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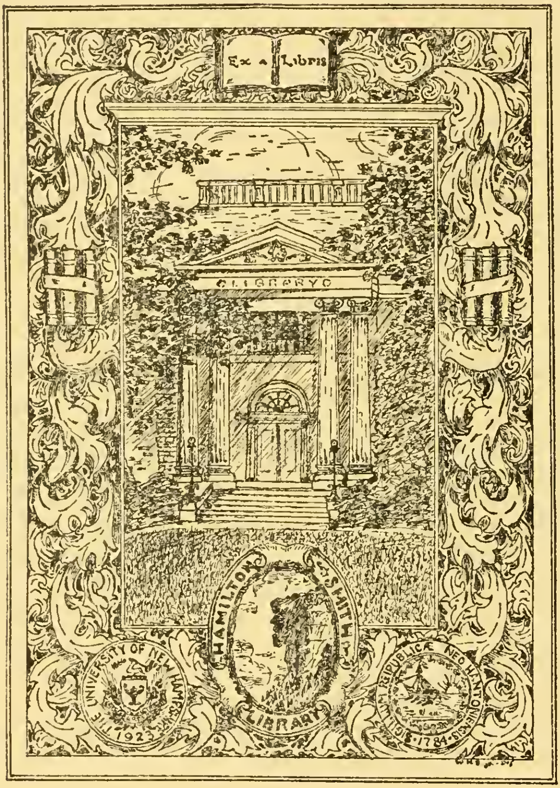
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ELECTRIC DAIRY COLD STORAGE

NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION
DURHAM, N. H.

SUMMARY

The practicability of electric dairy cold storage has been tested for two to four years on three retail dairy farms in the New Hampshire rural electrification experiment.

The storage rooms vary in size from 170 to 206.7 cu. ft. contents and have been operated under a variety of conditions with similar equipment of the dry room type.

Initial investments for mechanical refrigeration equipment were from $635 to $766, whereas initial investments for the ice method on the same farms varied from $135 to $775 with an average of $455. Yearly fixed charges were thus generally less for the ice method.

Cash or money-out-of-pocket expense for operating refrigeration was in general less for ice, but in one case was in favor of the electric method.

Current consumption or operating costs of the electric method ranged from $37.31 per year to $75.60 on rates varying from 3-1/7 cents to 7 cents per kwhr. The average was $54.80 per year. Operating costs (labor, ice and sawdust) for natural ice refrigeration ranged from $170.10 to $320.80 with an average of $238.09. Due to the almost entire elimination of labor, the operating costs for the electric method were consistently less than for ice. Operating costs with ice were approximately 150% to 440% greater, or an average of 320%.

Total operating costs for the year, including labor, interest and depreciation, averaged $118.33 for the electric method, and $236.56 for the ice.

The annual current consumption varied from 772 to 1,479 kwhs. during nine to twelve months. The bulk of the load was in July, August and September.

The storage rooms were designed to carry an average load of 300 quarts of bottled milk a day. Up to 420 quarts have been stored satisfactorily and under extreme temperature conditions.

The maximum outdoor temperatures contended with were 102° 104° in the sun at which time the cold storage was 50° on one farm and 44° on another.

The equipment operated about 50% of the total elapsed time on two farms and 40% of the time on the third.

Dairy cold storage consumed from 10% to 42% of the total amount of electricity used by each farm for a year. This percent varies according to the make-up of the remainder of the farm load.

The average total cost per cu. ft. of total contents was $1.18 for the ice method and $.62 for the electric.

The cost per 100 qts. of milk for a year was $.30 for the ice method and $.15 for the electric.

The equipment is pronounced desirable, practical and economical by all farmers using it.

It is foreseen that some farmers, by reason of good local conditions and requirements of keeping labor steadily at work, will find the use of ice cheaper. The more business a farm has, however, the more valuable will be the electrical equipment.

ELECTRIC DAIRY COLD STORAGE

By W. T. Ackerman

No figures are available as to the tons of ice annually harvested and placed in storage by New England dairymen during the winter to furnish refrigeration for the preservation of dairy products, such as milk and cream, through the warm summer months. The sight of men and teams engaged in these operations on rivers and ponds has led many to consider the farmer fortunate in obtaining ice so easily and cheaply at a slack period of the year.

Indeed, many farmers, by reason of labor and other particularly good local conditions, will for some time, no doubt, be in a position to obtain better general results, overlooking the superior qualities of mechanical refrigeration, by using ice.

The chief value of electric refrigeration, however, is in its elimination of the ice problem during the spring, summer and fall months, when the ice must be dug almost daily out of the icehouse, cleaned down, carried or drawn to the ice boxes or cooling rooms and loaded on the bunkers. Many dairy farms use three or four hundred pounds every other day, and the task requires considerable valuable time in the rush season.

In order to obtain information on the cost of electric dairy cold storage, studies were made on three of the farms in the series of experiments in rural electrification conducted by this Station in cooperation with the State and National Committees on the Relation of Electricity to Agriculture.

The experimental work herein reported is concerned with the storage of milk and cream in bottles on these three retail dairy farms. The fact that a considerable amount of surplus milk was always stored in cans has indicated that the same method is equally practical for bulk milk. Precooling in each case was accomplished by means of cold well or spring water.

COLD STORAGE ROOMS

The equipment used on each farm is of the dry room type, as distinguished from the wet tank type, and consists of an insulated room large enough to admit a person, as well as the load of milk and cream, and chilled through the medium of cold dry air. Due to the lack of data on the wet tank type comparative costs of the two methods are not entered into. Since the three rooms varied considerably in their arrangement, a general description of each is given as follows, and detailed figures are shown in Table I.

Farm No. 2. The cold storage room on this farm is located in an outside corner where barn and shed meet, convenient with respect to loading on the delivery truck as well as fairly near the dairy room where the milk is bottled. It is, however, exposed to the sun for some time during each midday in summer.

Originally cooled by ice, the room was converted for electric operation by applying a layer of insulating paper and cork board, varying in thickness from 1″ to 4″, to the inside walls using asphalt to cement the joints. To avoid decreasing the size of the room which was considered none too large, the thickness of cork was varied to even up the ir-

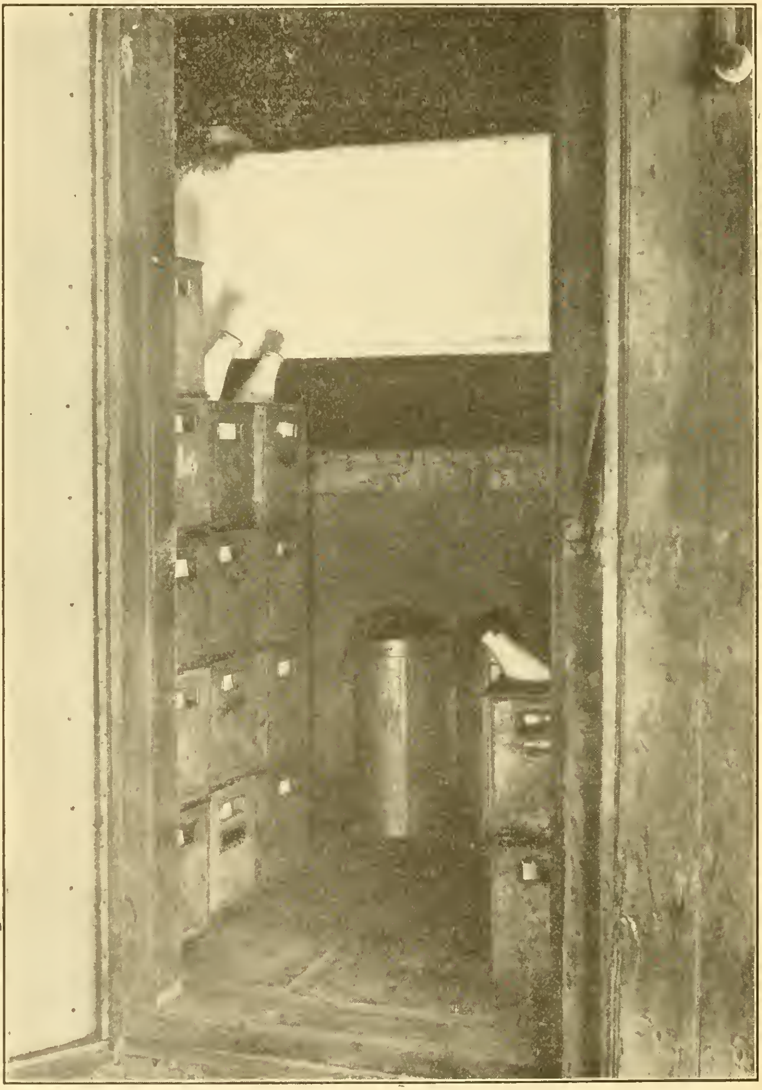

FIG. 1. View through the door of cold room on Farm No. 2. This is an old cold storage that was formerly cooled with ice and converted for the electric method. While the interior is left in the rough it is none the less serviceable except from the standpoint of sluicing down the walls.

regular interior surface. The efficiency of the insulation is, therefore, variable with different sections of the walls. To further conserve the inside space, corkboard was fitted in between the floor beams on the under side of the double-boarded floor. This cork is exposed to the outside air. The wooden side-walls and ceiling contain two air spaces. Corkboard was applied to the underside of the ceiling without lining or finish. The rack which formerly held the ice was used to support the brine tank located in the back of the room opposite the door (See Fig. 1). There is a 3⅔ ft. clear height between the rack and the floor.

Farm No. 4. In this case the room is in the ell connecting the house and barn, where it is well protected from any direct heat. The distance from the kitchen is slightly more than in the case of the average household refrigerator but not so far as many cellar cold rooms. It is some distance away from the cow stable, as it should be, and centrally located as regards precooling, bottling and the washroom where the utensils are cleaned. The delivery truck is handily loaded almost from the door of the cold room.

The old cooling room was entirely dismantled and a new room built in the same location according to standard refrigerator specifications, thus furnishing a fairly accurate cost figure for new construction. Two standing walls, the ceiling and floor of the old room, were utilized. For the benefit of any who may wish to construct similar rooms the details of construction will be given in some detail in a later bulletin. Due to its use for both dairy and house products the room is somewhat larger than the other cold rooms. The brine tank is located on the upper right side of the doorway as shown in Fig. 2 (Cover page).

Farm No. 1. The cold storage on this farm is located in the basement of the ell of the house adjoining a dairy room where bottles and utensils are washed and the milk is precooled and bottled. In addition to the brick wall in front and the stone foundation on the side, a three partition wall having two air spaces filled with paper was constructed on all four sides and the ceiling. The floor consisted of bricks laid in sand and then covered with concrete.

The walls were insulated with paper, followed by 3 inch corkboard with asphalted joints, after which the surface was finished with a cement coating and painted. Three inch cork was used in this case because the two air spaces in the walls were paper-filled, and because the room was located in a naturally cool basement. The concrete floor was left uninsulated for the first and second years' operation. The door contains two air spaces and is also insulated, but being of the wedging type without edge overlaps, is not strictly tight at the closing joints, especially at the bottom. The tank is located at the left of the door and is mounted on a rack similar to that built on Farm No. 4. The proportions of this room make it a compact but comfortable space to work in, though a height of 6½ ft. would give better headroom.

The door opens directly into the dairy room, which is quite steamy and warm every morning; and this moisture-laden atmosphere, added to the natural moisture-drawing qualities of the cement floor, causes quick and heavy coating of frost on the brine tank, making it necessary to defrost as often as every two weeks. This action has had its effect on the efficiency and current consumption of the equipment.

TABLE 1—*Farm Organization and Cold Room Specifications*

	FARM NO. 2	FARM NO. 4	FARM NO. 1
Men employed	3–4	3–4	4
Total acres	75	190	175
Tillable acres	30	65	100
Total cattle	36	27	45
Cows milked	36	19[2]	36
Quarts of milk retailed	300	300	300
Miles to town or city	1	2	2
Width in feet	5	5¼	7
Depth in feet	5½	5¼	4½
Height in feet	6⅓	7½	6
Sq. ft. of floor space	27.5	27.6	31.5
Total contents, cu. ft.	174	206.7	189
Cu. ft. for tank, valves, etc.	16	22.7	19
Storage contents, cu. ft.	158	184	170
Cork insulation	1 to 4 in.	4 in.	3 in.
Location of room	Open shed	Enclosed shed	Basement
Door location	End	End or side[1]	Side
Size of door	72″x30″	72″x36″	72″x32″
Built new or converted	Converted	New	Converted
Cement plastered inside	No	Yes	Yes
Painted white inside	No	Yes	Yes
Electric light inside	Yes	Yes	Yes
Floor surface	Sheet iron	Concrete	Concrete
Walls and ceiling insulated	Yes	Yes	Yes
Floor insulated	Yes	Yes	No
Compression latch on door	Yes	Yes	No
Tank baffled for circulation	No	No	No
Motor horse power	⅓	¼	¼
Automatic control	Breaker-point[3]	Mercoid	Mercoid
Tank Dimensions:—			
Length	56″	54″	45″
Width	20″	12″	12″
Height	20″	24″	24″
Total sq. ft. of surface	36.5[4]	31	26.5
Sq. ft. of unobstructed radiation surface	29.8	30	25.5
Sq. ft. of effective vertical radiation surface	18.3	22	19
Motor equipment location	Open shed	Closed shed	Basement

[1]Square room.

[2]Enough milk is purchased in addition from nearby farms to represent, it is estimated, a total of 40 cows.

[3]Being one of the first machines built by the company it is not equipped with the mercury tube or mercoid automatic control now used. The control in this machine is of the older, breaker-point type. The only trouble reported with the equipment, during the three and one half years of operation, has been with this device.

[4]Part of the total surface is not available to radiate cold to the room, because one end of the tank is placed in contact with the wall thereby blocking the radiation from that end. About one-half of the bottom of the tank is similarly blocked by the supporting rack.

STANDARD DATA

Machine: Manufacturer's name and trade name furnished on request.
Indirect expansion (brine tank), air-cooled, double cylinder reciprocating, gear-driven compressor using methyl chloride as a refrigerant.

Size: (a) Motor, 110 volts, 60 cycle, 1750 R.P.M., Type R.S. (b) Rated equivalent to 250 lbs. or 1/8 ton of ice in 24 hours at 4 lbs. gas back pressure. Against 10 lbs. back pressure has been found to have more than 33⅓% greater capacity.

TABLE 2—*Investment in equipment and annual fixed charges for electric refrigeration on three farms.*

	FARM NO. 2	FARM NO. 4	FARM NO. 1
Insulated Rooms			
Cost of original cooling room	$75.00	......	$125.00
Insulating materials	50.00	......	46.00
Labor, freight, electrical connections, etc.	......	$21.20	22.57
Combination dairy cooling room and household refrigerator constructed new, material and labor	......	234.50	......
Cost of insulated room	$125.00	$255.70	$194.45
Average **$191.72**			
Mechanical Equipment			
Installed value	510.80*	510.80	510.80
Total Cost	$635.80	$766.50	$705.25
Annual Fixed Charges			
Mechanical Equipment			
Interest at 5% on initial investment	12.25*	25.54	25.54
Depreciation at 5%	12.25	25.54	25.54
Rental charge at $2.00 per month	24.00*	......	......
Insulated room interest	6.25	11.75	9.72
Depreciation and upkeep at 4%	5.00	9.38	7.78
Servicing—none to date—estimated at not more than*	......	3.00	3.00
Total fixed charges	$59.75	$75.19	$71.58
Average **$68.84**			

*Actually the electric refrigeration unit on Farm No. 2 was secured on a rental basis requiring an initial investment of $225 with the privilege of later purchase. In this way the initial out-of-pocket expense was about one half that required of the others, but the farm operator does not own the equipment which may be a disadvantage. This method has been discontinued by the manufacturer, and the installed value has been used in the table.

†Servicing frnished on Farm No. 2 by company on rental basis. The labor of attendance is reported as being too small to attach any value to. This almost complete elimination of labor is one of the oustanding features of the electrical method.

Amount of Product: As used is considered to be able to carry an average of 300 quarts of milk in bottles per day.

Farm No. 2. Has carried a maximum load of 400 quarts of whole milk and cream in bottles and cases.

Farm No. 4. Has carried 420 qts. of whole milk and cream at 50° against 90° outside temperature as a maximum load.

Farm No. 1. 125 to 150 quarts has been the average load.

Method of Handling Milk. On all three farms the milk is precooled by running it over surface coolers which are chilled by cold well water. Water temperatures vary, but occasional tests indicate that the milk is reduced to about 60°-65° temperature or better, under favorable conditions. The milk is then bottled and placed in storage.

On Farm No. 4 it was found that 48.6% of the total day's milk goes into storage before 7 A.M., 31% about noon, and 20.4% around 7 P.M. The average quantity of milk at these hours is 116, 190 and 240 quarts respectively, the last being the average quantity held over night and the total for the day.

This method of operation, which is representative of conditions on the other farms, requires the most current in the morning and least as night comes on. The task of holding the entire load overnight is not believed to require much current as most of the milk has by that time been well chilled and must simply be held so. This would substantiate the original belief that the dairy cold storage is largely a daylight electric load.

Initial Investment for Electrical Refrigeration. The initial investment in equipment for the three farms is given in Table 2. In the lower half will be found the interest and depreciation charges, *i.e.*, the annual fixed expenses.

Current Consumption and Costs of Operation. Readings for 1924, 1925, 1926 and 1927 are given in Table 3 on a monthly basis. All equipment is operated on separate power or heating circuits which provide a somewhat lower rate if sufficient quantity of current is used. For average rate see Table 4, also New Hampshire Experiment Station Bulletin 228.

Refrigeration is usually started sometime in March, or April, depending on outside temperatures, where operations are not on a year-round basis, and is usually discontinued in the latter part of November. Through the winter months when natural outside temperatures are used, care must be taken that products do not freeze.

The months of May, November and December are representative of minimum operating expense conditions. The average monthly consumption throughout the year varied from 95 to 135 kwhs. with an average of 109 kwhs. The average monthly costs ranged from $3.94 to $7.56, with an average of $5.79.

The maximum consumption occurs usually in August but may also fall in July or September. The lowest maximum was 158 kwhs., the highest 230 kwhs., and the cost of operation varied from $6.51 to $14.00. The average maximum was 184 kwhs. and $9.82.

The annual cost is seen to vary from $35.13 when 772 kwhs. were used to $75.60 when 1080 kwhs. were used. The annual average consumption was 1045 kwhs. and average cost $54.80. It is evident that the length of time and cost of operation are controlled by temperature conditions which vary from year to year, being particularly affected

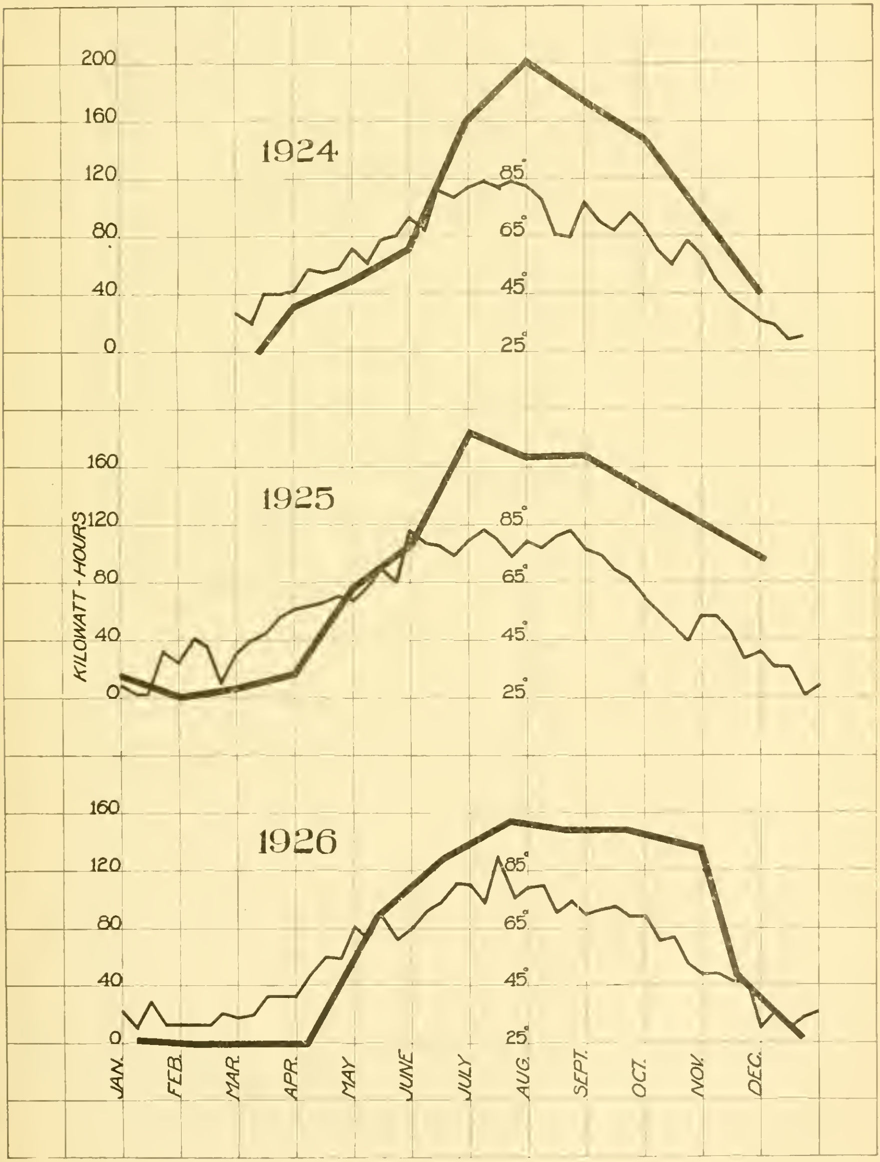

FIG. 3. Current consumption and outside temperature curves for 1924, 1925 and 1926 on Farm No. 2 showing the relation of the two factors. Kwhs. appear as the heavy curve and degrees fahrt. as the light curve.

TABLE 3—*Kilowatt-Hours and Current Costs Per Month*

	Kilowatt-Hours Per Month									
	Farm No. 2				Farm No. 4		Farm No. 1		Monthly Average	Average per Day of Operation
	1924	1925	1926	1927	1926	1927	1926	1927		
January	....	....	....	....	....	68	....	....	10.5	....
February	....	0	0	0	....	71	....	....	9	.4
March	0	6	0	28	0	86	....	0	15	1.5
April	30	18	0	75	21	127	0	15	35.7	3.5
May	47	75	115	74	131	128	71	94	91.9	4.0
June	70	105	115	121	158	168	106	135	122.0	5.4
July	160	183	137	152	164	183	139	170	161	5.9
August	200	167	158	186	208	207	155	191	184	5.5
September	174	168	141	157	164	163	230	160	170	3.9
October	147	145	106	116	149	132	33	125	119	2.9
November	94	115	81	76	127	109	29	81	89	1.3
December	40	96	4	12	65	62	9	22	38	.1
January	14	2	0	0	....	....	....	....	2	
Total	976	1080	857	997	1187	1505	772	993	1045	
Average per month of operation	**103**	**108**	**101**	**95**	**135**	**125**	**96.5**	**110**	**109**	**3.76**

TABLE 3 (*Continued*)—CURRENT COST PER MONTH

January	....	....	....	....	....	$2.13	....	....	$0.26	....
February	....	0	0	0	....	2.23	....	....	.28	$0.07
March	0	$0.42	0	$1.96	0	2.70	....	0	.63	.07
April	$2.10	1.26	0	5.25	$0.66	3.99	0	$0.68	1.74	.16
May	3.29	5.25	$8.06	5.18	4.12	4.03	$3.23	4.28	4.68	.20
June	4.90	7.35	8.06	8.47	4.97	5.28	4.82	6.15	6.25	.28
July	11.20	12.81	9.58	10.64	5.16	5.75	6.32	7.73	8.65	.32
August	14.00	11.69	11.06	13.02	6.54	6.51	7.06	8.68	9.82	.27
September	12.18	11.76	9.87	10.99	5.15	5.12	10.47	7.28	9.10	.22
October	10.29	10.15	7.42	8.12	4.68	4.15	1.50	5.69	6.50	.16
November	6.58	8.05	5.67	5.32	3.99	3.42	1.32	3.69	4.75	.07
December	2.80	6.72	.27	.84	2.04	1.95	.41	1.00	2.00	.02
January	.98	.14	0	0	....	....	....	....	.14	
Total	$68.32	$75.60	$59.99	$69.79	$37.31	$47.26	$35.13	$45.18	$54.80	
Average cost per month of operation	**$7.21**	**$7.56**	**$7.07**	**$6.65**	**$4.26**	**$3.94**	**$4.39**	**$5.14**	**$5.79**	**.19**

by early or late springs and falls as well as by the duration of hot weather in midsummer.

Farm No. 2. Figure 3 contrasts the current consumption with natural outside temperatures for the years 1924, 1925, and 1926 on Farm No. 2. (Average weekly temperatures from United States Weather Bureau Station at Durham, New Hampshire, 32 miles northeast of farm, April 2nd to June 7th. Readings from June 7th to November 11th were taken with a local thermometer.) Near the middle of March of each year it will be noticed that the temperature curve is rising to between 40° and 45° and refrigeration becomes necessary. Anticipating this the machines are started some time in advance. About June first the warm weather starts, with maximums occuring in July or possibly August. The current consumption curve rises in the same manner but reaches its peak in July with the bulk of the high, maintained load from June 1st to September 1st.

As soon as fall temperatures start to drop noticeably in September and October, the current consumption shows the same tendency to decline. When natural temperatures less than the 40°-45° point are assured, the current is shut off.

It will be noticed that the kilowatt-hour curves for 1924 and 1925 (Fig. 4) come to pronounced peaks, indicating some maximum condition. While hot summer weather appeared responsible for this, it seemed that the peaks were somewhat more pronounced than necessary. A careful inspection of the room disclosed a number of through leaks in the cork insulation due to carelessly made joints or other inattention to this very important part of the construction work. These were chinked in, and several layers of fibrous insulating board applied over thin or weak sections of the wall and floor. The refrigerator door, built by a local carpenter, which had been assumed to be insulated in some way, was torn open and found to contain only an air space and a piece of building paper. This was filled with many layers of the same insulating wall board. Cracks around the door

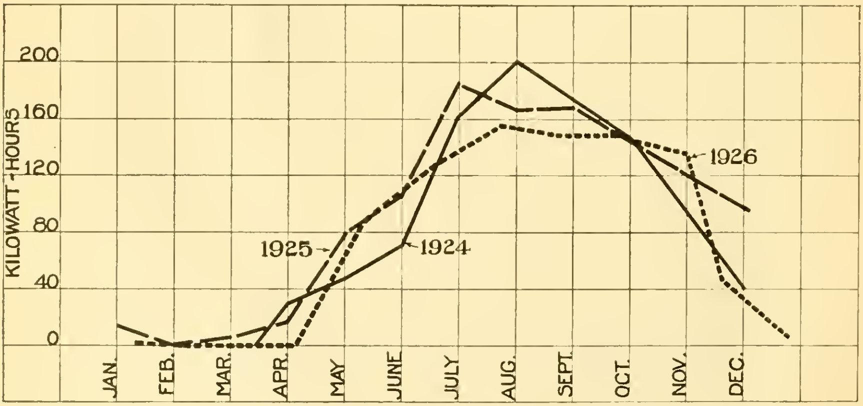

Fig. 4. Kwhr. curves for three years on Farm No. 2 show how consumption varies with yearly differences and how it can be lowered by proper insulation (see 1926 curve).

jambs were sealed with overlaps to prevent further leaks. The floor and lower half of the walls were then covered with heavy gauge galvanized iron to take the wear and make an easily cleaned surface.

The effect of this improvement in insulation is clearly evident in the curve for 1926 (Fig. 4). The sharp peaks of 1924 and 1925, caused by heavy leakage, disappear to be replaced by a nearly smooth curve showing much better operating characteristics. It will also be noticed that the curve stays well under the 160 kwh. mark, showing a decided saving in current over 1924 and 1925. That the equipment was not favored by mild weather is evident from comparison of the temperature curves for the three years. In fact a week of very warm weather which made an average reading of nearly 90°, the like of which did not occur in 1924 or 1925, placed only a slight additional load on the equipment (See high point in 1926 curve.)

Inside temperature readings for the room are not available for 1924 and 1925 and only a limited number for 1926. The operator states, however, that in the first two years he believes the temperature ordinarily was about 45°, running up to nearly 50° on hot days. Inside temperatures for 1926 were lower by two or three degrees without a change in the thermostat control for average days, and 47° was the highest recorded for the hot spell in July.

The total expense in improving the insulation was about $15 for material, spare time labor not included. Comparing the current consumption for 1925 and 1926 (length of time of operation being about the same) a saving of $15.61 occurred in 1926 which may possibly be credited to the improvement of the insulation. It would seem safe to say that two years of operation will pay for stopping the leaks. In addition lower temperatures are more easily maintained in the room, especially in hot weather when most needed.

The current used by the dairy cold storage was 47.2% of the total farm current consumption in 1925 and 37.4% in 1926. This is on a farm where no large size heating devices are used. (For rates here used and farm equipment see University of New Hampshire Experiment Station Bulletin 228, "Electricity on New England Farms.")

Farm No. 4. On this farm year-round operation is favored because it is felt that the cost of operating in the cold months is easily paid for in milk and cream saved from damage by the uncertainties of natural temperatures. The 135 kwhs. for 1926 is the average of 8¾ months and is, therefore, higher per month though the total for the year is less than in 1927. On a basis of twelve months' operation the amount per month drops to 125 kwhs. with a total for the year of 1505 kwhs. The corresponding costs are $4.26 and $3.94. A graphic record of the 1926 run is shown in Figs. 7 to 13.

The current consumed by the cold storage represents 18.8% of the total farm consumption in 1926, which increases to 27.5% in 1927 due to the twelve months' use of the equipment.

Farm No. 1. The most favorable operating conditions of any of the three farms are found here and consequently the least number of months of operation as well as the lowest total current consumption. The values given in Table 3 appear graphically in Figure 5.

The current consumed by this cold storage represents 11.1% of the

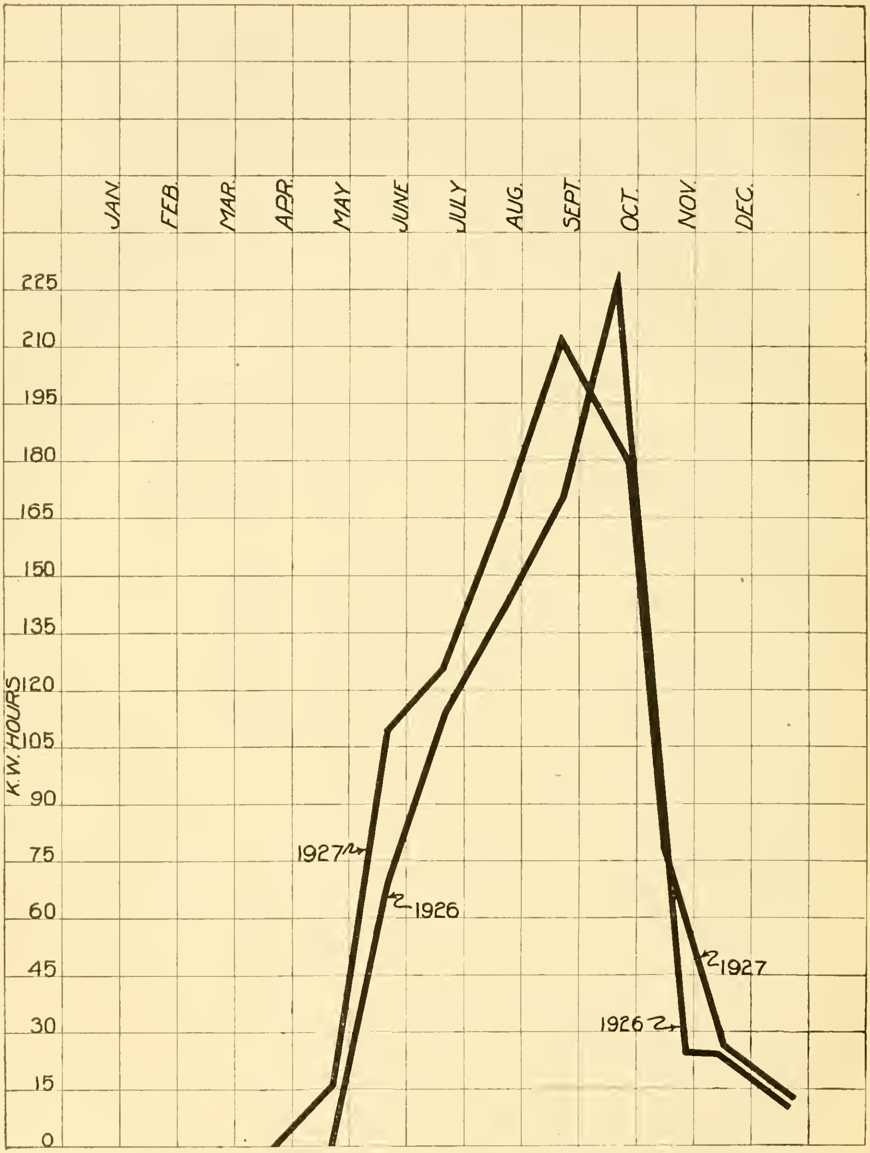

FIG. 5. The electric load of the dairy cold storage on Farm No. 1 for 1926 and 1927. This is the most concentrated load of any of the three farms being entirely confined to the 9 months period between April and December whereas in the other cases the load is extended over nearly the whole year. The bulk of the load is here, built up sharply and quickly between May 1st and Nov. 1st. If the difficulties mentioned were remedied the very sharp peaks would probably be rounded out a little more smoothly.

total farm load in 1926; while more current was used for this purpose in 1927, the percent drops slightly to 10.3% due to the increase in the total used.

Total Annual Costs. The current consumption, cost of electricity and annual total cost including the annual fixed charges, are given in Table 4.

TABLE 4—*Current Consumption, Operating and Annual Total Costs*

	FARM NO. 2			FARM NO. 4			FARM NO. 1		
	Kw. hours	Cost at 7c. a kwh.	Annual total cost	Kw. hours	Cost at $3\frac{1}{7}$¢ a kwh.	Annual total cost	Kw. hours	Cost at .0455c. a kwh.	Annual total cost
1924	976	$68.32	$128.07	......	....	....	......	....	....
1925	1080	75.60	135.35	......	....	....	......	....	....
1926	857	59.99	119.74	1187	$37.31	$112.50	772	$35.13	$106.71
1927	997	69.79	129.54	1505	47.26	122.45	993	45.18	116.76
Aver.	**978**	**68.46**	**127.72**	**1346**	**42.29**	**117.07**	**888**	**40.16**	**110.21**

EFFICIENCY OF OPERATION

Temperature Readings. Table 5 gives the average temperatures and their difference for each month in the cold room and for the outside air. Complete temperature readings were not attempted except on Farm No. 4 but were made for short periods through the year. While these partial readings are not conclusive, they give indications of what the quality of operation has been. Maximum and minimum readings are also given.

A test of temperature on a particularly hot day in 1927 on Farm No. 2 showed the following: in the sun—102-104°; in the shade 90°; barn walls 80½°; cold storage room, midpoint in its height 50°. Lower temperatures were maintained in 1927 than for previous years due to the improved insulation.

The advantageous location of the room in the basement on Farm No. 1 is to a certain extent counteracted by the warm steam-laden atmosphere every morning in the adjoining dairy room, and the uninsulated concrete floor in the room itself which is the cause of continual loss of cold as well as the admission of soil moisture. That the equipment has had to contend with moist air has been evident from the frequent necessity of defrosting the brine tank—as often as every twelve days. This points out the importance of locating the equipment at a point which has good dry air conditions. Possibly no other factor reduces the efficiency so much as frequent and heavy coatings of frost on the tank which result from moist surrounding air.

A test of temperature conditions around this storage was made on a day when the outdoor temperature was 97° in the shade. In the dairy room, while bottles were being washed, it was 86°. After the washing was over, it dropped to 74°. In an adjoining cellar room it was 72°.

TABLE 5—*Differences Between Temperatures Inside and Outside of Cold Room*

MONTH 1926	AVERAGE COLD ROOM TEMPERATURE			AVERAGE OUTSIDE TEMPERATURE		AVERAGE DIFFERENCE OUTSIDE AND INSIDE			DATES OR NUMBER OF DAYS' READINGS		
	Farm No. 2	Farm No. 4	Farm No. 1	Farms No. 2&4*	Farm No. 1	Farm No. 2	Farm No. 4	Farm No. 1	Farm No. 2	Farm No. 4	Farm No. 1
April	..	34.0°	(1927) 42°	40.2°	(1927) 54°	..	6.2°	(1927) 12°	Dates	Complete period April 2 to November 11	Days 4
May	..	40.2°	39°	53.0°	50°	..	12.8°	11°	..		28
June	44°	44.8°	41°	65.0°	62°	21°	20.2°	21°	17 to 31		12
July	45°	46.6°	45°	70.4°	66°	25.4°	23.8°	21°	1 to 31		21
August	4[illegible]	46.1°	44°	69.5°	74°	25.5°	23.1°	30°	1 to 19		1
September	..	43.0°	..	63.5	..	..	20.5	..	1 to 31		..
October	43°	39.8°	(1926) 50°	54.7°	(1926) 70°	11.7°	14.9°	(1926) 20°	20 to 31		18
November	40°	39.0°	..	47.8°	..	7.8°	8.8°	..	1 to 19		..
Average all readings	**43.5°**	**42.0°**	**43.5°**	**61.6°**	**62.6°**	**18.3°**	**19.6°**	**19.1°**			..
Maximum	54°	51°	55°	93°	74°	39°	42°	30°			..
Minimum	36°	33°	32°	41°	50°	5°	8°	11°			..

* Outside temperatures were taken in the building on the outside wall of the room after June 6 on Farm No. 4. Prior to that time U. S. Weather Bureau outdoor readings are used.

The cold storage temperature was 44°. The temperature of the air going to the cooling coils of the compressor was 74° and that leaving it was 84°.

The high cold room temperature reading shown in the table generally occured just after defrosting and dropped quickly as soon as the current was again turned on.

To obtain some idea of the effect of the uninsulated concrete floor, the soil just adjoining (one foot away from floor) was tested and found to be 60° four inches below the top of the bricks and 58° eight inches below the surface. Eight feet away from the room similar test showed 62° and 60°. This indicates the continual warfare between the machine and the floor—one attempting to hold the storage at 44° and the other presenting an opposing temperature of about 60°. Inasmuch as the coldest air in the storage falls to the floor, this is the most important surface to properly insulate. A concrete floor has no insulating qualities alone and transmits moisture very rapidly. These difficulties can be overcome by insulating underneath the concrete. The best practice is to double the amount of insulation that is required in the wall surfaces.

Time of Operation of Machine. Due to the system of automatic control, the times of day that machines operate were not obtained; but observation indicates that it is largely daylight operation on all three farms.

The percent of the total time that the motor equipment has operated

FIG. 6. The motor driven mechanical unit that is located outside of the room and connected to the brine tank which is placed inside the storage. The same style unit is used on the three farms.

TABLE 6—*Percentage of Time of Operation*

	Farm No. 2				Farm No. 4		Farm No. 1	
	1924 Mar. 14 to Jan. 1	1925 Mar. 1 to Jan. 2	1926 Apr. 15 to Nov. 20	1927 Mar. 14 to Dec. 20	1926 Apr. 2 to Nov. 11	1927 Dec. 21 to Dec. 20	1926 Apr. 22 to Dec. 22	1927 Apr. 22 to Dec. 20
Total time of period— Days	292	308	219	321	224	365	244	245
Hours	7008	7392	5256	7704	5376	8760	5856	5880
Kwhs. of current used	976	1080	857	997	1187	1505	772	993
Hours machine has run	3050	3375	2678	3110	3036	4240	2144	2780
Percent of total elapsed time machine has run	43.5%	45.6%	51%	40.4%	56.4%	48.4%	36.6%	47%

has been computed in Table 6. No recording device was used to obtain this information exactly, but figures were based on 320 watts on Farm No. 2, 355 on Farm No. 4, and 360 watts on Farm No. 1.

On the average refrigeration was required 277 days or 6,654 hours per year. Of this total the time that the equipment was actually operating was 3,052 hours or 46.1%. An average of 1,032 kilowatt-hours was used each year.

The results on Farm No. 4, which has the largest room, indicate that the equipment has adequate capacity for this type of work and is operating on an almost ideal time schedule. An even better percentage of operation occurs in the case of the other farms where smaller rooms are in use.

The advantage given the refrigeration equipment on Farm No. 1 from being placed in the basement is evident. In spite of the moist air and floor conditions already mentioned, the equipment was operated the least number of days, consumed the smallest amount of current and shows the lowest factor in the percent of time of operation of any of the three farms. It would appear, therefore, that a great advantage may be secured by location in a naturally cool place, and this equipment should show even better results when the difficulties already mentioned are corrected. Not every farm of course could advantageously locate the cold storage in a basement without unduly increasing the labor of handling the milk.

Temperature Difference Factors. Table 7 shows the kilowatt hours per cubic foot of room capacity per hour necessary to reduce the room

TABLE 7—*Current Found Necessary to Reduce Temperature One Degree*

	Kilowatt Hours Per Cu. Ft. Per Hour Per Degree Difference in Temperature		
	Year	Total contents	Storage contents
Farm No. 2	1924	.000044	.000049
	1925	.000045	.000051
	1926	.000051	.000056
	1927	.000045	.000051
Farm No. 4	1926 Apr. 2, to Nov. 11	.000045	.000051
	Apr. 2, 1926 to Apr. 20, 1927	.000040	.000042
	Apr. 2, 1926 to Dec. 20, 1927	.000042	.000047
Farm No. 1	1926	.000037	.000041
	1927	.000044	.000049
Average of three farms:		.0000436	.0000485

temperature by one degree over the outside air temperature.

The average difference between outside and inside temperatures was found to be approximately 18° in 1926 on Farm No. 2; 20° on Farm No. 4 and 19° on Farm No. 1.

Current Consumption per 100 qts. of Milk and per Cow. The current consumption per 100 quarts of milk is figured in Table 8 on the total estimated milk produced in twelve months, and on the milk handled during the period that artificial refrigeration was necessary.

Accurate records of the quantity of milk placed in cold storage were not attempted on Farm No. 2, and the daily average quantity of 300 quarts has been used. The milk route takes an average of 280 quarts per day, and 20 quarts extra was carried for emergencies. All of this 300 quarts is carried in cold storage, the greater part for 20 hours and the rest for 12 hours. The delivery truck leaves at 4:00 A. M. so that morning's milk (milked at 5:30 A. M.) must be held over. On this basis the farm handles at least 110,000 quarts of milk a year.

Likewise no record of the variations in the number of cows milked from day to day has been kept, and the milking herd as a whole has been considered. Inasmuch as this farm keeps the milking string up by buying fresh cows, rather than raising young stock, this figure should be reasonably accurate.

TABLE 8—*Operating Costs for Refrigeration*

	Per 100 Qts. of Milk Per Day for				Per Cow	
	The Entire Year		The No. of Days Machine Was Run			
Electric Refrigeration	Kwhs.	Cost	Kwhs.	Cost	Kwhs.	Cost
FARM NO. 2 1924	.892	$.062	1.11	$.077	27.1	$1.90
1925	.984	.068	1.17	.082	30.0	2.10
1926	.784	.055	1.09	.076	23.8	1.67
1927	.911	.064	1.04	.072	27.7	1.94
Average	**.882**	**.062**	**1.10**	**.077**	**27.2**	**1.90**
FARM NO. 4 1926	1.35	.042	1.88	.059	29.7	.935
1927	1.76	.056	1.76	.056	37.6	1.18
Average	**1.55**	**.049**	**1.82**	**.058**	**33.7**	**1.06**
FARM NO. 1 1926	1.41	.064	2.11	.096	21.4	.97
1927	1.81	.083	2.70	.123	27.6	1.25
Average	**1.61**	**.073**	**2.41**	**.11**	**24.5**	**1.11**

Two hundred and forty quarts is the average daily amount of milk stored on Farm No. 4 or 87,600 quarts per year; and, as stated before, 40 cows are considered to produce the total milk handled. Part of the morning's milk is precooled, bottled and delivered without going into storage, and the total milk handled is about 300 quarts per day. Only the quarts of milk stored are considered. The figures include the cost of refrigeration for the household, as this is a combination cold storage for dairy and house, and the actual cost per 100 quarts of milk and per cow would be less if used for the dairy only.

The figures for 1926 represent 9 months' operation. The comparatively low cost for current on Farm No. 4 is due largely to the favorable rate. (See Table 4 and New Hampshire Experiment Station Bulletin 228.)

The figures for 1927 on this farm show the increase in current used when twelve months operation is carried on. This particular farm is inclined to operate on a twelve months basis at present.

While Farm No. 1 handles about 300 quarts of milk and cream per day, only about 150 quarts are placed in the storage. Morning's milk is precooled, bottled and delivered without having reached the storage.

The results shown in the table resemble those obtained for Farm No. 4, both of which are less than for Farm No. 2, where about 300 quarts per day were stored. The cost per quart decreases with the number of quarts stored which would appear to substantiate the belief that if properly precooled the amount of milk placed in storage does not affect the current consumption greatly.

Test of Current Requirements. Four operating conditions were included in a test of the current requirements of the equipment in the fall of 1927. The results are given in Table 9.

Line voltage, gas pressures and temperatures were taken before starting. At the instant of starting the motor, the highest readings reached were taken to secure the maximum starting demand. No account was made of the damping effect of the meter. After the equipment had settled to a steady pace readings for average running conditions were taken, and just before the thermostat threw off the current, another set to note any increase in demand as the gas pressures changed.

From the above test it appears that the motor on Farm No. 2 is drawing 2.4 amperes which is less than its maximum capacity and insures cool running.

The motors on Farms No. 4 and No. 1, however, are continuously drawing .75 and .9 amperes over their rating with the result that they heat slightly, indicating that 1/3 H.P. motors should be used.

The higher of the two cold storage temperatures on Farm No. 4 is taken at a midpoint in the height of the room, and the lower one at a point 2 inches from the floor.

The figures for outside air in the case of Farm No. 1 are for the dairy room into which the cold storage opens.

Operating Characteristics of a Cold Room. Figures 7 to 13 give graphically the 1926 season's run of refrigerator equipment on Farm No. 4. They are based on readings taken three times each day, 4 A. M., 12 noon and 6 P. M. The complete data, which are too bulky to

TABLE 9—*Test of Current Requirements*

Conditions	Volts	Amperes	Watts	Gas Pressure		Temperatures	
				Low Side	Back Pressure	Cold Storage	Outside Air
FARM NO. 2 (⅓ h. p. motor) Before starting......	213	....	......	60 lbs.	14 lbs.	41°	54°
Starting............	213	5	1000	65 lbs.	10 lbs.	41°	54°
Running...........	211	2.4	320	75 lbs.	7 lbs.	41°	54°
Near end of run.....	211	2.4	320	85 lbs.	6 lbs.	41°	54°
FARM NO. 4 (¼ h. p. motor) Before starting......	117	....	......	70 lbs.	10 lbs.	46°–44°	70°
Starting............	112	10.2	1340	80 lbs.	8 lbs.	46°–44°	70°
Running...........	115½	4.75	350	90 lbs.	4 lbs.	46°–44°	70°
Near end of run.....	119	4.95	360	105 lbs.	4 lbs.	46°–44°	70°
FARM NO. 1 (¼ h. p. motor) Before starting......	118	....	......	57 lbs.	9 lbs.	36°	56°–53°
Starting............	113	10	1240	60 lbs.	7 lbs.	36°	56°–53°
Running...........	115	5.3	360	72 lbs.	3 lbs.	36°	56°–53°
Near end of run.....	114	5.2	365	74 lbs.	3 lbs.	36°	56°–53°

present here, are available to those who may have use for it, upon request.

The object in obtaining these data was to secure, as nearly as possible, a complete, practical record of the operating characteristics of a standard cold room of the dry air type. Much credit is due the co-operating farmer for the diligence and care in making the readings. Data on four principal factors were obtained; namely (1) outside air temperature; (2) cold room interior temperature, taken at a mid-point in its height; (3) current consumption in kilowatt-hours; and (4) the quarts of milk and cream stored. The average temperature referred to in the chart is the average of the day's readings.

On account of practical difficulties in making the observations, no data were taken on the moisture content of the air which also has an importance in the results obtained.

April. The equipment was installed and placed in operation the first of April, 1926, as indicated in the curves for that month. Up to the twentieth of the month the outside temperature was quite variable, ranging from 25° to 47°. During the same period the cold room or refrigerator temperature remained between 30° and 35° after the first two days required to cool off the equipment. Current consumption records were started on the 22nd, the day after which the outside temperature rose to above 60° and the room temperature went up to 42°—a difference of 18°. An average of somewhat less than 4 kilowatts of electricity was needed daily at the end of the month. The average room temperature for the month was 34° and that of the outside air 40.2°—a difference of 6.2°.

May. Outside temperatures on the 3rd went up to above 70°, and the cold room to 47°. Room temperatures for the month averaged 40° and outside temperatures 53°. Current consumption increased slightly near the end of the month as the coating of frost became thicker on the brine tank, but did not exceed 6 kwhs. a day. Slightly more than 4 kwhs. a day was the average for the first of the month.

June. Cool weather the first week of June, when the temperature

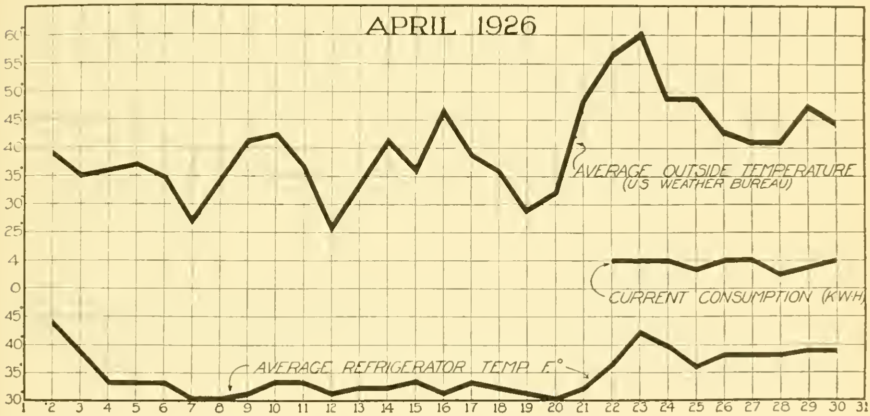

FIG. 7.

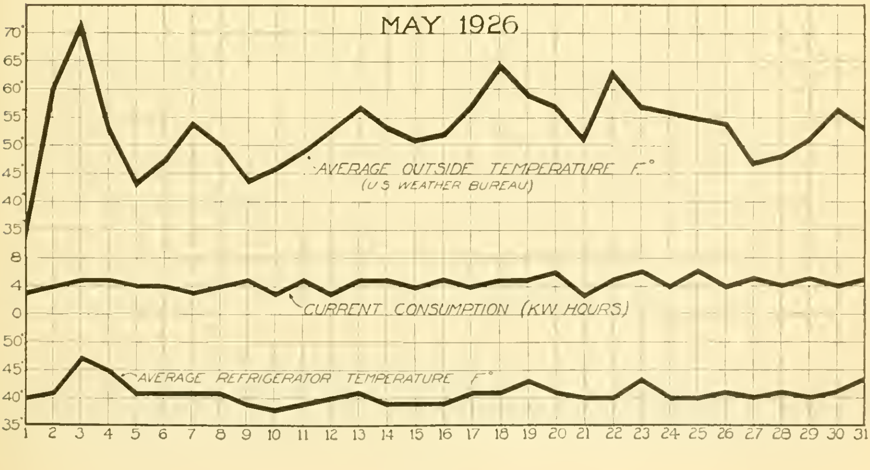

FIG. 8.

dropped to 47°, was followed by warmer weather with an average of 65°. The tank was defrosted on the 7th, when milk records were started, and the day following a large quantity of milk was stored. The average room temperature of 44° increased with the outside temperature and milk load to 47°. The room maintained an average tem-

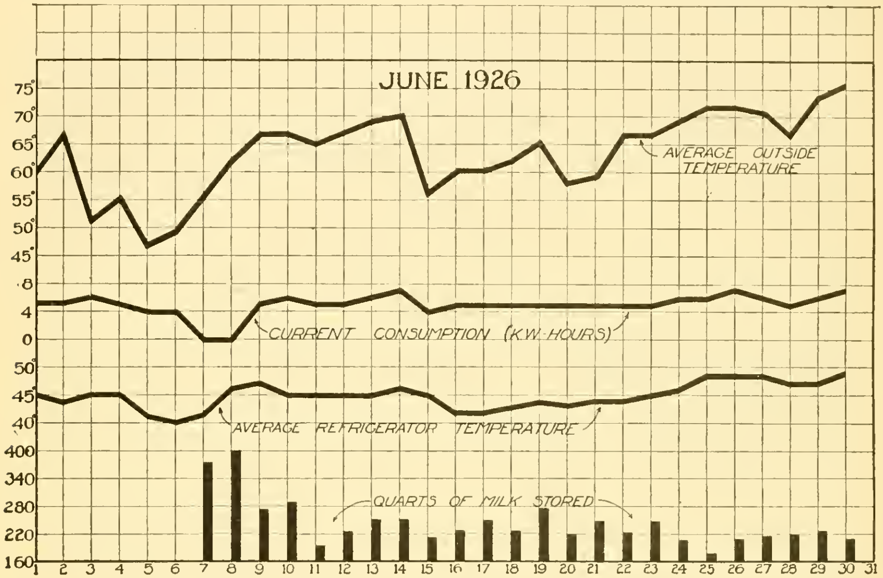

FIG. 9.

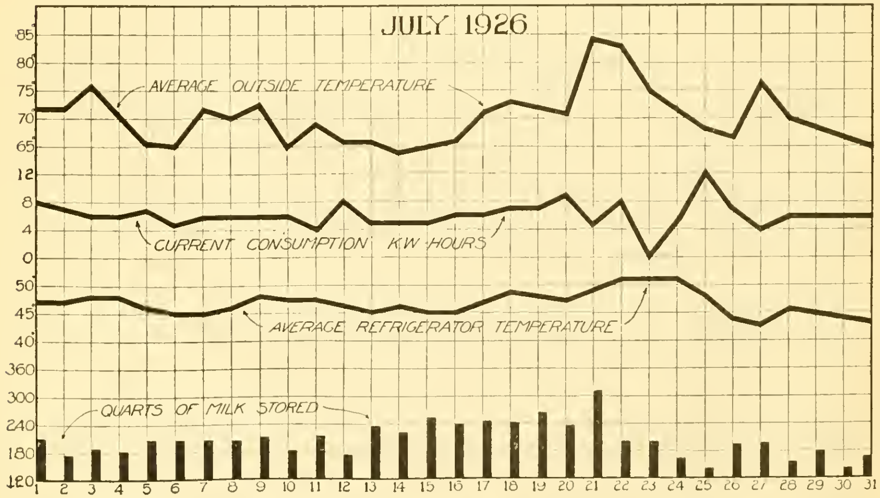

FIG. 10.

perature 20° lower than the outside air for the month, an average of about 5 kilowatt hours was used per day. The average milk load was not high and being well precooled did not influence the temperature and current consumption as much as did the outside temperature.

July. The outside temperature averaged 70°. With a moderate load of milk the room temperature averaged 47°. Warm weather on the 21st and 22nd, coupled with the defrosting of the tank on the 23rd, pulled the room temperature up over 50°. The current consumption to bring this back reached the high point of 12 kilowatts, or twice the average.

August. The ten degree rise to 80°—10° higher than the average for the month—caused a five degree rise in the cold room temperature and

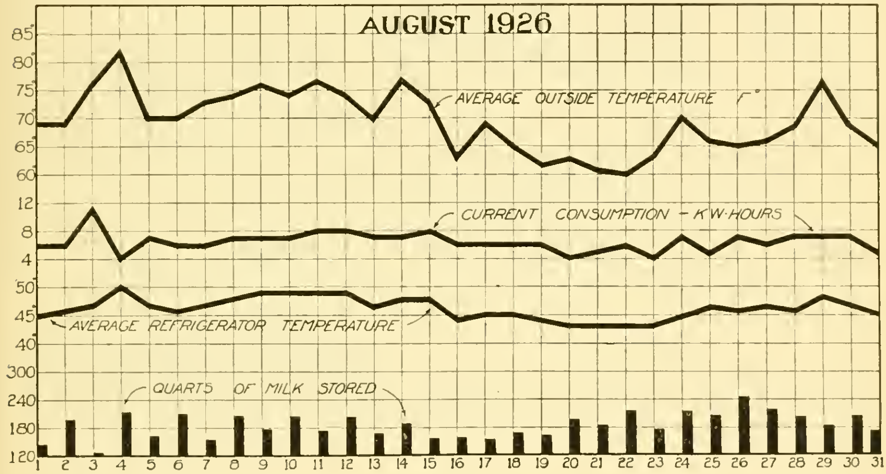

FIG. 11.

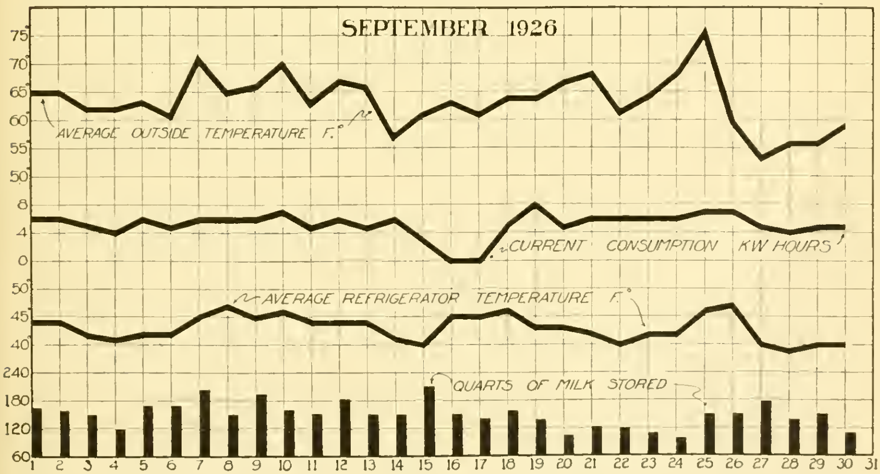

FIG. 12.

an increase in current consumption from the average of 7, to 11 kilowatt-hours a day. Current consumption stood at approximately 7 kilowatt-hours per day. An average room temperature of 46° was maintained.

September. Outside temperature averaged 64° for the month. The second and fourth week over 70° was registered. The cold room temperature averaged 43° dropping as low as 40° or less. Current consumption averaged about 6 kwhs. per day. The brine tank was again defrosted on the 16th.

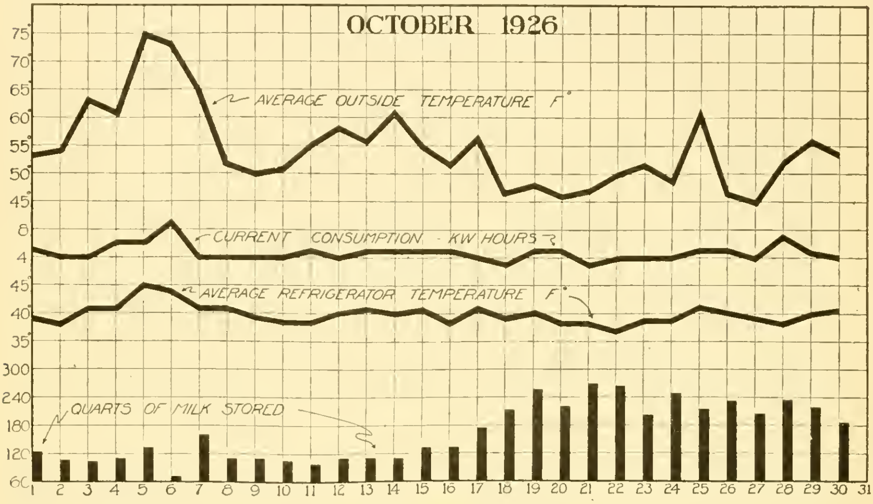

FIG. 13.

October. October started with a week of warm weather when 75° was registered but the average for the month was 55°. Cold room temperatures averaged 40°. The current consumption remained at approximately 4 kwhs. a day. The milk load the first half of the month was quite low but increased to a good size the last half.

November. Sometime in November outside temperatures reach the freezing point or lower, so that they may be utilized for holding the dairy products until delivery. This may involve some risk, however, unless care is taken that the milk and cream are not carried to the other extreme and frozen. In some cases intermittent operation of the refrigeration equipment may be carried on through the winter. The location of the cold room and the quality of its insulation will determine whether this is practical. A well constructed cold room will as effectively keep excessive cold out in the winter as it will keep cold in in the summer and therefore provides a very safe storage for the dairy products in cold weather, avoiding the necessity of carrying the milk and cream to a slightly heated location to protect it from frost.

The equipment was operated eleven days in November using about 5 kwhs. a day, maintaining 40° inside against 48° outside. The weather then turned cool and the machine was stopped. Intermittent operation was practiced through the winter.

COST OF REFRIGERATION USING NATURAL ICE

On all three of these farms fairly definite estimates were obtainable of the costs of natural ice refrigeration previous to the installation of electric equipment. Values commonly used on the farm are attached to the various operations to obtain a cost comparison of the two methods.

Allowances of 20% of the total tonnage of ice stored on Farms No. 2 and 4 and 12% on Farm No. 1 are deducted for household use or precooling milk.

Depreciation and upkeep on ice houses were estimated by the farmers at six to seven per cent on the basis of 14 to 16 year life. While the depreciation of cooling rooms, chilled with ice, is uncertain and governed by drainage and moisture conditions, 20 years is assumed on each farm to be the average useful life.

Two ice houses were built on Farm No. 2. The first was built by home labor and the second by contract.

The initial investment, interest and depreciation charges for ice refrigeration on the three farms are given in Table 10.

TABLE 10—*Initial Investment and Fixed Charges for Ice Refrigeration*

	FARM NO. 2		FARM NO. 4	FARM NO. 1
	Min.	*Max.*		
Ice house or storage	$350	$600	$50†	$250†
Dairy cold storage room	75	75	75	125
Ice pond	100	100	....	....
Ice tools, etc.	....	....	10	10
Total	$525	$775	$135	$385
Average of three farms ... $455				
Ice house—				
Interest on Investment	$17.50	$30.00	$2.50	$15.00
Depreciation	14.00	24.00	3.00	15.00
Upkeep	7.00*	12.00*	3.50*	5.00*
Ice tools—				
Interest	......	......	.50	.60
Cooling room—				
Interest on Investment	3.75*	3.75*	3.75	7.50
Depreciation	2.25	2.25	4.50	7.50
Upkeep	1.50	1.50	4.50*	3.75*
Ice pond—				
Interest	5.00	5.00	......	......
Upkeep	8.10	8.10	......	......
Total	$59.10	$86.60	$22.25	$54.35
Deducted for house or precooling	(1/5) 11.82	17.32	(1/5) 4.45	(1/8) 6.79
	(47.28)	(69.28)		
Total fixed charges for dairy cooling room	$58.28		$17.80	$47.56

The items starred (*) are considered cash or money-out-of-pocket expense as referred to later.
† Cost of partitioning off barn cellar or space in shed.

The stone cellar foundation was used for one side on Farm No. 4. The remaining three sides were roughly boarded up, using the supporting posts for corners. Rough boards, laid on logs, provided a floor on which the ice was placed and packed with sawdust in the usual way. Putting the ice in storage was easily accomplished by sliding it from the sled into the cellar over a chute. The labor of daily removal, however, was correspondingly increased in bringing it back up to the floor above. It is very probable that this case is representative of a minimum cost method for ice storage, from the standpoint of overhead expense.

Operating Costs for Natural Ice Refrigeration. Detailed estimates on the costs of operation with natural ice are given for each of the three farms in Table 11. The minimum values used refer to years when conditions for harvesting and storing ice made it a relatively easy task. The maximum values stand for years when considerable difficulty was experienced, due to poor weather conditions.

In the cool weather of late spring and early fall, the cooling room on Farm No. 2 required less attention, 2 loadings a week being considered as average, in midsummer 3 loadings a week, or more, were necessary. The minimum and maximum values allow for difficulties in servicing the cooling room which vary from year to year but are largely due to the condition of the ice in storage.

Seventy-two dollars ($72) additional labor was regularly hired on this farm regardless of conditions; therefore, this value alone is used for labor when considering cash or money-out-of-pocket expenses.

On Farm No. 4 the full amount of ice needed for the entire year was never put in, and it was necessary to purchase from $20 to $25 worth to finish out the season. The fact that the ice was dragged by hand from the cellar to the cooling room accounts for the absence of horse or truck labor in servicing. It is interesting to note that in one year the nearest sawdust was nearly ten miles away, which made it possible to haul but one load per day. All the ice for this farm varied from $235.55 to $291.30, but cost on an average of $263.43 per year. To this can be added about twenty dollars overhead or fixed charges. After deducting the value of the ice used for other purposes this makes a range of from $206.24 to $250.84 with an average of $228.54 for the total annual cost of maintaining and operating the cooling room with natural ice.

Although the ice storage on Farm No. 1 was located in the group of farmstead buildings, it was far enough away from the cooling room to require the use of a team or a truck. In this way the ice was brought to the same door that the milk is loaded from and accounts for the hauling charge. In this case all the ice costs varied from $170.10 to $219.50 with an average of $194.80, which is believed to be an under rather than an over estimate. After deducting the cost of ice used in the house, there is a range in expense from $196.40 to $239.63 or an average cost of $218.01 per year for the total cost of maintaining and operating the cooling room with ice.

Twenty Years Experience Using Natural Ice. Natural ice was used for refrigeration on Farm No. 2 from 1902 to 1923, and a review of this farmer's experiences shows the efforts made to develop greater ef-

TABLE 11—*Operating Costs for Natural Ice Refrigeration*

	Farm No.		
	2	4	1
Number of cakes stored	500–800	400–500	500
Cost per cake	(Owned Pond)	7c–10c	3c–5c
Total cost of ice	* (No charge)	$29.75–$42.50	$15.00–$25.00
Additional ice purchased	* 0	0	$20.00–$25.00
Hauling ice—cakes per load	......	12	22
Miles—round trip	¼	2–6	2
Days work (short day, 4-6 hrs.)	3–4	3–6	4–5
Men required	1	3–2	1
Teams required	1	3–2	1
Total man hours at 40c	17–23	68–90	32–40
Total horse hours at 20c	34–45	135–180	64–80
Charge per day—man and team	$4.50 (4+hrs.)	$6.00 (6+hrs.)	$6.40 (6+hrs.)
Total hauling cost	$13.50–$18.00	$54(⅓*)–$72(½*	$25.60–$32.00
Storing, packing, covering and cutting			
Days (6 hr.–7½ hr. & 7½ hr.)	4–5	10	4–5
Men required	5–6	1	2
Man hours	120+ to 180+	75	60–75
Total cost	$48.60–$72.60*	$30.00	$24.00–$30.00
Hauling sawdust			
Miles haul round trip	5–14	1–5	1
Loads hauled per day	1–2	2–4	6
Cost per load	$1.00	50c–$1.00	0–50c
Loads required per year	8–10	10	15
Cost of sawdust per year	$8.00–$10.00*	$5.00–$10.00	0–$7.50
Days of hauling	4–10	2–5	2–3
Men required	2	1	2
Teams required	1	1	1
Total man hours	48–120	19–38	28–34
Total horse hours	96–240	38–75	56–67
Charge per day—man and team	$4.80	$6.00	$6.00
Total sawdust costs	$46.40–$106.00	$20.00–$40.00	$22.50 (½*)–$34.50
Removing from storage, washing, cutting and loading ice bunkers			
Time required each filling—hrs.	1–1½	1–1½	¾
Number of fillings per week—(spring-fall and summer)	2–3	3–7	3–4
Total number of fillings—Apr. 15 to June 1 or 15	15	22	40
Total number of fillings—Sept. 15 to Nov. 15	15	22	43
Total number of fillings—June 1 or 15 to Sept. 15	39	107	98
Men required	2	1	2
Team or truck required	1	None	1
Cost per filling	$1.20–$1.80	$.40–$.60	$1.00
Total cost all fillings	$82.80–$124.20	$81.80	$83.00–$98.00
All ice, sawdust and labor costs	$191.30–$320.80	$235.55–$291.30	$170.10–219.50
Av. ice sawdust and labor costs	$256.05	$263.43	$194.80
Deducted for ice used in house or precooling milk–(⅕–⅕ and ⅛)	$38.26–$64.16	$47.11–$58.26	$21.26–27.43
Annual operating costs for cooling room	$153.04–256.64	$188.44–$233.04	$148.84–192.07
Annual fixed charges	$47.28–69.28	$17.80	$47.56
Total annual costs, cooling room	$200.32–325.92	$206.24–$250.84	$196.40–239.63
Av. an. total cost, cooling room	$263.12	$228.54	$218.01

* Cash or money-out-of-pocket expense.

ficiency and gives a picture of what the ice method involves. It is here given in the owner's expressive, though sketchy phrases, as taken down in note form.

"1902—Bought ice of company in nearby city for dairy cooler at cost of $100 to $130 a year. Ice company finally refused to go out of city limits to deliver.

"1903—Cut ice in river, ¾ to 1 mile away. Too much work and took too long—one and one-half weeks. Cutting was hired out. Ice hauled on wheels or sleds.

"1905—Got tired of hauling. Looked over meadow and saw that it was possible to dam it. Made plank and dirt dam 40 to 50 feet long. Took several years to get it fixed right. Stopped leaking after a while. Quite a bit of trouble keeping dam tight—repairs yearly—1½ acres flooded—4 feet deep. Quality of ice, good, bad and indifferent, but generally fairly clear.

"First ice-house built in 1903 or 1904 cost at least $200, rotted out in about 1917. Built in back of barns. Two air spaces, three walls, lot of trouble in building it. Second ice-house built at pond one-eighth mile from house in 1917 cost over $600. Put up tons of ice that never were used but had to haul only what was actually wanted. With the first house near the barn we hauled a lot of ice that just melted in storage. (Nearly twice the quantity of ice that will actually be required must be put in storage to allow for shrinkage.) Job required $75. for extra help, besides owner and two sons. Twenty inch ice had to be put in with power, thinner ice with pike poles. A week or a little more was required to put in 500 to 800 cakes measuring 18″ x 22″.

"Cooling room bunkers were filled two and three times per week using three to four hundred pounds each time and five to six hundred in hot weather, 200 pounds for house each time. Two men and horses or truck needed 1½ to 2 hours, washing off, cutting and putting it in bunker—mashed toes, jammed fingers and some cuss words.

"Sawdust quite a problem. Haul varied from one to five miles to nearest sawmill. Never less than $1.00 a load. Used 8 to 10 loads a year. Not much depreciation on cooling room from moisture, drained water off in good shape.

"Pretty poor refrigeration—up and down temperature. Temperature ran up while loading bunkers and seemed to take a lot of fresh ice to bring it back. Small left-over pieces were taken out, large fresh cakes put in, small pieces packed around. Two or three loads of hay to get in, cooler runs out of ice—let cooler go—sour milk on route next day—customers dissatisfied, etc. Quite a lot of trouble and loss by milk spoiling. Additional quality of milk and cream nearly pays for current. Wouldn't go back to ice even if it cost a lot more for electricity."

Comparison of Initial Investment. The initial investments required for the two methods are given in Table 12.

Inasmuch as the rental basis on Farm No. 2 is no longer offered by the manufacturer the usual purchase prices are best considered.

A low-priced ice house and home pond, the most expensive ice equipment, may still reduce the investment below the electric method. By

TABLE 12—*Initial Investments for Ice and Electric Refrigeration*

	Natural Ice Refrigeration		Electric Refrigeration	
	Minimum	Maximum	Rental	Purchase
Farm No. 2				
Ice House	$350.00	$600.00	......	......
Ice Pond	100.00	100.00	......	......
Cooling Room	75.00	75.00	$125.00	$125.00
Refrigeration Unit	......	......	225.00	510.80
Total Investment	$525.00	$775.00	$350.00	$635.80
Average	**$650.00**		......	......
Farm No. 4	$135.00		......	$766.50
Farm No. 1	385.00		......	705.25
Average of three farms	**$390.00**		......	**$702.52**

eliminating the ice pond this could be made still less but with a corresponding increase in yearly labor costs for hauling from some river or lake. Depending on the source of the ice, above comparison shows that the electric method may require a range in initial investment from equality with that required for ice, to as much as 466% greater outlay. Assuming a well built ice house the balance can be thrown in favor of electric operation. In such a case as Farm No. 2 it will be seen that the investment of $600.00 in an ice house would nearly equip a farm with electric refrigeration such as described.

It is obvious that with careful planning and manipulation the investment for using natural ice, which has considerable flexibility, could be reduced a great deal as compared to such a farm as No. 2 and especially from the standpoint of cash outlay. Without much doubt operating expenses would increase in such a case. Turning to the investment for electric operation it is apparent that this is a fixed quantity which there is little or no possibility of reducing, that it is quite sizable in amount and may require cash, although the installment payment plan is usually available.

However, when operating costs, quality and results of electric refrigeration are considered the matter appears in quite a different light.

TABLE 13—*Comparison of Costs of Ice and Electric Refrigeration*

	Natural Ice Refrigeration			Electric Refrigeration					
	Farm No. 2	Farm No. 4	Farm No. 1	Farm No. 2	% of ice costs	Farm No. 4	% of ice costs	Farm No. 1	% of ice costs
Fixed Charges:									
Maximum	$69.28	......	......	......	...	......	...	......	...
Minimum	47.28	......	......	......	...	......	...	......	...
Average	**$58.28**	**$17.80**	**$47.56**	**$59.75**	**102**	**$75.19**	**422**	**$71.58**	**150**
Operating Costs:									
Maximum	$256.64	$233.04	$192.07	$75.60	29	$47.26	20	$45.18	24
Minimum	153.04	188.44	148.84	59.99	39	37.31	24	35.13	24
Average	**204.84**	**210.74**	**170.45**	**68.46**	**33**	**42.29**	**20**	**40.16**	**24**
Annual Cash or money-out-of-pocket cost:									
Maximum	$106.20	$97.20	$44.19	$111.85	108	$84.55	87	$80.44	180
Minimum	90.60	64.60	30.63	96.24	106	74.60	115	70.39	230
Average	**98.40**	**80.90**	**37.41**	**104.72**	**107**	**79.58**	**98**	**75.42**	**200**
Total annual costs:									
Maximum	$325.92	$250.84	$239.63	$135.35	42	$122.45	49	$116.76	49
Minimum	200.32	206.24	196.40	119.74	60	112.50	57	106.71	54
Average	**263.12**	**228.54**	**218.01**	**128.21**	**48**	**117.48**	**51**	**111.73**	**52**

COMPARISON OF NATURAL ICE AND ELECTRIC REFRIGERATION COSTS

To compare these two methods on a cost basis the expenses are considered in four groups:—fixed charges, operating costs, cash or money-out-of-pocket costs and total annual costs.

To obtain a comparison all operations are given a value in Table 13, including interest, depreciation and upkeep. As many farmers are more concerned and interested in the cash or money-out-of-pocket expenses of operation, these are given separately. An original investment, in this case, is considered as if paid on an installment basis.

The percent of fixed charges of the electric method over the ice does not clearly indicate the situation, since the amount of money involved is relatively small. The range of difference in cost of the two practices is from $1.47 to $57.39, with $75.19 the greatest amount that is involved. In other words the percentage differences are great—as high as 422%—but the actual money represented is not of outstanding importance.

This is not the situation with regard to *operating costs* which are consistently and markedly higher for the ice method. Here a more appreciable amount of money is involved, the maximum being $256.64. The saving that the electric method may effect varies from $93.05 to as much as $185.78.

Considering these two groups together, it might be said that with comparatively little fluctuation in the fixed and operating costs for the electric method, the operating costs for the ice method may be increased from three to eleven times the fixed charges for ice refrigeration.

The annual cash or money-out-of-pocket expense for the electric type varies from 87% to 230% of the ice method with an average of 137%. However, as it is relatively easy to arrive at quite accurate values for the electric method, the possibility of error in values on the ice method is much greater and might vary the estimate here given. It would, therefore, appear safe to state that while these expenses are approximately the same for either method, judging from Farms 2 and 4, on the other hand, under favorable operating conditions, such as on Farm No. 1, the cash expense could be made distinctly in favor of ice.

The total annual costs, which summarize all costs including those already considered, show that the electric method ranged from 42% to 60% of ice refrigeration, the average being 50%.

The above indicates that, from a general standpoint, operation by electricity, neglecting the superior qualities of mechanical refrigeration, was more practical and economical on these farms than with ice, and by a considerable margin.

One owner's view is, briefly, "I wouldn't be without it."

Another states that the worst part of handling ice is the trouble of getting it in the winter which he feels, on his farm, is more of a bother than the summer work of keeping the ice boxes full, although he considers this troublesome also. This indicates the labor problem which is becoming more acute on active farms and how this method helps to eliminate it. His view of the whole situation is, "If we had the ice

TABLE 14—*Summary of Total Costs for Two Methods*

	Farm No.	Natural Ice			Electric Refrigeration			Percent Greater Cost of Ice		
		Max.	Min.	**Ave.**	Max.	Min.	**Ave.**	Max.	Min.	**Ave.**
Cost per cubic foot of total contents.	2	$1.63	$1.00	**$1.31**	$0.78	$0.68	**$0.73**	109%	47%	**79%**
	4	1.21	1.00	**1.10**	.59	.54	**.56**	116%	82%	**96%**
	1	1.27	1.04	**1.15**	.60	.56	**.58**	111%	86%	**98%**
Average		**1.36**	**1.01**	**1.18**	**.66**	**.59**	**.62**	**112%**	**72%**	**91%**
Cost per cubic foot of storage Contents.	2	1.80	1.10	**1.45**	.86	.76	**.81**	109%	45%	**79%**
	4	1.36	1.12	**1.24**	.66	.61	**.63**	106%	83%	**97%**
	1	1.41	1.16	**1.28**	.67	.63	**.65**	110%	84%	**97%**
Average		**1.32**	**1.13**	**1.32**	**.73**	**.66**	**.70**	**108%**	**71%**	**91%**
Cost per 100 quarts of milk for year.	2	.30	.18	**.24**	.12	.11	**.12**	140%	109%	**94%**
	4	.29	.23	**.26**	.14	.13	**.13**	107%	77%	**100%**
	1	.44	.36	**.40**	.21	.20	**.20**	109%	80%	**100%**
Average		**.34**	**.26**	**.30**	**.16**	**.15**	**.15**	**119%**	**89%**	**98%**
Cost per 100 quarts of milk for period machine has run.	2	.42	.26	**.34**	.17	.15	**.16**	156%	73%	**112%**
	4	.40	.23	**.30**	.19	.12	**.15**	110%	83%	**100%**
	1	.97	.80	**.89**	.46	.43	**.45**	115%	86%	**97%**
Average		**.60**	**.43**	**51**	**.27**	**.23**	**.25**	**127%**	**81%**	**103%**
Cost per cow per year	2	9.05	5.56	**7.30**	3.76	3.32	**3.54**	140%	67%	**106%**
	4	6.27	5.16	**5.72**	3.04	2.81	**2.92**	106%	83%	**96%**
	1	6.66	5.46	**6.06**	3.16	2.96	**3.06**	110%	84%	**98%**
Average		**7.33**	**5.54**	**6.36**	**3.32**	**3.03**	**3.17**	**119%**	**77%**	**100%**
Total Cost	2	$325.92	$200.32	**$263.12**	$135.35	$119.74	**$127.72**	140%	67%	**106%**
	4	250.84	206.24	**228.54**	121.63	112.50	**117.07**	106%	83%	**95%**
	1	239.63	196.40	**218.01**	113.71	106.71	**110.21**	102%	84%	**98%**
Average		**$272.13**	**$234.32**	**$236.56**	**$123.56**	**$112.98**	**$118.33**	**116%**	**78%**	**100%**

given to us and delivered at our door, we could hardly handle it to the cold storage for what our daily electric cost is for the same job."

The third owner's conclusion is, "I would not consider disposing of such equipment on any grounds."

On Farm No. 1 the ice method was developed with considerably less immediate outlay than the electric, and this may be quite a factor with some farmers. If the latter is arranged for on a time payment basis, it may be a point of less consequence.

Summary. Table 14 summarizes the results of the two methods as used on a total cost basis, in units of cubic feet of storage and total contents, 100 qts. of milk for a year or the period the machine was run, and per cow per year. Maximum and minimum values are given followed by the average in bold type.

With the values used and this method of computing the results the electric method effects an economy in obtaining refrigeration, as compared to ice, of a considerable amount. From this it appears that when operating with ice the range in costs varied from 45% to 156% more than with the electric method. Ice ran from 79% to 98% with an average of 91% more cost per cu. ft. of either total or storage contents, 94% to 112% more per 100 qts. of milk averaging 98% for the year or 103% more for the time the machine was run, and 100% more per cow per year and in total expense. Results obtained will vary with different values which may be placed on farm labor by different farmers, and this is the important point in arriving at a result for any given case. With the percentages noted it would appear, however, that electric refrigeration should be practical and successful on many farms of the business-like type already referred to.

FIG. 14. A chore now eliminated where the electric dairy cold storage has been installed. An ingenious labor saving arrangement to facilitate the getting in of ice on one of the test farms before the advent of electricity.