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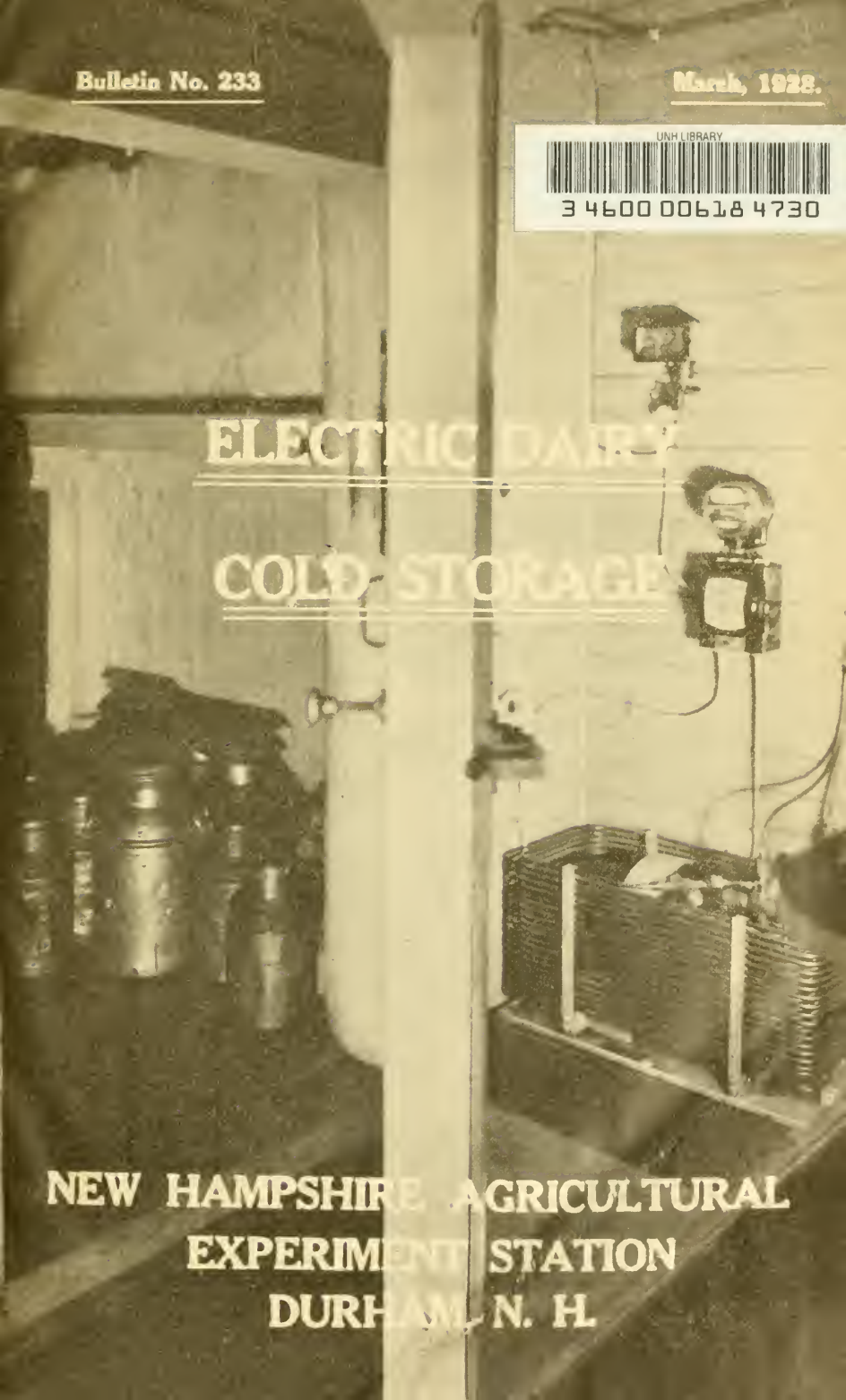

ELECTRIC DAIRY COLD STORAGE

NEW HAMPSHIRE AGRICULTURAL
EXPERIMENT STATION
DURHAM, N. H.

Bulletin No. 244 June, 1929

NEW HAMPSHIRE AGRICULTURAL
EXPERIMENT STATION

ELECTRIC HOUSEHOLD REFRIGERATION

By W. T. ACKERMAN

Fig. 1. Refrigerator on Farm No. 5

The University of New Hampshire

DURHAM, N. H.

ELECTRIC HOUSEHOLD REFRIGERATION

By W. T. ACKERMAN

The electric refrigerator proved one of the most desirable pieces of home equipment used on the experimental farms in the New England rural electrification project. Such was the conclusion reached by both the housewife and the farmer.

Seven farms cooperated in the electrification project. Six of the seven were equipped with household refrigeration units. The other farm continued to use ice. Three are retail dairy farms; two specialize in poultry; and the other, while caring for 10 head of stock as a side-line, is a fruit farm.

The six locations range from the southern boundary line of the state to Franklin, and from near the coast to a point midway on the east and west line.

No two farms were served by the same electric power company, and rates and service conditions varied accordingly. Four of the machines were installed and serviced by the local dealers who represented the manufacturer. Lacking convenient dealers to look after the equipment, two machines were installed and serviced by Boston distributors.

DESCRIPTION OF EQUIPMENT USED

Tables 1 and 2 and the following descriptions by farms describe the general working conditions. A variety of conditions were studied.

Two methods of obtaining refrigeration for foods are included:—(1) An individual refrigerator for the house, the accepted method, was used on five of the six farms. (2) A combination with the dairy cold storage, an alternate opportunity, was used on the sixth farm.

The two principal types of installations were also employed—the *self-contained complete cabinet unit* having all the equipment in one case, and the *separated unit.* In the latter, the refrigerator is placed at a point of convenience and the mechanical unit is located some distance away where it frequently works under better conditons.

The principal styles of equipment were represented, such as, (1) The modern *commercially built single cabinet unit,* (2) the *common commercially built refrigerator converted to electric operation,* and (3) the *home-made refrigerator converted to electric operation.*

CONDITIONS OF OPERATION

In four of the six cases, the same operating customs were used with the electric method as formerly were used with the ice, and in three cases the same refrigerator was used.

No attempt was made to record exactly the variations in temperatures for any extended period. All equipment was tested and set to produce refrigeration between 40°—50° F., and observations were made at intervals to determine whether the thermostats were working within these limits. Preliminary trials showed that in well insulated boxes considerably lower temperatures could be secured. In two cases with

TABLE I.—*Refrigerator Specifications.*

Farm	No. 1	No. 2	No. 4	No. 5	No. 6	No. 7
Family—Adults	3	3–4	3	3	3	5
Children	2	0	2	0	2	1
Type of Equipment	Self contained cabinet	Separated units	Combination	Separated units	Separated units	Self contained cabinet
Food storage space in cubic feet	5.5	30	9	8	6.2	9
Entire contents in cubic feet	7.3	43	9	11.3	9.4	14
Ice making trays	2	None	None	3	3	3
No. of Cubes	42	None	None	63	63	63
No. of lbs. capacity	6	None	None	7	7	7
Months operated per year	12	8	12	6	12	9
Cabinet type	Metal	Wood	Wood	Wood	Wood	Wood
Lining	Sh. Metal	Wood	Cement	Zinc	Porcelain	Porcelain
Cork insulation sides and top	1½″	None	4″	None	10 Walls	2″
Doors	2″	None	4″	None	Paper	2″
Bottom	2½″	None	4″	None	& Felt	2″
No. doors fitted with gaskets	1 Yes	4 No	1 Yes	3 No	3 No	4 Yes
Shelves	Wire	Wood	Wood	2 Slate 2 Wood	Wire	Wire
Compartments	1	4	1	3	3	4
Sq. ft. of shelf space	8.2	19	9	11.3	8½	12
Outside dimensions in ins.:						
Width	26½	51	18	42	37	41
Height	60¾	63	48	49	48	73
Depth	22¼	36	18	23	22	25
Weight in lbs.	391					666
New or old refrigerator	New	Old	New	Old	Old	New
Years old	1½	26	2	28	9	2
Cost of complete new refrigerator or unit	$260.00		(†)			$495.00
Cost to install	24.09		(†)			25.20

(†) Part of dairy cold storage.

TABLE II.—*Mechanical Units*

Farm	No. 1	No. 2	No. 4	No. 5	No. 6	No. 7
Motor h. p.	¼	¼	¼	¼	¼	1/6
Reciprocating Comp. Cylinders Drive Idler Speed—R.P.M.	 1 Belt None 350	 2 Gear None 300	 2 Gear None 300	 1 Belt None 310	 1 Belt None 310	 2 Direct None 1800
Air-Cooled Condenser	Yes	Yes	Yes	Yes	Yes	Yes
Refrigerant used	Sulphur dioxide	Methyl chloride	Methyl chloride	Sulphur dioxide	Sulphur dioxide	Sulphur dioxide
Location of unit	Enclosed in cabinet in kitchen	Basement	Entry	Basement	Entry	Enclosed in cabinet in dining room
Feet of tubing carrying to refrigerator	8	16	10	20	6	0
Type of chilling unit	Coil	Tank	Tank	Tank	Tank	Tank
Type of thermostatic control	Breaker-point	Breaker-point	Mercoid	Breaker-point	Breaker-point	Mercoid
Cost of mechanical equipment	‡	$225.00*	‡	$325.00	$250.00	‡
Cost to install	‡	0*	‡	$22.30	$18.70	‡
Cost of old refrigerator	$40.00	$25.00	$5.00	$30.00	$45.00	$50.00

‡ See cost of complete new unit in Table 3.

* Rental basis—no charge for installation.

the first settings, difficulty was experienced with freezing foods directly under the chilling units.

It will also be noted that the equipment was operated on a wide range of rates varying from three cents to seven cents per kilowatt hour.

The capacity of the refrigerator in each case satisfied the requirements of the farm household. The refrigerator on Farm No. 1, having 5.5 cubic feet of food storage space, is considered the minimum size, and the refrigerator on Farm No. 2, the maximum size to be recommended. The latter is too large for ordinary use, but would be a useful size for a farm that held reasonable quantities of market produce for opportune sale, or for a farm with a roadside or at-the-door business.

Two refrigerators (Nos. 1 and 6) operated on a 12 months basis; four operated only in warm weather. April or May was the usual time for starting in the spring, and December was the usual closing month in the Fall.

FIG. 2. Refrigerator on Farm No. 1

The average size of all units was 15.7 cubic feet of total contents and 11.3 cubic feet of food storage space. An average of 30 percent of the total space in the refrigerators was occupied by the chilling unit.

The average size of the four usual household type machines was 10.5 cubic feet of total contents and 7.2 cubic feet of food storage space.

All the common types and qualities of insulation ordinarily encountered were represented, ranging from a simple double wood wall, with no special insulation of any kind, to the modern heavily insulated type.

The table of refrigeration specifications shows considerable variation in the other details and conditions which prevailed during the tests. The general averages represent a good assortment of conditions.

Farm No. 1

The refrigerator on Farm No. 1 is a steel cabinet with white lacquer finish, insulated throughout with cork-board, trimmed with nickel-plated hardware, and furnished with castor glides. (Fig. 2). The interior is lined with hard-baked white enamel and equipped with heavy, rust-resisting, removable wire shelves.

The entire equipment is located in the kitchen, a room 8 feet wide and 16 feet long, without direct heat from a stove or furnace. An electric range is used for cooking. In winter the room is heated indirectly from the furnace by way of the dining-room door. The room temperature is about the normal temperature that is maintained in a home.

Farm No. 2

The refrigerator on Farm No. 2 was built into a corner of a working pantry 26 years ago. The construction consists of an inner and outer wall of ¾ inch matched hard pine sheathing, varnished on the outside, on a frame-work of studding. An air space and one or two layers of building paper are between the walls. No special insulation is used at any point. An outside icing door, without gaskets, opens onto the porch and admits cold air when the machine is not being operated. The interior is made entirely of unfinished hard pine

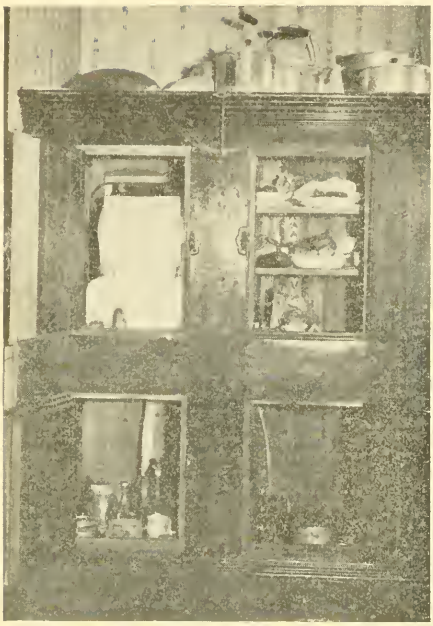

Fig. 3. Refrigerator on Farm No. 2

sheathing. This refrigerator is the largest in the group and contains much more storage space than is used. It may be seen in Fig. 3 that the lower compartments are only partially filled, and some are articles which do not require refrigeration. According to the housewife, the storage space could be reduced to 20 cubic feet of total content, or 10 cubic feet of storage space and 9 square feet of shelf space, and meet all the needs of the family.

The working pantry is 13 feet long and 8½ feet wide and resembles the kitchen on Farm No. 1 in that it receives heat indirectly from the kitchen and dining room. Therefore, average household temperatures prevailed. The family did not consider the lack of trays for ice cubes a disadvantage.

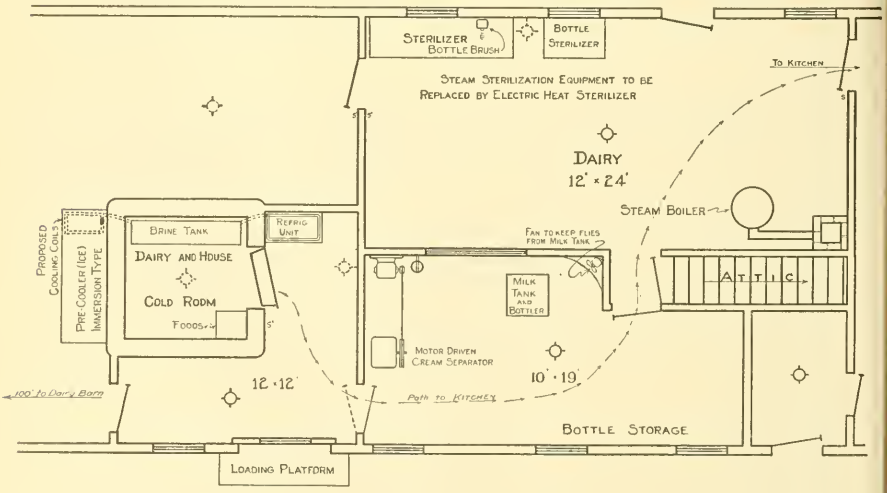

Fig. 4. Location and arrangement of cold storage which serves both the house and the dairy on Farm No. 4. Note the convenient arrangement in regard to other dairy equipment. It is not quite as convenient to the kitchen as it might be.

Farm No. 4

Refrigeration for the house on Farm No. 4 is obtained from the dairy cold storage. The construction of this room is given in detail in University of New Hampshire Experiment Station Bulletin No. 233 and Extension Circular 85.

A well ventilated cabinet, 18 inches deep, is built into an out-of-the-way corner in which foods may be stored without danger of being upset. As shown in Fig. 4 this room is located about 50 feet from the kitchen and therefore is not as convenient as the individual house unit. The operating costs, however, are greatly reduced by this method, which is shown in the current consumption and operating cost tables. The assumption that 1/10 of the upkeep may be charged to the household is made high intentionally to avoid favor. On a basis of cubic feet—elimating the more accurate but practically impossible procedure of attempting to determine the B.T.U.'s of heat in the food stored—the house compartment occupies only 1/20 of the total space, so that this latter fraction would probably be a closer estimate of the proportion of cost. The room is shown in Fig. 5 but the cabinet cannot be seen.

The equipment is subjected to modified outside temperatures all year around.

Although not equipped with ice trays, it has been found that ice cubes will slowly freeze in a tray placed on top of the brine tank.

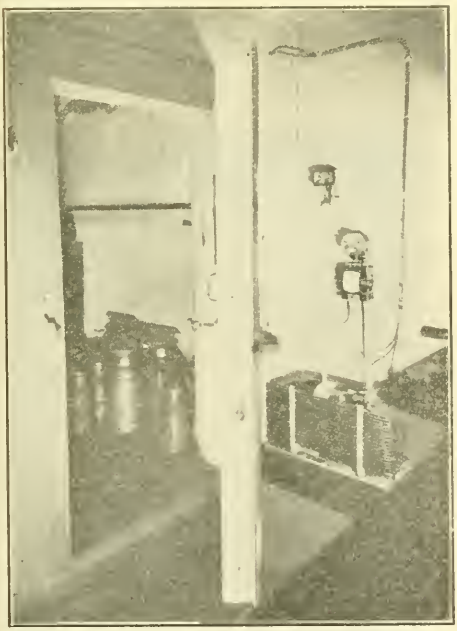

FIG. 5. Cold storage room and equipment on Farm No. 4.

Farm No. 5

The refrigerator on Farm No. 5 had been in use with ice for 28 years. It was converted to the electric method by placing the chilling tank in the ice compartment and the compressor unit in the basement. The wall construction consists of two walls of 3/4 inch clear white pine, a 3/8 inch air space, and two layers of insulating paper. The exterior surface is finished with paint and varnish. The interior is lined entirely with zinc. Two shelves are solid pieces of slate arranged to allow the cold air to circulate past the front and rear edges. Two shelves are of woven wire.

The refrigerator (Fig. 1) is located in a back kitchen which is also used as a laundry. Except on wash days this room is exceptionally cool all year

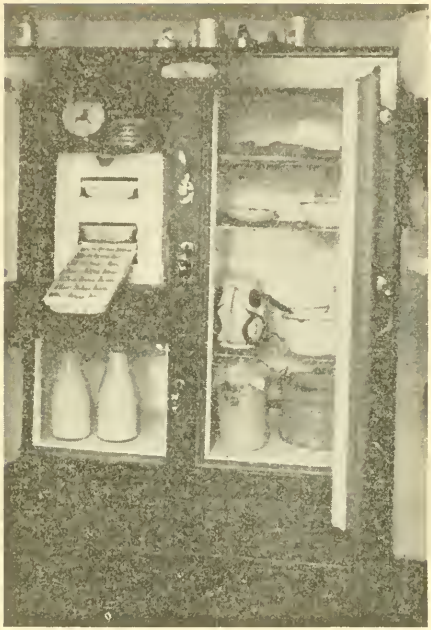

Fig. 6. Refrigerator on Farm No. 6

around, and the temperature, against which the equipment is working, is much lower than on any of the other farms. The results clearly show that the location of the equipment in a naturally cool place reduces the cost of operation considerably, and may compensate for poorer insulation. The compressor unit is also favorably located in a very cool basement.

Farm No. 6

On Farm No. 6 is a standard, good grade, commercial refrigerator, having a ¾ inch varnished oak case, two layers of insulating paper, a layer of felt, another of mineral wool, and a ⅜ inch wood sheathing inside. The compressor unit is located in a cool entry immediately in back of the refrigerator.

The interior lining is made of seamless porcelain, except the ice compartment, which is zinc lined. The corners are rounded. Shelves are of rust-resisting woven wire.

The refrigerator is cut into the wall of the pantry, and its back is exposed to the air of the cool entry. Formerly this arrangement permitted icing through a door in the rear without entering the house. The sides, top, bottom, and front are exposed to the temperature of the pantry which is heated only in the winter indirectly through the kitchen by the furnace. The opposing temperature is, therefore, somewhat below the average house temperature. The temperature in the entry, where the compressor is located, is always cool in summer and cold in winter. Fig. 6 shows the equipment.

Farm No. 7

The refrigerator on Farm No. 7 is a varnished oak cabinet in-

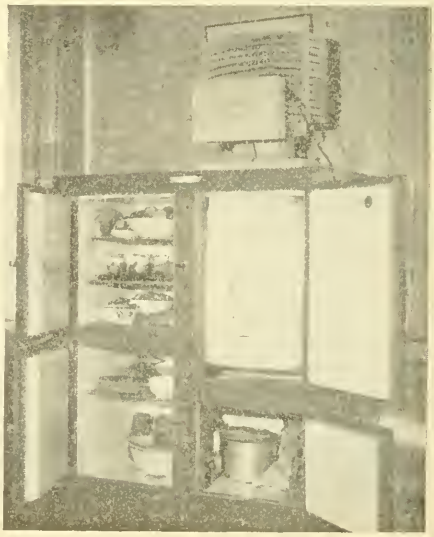

Fig. 7. Refrigerator on Farm No. 7

sulated throughout with corkboard. (Fig. 7). The interior lining is one-piece, vitreous porcelain on sheet steel. The corners are rounded. All exposed wood is said to be specially treated to preclude food odors and moisture. Heavy, rust resisting, removable wire shelves and nickled hardware are included. The mechanical unit is in the cabinet.

The entire equipment is located in the dining room of the home and is working against average house temperatures.

BREAKDOWNS AND CURRENT INTERRUPTIONS

No mechanical, electrical or other breakdowns of equipment occurred except in the case of Farm No. 1, where a leaky valve caused loss of gas. Repairing the leak required two trips of a service man which

TABLE III.—*Initial Investment and Fixed Charges of Ice and Electric Refrigeration.*

Farm	No. 1	No. 2	No. 4	No. 5	No. 6	No. 7	Ave.
For Ice. Use of ice house	Farm and House	Farm and House	Farm and House	House	House	House	
Years old in 1927	9	15	—	33	4	6	—
Original cost	* $250.00	$350.00 to $600.00	* $50.00	$200.00	$200.00	$100.00	$250.00
Total fixed charges on all ice equipment	$54.35	$72.85	$22.25	$12.00	$12.00	$13.33	$31.13
Percent charged to house	1/8	1/5	1/5	all	all	all	—
Amount charged against house	$6.79	$14.57	$4.45	$12.00	$12.00	$13.33	$10.52
Cost of old refrigerator	$40.00	$25.00	$5.00	$30.00	$45.00	$50.00	$32.50
Fixed charges on refrigerator‡	$2.00	$1.25	$0.25	$1.50	$2.25	$2.50	$1.62
Total fixed charges on all equipment for house	$8.79	$15.82	$4.70	$13.50	$14.25	$15.83	$12.15
For the Electric Method.							
Installed cost of entire new equipment	$284.09	†	$5.00	†	†	$520.20	(1 & 7) $402.15
Cost of electric equipment installed in old refrigerator	†	$250.00	†	$377.30	$388.70	†	$338.66
Total fixed charges—Interest, depreciation and upkeep	$14.21	$12.50	$0.25	$18.87	$19.44	$26.01	$18.20

* Cost of partioning off barn cellar or space in shed.

‡ Interest and depreciation.

† Refer to Table 2 for cost of mechanical equipment installed in old refrigerator.

cost $15.48. Current interruptions were never long enough to cause loss of refrigeration.

COMPARISON OF COST OF ICE AND ELECTRIC METHODS

Table 3 compares the initial investment and fixed charges for the ice and electric methods. Three of the farms used the ice equipment for both farm and house and three for the house only.

While the original cost and total fixed charges for the first group are higher than for the second, the reverse is true when the fixed charges are figured in proportion to the amount of ice used by house and farm respectively. Farms which handle a large quantity of ice have a relatively lower fixed overhead per 100 pounds than those which use it for the house only.

The average investment in ice equipment on the six farms was $250.00. One third of the total yearly fixed charges, an average of $10.52, is chargeable to the house refrigerator. The variation in fixed charges for house use, then, varies from 1/8 to all costs. These amounts vary from $4.70 to $15.83 with an average of $12.15 for the six.

The average ice refrigerator was found to cost $32.50. On Farm No. 4 the old dairy cold storage and a cool basement were used to keep the food which accounts for the low $5.00 cost. The greatest investment in an ice refrigerator was $50.00. The average interest and depreciation charge was $1.62; the limits were 25 cents and $2.50.

For electric operation the investment and fixed charges are appreciably greater. The investment for ice equipment was $282.50; $370.40 was the average amount invested for the electric method. This is an increase of 31 percent. (The tendency toward increased investment and fixed charges, and lower operating costs is characteristic of electrical equipment.) The total fixed charges were $12.15 for ice and $18.20 for the electrical method, a 50 percent increase.

Features of Combination Method

The house and dairy needs on Farm No. 4 were met by an expenditure of $766.50 for a single combination unit. Compared with $885.80 on Farm No. 2 and $989.34 on Farm No. 1, for two sets of equipment each, this represents a net saving of $120 and $225. With the improvements in construction that have been made recently, the cost of equipment similar to that on Farm No. 4 would be considerably less.

In addition to a marked saving in the initial cost there is also a very appreciable saving in the operating cost. As little as 30 percent of the current used by the other types was used by the combination method.

CURRENT CONSUMPTION

Tables 4 and 5 give the kilowatt-hours of current used per month and the cost on each of the six farms for the years 1926, 1927, and 1928. To these have been added the years 1924 and 1925 in the case of Farm No. 2.

A tendency to elongate the period of use on Farms No. 5 and 7 by earlier starting in the spring is noticeable. In 1927 both started operation June 1. In 1928 they started about the last of April.

TABLE IV.—*Kilowatt Hours of Current Used and Amount of Storage Space Cooled.*

Farm	No. 1	No. 2		No. 4	No. 5	No. 6	No. 7	Ave.	
Tot. cont. in cu. ft	7.3	43	43	9‡	11.3	9.4	14	15.7	
Food storage in cu. ft.	5.5	30	30	9	8	6.2	9	11.3	
Year	**1926**	**1924**	**1926**	**1926**	**1926**	**1926**	**1926**	**Average* per mo. of those operating**	**Average per day***
March		0	0	0					
April		15	0	2				15	.9
May		23	37	13		0	0	30	1.1
June		35	53	16		41	28	39	1.4
July		80	74	16		48	69	68	2.2
August	0	100	71	21	0	53	77	75	2.4
September	35	86	65	16	35	46	67	56	1.8
October	39	73	59	15	24	34	41	45	1.4
November	38	46	45	13	10	26	14	30	1.3
December	39	20	13	7	0	17	0	22	.7
Year's Total	151	478	417	119	69	265	296		
Year	**1927**	**1925**	**1927**	**1927**	**1927**	**1927**	**1927**		
January	40	7	0	7	0	14	0	20	.8
February	45	0	0	7	0	11	0	30	.9
March	34	3	0	9	0	20	0	19	1.1
April	38	9	11	13	0	26	0	21	1.4
May	43	37	45	13	0	36	0	40	1.4
June	45	52	65	17	34	47	41	47	1.5
July	50	91	75	18	32	51	75	62	2.1
August	51	83	71	21	38	63	73	63	2.0
September	43	94	61	16	35	45	69	58	1.9
October	42	68	55	13	18	36	65	47	1.5
November	41	44	38	11	9	31	23	31	.9
December	42	9	20	6	0	23	0	23	.9
Year's Total	514	497	441	151	166	403	346	**Average per Year**	395
Year	**1928**				**1928**	**1928**	**1928**	**1928**	
January	31				0	20	0	25	.8
February	51				0	14	0	33	1.1
March	32				0	26	0	29	.9
April	35				32	27	27	30	1.0
May	50				32	27	30	35	1.1
June	52				32			42	1.4
July	53				33			43	1.4
August	53				33			43	1.4
Year's Total	307				162	114	57		

TABLE IV.—(*Concluded*) *Kilowatt Hours of Current Used and Amount of Storage Space Cooled.*

Farm	No. 1	No. 2		No. 4	No. 5	No. 6	No. 7	Ave.	
Contents in cu. ft..	7.3	43	43	9	11.3	9.4	14	15.7	
Food storage in cu. ft.....	5.5	30	30	‡ 9	8	6.2	9	11.3	
Year	1927	1925	1927	1927	1927	1927	1927	Average* per mo. of those operating	Average per day*
Monthly:									
Average†.....	40	50		13	28	33	49	41	
Maximum.....	53	100		21	38	63	77	67	
Minimum.....	31	3		2	9	11	14	13	
Daily:									
Average†.....	1.3	1.7		.5	.9	1.1	1.6		1.4
Maximum.....	1.7	3.2		.6	1.2	2.0	2.5		2.4
Minimum.....	1.0	.3		.1	.2	.4	.3		.7
Ave. kwhs. per cu.. ft. total box capacity per hour ..	.008		.0016	.002	.003	.005	.006		

‡ Combined with the dairy cold storage and estimated to require 1/10 of the total current consumed.

† For the months and days operated.

* Farm No. 4 is not included in these averages for the reason that it is not an individual type machine, but is in combination with the dairy cold storage room.

The basis for an accurate judgment of comparative costs of operation is the kilowatt hours per cubic foot of total box capacity consumed per hour. Since continuous readings of inside and outside temperatures were not made, the degree of difference in temperature is unknown. These cubic foot ratings are given at the end of Table 4. A variation between .0016 kwhs. and .008 kwhs. occurred. The important influence of location of the refrigerator and compressor on the current consumed is also brought out.

Although the refrigerators on Farms No. 2 and 4 had the lowest current consumption, neither of them is the usual household type or size. The installation on Farm No. 2 is three or four times larger than the ordinary house refrigerator. The other, while listed at 9 cubic feet, is really a part of a 207 cubic foot dairy cold storage, and is not to be compared with a household machine. On both farms the same make of equipment is used with the same size of compressor. Brine tanks vary in size according to the contents of the two boxes. In neither case are the surrounding conditions considered better than average.

It was assumed that .002 kwhs. per cubic foot of total box capacity per hour was a reasonable charge for household requirements. This represents one-tenth of the entire capacity of the dairy cold room. Of the machines which represent the usual sizes of household refrigerators, No. 5 consumed the least current. The cabinet has no special insulation. This lack of protection caused the manufacturer who installed

TABLE V.—*Current Costs.*

Farm	No. 1	No. 2		No. 4‡	No. 5	No. 6	No. 7	Ave. *	Ave. per day all farms
Rate	4½c	7c	7c	3 1 7c	5c	3c	5 1 10c	4 2/3c	
1926		**1924**							
March		0		0					0
April		$1.05	0	$ .07				$1.05	$0.06
May		1.61	$2.59	.41		0	0	2.10	.08
June		2.45	3.71	.50		$1.20	$1.44	2.20	.09
July		5.60	5.18	.52		1.40	3.52	3.90	.13
August	0	7.00	4.97	.65	0	1.55	3.93	4.36	.14
September	$1.59	6.02	4.55	.52	$1.75	1.33	3.42	3.11	.10
October	1.77	5.11	4.13	.47	1.20	1.00	2.09	2.55	.08
November	1.73	3.22	3.15	.40	.50	.76	.71	1.67	.07
December	1.77	1.40	.91	.20	0	.47	0	1.14	.04
Year's Total	$6.86	$33.46	$29.19	$3.74	$3.45	$7.73	$15.11		
1927		**1925**							
January	$1.82	$0.49	0	$0.21	0	$0.41	0	$0.91	$0.04
February	2.05	0	0	.22	0	.32	0	$1.18	.04
March	1.55	.21	0	.27	0	.59	0	.78	.04
April	1.73	.63	$0.77	.40	0	.76	0	.97	.03
May	1.96	2.59	3.15	.40	0	1.05	0	2.19	.07
June	2.05	3.64	4.55	.53	$1.70	1.35	$2.09	2.56	.08
July	2.28	6.37	5.25	.58	1.60	1.49	3.83	3.35	.11
August	2.32	5.81	4.97	.65	1.90	1.84	3.72	3.34	.11
September	1.96	6.58	4.27	.51	1.75	1.32	3.52	3.23	.10
October	1.91	4.76	3.85	.42	.90	1.05	3.32	2.63	.09
November	1.87	3.08	2.66	.34	.45	.91	1.17	1.67	.05
December	1.91	.63	1.40	.20	0	.67	0	1.15	.05
Year's Total	$23.39	$34.79	$30.87	$4.73	$8.30	$10.80	$17.65	Av. per	yr. $21.
1928									
January	$1.40				0	$0.59	0	$0.99	
February	2.30				0	.41	0	1.35	
March	1.44				0	.76	0	1.10	
April	1.58				$1.60	.79	$0.23	1.05	
May	2.28				1.60	.79	1.53	1.55	
June	2.37				1.60			1.98	
July	2.42				1.65			2.03	
August	2.42				1.65			2.03	
Year's Total	$16.21				$8.10	$3.34	$1.76		
Monthly†:									
Average	$1.94	$3.95	$3.50	$0.40	$1.42	$0.91	$2.46	$2.36	
Maximum	2.42	7.00	5.25	.65	1.90	1.84	3.93	3.72	
Minimum	1.40	.21	.77	.07	.45	.32	.23	.56	
Daily†:									
Average	.06	.12	.11	.02	.05	.03	.08		.075
Maximum	.08	.23	.18	.03	.06	.06	.13		.12
Minimum	.05	.02	.03	.01	.01	.01	.01		.02

† For the months and days operated.
* Farm No. 4 is not included in these averages for the reason that it is not an individual type machine, but is in combination with the dairy cold storage.
‡ Combined with dairy cold storage.

the equipment considerable apprehension. Undoubtedly, the method of using white pine in the construction of this unit had more merit than was at first thought, but the unusually good results obtained are largely due to location. Both the refrigerator and compressor are situated in very cool and protected places.

The same make and size of mechanical equipment was used in No. 6 placed in a well insulated refrigerator. The refrigerator was located in a reasonably warm kitchen and the compressor unit was put in a cool entry. These two examples show that location is as important in the reduction of costs of operation as the quality of the refrigerator or cold storage cabinet. The advantage of cool surroundings may not be of sufficient value, however, to justify the sacrifice of a convenient location.

No. 7 and No. 1 are different makes of machines, but both, similar to No. 6, operate in a dining room or kitchen in house temperatures throughout the year. Both compressor units are of the self-contained type and work under the same conditions.

The average for the four strictly household units is .0055 kwhs. per cubic foot of total box capacity per hour. The extreme limits are .003 and .008. The high current consumption of No. 1 is believed to be due largely to the increased electrical demand of frequent starts. The operation of this machine is characterized by frequent short periods of running.

Evidence points to an increase in efficiency with an increase in size of refrigerator. (Table VI).

Table VI. *Kilowatt hours per cubic foot of total box capacity per hour*:

Farm No.	Total cu. ft. contents	Kwhs. per cu. ft. of total box capacity per hour
1	7.3	.008
6	9.4	.0053
5	11.	.0033
7	14.	.0059
2	43.	.0016

Since location, environment, and varying efficiencies of different types of compressor units have an effect, a conclusion cannot be positively drawn from these data.

The greatest amount of electric energy was registered in July, August or September. One hundred kilowatt hours was the largest amount recorded. Ten kilowatt hours was the lowest reading for a full month.

The average amount consumed by all except No. 4 varied from 28 kwhs. per month to 49 kwhs. The average for all months was 41 kwhs. Daily averages varied from .7 kwhs. to 2.4 kwhs.; 1.4 kwhs. was the average for all days. The maximum consumption for a year was 514 kwhs.; 151 kwhs. per year was the least; and 395 kwhs. was the average for all machines.

Figure 8 shows the power consumption curves on six farms. The 1927 curve includes records for a complete year as well as the readings for Farm No. 2 taken in 1925; and the curve marked 1926 includes the readings for the year 1924 for this same farm. The curves are the av-

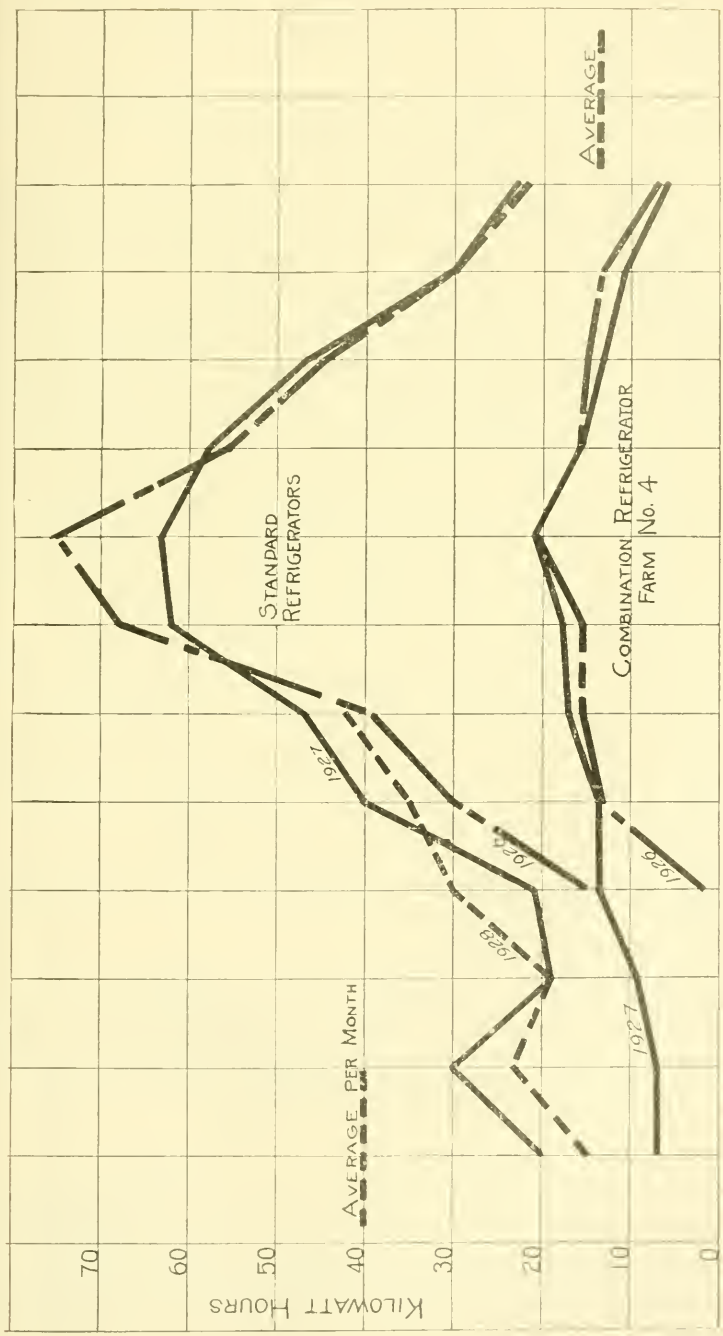

FIG. 8. The upper set of curves shows three years of averages of current consumption for five standard refrigerators. A comparison with the lower curve shows the saving made by the combination method. The averages are the average per month of twelve months readings.

erage of six sets of readings. Those from Farm No. 4 were not included in these averages, because the refrigerator is not the conventional household type.

The curve for 1928 is valuable only as corroborative evidence. The readings cover the starting period in the spring when the variations are most erratic. In June the test meters were removed.

Although the real refrigeration season does not start until March or April, there was an increased consumption in February which declined to the starting level in March. This repeated tendency may be explained by severe weather and poor roads—a condition which stimulates buying and storing foods in larger quantities. Also, at this time homes are often overheated to counteract the humid weather.

The operation of two machines on the full year basis held the curve away from zero at both the starting and closing points. The bulk of the load came in a nine months period. The heaviest consumption occurred between June and the middle of October. The peak load came in July or August and varied between 60 and 75 kwhs. per month. The average of 40 kwhs. a month is taken from the records of the year 1927. Since three machines were operated on a nine months basis, two for a full year, and one for only five months, to find the average yearly consumption of current one must multiply the average per month by about ten, which is the average number of months the machines were in operation, and not by twelve.

Due to favorable weather conditions, the declining curve in the fall tapers off smoothly and gradually in contrast to the irregular rising spring curve.

The current consumption curve on Farm No. 4 is beneath the curves for the five other farms and shows the distinct saving which results from the use of the combination method. The maximum consumption of 21 kwhs. for No. 4 was about equal to the minimum of the other types. The maximum for the other types is 75 kwhs.

A comparison of averages shows that this method can operate throughout the year on 30 percent of the current required for the other methods. The initial investment, too, is less.

Farms Operating on Short Season

Figure 9 shows the load curve for the four farms operating for the nine months between April and December. Farms No. 2 and No. 5 were the maximum and minimum power consumers respectively. The peak load, averaged for the four farms, is approximately the same as in Figure 8. Other tendencies are also much the same.

Power Consumption for Full Season

The curves in Figure 10 are for the two machines operating for the full year and, as might be expected, they show a more constant amount of current was consumed which is represented by a flatter, more even curve. It is particularly interesting to note the difference in these two machines. Both compressor and cabinet were located in the kitchen of a brick dwelling on Farm No. 1. The room temperature remained constant throughout the year which largely accounts for the flat load curve.

FIG. 9. Maximum, minimum, and average current consumption curves of household refrigerators operating on a nine months basis.

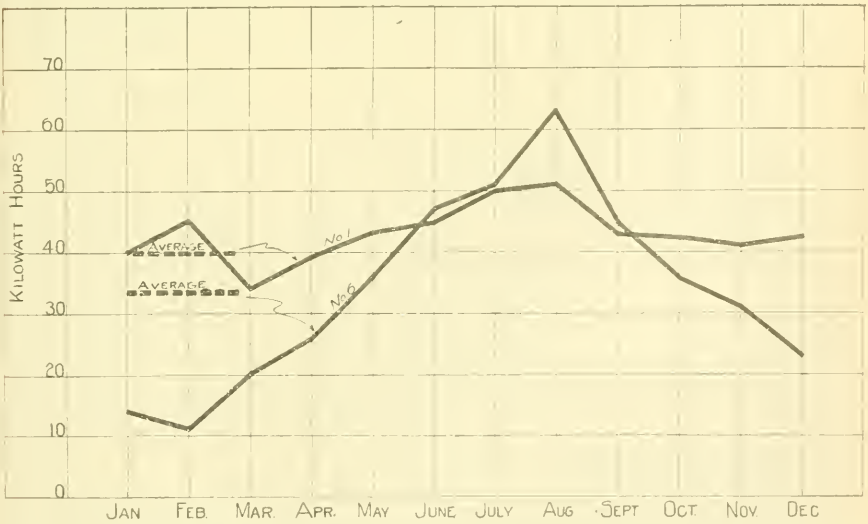

FIG. 10. Current consumption curves of two household refrigerators operating on a twelve months basis, showing two widely different load characteristics.

In the case of No. 6, however, the compressor and the back of the refrigerator projected into an entry which fluctuated in temperature according to the weather. The sides, front, top and bottom were exposed to the house temperature. The effect of the outside temperature changes on the exposed parts of the equipment is clearly indicated in the curve. In the cool months less current was consumed, and in the warm months a greater consumption occurred. Although the main part of the house is brick, the kitchen ell is of wood.

This situation gave a maximum of service at a minimum of cost. While these exact conditions could hardly be duplicated, the importance of giving careful attention to location is illustrated. The compressor unit, particularly, should be located where the heat from the refrigerator can be discharged into cool air.

The average kilowatt hours of current per month were 40 and 33 in these two cases.

CURRENT CONSUMPTION PER CUBIC FOOT PER HOUR

Table 7 shows the kilowatt hours of current which were consumed per cubic foot of total contents and storage contents per hour. The table also shows the approximate percent of the total elapsed time that the machine unit operated. Tests to determine the demand of each motor were not made; a demand of 320 watts was assumed in each case, except on Farm No. 4, where the same figures were used as for the dairy cooling room. (See University of New Hampshire Experiment Station Bulletin No. 233). This also accounts for the unusually high figure on Farm No. 7 where 225 watts were assumed to have been used.

The refrigerators on Farms 1 and 6, it will be recalled, were operated 12 months of the year and show a generally higher consumption per cubic foot than the others which were operated only during the warm

TABLE VII.—*Kilowatt Hours of Current Consumed per Cubic Foot per Hour.*

Farm No.	1	2	4	5	6	7	* Ave.
Total contents—ave.	.0080	.0016	.0023	.0033	.0053	.0059	.0048
Maximum	.0097	.0031	.0028	.0044	.0089	.0074	.0067
Minimum	.0068	.0004	.0004	.0007	.0017	.0009	.0021
Storage content—ave.	.0106	.0024	.0023	.0047	.0081	.0092	.0070
Maximum	.0129	.0045	.0028	.0062	.0135	.0115	.0097
Minimum	.0091	.0005	.0004	.0010	.0027	.0014	.0029
Number days machine has been used	485	1024	589	406	582	327	565
Percent of total time machine was run	17¾%	13%	52.4%	7½%	15%	36%	*19%

* Does not include refrigerator on Farm No. 4.

TABLE VIII.—*Ice, Sawdust, Hauling and Labor Costs for the Three-Year Period Before Installation of Electric Method.*

Farm*	No. 1	No. 2	No. 4	No. 5	No. 6	No. 7	Ave.‡
Number cakes for house	125	200		200	150	125	140
Price per cake				7c.		8c.	
Total ice cost				$15		$10	
Miles haul round trip				6–8	3	1½	
Hauling and Housing:							
Man hours				13		20–30	
Truck hours						10	
Team hours				13		15	
Total hauling cost.				$37.00		$16.00	
Sawdust costs:							
Loads per year				3		1	
Costs per load				0		$1	
Man hours				10		10	
Truck hours				10			
Team hours						5	
Total sawdust costs				$6.40		$7.00	
Total operating costs	$12.34	$42.41	$14.68	$58.40	$30.00	$33.00	$35.21
Servicing:							
Months of operation	7–7½	7½–8	9	5	8	6	
Ave. lbs. per charge	50	150	–	75	75	150	100
Charges per week:							
Spring, and Fall	3–4	2	–	2	2	2	2
Summer	3–4	3	–	3	2	3	3
Total charges per year	60	67		56	70	52	61
Man hours a charge	½	⅓		¼	½	½	
Man hours a year	30	22		14	35	26	25
Total cost	$12.00	$8.80	$8.18	$5.60	$14.00	$10.40	$9.83
Labor cost per month	$1.71	$1.10	$0.90	$1.12	$1.75	$1.73	$1.38
Refrigerator also used for retail farm produce	none	none	mostly	none	some	some	
Total maximum cost	$27.43	$64.16	$25.00				$38.86
Total minimum cost	$21.26	$38.26	$20.62				$26.71
Average cost	$24.34	$51.21	$22.86	$64.00	$44.00	$43.40	$41.63
Average cost per month of operation	$3.24	$6.40	$2.54	$12.80	$5.50	$7.23	$6.29

* On farms 1, 2 and 4 the ice formerly used by the house refrigerators amounted to 1/8, 1/5, and 1/10 respectively of the total ice each year.
The same fraction of the total costs has therefore been assigned in each case except with No. 4 where it was doubled to prevent favoring the combination method.
‡ Farm No. 4 is not included in these averages.

months. The refrigerator on Farm No. 7, however, was an exception and used more current.

Figures on the minimum amounts of current consumed are the least dependable because they represent the start and close of the seasons when the machines were used intermittently. They were operated from 7½ percent to 36 percent of the total time. The general average was 19 percent.

COST OF ICE

Without regard to the quantity of refrigeration needed for a farm, the processes required are much the same, and involve: (1) Building and maintaining an icehouse; (2) cutting the ice and supplying labor to put it in storage; (3) providing the delivery system; (4) tying up money for considerable periods of time, and (5) the use of labor and materials which, by the new method, can be released to more profitable work.

On farms which require considerable ice, the cost per hundred-weight delivered in the refrigerators, cooling rooms, or tanks is less than on other farms. The cost on dairy farms is usually low.

On farms which require ice for house use only, the same steps are necessary, and, therefore, the cost per hundred-weight for the smaller quantity of ice is greater. Doubling the amount of ice stored does not double the cost; certain overhead charges change little.

On account of widely varying conditions, it is difficult to find an average cost per hundred-weight for ice delivered to the cooling chamber on the farm. In general it costs as much as in the city during the same season; during the period of the tests the cost was 50 to 60 cents per hundred-weight.

Each farm placed a slightly different value on the various operations involved in harvesting ice. (Table 8). To find an equal basis for comparison, forty cents an hour was assumed to be the value of man and team labor.

On the first three farms the ice used for the house refrigerator was a part of the total required for both the dairy and house.

On Farms No. 5 and 7 the ice was put in by the farm help, but on Farm No. 6 the work was contracted for at a fixed price.

Due to the quantity of ice handled, the first three farms were able to effect an economy over the last three. Only under extreme conditions did the cost of ice in the first group for the house equal the high cost of the second group. The cost varied from $20.62 to $64.16 for Farms No. 1, 2, and 4; the average was $36.14. The variation for the latter farms was from $43.40 to $64.00 with an average of $50.46. The average total cost for all farms was $41.63. Monthly average costs were $6.29. Daily average costs were 21 cents.

CONCLUSIONS

Three general sets of conditions are represented by the seven farms: (a) Farms that have need for and operate only a household refrigerator (Farms Nos. 5, 6, and 7); (b) farms that must operate both a household refrigerator and a cold storage for large quantities of marketable products (Farms Nos. 1, 2, and 4); and (c) farms which require refrigera-

tion for the house and also need a limited amount of cold storage space for a small amount of marketable produce. The refrigerator on Farm No. 2, although market products have not been stored in it, is of adequate size for this practice. Under such usage the current consumption would be somewhat higher.

For farms in the first group, electric refrigeration offers a means of eliminating the ice problem and its difficulties. In such a case, ice house, equipment, labor, trouble of getting ice in, are all for the sole purpose of providing for the household.

Farms that fall in the second group consider the problem of the farm cold storage plant first, which eliminates the bulk of their ice requirements, but, unless the house refrigeration problem is similarly handled, the problem is only partly solved. Where mechanical refrigeration is used, the logical plan is to get away from ice entirely. Either two separate units are required, one for each purpose, or the house and farm requirements must be combined. (Farm No. 4).

In the third group the double requirement may be readily met by the use of a large size commercial or home-made electric refrigerator for both house and farm products.

Some farms undoubtedly are in a position to continue to use ice to better advantage due to local conditions, labor, investment, etc.; for others and where electricity is available, mechanical refrigeration offers a successful solution to the ice problem.

Results Compared to Other Sections

Results obtained in other states are given in Table 9. While in some cases the data are in the form of advance or partial reports rather than

TABLE IX.—*Comparison of Results with Those of Other States.*

	Ave. per month	Ave. maximum per mo.	Ave. minimum per mo.	Highest individual reading	Ave. annual consumption	No. of farms	Months of test
New Hampshire ..	**41**	**67**	**13**	**100**	**395**	**6**	**30**
Illinois (1)	31.1	44.3	26.5	99	372	7	6
Iowa (2).....	52.4	77.5	21	104	628	8	3 to 33
Idaho (3).....	35.2	67.6	9.6	75	395	3	12
Wisconsin (4).....	25			67	300	1	

(1) E. W. Lehmann, University of Illinois, Farm Mechanics Dept., Report of March, 1926. Term of observations September to January 1925-26. Size of units not given.

(2) F. J. Zink and F. D. Paine, Iowa State College, Engineering Experiment Station Vol. XXVII, No. 12, July 1928, Report No. 6. Refrigerators varied in size from 4.5 to 35.5 cu. ft.

(3) H. Beresford, University of Idaho, Agricultural Experiment Station, Department of Agricultural Engineering. Progress Report No. 5, May 1929. Three refrigerators of 7 cu. ft. each.

(4) E. R. Meacham and W. C. Krueger, Wisconsin Committee on Relation of Electricity to Agriculture, Summary Report, June 1925. Capacity of refrigerator not given.

final results, and cover only a part of a year or a limited number of refrigerators, they are of general interest.

The averages for Illinois are probably low, as they cover only the fall of the year the project was started. The average annual consumption of 372 kwhs. was computed using 31.1 kwhs. as the monthly average.

The figures for Wisconsin were also taken from a progress report in the early stages of test and cover only one case.

Opinions Expressed by Operators

The views expressed by the housewives indicated that uniform opinions were being formed as to the worth of electric refrigeration. No complaints were made about unsatisfactory temperatures or keeping qualities, and all agreed and readily appreciated that better refrigeration was being obtained from the electric method. No one reported even a small loss from spoilage.

Many times cases of keeping foods for long periods of time in excellent condition were mentioned. The cleanliness of the electric method, both in regard to the sanitary condition of the food storage spaces and the floors and rooms, pleased the housewives, and the men were equally pleased with the relief from a chore requiring considerable time.

The noise of operation was noticed by all at the outset of the experiment, but this was quickly become accustomed to. Only one machine, now an obsolete type, became distinctly noisier with age.

Some objected to the incorrect use of the term *ice cream*. Several users learned that sherbets, frozen puddings, ices, etc., could be made in the freezing units, but that ice cream made from cream requires constant stirring while freezing and could not be satisfactorily made in the refrigerators.

SUMMARY

Tests of the merits of electric refrigeration in the home were made on six farms.

Electric refrigeration was judged one of the most serviceable and desirable major electrical units for the farm home.

Two methods of household refrigeration were studied: (1) separate house units, and (2) in combination with dairy cold storage.

Both self-contained and separate types of units were employed.

Three principal styles of equipment were represented: (1) Commercially built single cabinet units, (2) common commercially built refrigerators converted to electric operation, and (3) home-made refrigerators converted to electrical operation.

Both insulated and uninsulated cabinets were used.

Breakdowns and current interruptions were very limited.

The refrigerators varied in size from 5.5 cubic feet of food storage space to 30 cubic feet. The average size of refrigerators was 10.5 cubic feet total contents and 7.2 cubic feet food storage space.

The original investment in electric equipment averaged $370.40 compared to $282.50 for the ice method. The fixed charges of the two methods were $18.20 and $12.15 per year.

The combination dairy and household storage represented the lowest investment.

Current consumption on the five standard type refrigerators averaged 41 kwhs. per month. The average maximum consumption was 67 kwhs. The average minimum consumption was 13 kwhs. The highest average consumption for one month was 100 kwhs.

The current consumption for household refrigerators varied from .0016 to .008 kwhs. per cubic feet of total box capacity.

While 514 kwhs. and 151 kwhs. were the largest and smallest annual amounts of current consumption, 395 kwhs. was the average for the year.

Household storage operated in combination with the dairy required ⅓ the power used by standard types.

The heaviest peak load occurred in July, August or September.

The average annual cost of operation was $20.97.

The average monthly cost was $2.36; the average daily cost was 7½ cents.

The average time of operation of compressor units was 19 percent of the total elapsed time.

Total annual costs for using ice averaged $41.63 per year with extremes of $22.86 and $64.00. The average monthly cost for ice was $6.29; the daily average was 21 cents.

Distinctly superior refrigeration was obtained from the electric method.