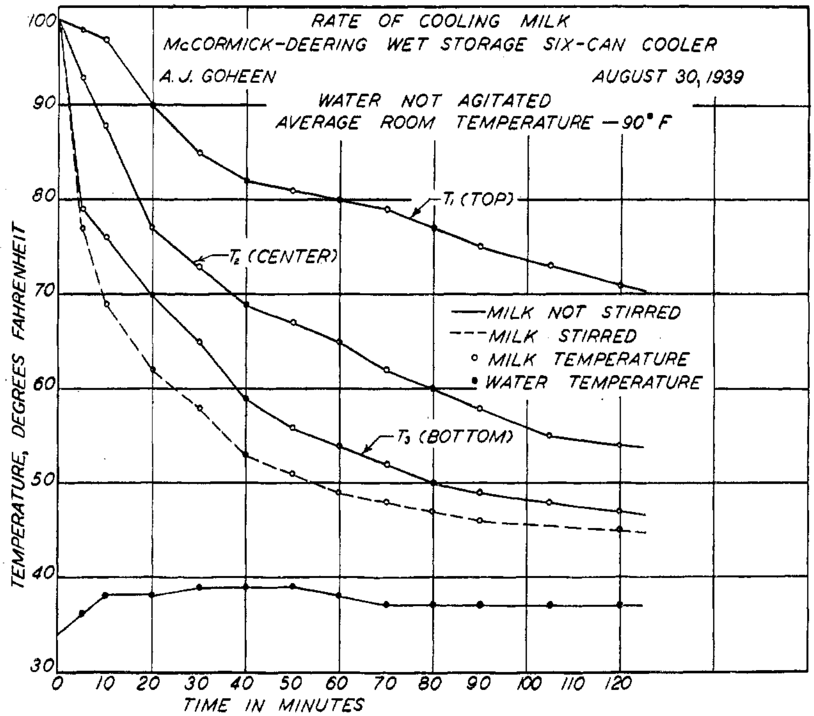

FIG. 8.—The effect of agitating the milk upon the rate of cooling in 10-gallon cans.

cooled to the 50° mark within 1 hour, but the top required over 6 hours to reach that point. When the water was agitated, the milk temperatures, both at top and bottom, were lowered to 50° within 1 hour. With a unit of this kind, effective cooling to fulfill the requirements of grade "A" milk cannot be accomplished without agitating the water in the tank.

The curves in Figure 8 show a similar effect when the milk within the can was stirred with the small motor-driven fans (Fig. 4). Cooling was not effective when the milk was not stirred as the temperature of milk on the top of the can was

70° after two hours in the tank. When the milk was stirred continuously, the temperature was lowered to 50° in 55 minutes.

The effect of agitating both the water and milk is shown in Figure 9. This test was conducted on a 6-can wet-storage unit during hot weather. Although agitating the water alone

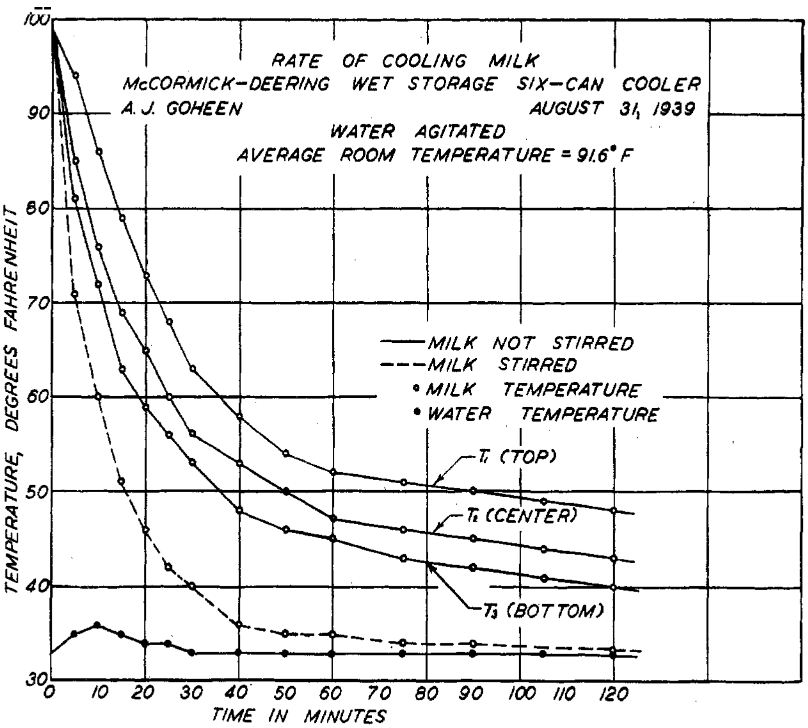

FIG. 9.—Effect of agitating both milk and cooling water upon the rate of cooling milk in 10-gallon cans.

proved to be effective in lowering the average temperature to 50° in 1 hour, the top of the can was still slightly above 50°. When both water and milk were agitated, the cooling rate was much more rapid and the milk was cooled from 100" down to 50° in 16 minutes.

Effect of Ice Bank on Rate of Cooling. In the normal operation of a milk cooler in which the water bath temperature is maintained between 34° and 38°, ice will form on the cooling coils, storing up refrigerating capacity for the heavy load of warm milk. The effect of this ice bank is shown by the curves in Figure 10 which shows the temperatures of the milk and the bath water when operated with and without a 3-inch ice bank. When four cans of milk were placed in a tank without the ice bank, the milk was cooled more slowly and the temperature of the bath water rose to meet the milk temperature at about 46°. With the ice bank on the coils, the rate of cooling

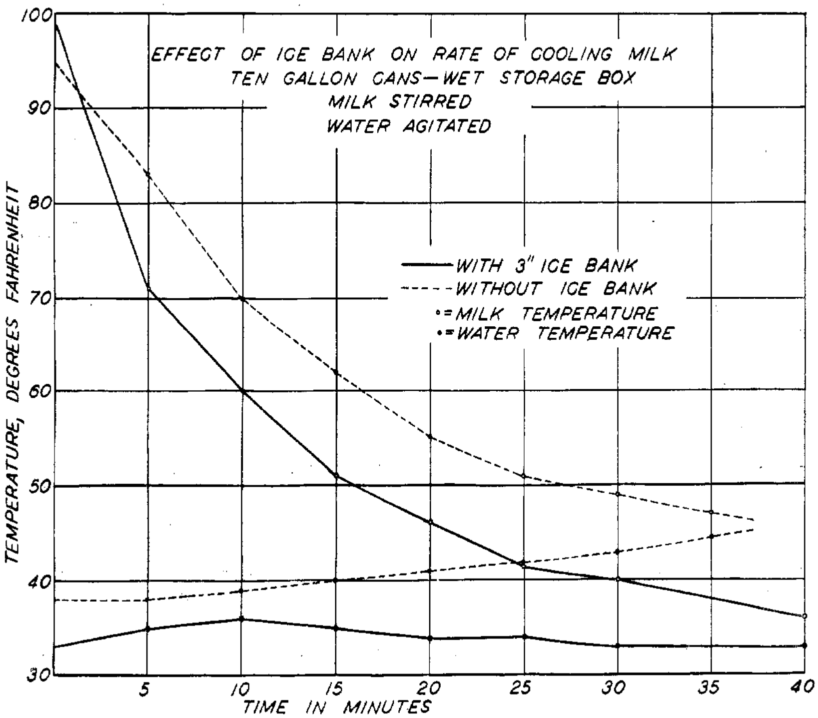

FIG. 10.—Effect of an ice bank upon the rate of cooling milk in 10-gallon cans in a wet storage box.

was more rapid and the bath water temperature remained at a lower level.

It is not necessary that a cooler have an ice bank, but it must have enough refrigeration capacity to cool the milk promptly. One pound of ice having a temperature of 32° when melted and raised 6" absorbs 150 B. T. U. It requires 25 pounds of water when raised 6° to absorb a similar amount of heat. Manufacturers utilize an ice bank to decrease the size and original cost of the unit. For the best operation there should be just enough refrigeration stored in the form of ice to cool the load of warm milk.

Cooling Rates with Dry-Box Coolers. All dry-box coolers use a surface cooler as a means of quickly cooling the milk. The rate of cooling when using a surface cooler is dependent upon a number of factors and as all of these factors are variable, there was not the uniformity of cooling with the dry coolers as with the wet-storage coolers. The important factors governing the rate of cooling with a dry box and surface cooler

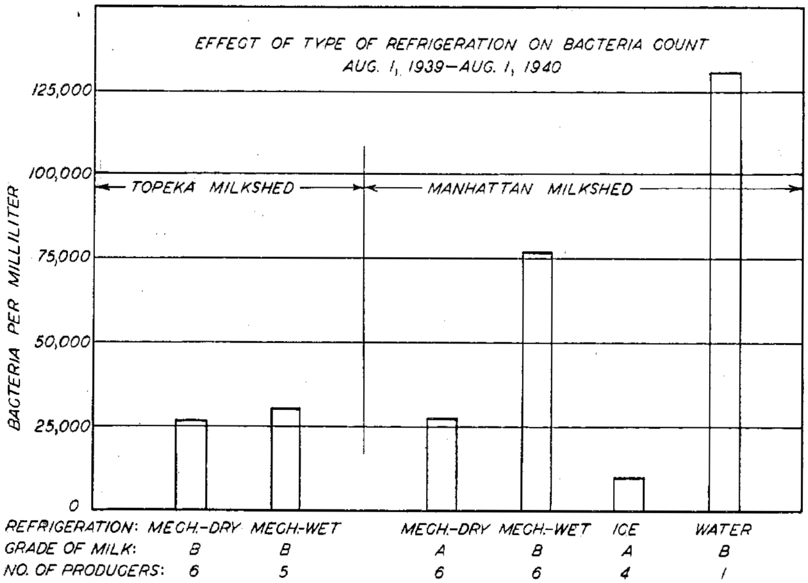

FIG. 11.—The average bacteria count of milk cooled by different methods.

are: The temperature of the brine circulated through the surface cooler, rate of milk flow over the surface cooler, the initial temperature of the milk, and the room temperature. The temperature of the brine of the various dry-box coolers, as noted on the farms studied, varied from 18° to 34°, the average being about 25°. The rate of milk flow over the surface cooler depended upon the brine temperature and the final milk temperature desired. The time required to cool one 10-gallon can over the surface cooled varied from 10 to 16 minutes, the average being approximately 14 minutes. Producers using this method cooled milk to a point which varied from 46° to 33°. Most producers using the surface cooler lowered the temperature of the milk to about 40°.

The effect of the method of refrigeration on the bacterial count for 28 producers in the Topeka and Manhattan milk-

TABLE 1. *Electrical energy consumed by milk coolers. Kilowatt-hours per 100 pounds of milk cooled each month, August 1, 1939 to July 31, 1940.*

Dairy farm No.	Type of refrigerator	Milk grade	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	MONTHLY MEAN Bacteria per ml.	MONTHLY MEAN Lbs. Milk cooled	MONTHLY MEAN Total kw.-hrs.	MONTHLY MEAN Kw.-hrs. per cwt.
MANHATTAN MILKSHED																		
Mean monthly temperature			75.9	76.3	61.8	44.8	39.0	13.6	31.6	43.5	53.6	63.6	74.4	83.7				
1	Dry Box	A	3.07	2.71	2.40	1.66	1.11	1.05	1.48	1.23	1.45	1.64	1.75	2.08	57,800	10,943	187	1.71
2	" "	A	2.22	2.30	1.41	0.79	0.67	0.38	0.60	0.67	1.36	1.65	2.27	3.00	28,700	11,897	169	1.42
3	" "	A	2.40	2.61	2.26	1.33	0.93	0.64	0.60	0.74	2.14	3.00	2.02	2.60	19,700	6,381	117	1.83
4	" "	A	3.75	3.04	2.02	1.92	1.29	0.74	1.96	3.14	1.78	2.05	2.51	4.84	4,000	10,741	248	2.31
5	" "	A	3.27	2.00	1.37	1.14	0.54	0.34	0.55	0.73	1.27	1.75	3.33	3.13	14,100	9,454	140	1.48
6	" "	A	1.97	1.96	0.79	0.86	0.76	0.50	0.64	1.00	0.95	1.44	1.74	2.21	28,900	21,179	261	1.23
	Mean for dry boxes		2.78	2.43	1.71	1.28	1.05	0.61	0.97	1.25	1.49	1.92	2.27	2.98				
7	Wet Box	B	1.72	1.75	1.07	0.80	....	....	....	0.73	1.09	1.34	1.88	2.63	126,700	4,621	66	1.42
8	" "	B	1.52	1.83	1.28	1.05	0.95	0.70	0.95	1.02	1.27	1.74	2.49	2.06	122,100	4,334	128	1.37
9	" "	B	2.15	2.02	1.70	1.03	1.22	0.79	0.84	0.84	1.03	1.76	2.64	5.21	99,400	9,466	154	1.63
10	" "	B	3.77	3.98	2.76	1.98	1.34	0.19	1.35	1.55	1.82	2.45	1.42	1.56	28,100	5.084	94	1.84
11	" "	B	2.34	2.51	1.49	1.08	1.07	0.09	0.57	0.97	1.32	2.27	2.41	2.39	28,100	9,914	150	1.51
12	" "	B	2.52	2.84	1.75	1.52	0.98	....	....	....	....	....	....	....	54,000	4,450	91	2.04
	Mean for wet boxes		2.34	2.49	1.67	1.25	1.11	0.44	0.93	0.92	1.31	1.91	2.17	2.77				
Mean for Manhattan			2.56	2.46	1.69	1.27	1.08	0.54	0.95	1.10	1.41	1.92	2.22	2.88				
TOPEKA MILKSHED																		
Mean monthly temperature			77.8	77.0	64.1	44.9	37.7	13.8	31.8	43.2	54.3	64.4	75.2	82.6				
1	Dry Box	B	2.40	2.15	1.48	1.03	0.86	0.38	0.64	0.90	1.40	1.62	2.15	2.49	6,100	7,631	109	1.43
2	" "	B	2.82	3.19	2.11	1.47	1.11	....	....	1.57	1.85	1.91	2.68	3.52	18,800	5,463	122	2.23
3	" "	B	3.72	3.82	3.66	3.45	1.90	....	2.80	1.45	2.70	2.98	3.14	3.98	34,000	6,141	187	3.05
	Mean for dry boxes		2.98	3.05	2.42	1.98	1.29	0.38	1.72	1.31	1.98	2.17	2.66	3.33				
4	Wet Box	B	2.26	1.47	0.92	0.75	0.59	1.13	0.93	0.97	1.24	1.48	2.69	1.29	29,600	7,784	105	1.35
5	" "	B	1.15	1.19	0.79	0.72	0.72	....	....	....	1.33	1.24	1.38	1.87	5,500	7,410	84	1.13
6	" "	B	2.07	1.80	1.23	0.87	0.60	....	....	....	1.09	1.30	1.76	2.12	78,700	7,385	104	1.40
7	" "	B	1.25	1.42	0.84	0.73	0.59	....	0.52	0.56	0.83	0.96	1.15	1.39	28,800	28,656	270	0.94
8	" "	B	1.85	1.98	1.61	1.37	1.11	0.35	0.89	1.22	1.46	1.30	1.64	2.02	17,500	5,233	75	1.44
	Mean for wet boxes		1.72	1.57	1.08	0.89	0.72	0.74	0.78	0.92	1.19	1.26	1.72	1.74				
9	Walk-in	A	1.67	1.86	1.19	0.78	0.68	0.36	0.61	0.83	1.29	1.47	2.24	2.54	71,200	28,445	361	1.27
10	" "	B	2.46	2.42	1.58	1.16	1.05	0.41	0.80	1.30	1.61	1.88	2.20	2.58	17,900	9,577	157	1.64
11	" "	A	....	4.50	2.89	2.02	1.62	....	....	....	....	....	....	....	9,500	13,849	382	2.76
	Mean for Walk-in		2.06	2.93	1.89	1.32	1.12	0.38	0.70	1.06	1.45	1.67	2.22	2.56				
Mean for Topeka			2.16	2.35	1.66	1.30	0.98	0.53	1.03	1.10	1.48	1.61	2.10	2.38				
Mean for Manhattan-Topeka			2.38	2.28	1.68	1.29	1.03	0.54	0.98	1.10	1.44	1.77	2.16	2.64				

sheds is shown in Figure 11. It is notable that when cooling with ice, milk with a low bacterial count was produced. It is also notable that all bacterial counts, except where water was used for cooling, were well below those specified by the standard milk ordinance.

The record of one year for 23 dairy farmers in the Manhattan and Topeka milksheds is shown in Table 1. These producers operated mechanical coolers and produced grade "A" or grade "B" milk. The producers of grade "A" milk were also distributors, while the grade "B" producers sold to pasteurizing plants. This table shows the grade of milk produced, the monthly bacterial count, quantity of milk cooled, kilowatt-hours per month, the kilowatt-hours per 100 pounds of milk cooled, and the monthly mean temperatures for the Topeka and Manhattan milksheds.

The monthly average energy requirements for the different types of mechanical coolers is summarized in Table 2. It was noted from Table 1 that all the dairymen using wet-storage coolers were grade "B" producers. The dairymen in the Topeka milkshed sold their milk to a pasteurizing plant which required them to meet grade "A" cooling requirements. All records from the Topeka milkshed are comparable since all producers had to meet the same cooling requirements.

The grade "B" producers in the Manhattan milkshed were not required to meet grade "A" cooling requirements; however, several of them did meet these requirements to obtain a lower bacterial count. The energy consumption for the wet storage coolers was higher in the Manhattan milkshed than the Topeka milkshed. It was the practice of the grade "B" producers in the Manhattan area to sell to a pasteurizing plant and they did not cool their morning's milk. Since only the evening milk was cooled, the coolers were not loaded to capacity, which accounts for the higher unit energy consumption per 100 pounds of milk.

The average monthly energy consumption is practically the same for the wet and dry boxes in the Manhattan milkshed, while in the Topeka milkshed where they both meet the same cooling requirements, the wet-box method required less energy per 100 pounds of milk cooled. The average for the Manhattan and Topeka milksheds shows the wet box to require 22 percent less energy per 100 pounds of milk cooled.

The energy requirements for cooling 100 pounds of milk varied with the mean monthly temperature as illustrated by the curves in Figure 12. The largest energy requirement occurred during the warmest month and the lowest during the coldest month.

TABLE 2. *Energy requirements in kilowatt-hours per 100 pounds of milk cooled by different methods during August 1, 1939 to August 1, 1940.*

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Mean
MANHATTAN MILKSHED													
Mean temperatures	76	76	62	45	39	14	32	44	54	64	74	84	
Wet storage	2.13	2.32	1.55	1.18	1.09	0.48	0.86	0.98	1.23	1.89	2.16	2.56	1.60
Dry Box	2.55	2.30	1.44	1.18	0.85	0.61	0.97	1.18	1.39	1.78	2.17	2.84	1.59
Average kw.-hrs.	2.36	2.31	1.48	1.18	0.94	0.56	0.94	1.11	1.34	1.81	2.17	2.74	1.60
TOPEKA MILKSHED													
Mean temperatures	78	77	64	45	32	14	32	43	54	64	75	83	
Wet storage	1.50	1.50	0.96	0.82	0.65	0.83	0.64	0.70	1.03	1.16	1.57	1.56	1.44
Dry box	3.00	3.02	2.32	1.81	1.29	0.38	1.54	1.25	1.90	2.13	2.65	3.27	2.17
Dry box walk-in	1.86	2.70	1.69	1.15	1.00	0.37	0.66	0.96	1.38	1.58	2.28	2.55	1.73
Average kw.-hrs.	1.85	2.21	1.45	1.08	0.90	0.46	0.80	0.91	1.30	1.46	1.97	2.19	1.53

Time of Operation. The total number of hours a day a compressor operates is dependent upon the load in the cooler and the temperature difference between the milk to be cooled and

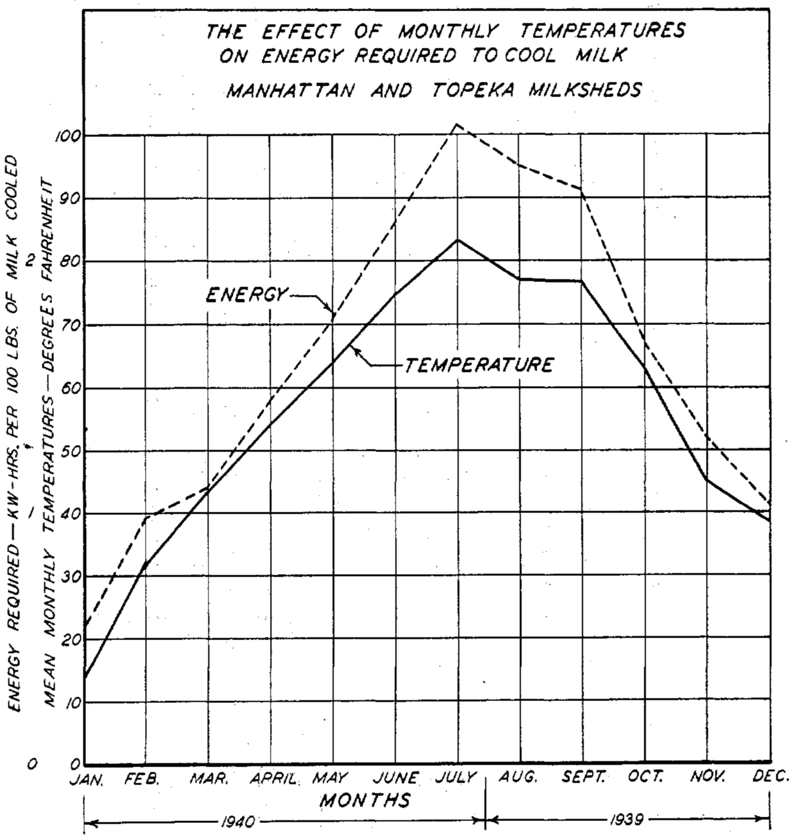

FIG. 12.—The relationship between atmospheric temperatures and the amount of electrical energy required to cool milk at different months.

the cooling box. The results of a series of tests are presented in Tables 3, 4, 5 and 6. The compressor operated more during the day than night which could be attributed to the slightly warmer temperature and the opening and closing of the box during the day.

LABORATORY TESTS ON MILK COOLERS

Laboratory tests were made on five types of coolers to check the field data and to study other factors which did not lend themselves readily to field study. The five types were: Wet storage having pneumatic agitation; wet storage having me-

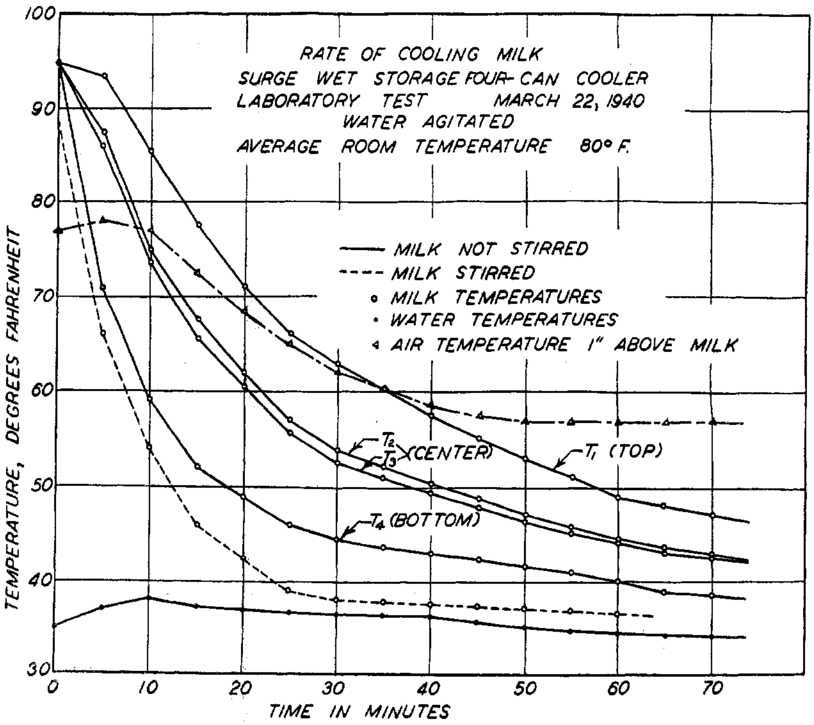

FIG. 13.—Rate of cooling milk in 10-gallon cans in a wet storage cooler when both milk and cooling water were agitated

chanical agitation; wet storage cooler using a surface cooler; a dry-storage cooler using a surface cooler; and a dry storage cooler with a built-in surface cooler, the surface cooler being an integral part of the unit.

In the loading of the refrigerators an attempt was made to duplicate the daily cycle of the cooler under ordinary farm conditions. The loads were placed in the refrigerator at 7 o'clock each evening and at 8 o'clock each morning.

For convenience, water was used instead of milk throughout the entire series of laboratory tests. It requires nearly the same amount of energy to cool an equal volume of milk and water. Milk has a specific heat of 0.93 B. T. U. per pound per degree F. and weighs 8.6 pounds per gallon, while water has a specific heat of 1.0 B. T. U. per pound per degree F. and weighs

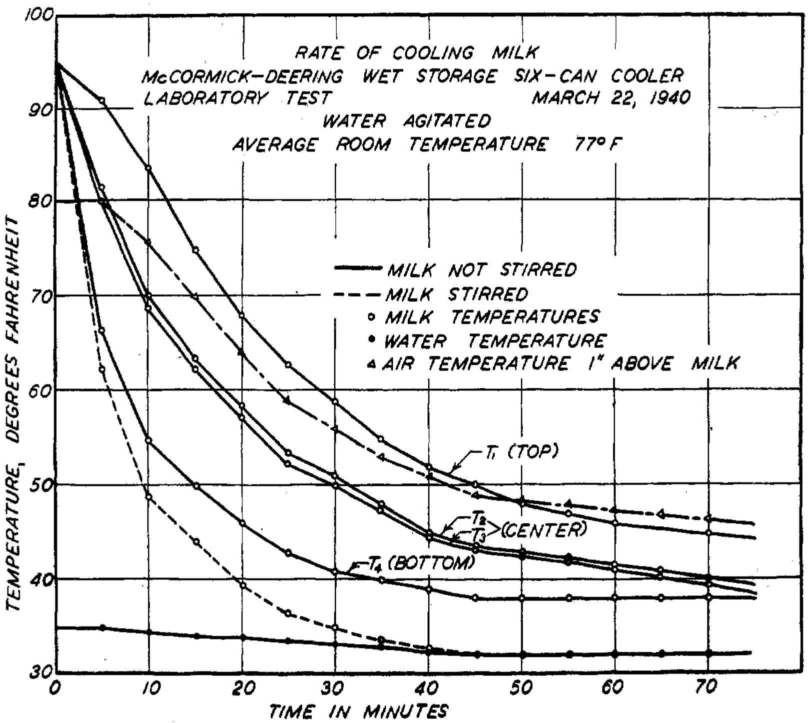

FIG. 14.—Effective and rapid cooling can be obtained when both milk and cooling water are agitated. This diagram compares the rates of cooling when milk is not stirred and when it is stirred.

8.45 pounds per gallon. The total amount of heat to be removed per gallon per degree of water is slightly higher than milk. The water used was heated by steam to an initial temperature of 95°.

The common practice for a producer who sells milk in 10-gallon cans is to cool and store the evening milk until morning. In all the tests on the wet storage coolers, the evening milk was cooled for one hour with the agitator operating and the cans of water stored in the cooler until morning. The morning milk was cooled with the agitators operating for one hour, after which processes the morning and evening milk would be ready for delivery,

Similar methods were used on the dry-storage coolers which were equipped with aerators, in which case both morning and

TABLE 3. *Results of laboratory tests of a McCormick-Deering six-can wet-storage box.*

	Time of operation during each 24 hrs.		Average room temperature degrees F.	Energy consumed kw.-hrs.	Kw.-hrs. per 100 lbs.
	Hours	Minutes			
Test No. 1					
No load	4	25	80.2	3.51	......
	4	30	75.0	2.36	......
	3	50	76.9	1.91	......
Average	4	15	77.4	2.59	......
Test No. 2					
2 cans cooled	11	10	81.6	6.11	......
1 can stored	9	40	76.5	4.51	......
overnight	9	15	80.6	4.81	......
Average	10	02	79.6	5.14	3.03
Test No. 3					
4 cans cooled	17	50	81.0	8.41	......
2 cans stored	14	15	81.6	7.01	......
overnight	14	35	81.5	7.81	......
Average	15	35	81.4	7.74	2.76
Test No. 4					
6 cans cooled	18	10	74.2	9.21	......
3 cans stored	18	50	80.3	9.31	......
overnight	17	15	83.3	8.61	......
Average	18	05	79.3	9.04	1.78
Test No. 5					
8 cans cooled	21	50	78.5	11.61	......
4 cans stored	19	05	82.5	9.81	......
overnight	21	15	80.1	10.51	......
Average	20	43	80.3	10.64	1.57
Test No. 6					
10 cans cooled	24	....	79.5	11.71	......
8 cans cooled	24	....	83.2	13.51	......
overnight	24	....	81.8	12.01	......
Average	24	....	81.5	12.41	1.46
Test No. 7					
12 cans cooled	24	....	82.9	12.51	......
6 cans stored	24	....	85.7	13.31	......
overnight	24	....	77.8	13.53	......
Average	24	....	82.1	13.11	1.29

evening milk was first cooled over the aerator. The evening load was stored.

Before beginning the series of tests, the compressors were run for 48 hours to insure normal operation of the unit. The coolers were loaded at various capacities and each test was run for a three-day period. Daily records were kept on the time of operation, temperatures, and energy consumed. The milk and brine temperatures were observed at the beginning and end of each loading.

Rates of Cooling. The rates of cooling of two types of wet-storage coolers are shown in Figure 13 and 14. As previously stated, T_1, T_2, T_3, and T_4 are temperatures at various levels in the can (see Fig. 4). Both tests show that the milk was cooled

TABLE 4. *Results of laboratory tests of a Surge four-can wet-storage box.*

	Time of operation during each 24 hrs.		Average room temperature degrees F.	Energy consumed kw.-hrs.	Kw.-hrs. per 100 lbs.
	Hours	Minutes			
Test No. 1	3	35	79.0	1.4	....
No load	3	40	80.2	1.8	....
	3	40	80.0	1.6	....
Average	3	38	79.7	1.6	....
Test No. 2	8	55	81.1	4.25	....
2 cans cooled 1 can stored	8	15	81.5	4.15	....
overnight	8	30	81.4	4.25	....
Average	8	33	81.3	4.22	2.48
Test No. 3	12	50	80.3	5.75	....
4 cans cooled 2 cans stored	12	55	74.2	5.15	....
overnight	12	50	83.5	6.15	....
Average	12	52	79.3	5.68	1.68
Test No. 4	15	35	79.5	6.75	....
6 cans cooled 3 cans stored	17	40	83.2	8.25	....
overnight	17	20	81.8	7.95	....
Average	16	52	81.5	7.65	1.50
Test No. 5	17	32	74.0	7.75	....
8 cans cooled 4 cans stored	17	35	78.5	7.75	....
overnight	17	50	82.6	8.75	....
Average	17	39	78.4	8.08	1.19

to 50° or less in one hour. By comparing these data with Figures 7, 8, and 9, it can be seen that the milk cooled slightly faster in the laboratory than in the field. This no doubt was due to somewhat lower room and initial temperatures in the laboratory and also due to the fact that the laboratory coolers were properly checked and adjusted before the test was started.

The data in Tables 3, 4, and 5 show that the daily energy consumption was least at no-load and increased with the load

TABLE 5. *Effect of circulating well water through top half of surface cooler with a Surge four-can wet-storage box.*

	Time of operation during each 24 hrs.		Average room temperature degrees F.	Energy consumed kw.-hrs.	Kw.-hrs. per 100 lbs.
	Hours	Minutes			
Test No. 1 Water from cooler through surface cooler 8 cans cooled. 4 cans stored overnight	18	30	80.1	8.90	......
	19	55	82.9	9.49	......
	19	55	85.7	9.78	......
Average	19	27	82.9	9.38	1.38
Test No. 2 Well dater* through top half of surface cooler. Water from cooler through bottom half. 8 cans cooled. 4 cans stored overnight.	13	....	81.6	6.23	......
	12	05	76.5	5.57	......
	12	40	80.6	6.15	......
Average	12	35	79.6	5.98	0.93
Test No. 3 Water from cooler through surface cooler. 4 cans cooled. 2 cans stored overnight.	13	07	82.0	6.39	......
	12	....	79.0	6.11	......
	12	....	82.5	6.40	......
Average	12	22	81.2	6.30	1.85
Tst No. 4 Well water* through top half of surface cooler. Water from cooler through bottom half. 4 cans cooled. 2 cans stored overnight.	9	30	80.0	4.41	......
	8	15	74.6	4.40	......
	7	43	75.4	3.00	......
Average	8	29	76.7	3.94	1.16

*Well water temperature 60 degrees F.

until the rated capacity of the machine was reached. The unit energy consumption varied inversely as the load, being the lowest at rated capacity of the machine. Figure 15 illustrates

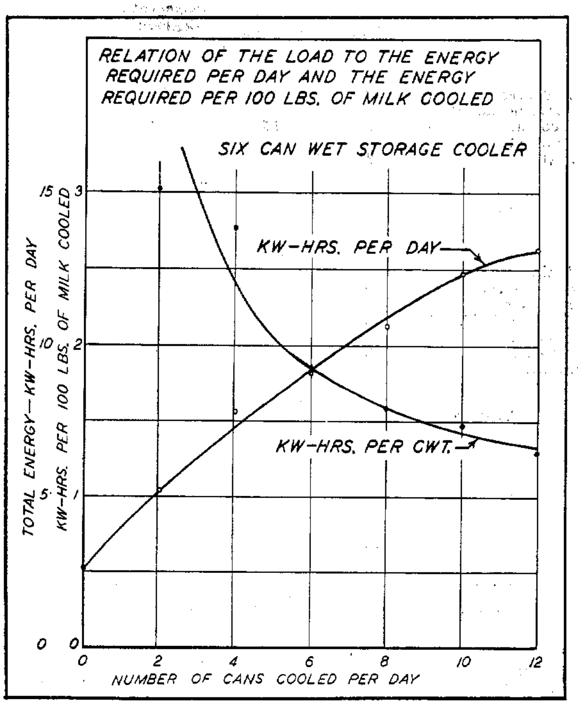

FIG. 15.—Showing the relation between number of cans cooled per day and consumption of electrical energy.

the relation of the load to the energy required per day and the energy requirement per 100 pounds of milk cooled. The no-load energy requirement for the different coolers varied from 1.6 to 2.59 kw.-hrs. per day. The energy requirement for no load was: 19.7 and 28.6 percent of the energy requirement at rated load. The energy at no load is required to maintain the temperature difference between the box and the room. A high no-load energy consumption indicates that there is a wide temperature difference or that the box is lacking in insulation.

Effect of Surface Cooler on Energy Requirements. The effect of the surface cooler upon the energy requirement is shown in Table 6. When cooling four cans of milk per day using the surface cooler, the energy consumption was 6.3 kw.-

hrs. per day, and when the milk was cooled by immersion, the daily energy requirement was 5.68 kw.-hrs. or a saving of 0.62 kw.-hr. per day by cooling in wet storage. When the cooling was increased to the rated capacity of the cooler, eight cans per day, the saving was 1.3 kw.-hrs. per day. Expressing these values in percentages, the increase in energy consumption due to the surface cooler was 10.9 and 16.1 percent respectively.

TABLE 6. *Electrical energy requirement by a four-can wet-storage cooler with and without a surface cooler.*

No. of cans cooled per day	Without surface cooler		With surface cooler		Extra eneregy required by surface cooler per day
	Kw.-hrs. per day	Kw.-hrs. per 100 pounds of milk	Kw.-hrs. per day	Kw.-hrs. per 100 pounds of milk	
0	1.60	......	......	......	......
2	4.22	2.48	......	......	......
4	5.68	1.68	6.30	1.85	0.62
6	7.65	1.50	......	......	......
8	8.08	1.19	9.38	1.38	1.30

Initial temperature of milk 94° F.
Final temperature of milk 40° F.
Room temperature (mean) 80° F.
Compressor rating 2790 B. T. U. per hour.

Effect of Water through Top Half of Surface Cooler. The energy saved by the wet storage cooler was 2.3 kw.-hrs. per day when cooling four cans per day, and when the cooler was loaded to eight cans per day, or full rated load, the saving was 4.4 kw.-hrs. per day (Table 7). Expressed in percentage, the energy saving was 37.5 and 36.2. The daily energy saving for the dry-box cooler when four cans per day were cooled was 2.41 kw.-hrs. and when cooling six cans per day was 1.67 kw.-hrs. This gave a saving of 29.3 and 18.5 percent. These tests show that the average saving when running water through the top half of the surface cooler was 30.4. This saving in energy would result in about 15 percent reduction in the total cost of cooling milk.

It is suggested that all dairymen using surface coolers utilize water, if possible, as a means of lowering the cooling costs. If running water is available, it is a simple matter to pipe it

TABLE 7. *Electrical energy requirements for a four-can wet-box cooler and a four-can dry-box cooler with and without well water through the top half of the surface cooler.*

No. of cans cooled per day	Without well water		With well water		Energy saved by running well water through top half of surface cooler
	Kw.-hrs. per day	Kw.-hrs. per 100 pounds of milk	Kw.-hrs. per day	Kw.-hrs. per 100 pounds of milk	
WET STORAGE					
4	6.30	1.85	3.94	1.16	2.36
8	9.38	1.38	5.98	0.94	4.40
DRY STORAGE					
4	8.26	2.43	5.85	1.72	2.41
6	9.03	1.77	7.36	1.44	1.67

Initial temperature of milk 94° F.
Final temperature of milk 40° F.
Average room temperature 80° F.
Temperature of well water 60° F.

through the top half of the surface cooler. Many producers pump water by electricity and pipe the water through the surface cooler. The water from the surface cooler may be piped to the stock tank. Since the water is needed by the livestock, the additional expense of running it through the top half of the surface cooler is small.

COSTS OF COOLING MILK

The total cost of cooling milk may be divided into fixed charges and operating costs. Fixed charges are those which depend upon the first cost and life of the unit such as depreciation, interest, repairs, taxes and insurance.

Depreciation may be due to wear and tear on equipment, to action of nature, causing decay and rusting, to obsolescence of equipment, and to minor factors. The proper rate of estimating depreciation for milk-cooling equipment is debatable. In the survey, most of the installations were found to be less than one year old. The average estimated life of installations reported by dairymen was 1.6 years. The life of these units is estimated to be 10 years, which may be longer than they will actually be serviceable. On this basis, depreciation was calculated at 10 percent.

Interest was computed annually at 6 percent on one-half valuation, which is the same as 3 percent of the first cost of the unit.

Repairs are usually necessary over a period of years to replace the parts becoming worn and broken. Repairs required for some of the installations in the field tests were numerous.

TABLE 8. *Comparative costs of cooling 100 pounds of milk during July, August, and September, 1939*

Method of Cooling	Wet Storage	Dry Storage	Ice
Original cost (average)	$275.00	$355.00	$200.00
Fixed costs:			
Depreciation at 10%	$2.29	$2.96	$1.66
Interest at 3%	.69	.89	.50
Repairs at 3%	.69	.89	.50
Operating costs:			
Energy at 3c per kw.-hr.	5.19*	8.61*	....
Ice at 30c per cwt.	....	....	27.00
Labor at 30c per hr.	....	....	2.25
Hauling	....	....	3.00
Fuel	....	....	.75
Oil	....	....	.30
Total cost per month	$8.86	$13.35	$35.96
Amount cooled	9,305 lbs.	11,130 lbs.	8,850 lbs.
Cost per 100 pounds milk	9.52c	11.7c	40.6c

* Actual cost of energy consumed on farms studied.

They included temperature controls, repairing of leaks, and adding new refrigerants. In one case the compressor valves had to be replaced. One of the machines during the month of January was found to have moisture in the refrigerant which froze and the cooler ceased to function until the moisture was removed. One dairyman replaced a motor because of a burned-out armature winding.

Most of the cooling units had been in use for so short a time that no worth-while data were available on cost of repairs. For this study, cost of repairs were computed at 3 percent of the original cost.

Taxes and insurance were omitted because the charge was small and would be approximately the same for each method of refrigeration.

The operating costs are those which vary with the load or amount being cooled and the temperature. The operating cost for the motor-driven mechanical refrigerators (wet- and dry-storage coolers) was the charge for electrical energy consumed.

TABLE 9. *Comparative Costs of Cooling 100 pounds of milk during one year, Aug. 1, 1939 to Aug. 1, 1940.*

Method of cooling	Wet Storage	Dry Storage
Original cost (average)	$275.00	$355.00
Fixed costs:		
Depreciaton at 10%	$2.29	$2.96
Interest at 3%	.69	.89
Repairs at 3%	.69	.89
Operating costs:		
Energy at 3c per kw.-hr.	3.63*	6.09*
Total cost per month	$7.30	$10.83
Amount cooled	9,031 lbs.	11,808 lbs
Cost per 100 pounds milk	8.05c	9.16c

* Actual cost of energy consumed on farms studied.

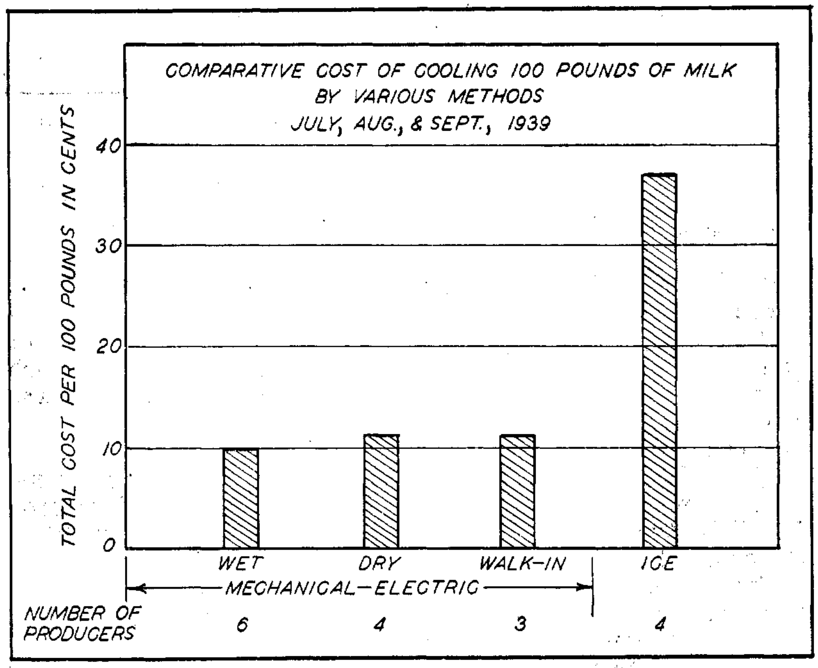

FIG. 16.—A comparison of the costs of cooling milk by four different methods.

The charge for electric energy in this study was determined by meters installed on the units studied. Electric energy was computed at three cents per kw.-hr. which may be higher than the rate paid by most dairymen. Some producers reported that their energy used for cooling milk cost them 1.5 cents per

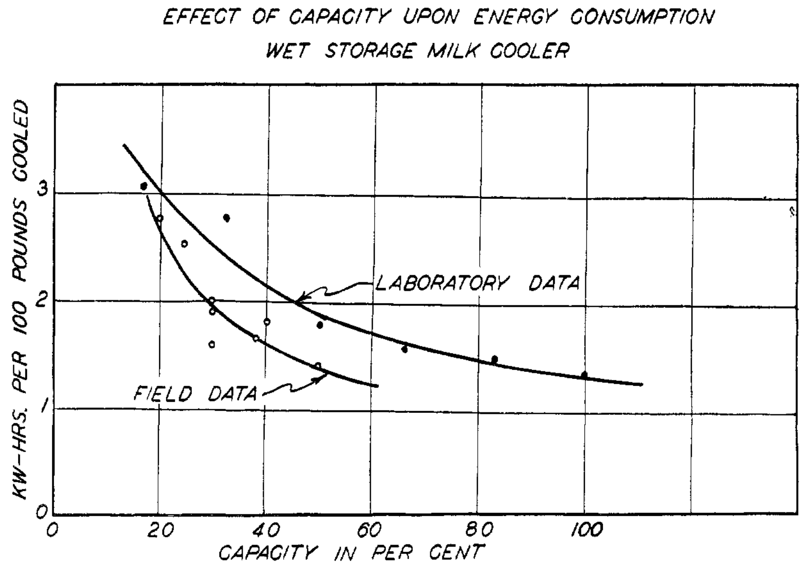

FIG. 17.—The effect of the cooling load in percent of rated capacity upon the energy consumption of wet storage coolers.

kw.-hr. because they had installed their cooling unit last and were using current at the 1.5-cent rate.

Table 8 gives the method of calculating and the comparative cost of cooling milk for July, August, and September, 1939. Table 9 gives the cost of cooling milk by wet and dry storage for the year, August 1, 1939 to August 1, 1940. Figure 16 shows a column diagram of the comparative costs of cooling 100 pounds of milk by various methods.

The results of the laboratory tests on mechanical coolers definitely indicated that one of the factors governing the energy consumption per 100 pounds of milk cooled was the percent of rated capacity at which the cooler was operated. Most of the producers using mechanical refrigeration were using equipment having a capacity much larger than needed for their present production. Many of the dairymen purchased large units with the idea of increasing their production. In Figure 17 are shown the result of both field and laboratory tests on the effect of the size of cooling load upon the unit energy consumption for wet-storage coolers. From the curve it is shown that as the load increases in percent of rated capacity, the energy consumption per unit of milk was lowered. The lowest consumption should occur at rated capacity of the machine. These data indicated that the energy requirement of

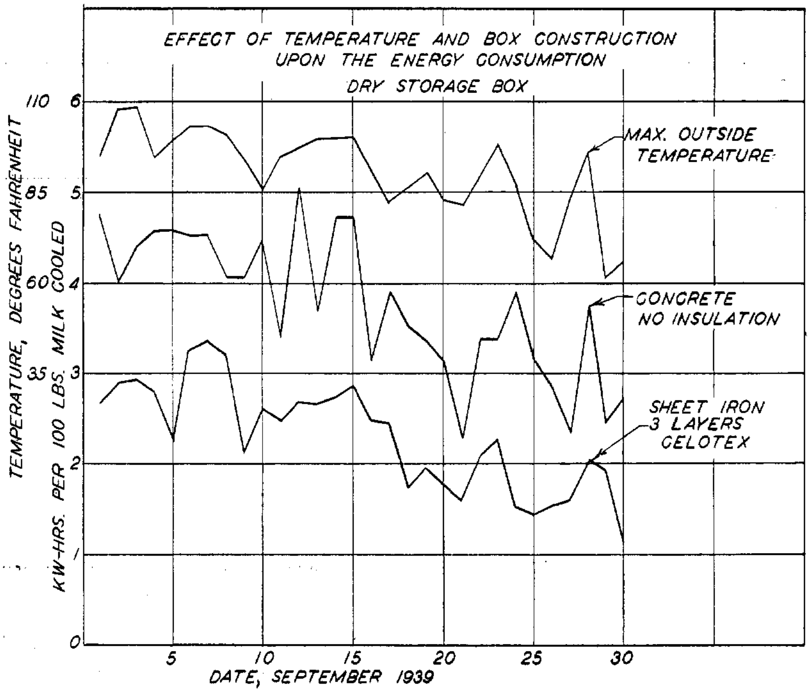

FIG. 18.—Effect of temperature and box construction upon the energy required to cool milk.

the farm units was less than those operated in the laboratory, which was due no doubt to the higher temperature in the laboratory and the fact that the milk was cooled to a lower temperature in the laboratory than was common practice among most dairymen.

INSULATION OF COOLING BOXES

There were several home-made boxes in the Manhattan and Topeka milksheds. It was possible to study the operating costs of the various types of boxes having different insulating materials. Included in the group was a home-made non-insulated concrete box, an insulated concrete box, a sheet iron box hav-

TABLE 10. *A comparison of the electrical energy required by an uninsulated concrete box and a commercial insulated box.*

Month	Mean atmospheric temperature	Concrete box—not insulated			Commercial dry box—insulated*		
		Lbs. Milk cooled	Total kw.-hrs.	Kw.-hrs. per cwt.	Lbs. milk cooled	Total kw.-hrs	Kw.-hrs. per cwt.
Aug.	77.8	6,848	255	3.72	10,664	262	2.46
Sept.	77.0	6,168	236	3.82	8,493	207	2.42
Oct.	64.1	5,263	193	3.66	9,614	152	1.58
Nov.	44.9	4,377	151	3.48	9,638	112	1.16
Dec.	37.7	7,841	149	1.90	9,601	110	1.05
Jan.	13.8	....	......	......	9,418	39	0.41
Feb.	31.8	5,468	156	2.80	8,197	66	0.80
Mar.	43.2	5,553	80	1.45	9,764	127	1.30
Apr.	54.3	4,958	134	2.70	10,307	166	1.61
May	64.4	6,297	188	2.98	10,251	196	1.88
June	75.2	7,941	249	3.14	9,260	204	2.20
July	82.6	6,835	272	3.98	9,714	251	2.58
Mean	......	6,141	187	3.05	9,577	157	1.64

* Saving effected by insulated box was 42.6%.

ing some insulating materials, and commercial boxes of similar size. Figure 18 shows the effect of temperature and box construction upon the energy consumption of two dry-box storage units. These data shows that the saving was 50 percent in energy required in favor of the insulated tank.

The monthly record for the production, bacterial counts, and energy consumption for two producers living in the same neighborhood in the Topeka milkshed is contained in Table

TABLE 11. *Electric energy consumed by commercial and home-made cooling boxes.*

	Home-made Boxes			Commercially-built Boxes*		
	Pounds of milk cooled	Kw.-hrs.	Kw.-hrs. per 100 pounds of milk	Pounds of milk cooled	Kw.-hrs.	Kw.-hrs. per 100 pounds of milk
			WET STORAGE			
	4,621	66	1.42	9,334	84	1.13
	9,914	150	1.51	7,140	104	1.40
	5,084	94	1.84	7,385	105	1.30
Av.	6,536	103	1.59	7,953	98	1.28
			DRY STORAGE			
	10,943	187	1.71	11,897	169	1.42
	6,141	187	3.05	7,633	109	1.43
Av.	8,542	187	2.37	9,765	139	1.43

* Saving effected by commercial wet boxes was 18.2% and the saving by commercial dry boxes was 39.7%.

10. Both dairymen were using the same make and size of refrigeration unit and surface cooler; both were storing milk in a dry-box cooler. One producer was using a 4-inch concrete tank set partially in the ground for his storage box. The lid was well insulated but the concrete walls and floor had no insulation. The other producer was using a commercially-made walk-in dry box. The average monthly energy requirements per 100 pounds of milk produced was 3.05 kw.-hrs. for the concrete box and 1.64 kw.-hrs. for the commercial box. The saving was 46.2 percent in favor of the insulated box. The monthly averages for comparable producers using commercially built and home-made storage boxes are shown in Table 11. These data stress further the importance of insulation in lowering the energy requirement for cooling milk and clearly show that the insulated box, although having a higher first cost, was a good investment.

SUGGESTIONS FOR COOLING MILK

Water is not available in Kansas during the summer months at a low enough temperature to meet grade "A" cooling requirements. Water 60° or less may be used effectively to cool milk which is to be delivered to the pasteurizing plant. When cooling milk in 10-gallon cans by well water it is desirable to stir the milk about three times during the first hour to increase the rate of cooling. Movement of the cooling water is also important in the rate of cooling, and therefore it is suggested that a small tank be used for cooling milk. A small volume of water will move more rapidly than a larger volume provided the supply is pumped through at a constant rate. Water used for cooling milk may be utilized for watering livestock or for garden irrigation. Well water may also be pumped through surface coolers for effective cooling.

Cooling with ice has been used extensively in Kansas. The high cost of ice, the introduction of mechanical coolers, and the availability of low-cost electricity have resulted in the diplacement of ice cooling. In areas where labor is cheap and the cost of ice low, ice cooling may be satisfactorily used. The primary requisite when using ice is to utilize all of its cooling capacity. This means that a storage box of proper size, insulation, and construction should be secured. The water leaving the surface cooler should be used to help cool the bottles. Natural ice or cold water from an outside storage tank may be used in the colder months, thereby lowering the amount of ice to be purchased.

The increase in number of mechanical milk coolers used on Kansas farms has been rapid. This popularity is due to their low operating cost, convenience, and efficiency. Many dairymen stated they would not go back to using ice even if it were cheaper, because of the convenience of the mechanical cooler. A mechanical cooler is a relatively simple machine, but it must be properly installed, adjusted, and maintained if it is to give its owner lasting and trouble-free performance.

In the selection of this equipment one should consider the size required, the reliability of the manufacturer of the unit, and the insulation of the box, as well as the first cost.

When operating a mechanical cooler it should be properly adjusted for the desired temperature. Lower temperatures than needed increase the heat losses through the walls of the box and the operating cost of the box. Install and wire the electric motor properly, being sure that the motor is adequately protected by a fuse box or circuit breaker. Several motors belonging to the dairymen included in this investigation were damaged because of the lack of proper protection.

In cooling or refrigeration, insulation is of paramount importance. This is especially true if a home-made box is used. The box should be insulated on all sides, top, and bottom. Two inches of cork or its equivalent in insulating value are generally recommended for milk cooling boxes

SUMMARY

1. In a 1939 survey of 1,144 Kansas dairy farms it was found that 24.55 percent of the farmers produced grade "A" milk, 74.45 percent grade "B", and one percent grades "C" and "D".
2. Cold air was found practically worthless for cooling milk stored in 10-gallon cans.
3. If water having a temperature of 60° or less is available, its use of cooling to meet the temperature requirement of grade "B" milk was satisfactory, provided proper methods were used.
4. When well water was used to cool milk stored in 10-gallon cans, the rate of cooling could be increased considerably by stirring the milk several times. When both the water and the milk were agitated continuously, milk was cooled to 64" in one hour, with well water at 58°.
5. When using the mechanical wet-storage unit, the rate of cooling could be markedly increased by agitating the cooling water. Milk was cooled from 94° to below 50° in one hour when cooling water was agitated.
6. When using the mechanical wet-storage unit, the rate of cooling could be increased considerably by stirring the milk. When both the cooling water and milk was agitated, the milk was cooled below 50° in 12 to 16 minutes.
7. The average amount of ice used by four grade "A" producers to cool 100 pounds of milk during the months of July and August was 107 pounds, while for four grade "B" producers an average of 41.6 pounds of ice was used.
8. The average total cost of cooling milk with ice during July and August, 1939, by four producers meeting grade "A" requirements was 38 cents per 100 pounds of milk.
9. A low bacterial count in milk could be maintained when cooling with ice if the proper methods were used.
10. The average total cost of cooling milk by the mechanical wet-storage method was 8.05 cents per 100 pounds of milk cooled, while with the dry-storage method the cost was 9.16 cents per 100 pounds.

11. The cost of cooling milk when using the mechanical wet-storage method was reduced 25 to 50 percent, depending upon conditions, by operating the coolers at their full rated capacity.
12. An insulated concrete storage tank required 50 percent less electrical energy to cool milk than a similar tank without insulation.
13. Laboratory tests shown that the energy required to keep the wet-storage box cool varied from 19.8 to 28.7 percent of the total energy required to cool milk at the rated capacity of cooler.
14. The most satisfactory method for cooling milk was mechanical refrigeration operated by an electric motor.