UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

The Red Wing Project on Utilization of Electricity in Agriculture

Price: 50 cents

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Division of Agricultural Engineering

University of Minnesota
Agricultural Experiment Station

The Red Wing Project

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E. A. Stewart,* J. M. Larson,† J. Romness

INTRODUCTION

To study the possibility of meeting the growing demand for electric service on Minnesota farms, a state committee on "The Relation of Electricity to Agriculture" was organized in September, 1923. The chairman of this committee was James F. Reed, president of the Minnesota Farm Bureau Federation. Other members were W. C. Coffey, dean of the Department of Agriculture, University of Minnesota; Herman Schmechel, state senator and farmer; Isaac Emerson, state representative and farmer; A. C. Bryan, farmer; C. S. Kennedy, Ottertail Power Company; Charles F. Stuart, Northern States Power Company; W. S. Heald, Minnesota Light and Power Company; and E. A. Stewart, Division of Agricultural Engineering, University of Minnesota, secretary. The Division of Agricultural Engineering of the University had been making a study of electric service and rates for Minnesota farms. The committee on Relation of Electricity to Agriculture was organized to assist in carrying forward the study of farm electric service and rates.

The committee having been organized, the Division of Agricultural Engineering of the University outlined a project on "The Utilization of Electricity in Agriculture." Through this project it was hoped to determine whether electric service at reasonable rates could be used with profit on Minnesota farms. The project was familiarly known as "The Red Wing Project" and was listed as Project No. 17 in the records of the Minnesota Agricultural Experiment Station, and was approved by the administration of the station in November, 1923. The object of the project was declared to be: "To determine the optimum economic uses of electricity in agriculture and to study the value of electricity in improved living conditions on the farm." Plans having been formulated and the Burnside community near Red Wing having been selected for the construction of a test line, a "high line" to carry service to the farms of the community was built in December

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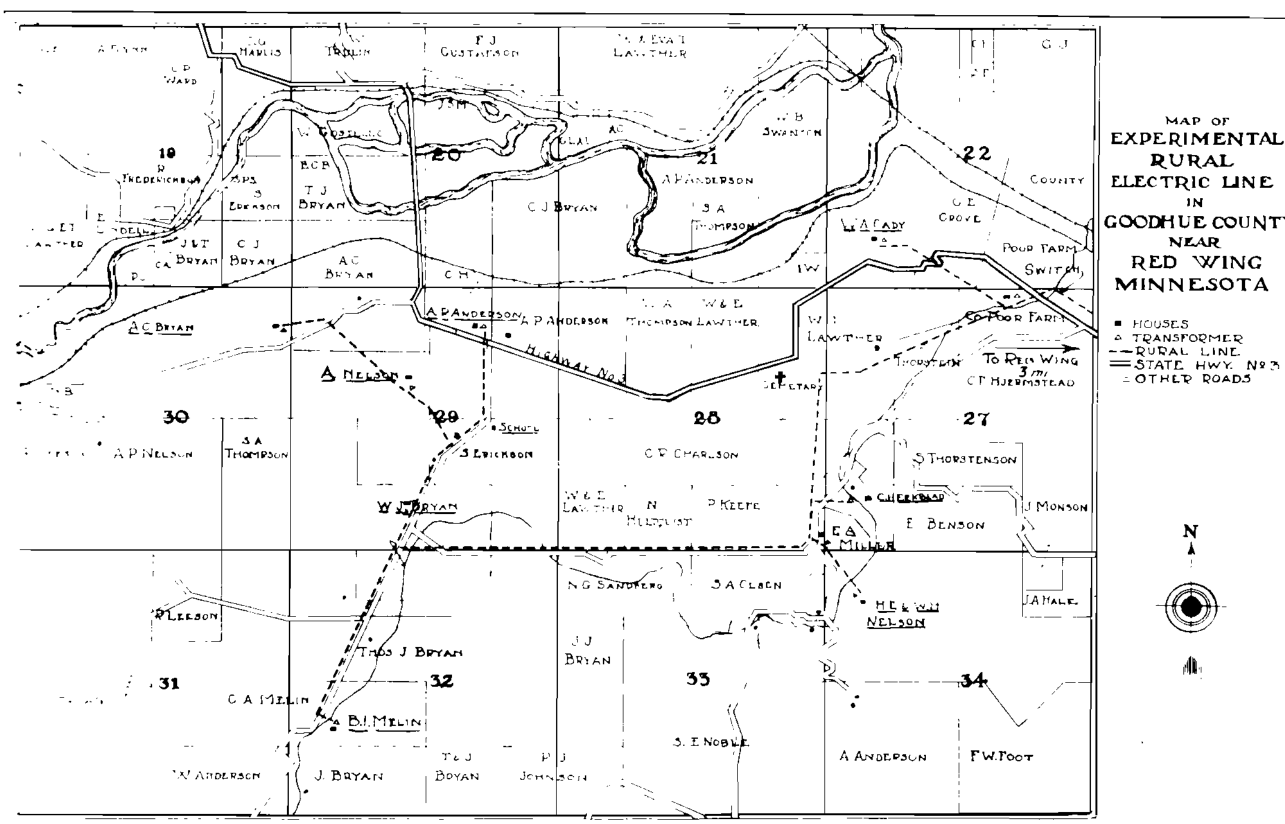

Fig. 1. Location of rural electric line and farms where experimental work was conducted.

and electricity was turned on for the first time December 24, 1923. It is believed that this was the first experimental rural electric line in the world. People in other states became interested and other test lines and experimental projects were organized. Twenty-three other states are now conducting investigations of a similar nature. Foreign countries also have taken up the work.

According to the plans, the Division of Agricultural Engineering of the University was to do the major part of the work, the Divisions of Farm Management and of Home Economics co-operating in certain phases of the work.

In order to meet the expenses of the project, an agreement was drafted whereby the University was to assume the cost of office and laboratory space, office help, and general supervision; the Northern States Power Company, all costs of building the experimental line and supplying the watt-hour meters for measuring energy consumption, and the Committee on Relation of Electricity to Agriculture provision for a fund of \$5,000 for the biennium ending June 30, 1925. This agreement, which was renewed twice afterward, was approved by the Board of Regents of the University of Minnesota in April, 1924.

The experimental work was originally carried on on eight farms of the Burnside community.[1] One farm was added later.

ACKNOWLEDGMENT OF FINANCIAL SUPPORT

Financial support for the Red Wing Project was derived from the Northern States Power Company, manufacturers of electrical and farm equipment, the farmers of the Burnside community, the State Committee on the Relation of Electricity to Agriculture, and the University of Minnesota.

The Northern States Power Company, which built the original line in 1923, later changed this to an all-copper line and in 1926 increased the voltage to 6,900. This company also lent the University more than 100 meters for testing purposes. Seventy-nine manufacturing companies placed at the disposal of the university equipment for use on the project. The farmers on the route assisted by permitting interference with their regular routine, by installing recommended systems of wiring and water supply, and by boarding extra help employed on the project.

The contributions from the various sources are shown in Table I.

TABLE I

Contributors to the Fund for Expenses of the Red Wing Project to June 1, 1928

University of Minnesota	\$ 9,374.04
State Committee on the Relation of Electricity to Agriculture	17,500.00
Northern States Power Company	
Line costs	12,308.00
Meters loaned	1,000.00
Seventy-nine manufacturing companies	21,632.07
Co-operating farmers at Red Wing	13,344.38
Total	\$75,158.49

The uses made by the University of the funds listed in Table I are given by years in Table II, the fund supplied to the University by the state committee being designated as "Special fund, Budget 890."

CHARACTERISTICS OF CO-OPERATING FARMS

The Burnside community is in a district of hills, fertile narrow valleys, and rolling uplands. It was selected for the experiment because it presented certain difficulties in line construction and in the uses of electricity on farms, which, it was believed if overcome, would point the way to the satisfactory use of electricity on the average farm in Minnesota. Both farms and farmers were considered fairly representative of Minnesota generally. Tables III, IV, V, and VI give data as to the characteristics of the farms in the project, according to a survey made January 1, 1924, by L. F. Garey of the Division of Farm Management, University Farm.

[1] A map of the Burnside community, showing the location of the experimental line and the eight original farms is shown in Figure 1.

TABLE II

Use of University and State Committee Funds, November 1, 1923 to June 1, 1928

Expenditure	1923-24	1924-25	1925-26	1926-27	1927-28	Total
Salaries	\$ 968.00	\$3,059.00	\$2,809.50	\$3,037.25	\$3,328.30	\$13,292.05
Miscellaneous labor	166.00	956.26	854.10	839.80		2,816.16
Supplies	25.95	388.46	820.45	524.87	102.30	1,862.03
Equipment	431.36	558.38	122.50	324.28	552.11	1,988.63
Miscellaneous expense	......	35.88	62.60	6.80	19.60	124.97
Traveling expense	398.30	2,060.30	1,307.51	1,795.00	1,229.09	6,790.20
Total	\$1,989.61	\$7,058.28	\$6,066.75	\$6,528.00	\$5,231.40	\$26,874.04
State Committee Budget No. 890	\$ 222.22	\$4,751.88	\$4,888.22	\$5,190.68	\$2,447.00	\$17,500.00
University General Fund	1,767.39	2,306.40	1,178.53	1,337.32	2,784.40	9,374.04

TABLE III

Original Farm Survey of Red Wing Farms, January 1, 1924

	A. C. Bryan	W. J. Bryan	W. A. Cady	C. H. Eckblad	B. I. Melin	F. A. Miller	A. Nelson	Nelson Bros.	Average
Acres in farm	720	366	274	106	257	170	130	296	301.0
Cultivated area	360	225	150	160	160	80	55	150	168.2
Leased area	...	...	165	...	140	...	...	...	152.5
Horses	8	8	6	5	9	7	3	6	6.5
Dairy cattle	...	40	14	4	2	12	10	12	13.4
Other cattle	150	44	32	5	29	28	6	44	42.2
[illegible]	60	94	28	3	155	27	18	56	55.12
[illegible]	100	60	150	40	100	150	45	50	86.8

TABLE IV

AGRICULTURAL ENGINEERING SURVEY, DECEMBER 1, 1923

	A. C. Bryan	W. J. Bryan	W. A. Cady	C.H.Eckblad	B. I. Melin	F. A. Miller	A. Nelson	Nelson Bros.
Lighting	House, acetylene; barn, kerosene	Isolated electric	Kerosene	House, acetylene; barn, kerosene	House, gasoline system; barns, kerosene	House, gasoline; barns, kerosene	Kerosene	Kerosene
Heating	Warm air, piped	Warm air, pipeless	Stoves	Warm air, piped	Stoves	Stoves	Stoves	Stoves
Water systems	Well water, gravity cistern pump	Well water, gravity cistern, hydropneumatic	None	Cistern, hydropneumatic	Cistern pump	Cistern pump	None	None
Sewage disposal	Cess pool	Single chamber septic tank	Privy	Single chamber septic tank	Privy	Privy	Privy	Privy
House	9 rooms, bath and basement	11 rooms, bath and basement	6 rooms and basement	9 rooms, bath and basement	12 rooms and basement	10 rooms and basement	7 rooms and small cellar	9 rooms and basement
Laundry	Cold room at rear*	Cold room at rear	None	Room at rear	Cold room at rear	Cold room at rear*	None	None
Cow barn	Large, fair condition	Large, good condition	Small, poor condition	Small	Medium, fair condition	Medium, good condition	Small, poor condition	Medium, fair condition
Horse barn	Large, fair condition	With cattle	With cattle	With cattle	With part cattle	With cattle	With cattle	Medium, poor condition
Grain storage	Good granary, large	Poor granary, part in barn	Fair granary, small	Good granary	Poor, in barn	Fair granary	Good granary	Good granary, large
Corn storage	Double crib	Single crib, large	None	Single crib	Single crib, small	Crib and hog house	Single crib	Double crib
Machinery shed	Fair, not adequate	Good	Not adequate	Fair	Not adequate	Good	Fair	Good

* These cold rooms are additions built to the house and not finished inside.

TABLE V

INVESTMENT ON RED WING FARMS, JANUARY 1, 1924

	A. C. Bryan	W. J. Bryan	W. A. Cady	C. H. Eckblad	B. I. Melin	F. A. Miller	A. Nelson	Nelson Bros.	Average
Machinery	$ 2,400	$ 2,593	$ 2,524	$ 1,785	$ 2,396	$ 1,315	$ 553	$ 1,594	$ 1,895.00
House	4,300	4,000	2,000	4,000	4,500	1,200	2,000	5,000	3,375.00
Barns	3,500	3,800	500	2,500	2,500	2,500	800	1,500	2,200.00
Land and other bldgs.	58,000	27,900	22,276	18,300	18,750	14,300	10,200	13,500	22,890.75
Livestock	12,500	5,110	2,622	925	9,445	2,330	972	3,256	4,045.00
Supplies, grain, etc..	3,500	685	3,552	1,120	4,022	1,082	1,810	1,395	2,145.75
Total investment ..	$84,200	$44,088	$33,474	$28,630	$41,613	$22,727	$16,335	$26,245	$37,151.50
Per cent of each	%	%	%	%	%	%	%	%	%
Machinery	2.85	5.86	7.54	6.35	5.75	5.79	3.39	6.07	5.1
House	5.11	9.08	5.97	13.97	10.8	5.28	12.24	19.05	9.08
Barn	4.16	8.63	1.49	8.73	6.00	11.00	4.89	5.71	5.92
Land and other bldgs.	68.76	63.28	66.55	63.91	45.05	62.92	62.44	51.45	61.6
Livestock	14.84	11.60	7.83	3.23	22.69	10.2	5.95	12.4	12.5
Supplies	4.28	1.55	10.61	3.91	9.9	4.85	11.08	5.31	5.77

TABLE VI

SOURCES OF INCOME, THREE-YEAR AVERAGE

Sources	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Bros.	C. H. Eckblad	F. A. Miller
Crops	24	..	19	20	11	37	10
Dairy products..	17	38	..	24	21	18	30
Hogs	14	37	3	9	16	8	21
Cattle	3	12	76	11	18	..	15
Poultry ...	1	13	1	2	..	8	5
Other	4	..	1	2	1	10	7
Inventory increase..	37	..	..	32	33	18	12

HIGH-LINE CONSTRUCTION

The Northern States Power Company already had a 2,300-volt line extending 3.3 miles west of Red Wing to supply the Goodhue County Farm. The experimental line was an extension of the county farm line.

The total number of possible consumers on the experimental line, built in October and November, 1923, was 19. As originally built, the line was 6.2 miles long and supplied 10 actual consumers. In the following spring the line was extended 0.1 mile in order to provide for another consumer. The cost of construction was increased because the work had to be done in bad weather in order that it might be completed before the ground was frozen.

In order to determine results obtainable from different types of construction, it was decided to try:

(a) 2,300 volt, single-phase, grounded, iron messenger wire.

(b) 2,300 volt, single-phase, ungrounded, all copper wire.

(c) 6,900 volt, single-phase, all copper wire.

A detailed description of the line as originally built to supply 11 consumers is given in Table VII, and a detailed list of material used, in Table VIII.

The actual cost of construction as compared with the estimates made by the engineer of the Northern States Power Company as the basis on which the rate was determined was as follows:

COST OF ORIGINAL LINE—TYPE (a), 11 CONSUMERS, 6.3 MILES

	Estimated cost	Actual cost
Material	$4,645.00	$4,360.01
Labor	900.00	1,704.99
Insurance and interest	....	117.11
Engineering and superintendence	1,129.00	1,106.03
Cost without meters	$6,674.00	$7,288.14
Meters	....	110.00
Cost including meters		$7,398.14

The entire over-run of the actual cost was in the labor. The labor cost was about 25 per cent higher than on similar lines built by the same company elsewhere. The probable causes of the over-run were the difficulties under which the poles were set, the hilliness of the region, the necessity of cutting and trimming many trees, and the inefficiency of the labor crew which was assembled from farm hands of the neighborhood inexperienced in the kind of work involved; also, the fact that owing to the shortness of the time available for building, poles with seven-inch tops, which were on hand, were used instead of poles with six-inch tops, which would have been satisfactory, and an error in routing which made it necessary to reroute and dismantle a short part of the line. The excess cost should be subtracted from the actual cost in arriving at a fair investment value. The result from deducting the excess costs becomes clear in the following:

Actual cost, including meters		$7,398.14
Reductions		
Excess labor owing to type of crew	$350.00	
Use of poles with 7-inch tops	166.00	
Rerouting of line	26.12	
	$542.12	
Overhead on above	108.04	
Reasonable reductions in cost		650.16
Actual cost less reasonable reductions		$6,747.98

As this corrected value is about $100 more than the estimated cost prepared in advance of the building of the line, it may be assumed that the rate based upon this estimated cost was a fair one.

Change to All-Copper Line

The 2,300 volt grounded iron messenger wire line was not satisfactory. The grounded wire did not carry any appreciable amount of current and the resistance through the iron wire caused such a high primary voltage drop that it was impossible to operate 5 h-p. motors and ranges at two or more places simultaneously without bringing the secondary voltage below 100. The line was reconstructed in August, 1924, to provide better voltage. The two transformers with secondaries connected together to isolate the farm line from the city substation were taken out, and a copper line consisting of three No. 8's stranded was substituted for the ¼-inch Siemens-Martin iron wire. The cost of reconstruction was as follows:

For new material added			
Materials		$1,760.75	
Labor		41.07	
Transportation		3.85	
Insurance and interest		11.87	
Engineering and superintendence		220.65	
Total cost of new additions			$2,038.19
Removal of old material			
Labor cost		$ 17.77	
Materials removed			
37,960 ft. S.-M. steel ¼-inch wire	$455.52		
264 lbs. No. 8 copper-clad wire	50.37		
135-3 bolt guy clamps	37.03		
Total value of material removed	$542.92		
Value labor for installing	48.03		
Interest and insurance	10.86		
Engineering and superintendence	100.98		
Total original cost of removed material			702.79
Net value added to line			$1,335.20
Original cost less reductions			6,747.98
Total value of reconstructed line.			$8,083.18
In addition 25-ampere meters were substituted for 5-ampere meters			
Value of new meters	$172.26		
Value of meters removed	110.00		
Difference in value of meters			62.26
Total probable value of reconstructed line and new meters			$8,145.44

Summary of investment made by Northern States Power Company up to October 1, 1924

Total costs		
Original line cost	$7,398.14	
Reconstruction cost	2,038.19	
New meters	172.26	
Labor on removal of materials	17.77	
		$9,626.36
Deductions		
Value of meters removed	$ 110.00	
Value of materials removed	542.92	
		652.92
		$8,973.44
Loss to Power Company		$ 827.80

The loss to the Power Company was caused by (1) excessive cost of original line, and (2) reconstruction of line by changing it to an all-copper line. The line was left in this condition from October 1, 1924, until August 1, 1926, and the service was given to the farmers on the basis of a fixed charge of $6.90 a month for each customer, as determined from the original estimate.

The monthly fixed charge for service based on the fair value of line as given above ($8,145.44), and on a maximum demand of 23 kw., assuming a diversity factor of 2, as between this line and other consumers, would have been about $11.76 per consumer, with 11 consumers. If the 19 possible consumers had been given service at this cost, the fixed charge per consumer would have been $7.46. The cost of service based on a fair cost of line was about $4.30 a month for each consumer more than the company had been receiving for the service charge.

Change from 2,300 to 6,900 Volts

The line drop at 2,300 volts, in the operation of a 15 h-p. motor, near the end of the line was very noticeable. The variation was as much as 20 per cent at times. In order to compensate for part of this voltage drop, a voltage booster was installed at the city limits. This gave an unsatisfactory high-voltage on light load, but helped materially in maintaining the proper voltage while the motor was operating. In the summer of 1926, the line was changed to 6,900 volts. Seventeen thousand-volt insulators were substituted for 7,500-volt insulators, and the transformers were changed to 6,900 220/110 volt type.

Cost of changing from 2,300-volt to 6,900-volt line:			
New material and charges			
Materials		$2,010.57	
Labor		169.72	
Transportation		30.23	
Insurance		7.48	
Engineering and overhead		212.24	
Total cost of new additions			$2,430.24
Removal of old material			
Labor cost, insurance and transportation		$ 40.70	
Materials removed			
2,300-volt transformers	$506.58		
Lightning arrestors	130.42		
Cut-out boxes, plugs and miscellaneous	67.56		
Total value material removed		713.56	
Labor for original installation		142.71	
Insurance, interest, etc.		14.27	
Engineering and overhead		128.40	
Total original cost of removed material			998.94
Net value added to line			$1,431.30
Probable value of reconstructed 2,300-volt line			8,195.81
Total probable value of 6,900-volt line			$9,627.11

After the line was reconstructed, several new consumers were connected to the line. The costs were as follows:

Consumer	Material	Labor	Overhead	Total
J. B. Lokkesmoe	$ 210.83	$ 54.07	$ 35.06	$ 299.96
Orphanage	208.30	28.68	27.46	264.44
H. Bryan	168.40	11.18	22.45	202.03
E. Benson	425.58	114.45	74.37	614.40
P. Walsh	111.45	19.15	15.58	146.18
Total	$1,124.56	$227.53	$174.92	$1,527.01

Had the line been constructed originally as it stood after the change to a voltage of 6,900, the probable total value would have been:

Value of 6,900-volt line	$ 9,627.11	
Connections since 1926	1,527.01	
Total cost of line	$11,154.12	
Total investment by Northern States Power Company		
Original line cost	$ 7,398.14	
Cost in 1924, changing to all copper	2,038.19	
New meters	172.26	
Labor for removal of material in 1924	17.77	
Cost in 1926, changing to 6,900 volt	2,430.24	
Labor cost, removal of material in 1926	40.70	
Cost of connections since August 1, 1926	1,527.01	
Gross cost of line, service and meters		$13,624.31
Deductions		
Meters removed in 1924	$ 110.00	
Line materials removed in 1924	542.92	
Line materials removed in 1926	713.56	
Total deductions		1,366.48
Total investment by Northern States Power Company		$12,257.83
Cost of changing line, etc. (loss to Northern States Power Company)		$ 1,153.88

If the monthly fixed charges were to be based on the probable cost of line as rebuilt, serving 16 farmers, the fixed charge would be about $9.54 a month for each consumer.

TABLE VII

HIGH-LINE SPECIFICATIONS

Description

Poles—35 ft., 6-in. top, Western cedar, ½ in. guaranteed penetration, butt treatment.

Spans—275 ft. average.

Cross arms—No cross arms used except for transformer framing. Steel pole top pins used, with 1-in. thread.

*Conductors—3 No. 8 twisted copper wires used for the top conductor. The lower conductor ¼-in. Seimans-Martin steel strand, grounded at each pole to No. 6 BB galvanized wire.

Ground wires—Ground wire down each pole, No. 6 BB galvanized attached to aerial ¼-in. Seimans-Martin, which acts as one leg of the conductor circuits.

Insulators—Porcelain 6,600-volt insulators used, pin type, and 6,600-volt strain insulators on dead ends.

Pins—Steel pole top pin, 1-in. lead thread.

Voltage—2,300 volts, single-phase grounded line.

Length of line—Main line built by Northern States Power Company, 6.3 miles.

Consumers—Number of consumers estimated, 19.

Transformers—3 kw. transformers at each farm with three exceptions, where 5 kws. were used.

Total length of line—6.3 miles. The line was so routed that it was not necessary to build any farm secondaries, all transformers being located within a few feet of the barnyard.

* Both conductors were made copper when line was rebuilt in 1924.

Fig. 2. The B. I. Melin farmstead. Such an arrangement of buildings makes the wiring costly.

TABLE VIII

CONSTRUCTION EXPENDITURES AS OF JULY 31, 1924

Ream out bolt holes in galvanized iron clamps	$ 3.00
Red cloth	.50
Nails	1.05
Misc. supplies and fittings	23.91
Lumber	3.65
Use of tractor	5.00
Washers	.60
Freight	9.15
Expense of C. Wagner (farm line survey)	58.33
4 No. 1601 Haven steel hooks	10.28
12 14 x ⅝ in. eyebolts	2.14
5 14 x ⅝ in. space bolts	.82
50 16 x ⅝ in. space bolts	6.85
10 18 x ⅝ in. space bolts	2.09
4 18 x ⅝ in. space bolts	.74
19 16 x ⅝ in. through bolts	2.23
14 18 x ⅝ in. through bolts	1.75
8 10 x ⅝ in. through bolts	.73
21 4 x ½ in. lag bolts	7.18
80 3 x ½ in. lag bolts	2.08
30 ½ x 30 in. galvanized machine bolts	4.77
26 ½ x 30 in. machine bolts	4.13
32 4 x ⅜ in. carriage bolts	.58
165 10 x ⅝ in bolts	13.20
134 12 x ⅝ in. bolts	12.73
1,000 ft. ⅜ in. guy cable	15.00
800 ft. 5/16 in. guy cable	14.40
30 Pierce 8 in. galvanized guy guards	48.94
100 guy shim hooks	9.00
85 guy shims	3.31
24 Mathews screwlix anchors	75.38
6-8 ft. x ⅝ in. anchor rods	5.10
35 No. 4 Ddb. tube connective sleeves	3.50
549 No. B B iron wire	35.07
3998 lbs. 3 strand No. 8 M.H.D. wire	795.54
264 lbs. No. 6 W.P. wire	23.51
134 lbs. No. 4 W.P. wire	28.11
37,960 ft. ¼ in. Seimans-Martin guy wire	455.52
675 ⅝ in. washers	13.45
16 ¾ x 4 in. washers	.96
56 clevices for porcelain insulators, L.M. 1719	16.80
52 dead ends clevices	7.18
2 large clevices	.65
6 spool insulators No. 680	.54
155 porcelain insulators (6,600 W. 1 in. pin)	34.14
50 No. 602 strain insulators	6.95
59 porcelain strain insulators 5,000 V.O.B. No. 25314	46.35
45 3½ x 4 ft. 7 in. cross arms, unbored	38.25
16 48 in. angle braces	10.71
30 28 in. cross arm braces	3.60
4 4 ft. pine cross arms	3.85
18 primary fuse plugs	7.06
17 G. E. primary fuse boxes	15.18
1 2,200 volt fuse box	.94
16 2,300 volt choke coils	8.16
16 2,300 volt Westinghouse lightning arrestors	83.41
1 2,500 volt choke coil	.72
1 2,500 volt auto valve lightning arrester	5.22
30 ½ x 19 x ½ in. pipe spacers	4.50
4 ¾ x 3 spacers	.08
50 ⅝ in. eyelets	15.50
180 ft. ¾ in. galvanized pipe	12.60
185 ⅝ Crosby clips	32.43
215 3-bolt clamps	60.14
12 3-point N.S. sec. racks	7.37
1 3-point sec. rack	.27
50 ⅜ in. thimbles	2.00
2-in. tape	.89
18 lbs. solder	5.18
75 lbs. staples	3.52
8 40-ft. poles	124.80
120 35-ft. poles	1,563.59
135 pole top pins, 1 in. thread, lead head	58.05
19 drive pins	5.19
7 Westinghouse 3 kw. transformers	266.64
2 G. E. 5 K.V.A. transformers	123.80
1 5 K.V.A. transformer	65.00
1 reel N.S.P. Co. No. 4650	10.00
Telephone and telegrams	15.80
Final charge for cutting down trees	25.00
8 4 x ½-in. light holes	.27
1 ground pipe 8 ft. x 2/4 in.	.68
2 B.E.	.23
5 ¼-in. Crosby clamps	.65
50 lbs. No. 6 Hard drawn wire	6.70
625 ft. ¼-in. messenger wire	11.25
Total material charges	$4,416.18
Credits, material returned	56.17
Total cost of materials for line	$4,360.01

WIRING THE FARMSTEADS

One of the first problems to be considered in supplying farms with electric current is the correct wiring of the farmstead. This problem had not been solved when the Red Wing Project was started. The general practice had been to place the transformer at the roadside or in the yard near the road, place the meter and entrance switch in the house and distribute from this point to the other buildings for light and small power. The early wiring on the Red Wing farms was handled largely in this manner. The power com-

Fig. 3. Roadside location of transformer, at the home of Frank Miller.

pany had been accustomed to place entrance switches and meters in the basement of the house. Variations were made, however, to get information on other methods. At B. I. Melin's and C. H. Eckblad's, the meter and entrance switch were placed in the back kitchen or laundry room; at W. J. Bryan's they were placed in the entry room or milk room in the barn; and at Arthur Nelson's they were placed in the pantry.

In order to provide for the use of a 5 horse-power motor and an electric range on 3 kva. transformers without overloading them, double throw switches were installed at first so that both devices could not be used at the same time. This complicated the wiring. Later, being found to be unnecessary, all such switches were discontinued. The extra cost for this trial connection is not included in the wiring costs. All yard wiring for large power use and all service leads were No. 6 R.C. copper wire. These wires were large enough for most places if the transformers and entrance switches were properly placed. Voltage tests, when ranges were in use, with the transformer at the road side, showed a voltage as low as 99.5 at the range at one installation and as low as 100 volts at another. These tests indicated that long secondary runs gave very poor voltage. This condition is discussed more completely under voltage regulation. Regulation in some cases was so bad that the transformers were moved into the yards, and in other cases larger secondary wires, such as No. 2, were used. Moving the transformer into the yard was the most satisfactory way of improving voltage regulation.

Since good voltage was necessary to operate 5 h-p. motors at their overload capacity, it was found desirable to locate the transformers centrally in the yard. Figures 5, 7, and 9 show the wiring for three of the farmsteads as originally wired, while Figures 6, 8, and 10 show how these should have been wired to give satisfactory voltage regulation. To change the wiring on all of these places according to plans which were developed as a result of this study, would be quite expensive, and only a few changes will actually be made in order to improve the condition at minimum cost.

A long run from the transformer to a motor used at the granary or silo is necessary on the farmstead of the Nelson brothers (Fig. 5). The 5 h-p. motor ran "hot" under such low voltage conditions and would not carry the momentary overloads. The length of wire for both motor and range operation should be shortened, as shown in Figure 6. The transformer should be placed at the corner of the yard, and the meter and main distribution panel in the pump house.

Where buildings are strung out as in the case of the farmstead of A. C. Bryan (Fig. 7), the distance from transformer to the motor near the silo is nearly 500 feet. Under such a condition, a 5 h-p. motor is not able to pull even its full rated horse-power without a drop of 30 or 40 volts from 230 volts, unless very heavy secondary wires are used. Placing the meter in the basement of this house at the far side from the barns made a very expensive wiring job with nearly $100 worth of wiring in the house basement. If this farmstead were wired according to the plan shown in Figure 8, satisfactory service could be delivered at all points and the cost of wiring could be reduced by at least 20 per cent. It might seem, in this case, more desirable to place the meter and main distribution panel in the granary instead of in the shop. This would be a more central location, but the large amount of dust, flour, etc. makes a granary an undesirable location for a meter.

The arrangement of buildings at the farmstead of W. A. Cady offers a very good opportunity for a concentrated wiring layout, but the original plan as shown in Figure 9 did not take advantage of the farmstead plan. Note the very long run from the house to the "feedery" and silo. The length of wire from the transformer to the motor at the "feedery" could be reduced about one-half by the plan shown in Figure 10.

These three plans are discussed here to show the way in which such wiring has been done ordinarily and how it should be done in order to give satisfactory service. The yard wiring for control of the yard light is not shown as it might cause confusion. The location of the yard light, and yard outlets for use with a portable motor for such purposes as silo filling, sawing wood, etc., are shown on the diagrams.

In order to show more clearly the method of wiring as recommended in the plans shown in Figures 6, 8, and 10, a schematic diagram of the wiring plan for the farmstead of A. C. Bryan, as shown in Figure 8, is given in Figure 11. A brief explanation of this method of wiring, as shown in Figure 11, is given below. The three service wires (No. 6 copper) are taken from the transformer (preferably through a conduit entrance, (Fig. 16) to the "main entrance switch" and meter in the shop. From the switch-box the wires go to the "main distribution panel." Four circuits lead out from this panel box: 1, the main power circuit, to the barns; 2, the main power circuit, to the house; 3, the light circuit, for garage and shop; and 4, the power circuit, for the garage. Two branch circuits are taken from the power circuit to the barns before this circuit enters panel box "B." One two-wire circuit is for lighting the barn and old poultry house, while a three-wire circuit is taken to panel box "C" in the cattle barn. Several circuits are taken from this panel box to supply the barns with light and power. On the circuit to the horse barn a branch circuit of two No. 10's is taken off to supply the lights, etc., at the poultry house. Where the size of wire is changed as in this case from a No. 6 to a No. 10, it is necessary to use a fused switch where the service enters the poultry house. The power circuit to the house is taken to panel box "A," and circuits from there supply the house with light and power, and also a yard outlet. No. 6 wires are used throughout where 230 volt service for power is made available.

Just recently one farmer, Emil Benson, has been given electric service from the experimental line and has had his farmstead wired according to plans like these. A diagram of his farmstead and the farmstead wiring plan is shown in Figure 12. Note the location of the "main entrance switch," meter, and "main distribution panel" in the milk room. This type of wiring gives good voltage regulation.

Figure 13 shows the sturdy type of transformer pole mounting that has been used. Note the use of fused cut-outs on the cross arm, and the protected ground wire on the side of the pole. The service leads and the outcoming power circuit for the barn are shown where they enter and leave the milk house through conduits. Wires for the yard light can also be seen. The "main entrance switch," meter, and main distributing panel are shown in Fig. 14. The unfused circuit is the house circuit, and the lower circuit is for lights, etc. in the milk house. The panel box "A" in the summer kitchen of the house is shown in Figure 15. The house is small and has only two circuits for lights and convenience outlets. The upper fuse block is for a future range connection.

More details on farmstead wiring can be found in the bulletin "Farmstead Wiring for Light, Heat, and Power" published by the National Committee on the Relation of Electricity to Agriculture.

WIRING THE FARM BUILDINGS FOR LIGHT AND POWER

Many farmers have been deprived of the chance to make electricity their efficient and profitable servant because of inadequate wiring. Cheap, skimpy wiring should not be allowed in farm homes. Such wiring is a fire hazard, a life hazard, and makes it impossible for the farmer to use electric service to the best advantage.

The isolation of the farm home makes it essential that wiring systems be so installed as to reduce to a minimum the fire hazard and the need for repairs. It is expensive to secure city help to repair farm wiring, and many farm homes in which poor wiring jobs have been done go along year after year with wires dangling loosely from walls, with switches broken, and with poor connections temporarily toggled up. A good wiring job, properly installed, with adequate switches, fuses, and numerous outlets, will do away with the chance of mechanical injury to the system and will eliminate almost entirely the necessity for repairs.

All wiring—farm as well as urban—should be installed according to the standards established by "The National Electric Code" and should conform to the recommendations of "The National Electrical Safety Code." Copies of the former bulletin may be obtained from the Underwriters Laboratories, 207 East Ohio Street, Chicago, Illinois, and copies of the latter from the Superintendent of Documents, Government Printing Office, Washington, D. C., for a nominal price.

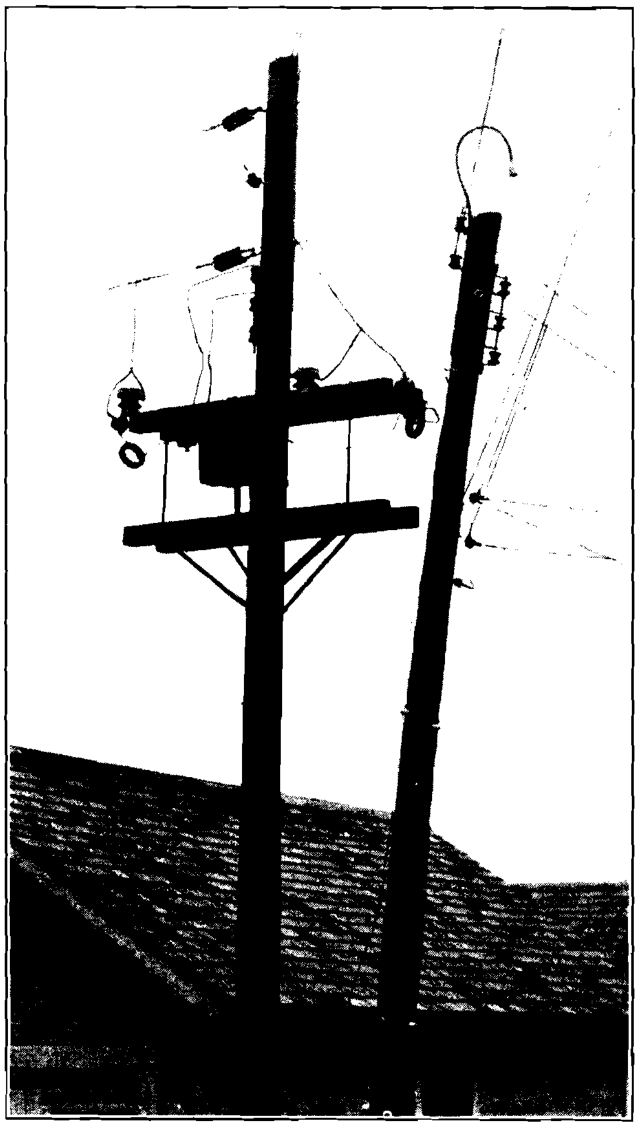

Fig. 4. Typical farmyard transformer installation, with choke coils and lightning arrestors.

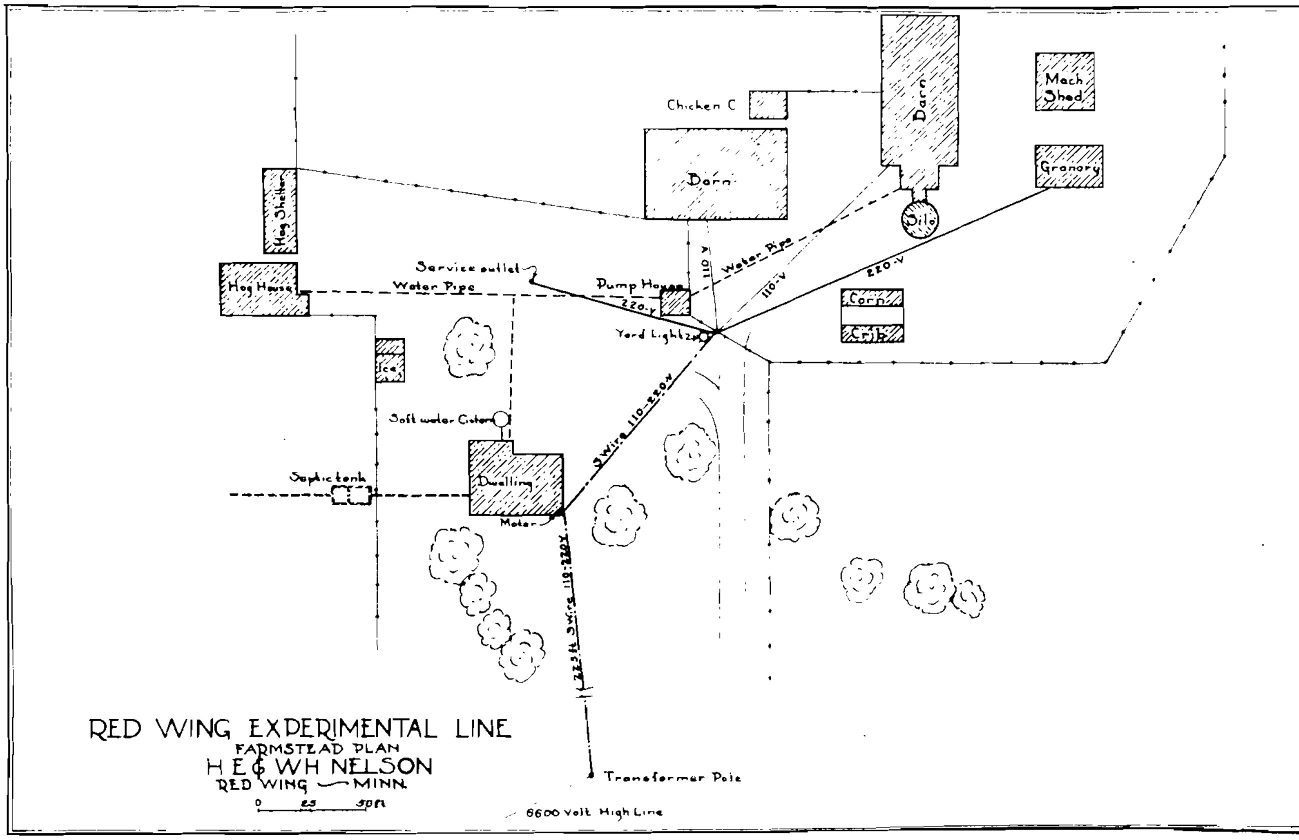

Fig. 5. Original wiring plan, H. E. and W. H. Nelson farm. Location of transformer made long secondary lines to barn and granary necessary.

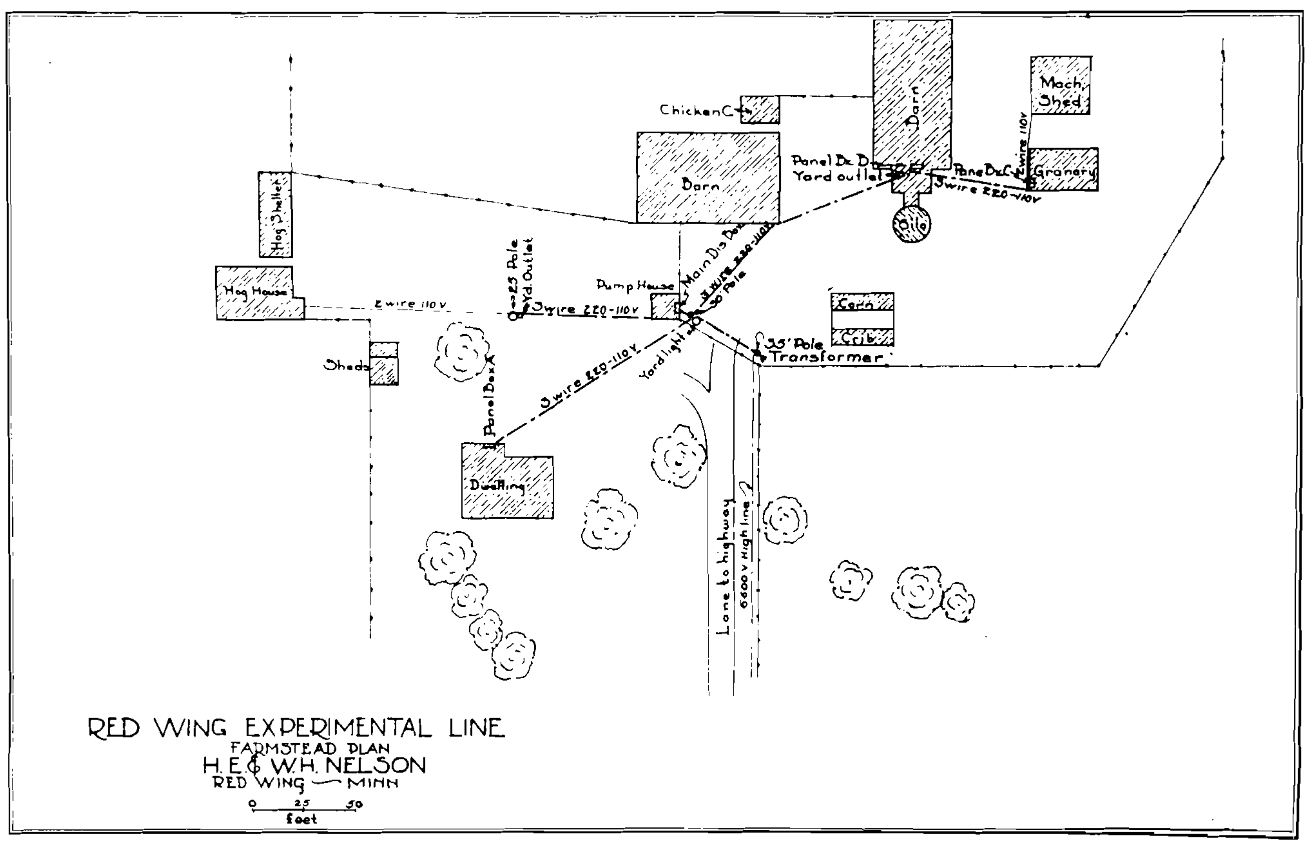

Fig. 6. Revised wiring plan, H. E. and W. H. Nelson farm. Transformer in yard, near pump house, shortens secondary runs to house and barns.

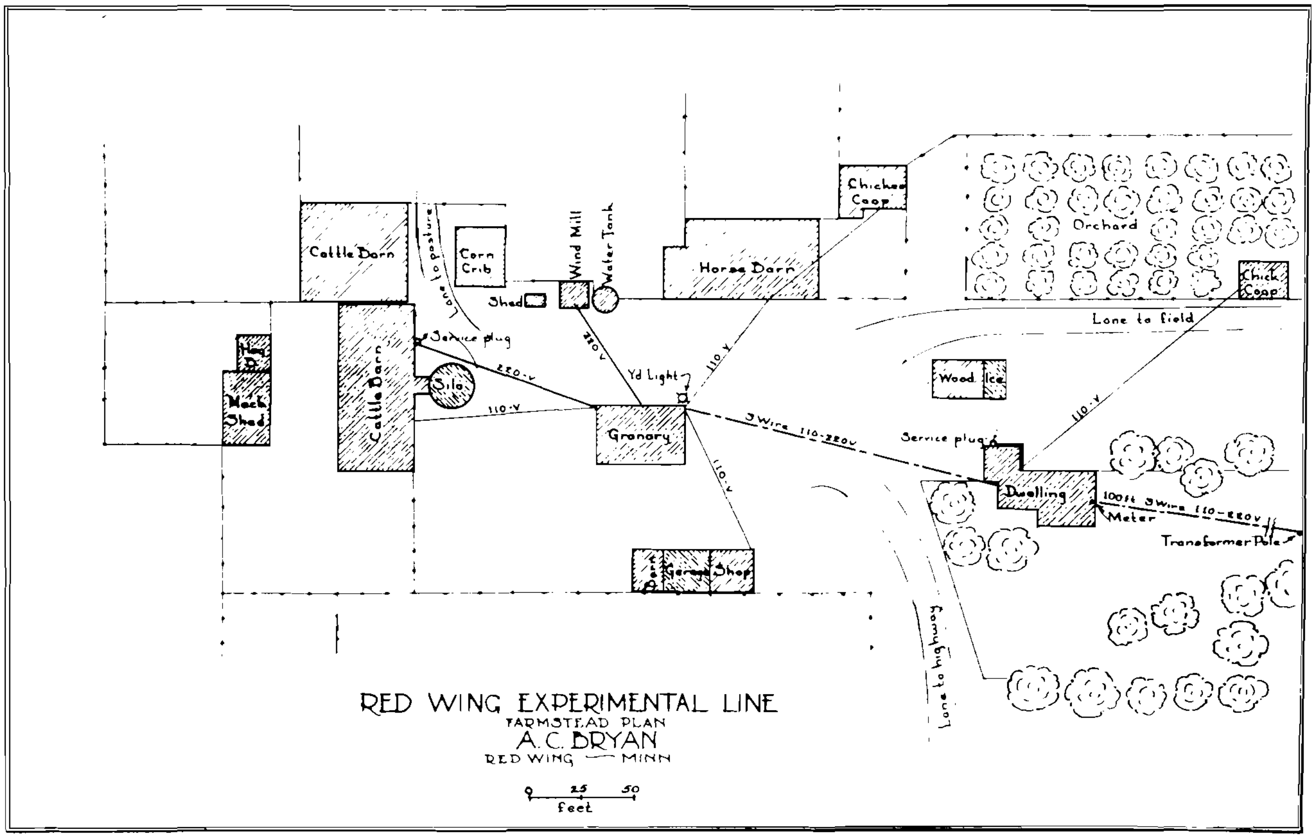

Fig. 7. Original wiring plan, A. C. Bryan farm. Transformer at side of yard necessitated extremely long secondary lines to cattle barn and silo.

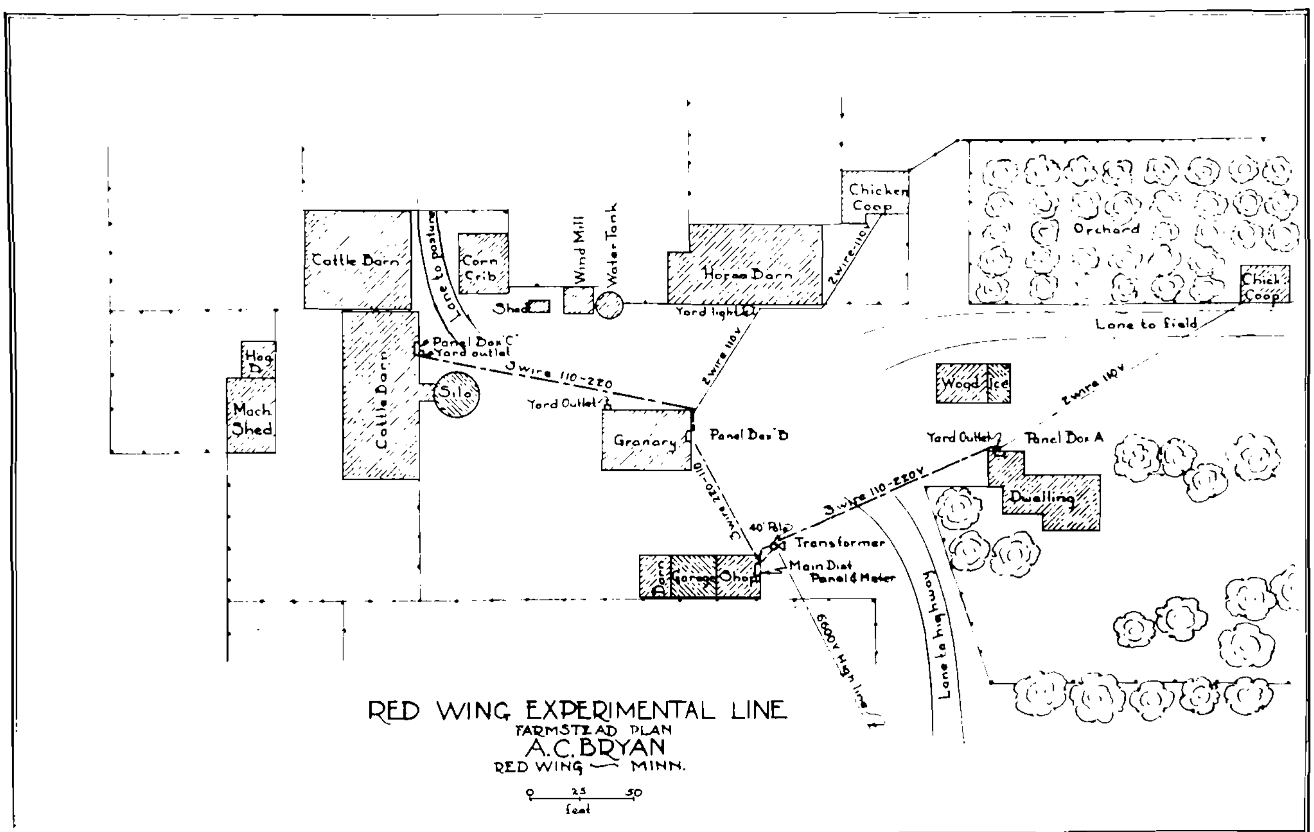

Fig 8 Revised wiring plan, A. C. Bryan farm. Transformer near shop, with short secondary lines to barn, granary, and house.

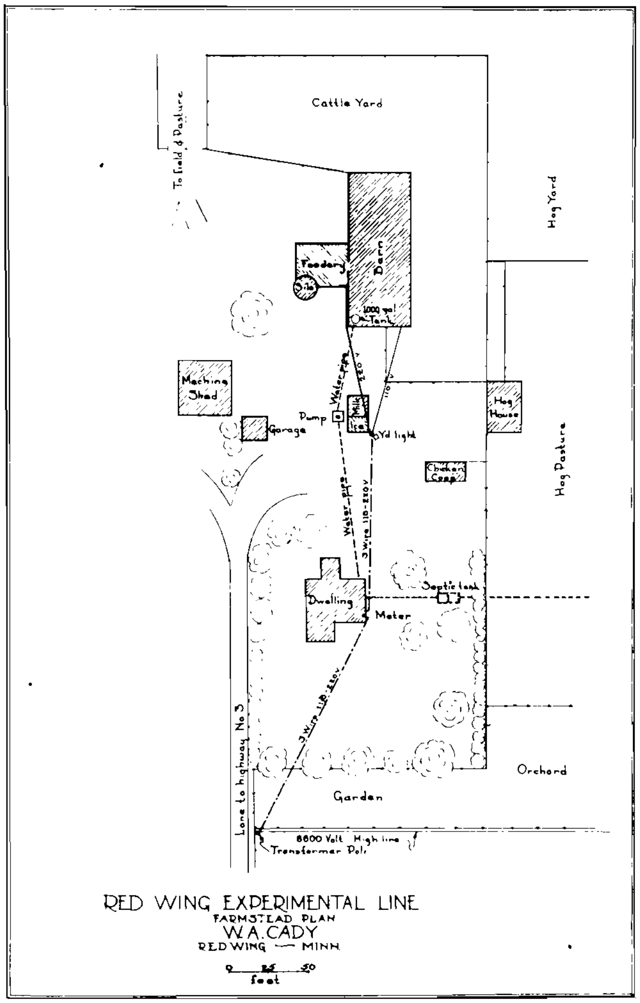

Fig. 9. Original wiring plan, W. A. Cady farm. Transformer in farm lane. A conventional plan.

Space in this bulletin is not available for more than a meager treatment of the general principles involved and a statement of what was done in wiring the homes and farm buildings on the Red Wing Project.

Wiring of Farm Homes

Plans of all homes were submitted to the Committee on Farm Wiring, of the American Society of Agricultural Engineers. The chairman of this committee was a member of the staff of the National Lamp Works, at Cleveland, Ohio, and the engineers of the company worked out plans for wiring and lighting the homes. The plans were modified to fit local conditions, and particularly farm conditions. The farm homes now have very complete, adequate wiring systems, and yet systems that are not elaborate or expensive. The lighting is good. It has been said that these eight homes are the best lighted farm homes in America. "Best lighted" does not mean that they necessarily have large lamps or expensive fixtures, but rather that they have adequate lighting, adapted to the uses for which it is intended. The National Lamp Works and the committee mentioned above have continued their study of farm lighting and the chairman of this committee has written a bulletin on "Farm Lighting," published by the National Lamp Works, which gives excellent information.

In order to indicate the type of wiring systems installed, the wiring plans for the home of H. E. and W. H. Nelson are shown in Figures 17 and 18. The wiring symbols are given on Figure 17 and a complete list of the 34 light and convenience outlets is given in Table IX. The size of the lamps, height of lamps or outlets, locations of lamps and outlets, and types of lamp switches and fixtures are also given in this table. In addition to the 34 outlets for light and convenience receptacles, there are 21 switch outlets, making a total of 55 outlets. The switch for the kitchen light is near the rear door and near the stairs, not near the dining room door as is found in city practice. The switch for the dining room light is near the kitchen door, and not near the hall or living-room door as is frequently the case. The switch for the living-room light is placed near the door leading to the living-room from the kitchen through the den. In a similar way, the switch for the light in the den is at the door to the kitchen. The den serves as an office and reading room. These switches are located for travel from the kitchen to these other rooms. Farm families enter these rooms from the kitchen end of the house much oftener than they do from the front part of the house. The switch

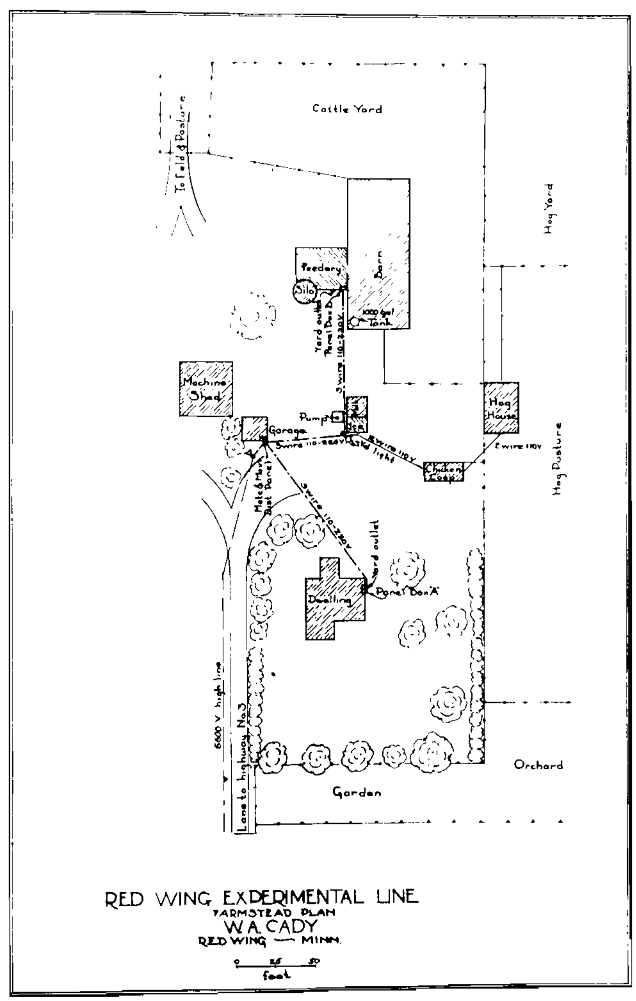

Fig. 10. Revised wiring plan, W. A. Cady farm. Transformer near garage, with short secondary lines.

TABLE IX

WIRING KEY, NELSON BROTHERS

No.	Location	Outlet	Watts*	Mounting heights	Wall or ceiling	Control	Fixture
1	Living-room	Light	200	6′-6″	Ceiling	Push wall switch	Silver and blue hanger
2	Living-room	C.O.†	...	3½″	Base board	....	Flush plate
3	Porch	Light	50	8′-4″	Ceiling	Push inside wall switch	White globe
4	Front hall	Light	50	8′-16″	Ceiling	Push wall switch	2¼″ W. E. with shade 5370
5	Dining-room	Light	100	5′-0″	Ceiling	Push wall switch	Verde Antique
6	Dining-room	C.O.	...	3½″	Base board	....	Flush plate
7	Dining-room	C.O.	...	3½″	Base board	....	Flush plate
8	Bedroom	Light	50	8′-8″	Ceiling	Push wall switch	Open ornate shade
9	Bedroom	C.O.	...	3½″	Base board	....	Flush plate
10	Den	C.O.	...	3½″	Base board	....	Flush plate
11	Den	Light	100	7′-0″	Ceiling	Push wall switch	White enamel bracket
12	Back porch	Light	50	8′-4″	Ceiling	Push wall switch	Closed white globe
13	Kitchen, over sink	Light	50	5′-5″	Wall	Snap switch on bulb	White open shade
14	Pantry	Light	50	8′-8″	Ceiling	Push wall switch	Kitchen unit with 9″ Trojan
15	Kitchen	Light	50	8′-8″	Ceiling	Push wall switch	Closed white globe
16	Kitchen	Iron receptacle	Iron 550 indicator	4′-5″	Wall	Wall switch	With indicator
17	Rear entry	Light	30	8′-8″	Ceiling	Push wall switch	Closed white globe
18	Kitchen	C.O.	...	3½″	Base board	....	Flush plate
19	Kitchen	Range	...	16½″	Wall	....	....
20	S.W. bedroom	Light	50	7′-8″	Ceiling	Push wall switch	Ornamented open shade
21	S.W. bedroom	C.O.	...	3½″	Base board	....	Flush plate
22	S.W. bedroom closet	Light	50	6′-8″	Wall	Pull chain	Open bulb
23	W. bedroom	Light	50	7′-8″	Ceiling	Push wall switch	Ornamented closed globe
24	W. bedroom	C.O.	...	3½″	Base board	....	Flush plate
25	W. bedroom closet	Light	50	6′-8″	Wall	Pull chain	Open bulb
26	N.W. bedroom	Light	50	7′-8″	Ceiling	Push wall switch	Ornamented closed globe
27	N.W. bedroom	C.O.	...	3½″	Base board	....	Flush plate
28	Hallway	Light	50	7′-4″	Ceiling	Push 4-way wall switch	Wrought and glass shade
29	Bathroom	C.O.	...	3½″	Base board	....	Flush plate
30	N.E. bedroom	C.O.	...	3½″	Base board	....	Flush plate
31	Bathroom	Light	25	....	Wall	Wall switch	White enamel with 5243 x 9″ rose decorated glass
32	Bathroom	Light	50	....	Wall	Wall switch	White enamel with 5243 x 9″ rose decorated glass
33	N.E. bedroom	Light	50	....	Ceiling	Wall switch	Open white shade
34	Basement	Light	80	....	Ceiling	Snap switch, head of stairs	Open bulbs

* In every case one light is used except in the basement.
† Convenience outlet.

TABLE X

SUMMARY OF WIRING COSTS

	W. A. Cady	A. M. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad house	C. H. Eckblad out-buildings	F. A. Miller	W. J. Bryan*
Wire	$ 58.85	$ 62.68	$105.10	$ 80.68	$ 55.84	$ 47.25	$ 51.10	$ 88.60	$ 29.38
Knobs and tubes...........	8.03	7.93	24.50	15.32	13.89	9.60	6.50	10.00	11.46
Loom	12.72	12.86	22.55	17.99	16.06	23.25	4.48	26.00	21.22
Switches and fuses........	20.20	27.55	43.40	39.25	33.25	28.00	17.15	12.50	18.55
Receptacles		7.05	11.75	4.45	10.25	11.25	1.15	8.00	4.95
Miscellaneous	20.10	17.28	39.00	25.80	21.92	4.50	13.79	25.10	11.65
Total material	$119.90	$135.35	$246.30	$183.49	$152.11	$123.85	$ 94.17	$170.20	$ 97.21
Labor at $1 per hour.......	51.80	67.55	111.80	83.00	99.98	46.50	57.00	69.17	65.00
Total, labor and materials	$171.70	$202.90	$358.10	$266.49	$252.09	$170.35	$151.17	$239.37	$162.21
Material, per cent	70	67	69	69	60	73	62	72	60
Labor, per cent	30	33	31	31	40	27	38	28	40
Lamps	$ 13.64	$ 7.20	$ 17.60	$ 11.30	$ 14.99	$ 3.80	$ 4.46	$ 9.40	$ 11.92
Fixtures	79.56	90.84	117.60	153.12	153.88	147.40	......	88.92	†
Total	$264.00	$300.94	$493.30	$430.91	$420.96	$321.55	$155.63	$337.69	$174.13
Number of outlets.........	55	38	88	68	93	51	18	69	
Cost of wiring per outlet...	$ 3.12	$ 5.33	$ 4.07	$ 3.92	$ 2.71	$ 3.34	$ 8.40	$ 3.47	
Total cost per outlet.......	4.81	7.94	5.62	6.34	4.53	6.30	8.65	4.90	

* W. J. Bryan's farm had an individual lighting plant before experimental work was started. Additions were made to the wiring as given above.
† Previously installed.

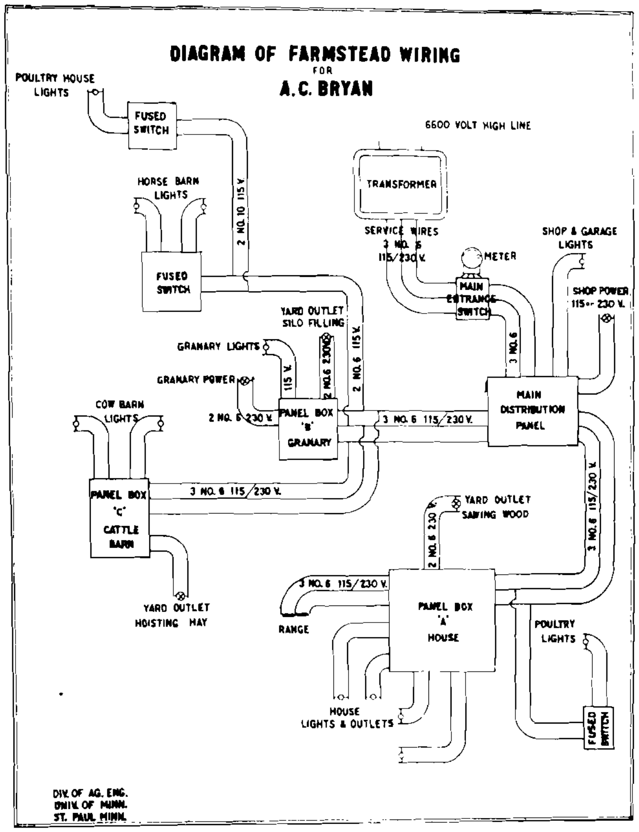

Fig. 11. Diagram of wiring on A. C. Bryan farm, as revised (Fig. 8). Three-wire service, No. 6 wires, to all principal buildings.

for the pantry is placed in the kitchen. This is convenient when carrying materials out of the pantry and saves going back into the pantry to turn out the light. All rooms, on both the first and second floors, have convenience outlets, with the exception of the halls. All of these outlets are useful and are used. The two closets that are used the most have lights in them. The hall on the second floor is long and requires switches at both ends. Since it was desirable that this light should also be controlled from a switch on the first floor, the installation required two three-way switches and one four-way switch. By the use of these switches the hall light can be turned on or off at any one of the three places. This is a cheaper and more convenient method than to use two lights and two sets of three-way switches as is frequently done in such cases. The bracket lights in the bathroom are controlled by a wall switch, and a convenience outlet is also provided for the use of a glow heater, curling iron, hair dryer, or other similar convenience.

Rooms in the home of H. E. and W. H. Nelson are not very much used as passageways to and from other rooms. The den is used in this way to a small extent, but it is seldom that the den light is turned off when the room is used as a passageway. In many homes, however, several downstairs rooms may be used as passageways, such as dining-rooms, and summer kitchens or laundry rooms. In some homes also, rooms are so located that they may be entered equally often from each of two doorways. In such cases the lights in these rooms should be controlled by two three-way switches, one located near each door. Such conditions as explained above are shown in the plans for a very well arranged seven-room home shown in Figures 19 and 20. The wiring plan for this home was developed after a study of wiring on the Red Wing farms, and represents the highest type of farmhouse wiring practice. All rooms are provided with double convenience outlets, and the first floor bedroom, living-room, and dining-room have several such outlets. Double outlets are recommended in all cases. Every closet has a light controlled by a pull chain switch. Such lights are more convenient, generally, when placed on the wall beside the door instead of above the door.

The wiring of farm homes should conform as closely as possible to the following suggestions:

1. Lights for general room lighting, placed on the center of the room, should be controlled by wall switches.

2. Drop cords should not be used, but if they are, wall switches should be used to control the light instead of using light sockets with snap switches.

3. Convenience outlets should be placed in every room where appliances may be used. Lamp receptacles should not be used for convenience outlets, because such use adds to the breakage of lamps and fixtures.

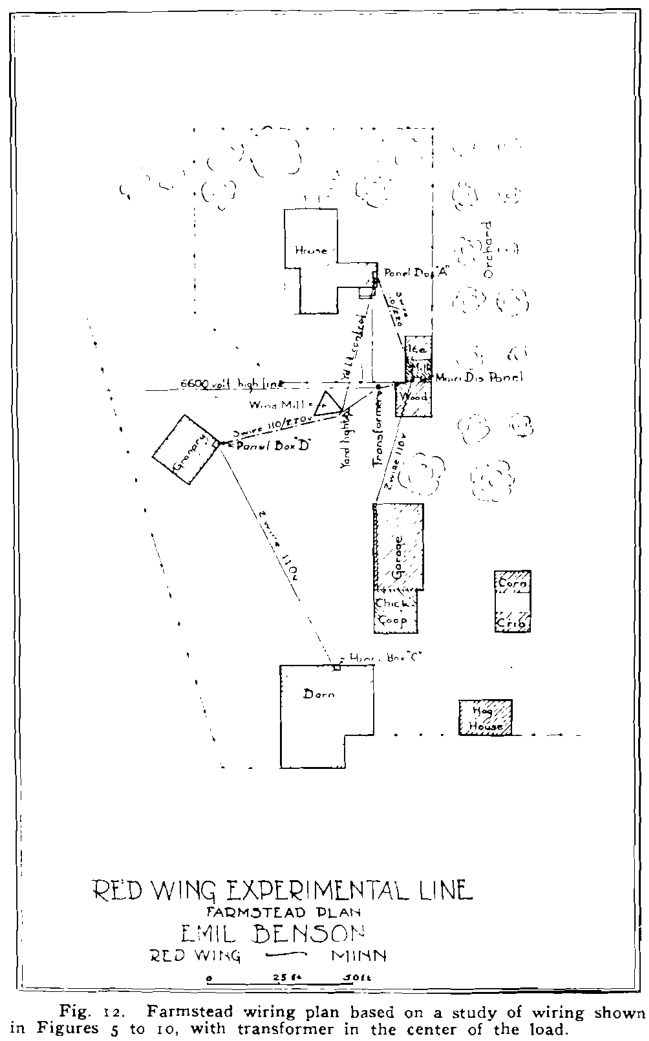

Fig. 12. Farmstead wiring plan based on a study of wiring shown in Figures 5 to 10, with transformer in the center of the load.

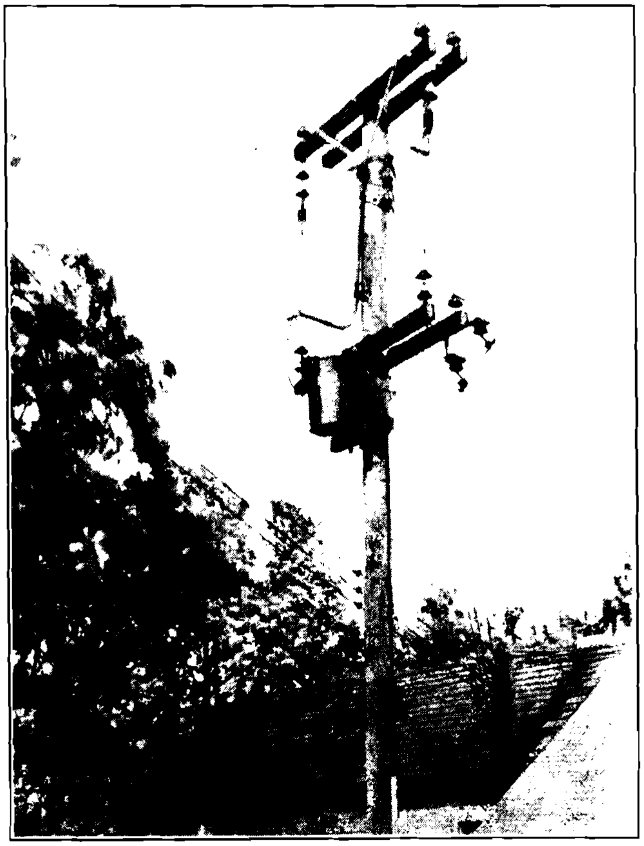

Fig. 13. Transformer mounting on pole in dooryard of the Emil Benson farm. The installation is well protected with good insulators, fused cut-outs, and choke coils. The conduit entrances to, and exits from, the building containing the distribution panel are worthy of notice.

4. Three-way switches should be used in rooms in which lights are to be turned on or off at two places in a room.

5. Two circuits should be used for most small homes, and at least four circuits for the average farm home such as is shown in Figures 19 and 20.

6. The effectiveness of electrical service depends on the completeness of the wiring system.

Wiring of Barns

Practically all of the general statements made in regard to the wiring of homes apply to the wiring of barns. Space cannot be devoted in this bulletin to a discussion of the different kinds of wiring, such as knob and tube, rigid conduit, flexible conduit, or flexible cable, metal molding, and the new type of non-metallic sheathed cable. Combinations of these were used on the Red Wing farms. Entrances to buildings were generally made with conduit, some short circuits for connecting equipment were made with flexible cable, but knob and tube or cleat work was used for most of the wiring. The new material, non-metallic sheathed cable, was not available at that time. Anyone of these types may be used if properly installed. The rigid conduit method, which may seem to be the most desirable (usually at higher cost, however) for new houses, offers a real problem when installed in old houses or in barns and stables. Condensation of moisture in the conduit in stables often causes short circuits. Where conduit is used in stables, care should be exercised to provide drains at all low points. Joints at junction boxes should be made nearly air-tight and only sheradized conduit should be used.

The barn wiring should be controlled by a master cut-out or switch in a panel box, and provision should be made for fuses for different circuits if more than one light circuit is used or if power is used in the barn. The light circuits should be provided with wall switches at convenient points, so as to eliminate the use of inconvenient and dangerous drop cords and sockets with snap switches. It is desirable to use several wall switches and divided lighting circuits so that all lights do not need to be on at once. In Mr. Miller's barn, at Red Wing, there are eight switches: one three-way for the yard light; two three-way for feed alley lights; one for lights in hay loft; and four for two sections of lights each, for horse stalls and cow stalls.

Two new barns were built on Red Wing farms, and were equipped for the use of electricity. The floor plan of the barn on Nelson Brothers' farm is shown

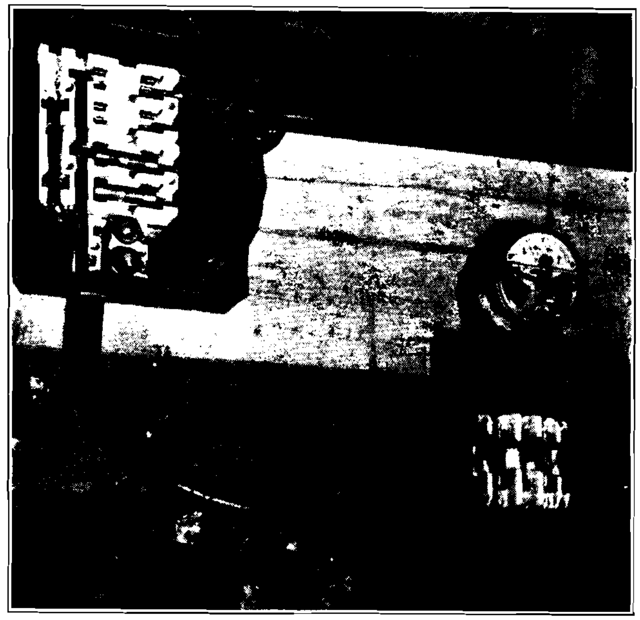

Fig. 14. Main entrance switch, with meter, at the right, and distribution panel at left. The lower fuse-block, with plugged fuses, is for light in the milk house: the two other fuse-blocks supply the barn and house circuits.

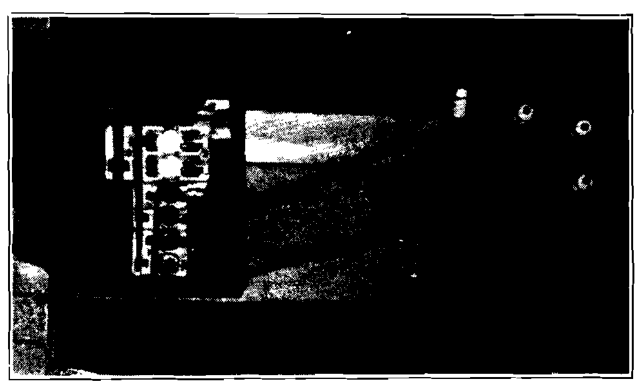

Fig. 15. Panel box for the house, showing the two circuits for house lighting and a large fuse-block for a future range connection.

in Figure 21. The wiring plan of this barn shows the location of the lights, switches, etc. The lights are well located and sufficient in number if 60 or 75 watt lamps are used. If smaller lamps are used, then at least five more would be necessary to give good illumination. Switches are placed near the doors or alleys where the farmer is most likely to reach them. This barn may be entered through the feed room or through the door at left side of feed room. Consequently one set of lights (those behind the cattle) are controlled by two three-way switches. Switches for the electric ventilating fans are placed where they are most conveniently reached, and at the same points where the fan doors are opened.

A very complete barn wiring job is shown on the floor plan of the barn on the farm of W. A. Cady given on page 52 of this report. He has used more lights of a similar size than are shown in Figure 21. More lights give better illumination with fewer shadows, but cost slightly more.

Cost of Farm Wiring

The cost of farm wiring will vary widely, depending upon the quality and completeness of the installation. As stated before, the average town electrician does not give the farmer an adequate or satisfactory job. One electrician quoted one of the Red Wing farmers a price of $78 for a complete wiring job including drop cords and lamps. This would have been a very unsatisfactory job, inadequate and uneconomical. When the work was done by the man, according to plans calling for wall switches, proper sized lamps, and an adequate wiring system, with a few convenience outlets, the job cost $147.05, not including fixtures. The fixtures for the house cost $79.56, making a total cost for the house wiring and fixtures of $226.61, which is nearly three times the cost of the original inadequate job proposed.

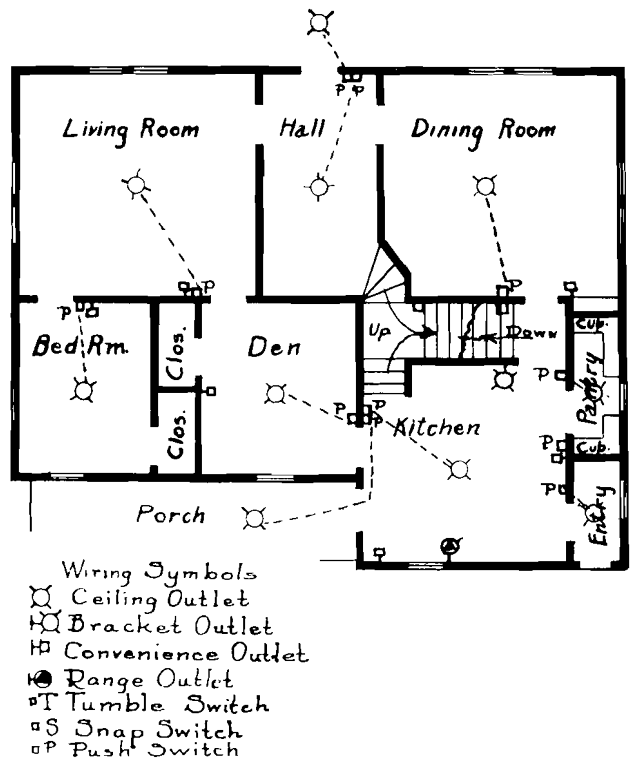

Fig. 17. Original wiring installation at the home of H. E. and W. H. Nelson, showing location of lights, switches, and outlets on first floor. All lights controlled by wall switches.

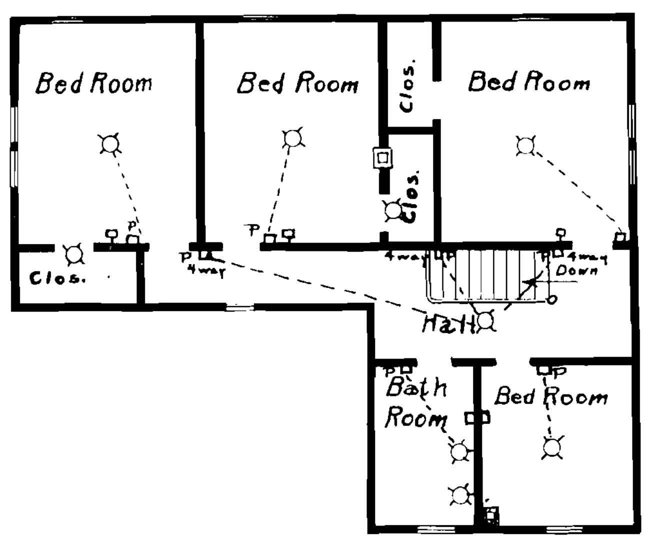

Fig. 18. Original wiring, second floor. Three-point control on hall lights, and wall switches to control lights in bathroom.

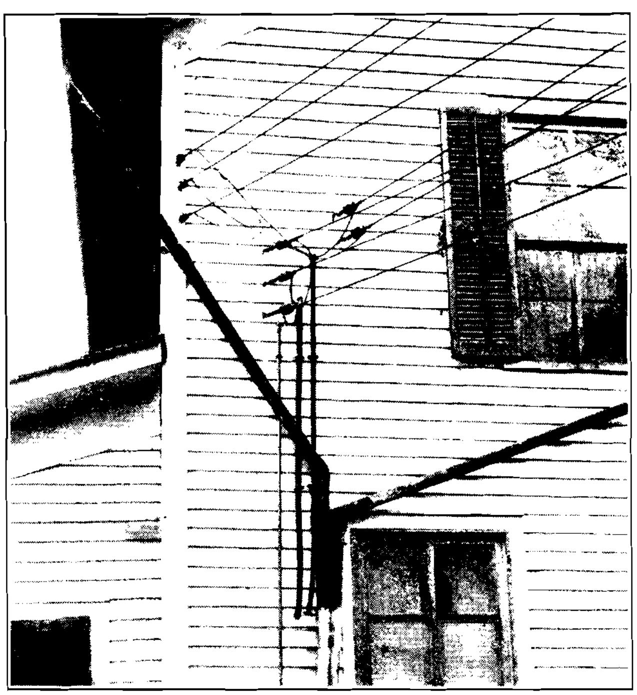

Fig. 16. A desirable type of entrance and exit for a farm building. The strain insulators, conduit entrance, and galvanized pipe ground rod are worthy of attention.

Many farmers have felt that they could get their farm homes and outbuildings wired for a cost of $100 to $150. Such wiring systems are not recommended. They are costly to keep up; they are not usually kept in proper condition; and they are fire and life hazards, as well as extremely inconvenient. Someone has aptly said that a poor wiring job robs a farmer of one half of the benefits of electric service.

Farm buildings consisting of a six- or seven-room house, a combination barn, or two barns, and other outbuildings, will require an expenditure of $175 to $350

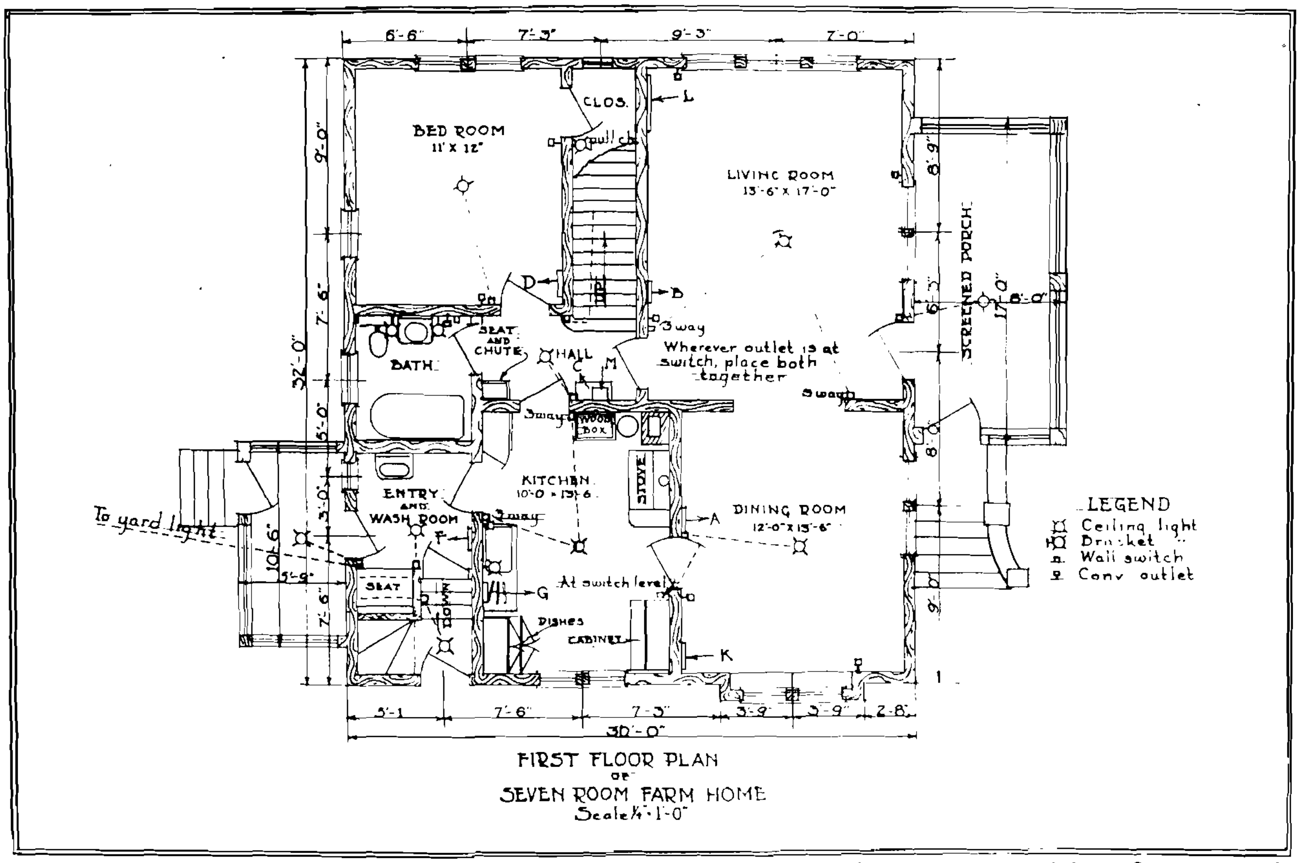

Fig. 19. Wiring diagram based on studies of a modern farm home. Three-way switches in living-room and kitchen. Convenience outlets numerous and well placed.

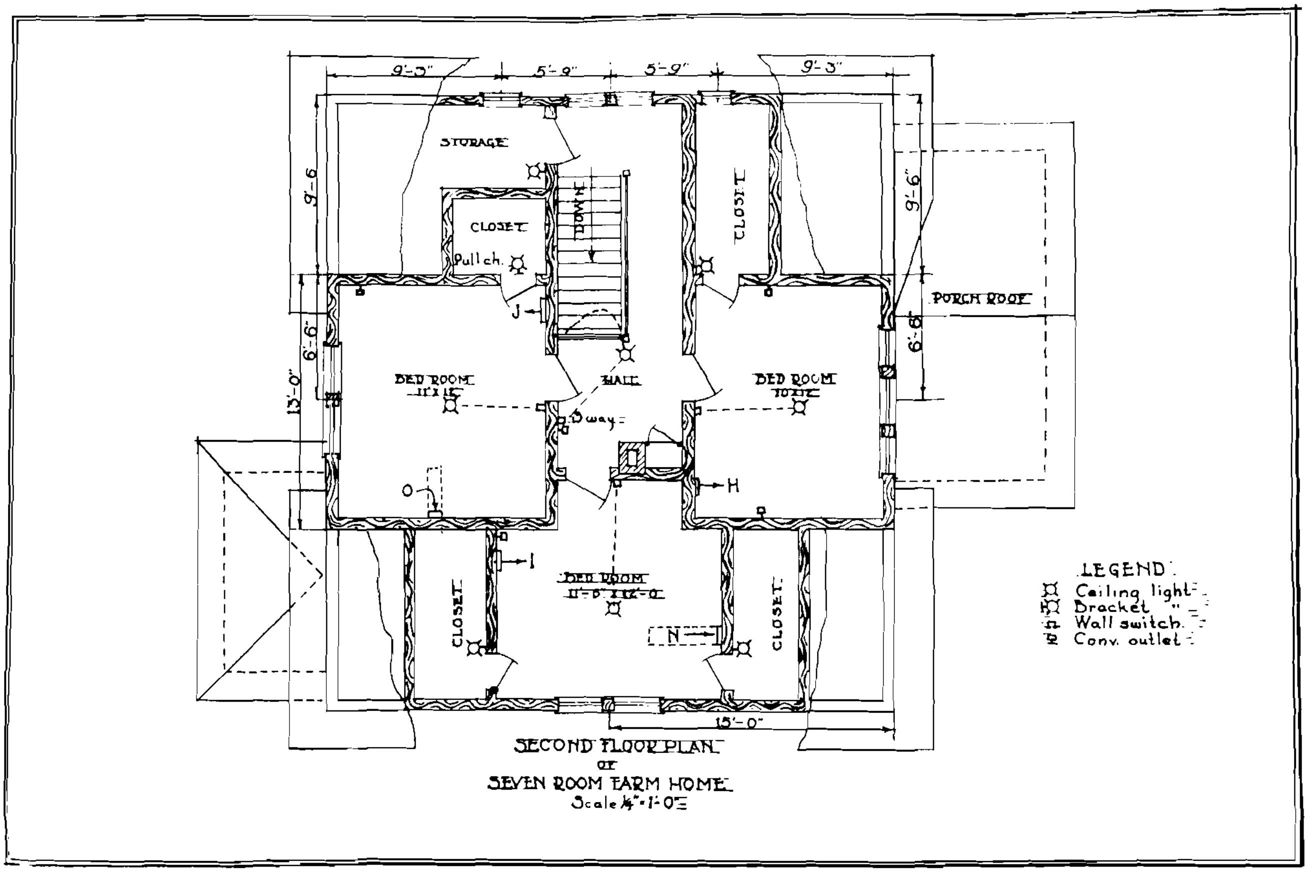

Fig. 20. Wiring for second floor of a modern farm home. Lights in closets and outlets in rooms.

for a fairly complete, good quality wiring job. In addition to this, the fixtures and lamps may cost from $30 to $150 depending upon the farmer's desires. Cheap fixtures are a poor investment. The cost for fixtures at present prices will seldom be below $50 for a six- or seven-room house.

The cost of wiring the Red Wing farms is given in Table X. The costs do not include some wiring for power, wiring for the installation of test meters, as shown in Figure 22, and ranges together with the double-throw switches that were installed for experimental purposes and paid for by the state committee. Long runs of outside wiring are the cause of the large variation in costs. The type and size of the house are other factors.

FARM LIGHTING

In order to have good lighting, certain basic principles must be observed. There must be enough light; it must be properly distributed; and the light source must be properly located. Farmers have usually been accustomed to lights of low intensity, and to one source of light. They want electric lights for the sake of convenience usually, but do not know or realize that better illumination can help them in various other ways. Many tests in factories have shown that high intensity illumination and proper distribution of light have reduced fatigue and increased the output of workers. Experiments have been conducted on farms which have shown that the time required to do chores in well lighted barns is less than in poorly lighted barns. A reduction of about 14 per cent was found in one case in Kansas.

The homes and barns on the Red Wing farms are now well lighted. Altho the farm owners were given an opportunity to decide on the types of lighting fixtures they wanted, certain types were recommended, light sizes were determined, and the location of the lights was largely determined by the wiring plans. As a result, the Red Wing farm homes and outbuildings have been equipped for fair lighting, but there is considerable variation owing to the farmers' selection of fixtures and sometimes the replacement of large lamps with smaller ones. The data in Table XI show how much light is provided for each room in the homes. The illumination data are taken directly under the lighting unit at a level of 32 inches from the floor and are given in foot candles. A foot candle is the illumination produced on a surface one foot from a one-candle-power lamp. Good practice for kitchen lighting is 7 foot candles or the amount of light on a surface pro-

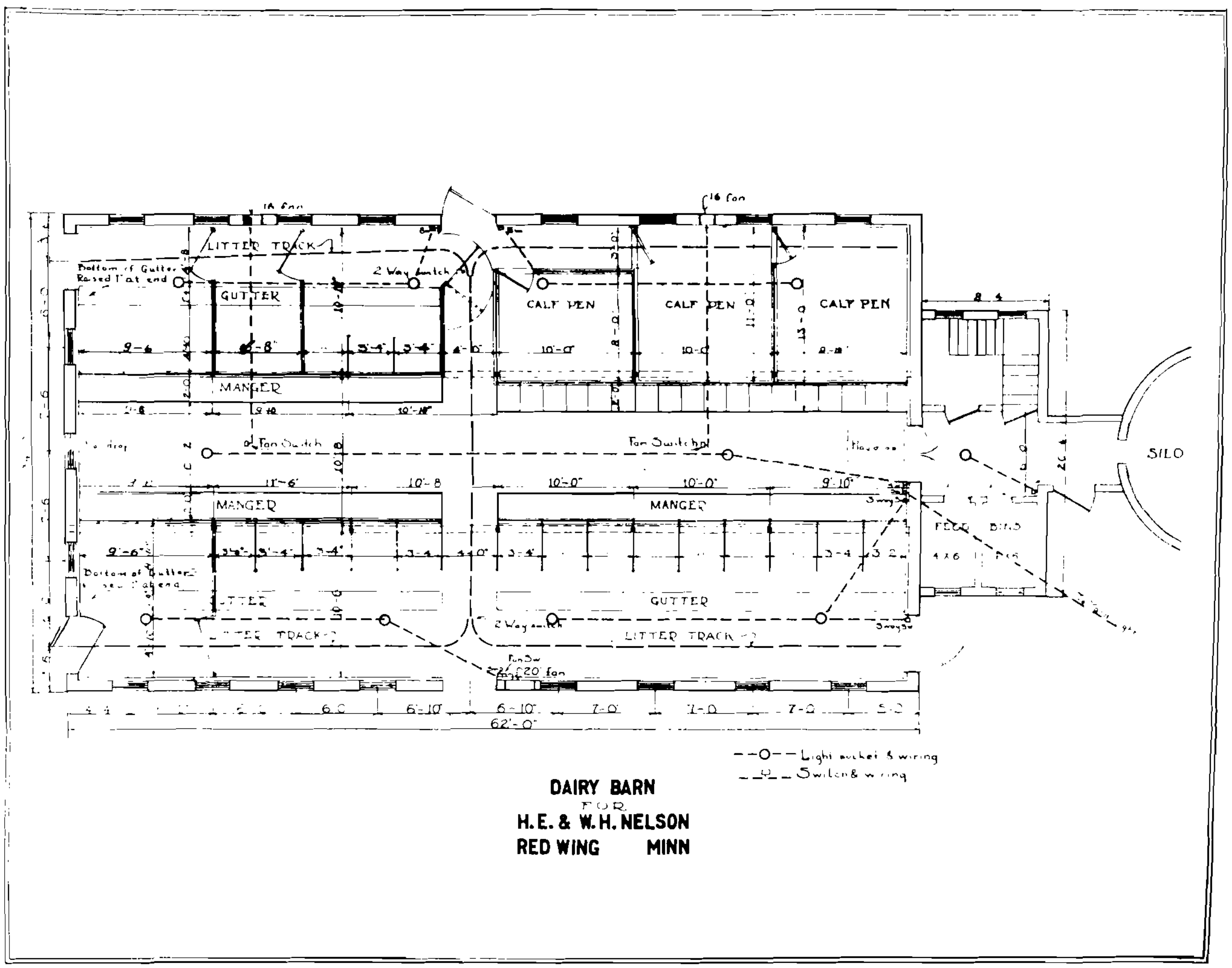

Fig. 21. An adequate wiring system for a dairy barn. Five separate circuits controlled from conveniently located switches. Three-way switches on one set of lights.

TABLE XI

ILLUMINATION IN FARM HOMES (FOOT CANDLES*)

Room	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	F. A. Miller	Emory Johnson	Good practice
Kitchen	3.5	0.5	7.0	4.0	4.5	5.0	11.0	7.0
Dining-room	7.0	16.0	5.0	17.0	16.0	7.0	11.0	10.0
Living-room	10.0	7.0	2.7	4.5	10.0	3.2	5.0	5.0
Bedroom	2.5	5.5	6.0	4.5	4.5	2.5	3.0	3.5
Laundry	4.5	....	11.0	0.5	2.5	8.0	0.0	7.0

* A foot candle is the intensity of illumination on a surface one foot from a one-candle-power lamp.

TABLE XII

LAMP SIZES*

Room	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	F. A. Miller	Emory Johnson	Good practice
	Watts	Watts	Watts	Watts	Watts	Watts	Watts	Watts
Kitchen	60	75	75	75	75	75	75	75
Dining-room	(4)40	(3)50	(4)25	150	100	75	(2)50	100
Living-room	(3)50	150	(5)25	(4)25	200	(3)25	(2)50	150
Bedroom	40	75	(2)50	50	50	50	50	75
Laundry	50	....	75	75	40	50	25	75

* Unless number is given 1 lamp is used.

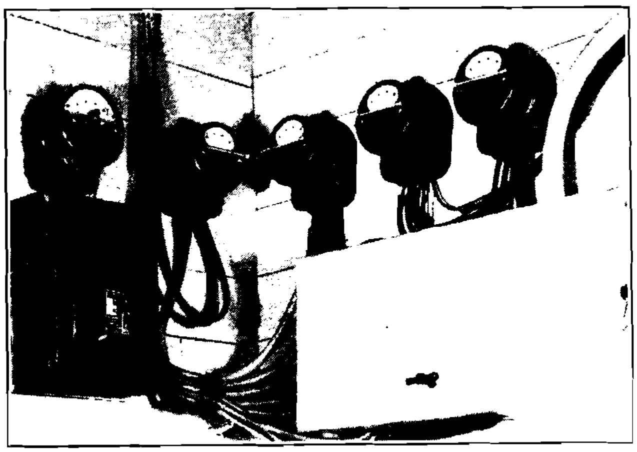

Fig. 22. Bank of meters for measuring electricity used in experimental work. Master meter and entrance switch at the left. Main distribution panel at the right.

duced by seven candles at a distance of one foot. When the data in Table XI are compared with the data in Table XII, it can be seen that the illumination is not proportional to the lamp wattage. The variation in kitchen illumination is quite striking when all excepting one have a 75-watt lamp and all are the same type of fixture excepting one. The size and height of the kitchens and the type of wall surface made the difference. The type of fixtures used at Johnson's farm differed from the others. The illumination directly beneath the lamp is not a true indication of the lighting quality of the lamp. The distribution is important. The living-room fixtures at A. C. Bryan's, for instance, are of the candle type. While the illumination directly under the lamp was only 2.7 foot candles, yet at a distance of five feet from this point was 2.75 foot candles. The lamp in Mr. Cady's living-room was a three-pendant light fixture and while it gave an illumination of 10 foot candles just beneath it, the illumination was only 4.5 foot candles at a distance of five feet. The illumination in Mr. Bryan's living-room would be highly satisfactory if 40-watt instead of 25-watt lamps were used. Mr. Bryan's lamp fixture is shown in Figure 23. This is a good type of fixture for general room illumination if used in rooms with light colored ceiling. As stated earlier in the report, single lamp fixtures are cheaper and give very good general illumination. Such a fixture is shown in Figure 24. These fixtures are suitable for dens, living-rooms, or bedrooms. A desk lamp is shown in Figure 24. This is a highly desirable method of lighting for desk work. About two-thirds of the light fixtures in the main rooms of the Red Wing homes are single lamp fixtures as can be noted from Table XII. The bedroom lighting is almost entirely by single lamp fixtures. Drop

Fig. 23. Type of lighting fixture for living-room, giving good light distribution.

Fig. 24. An excellent inexpensive lighting fixture for general room illumination. Supplemented with a desk lamp for close work.

cords were not used in any of the houses. Bedroom lights and other single lamp fixtures are hung from chains as shown in Figure 24 or are placed at the ceiling.

The illumination throughout a room depends upon the type of fixture used. Tables XV to XXI give data showing the type of fixture, size of lamps, and the illumination taken at three different points in the rooms for all homes on the experimental line, excepting Eckblad's.

Data taken from these reports are given in Table XIII. Distribution of light in the kitchen is secured in one case while it is not in the other. The two dining-room fixtures are very good illustrations of what can be secured in illumination by choosing the proper fixture. A room used strictly as a dining-room requires illumination on the table and not at the sides of the table, such as is given by the lamp shown in Figure 25. The second type of dining-room fixture gives good general illumination but should be equipped with four 40-watt lamps to give proper table illumination. Note the difference secured in the living-room illumination. The former room has a type of shade on the fixture that distributes the light, while the later one has shades that are deep and concentrate the light beneath them.

In addition to general room lighting, it is desirable to use special lighting fixtures for desk lighting, and for lighting the kitchen sink as shown in Figure 26. Several types of wall bracket units, usually in white enamel and with white shades, are suitable for this use. Bathroom lighting with a single overhead lamp is not very satisfactory. Two lights, one on each side of the mirror as shown in Figure 27, are better than one light above the mirror. When it is necessary to reduce the cost of wiring, the center ceiling light may be omitted in the bathroom when two bracket fixtures are used. Bracket lights should be controlled by a wall switch to prevent the breaking of the fixture by using the snap switches on the lamp sockets.

Yard lights save much time and they are considered very valuable by farmers who have used them. Many farmers use two. Yard lights in general are controlled from two points (house and barn or yards) by three-way switches. A 200-watt lamp is usually required for good yard lighting. The light may be located on the corner of the barn as shown in Figure 28, where illumination on one end and one side of the barn is all that is necessary. The gable end of a barn is also used very frequently. When the yard is so large that a pole for carrying the farmstead wire is required, the pole may carry the yard light, as shown in Figure 29. The conduit entrance is on the side of this barn.

A barn well lighted, as shown in Figure 28, is a pleasant place in which to work. Good lighting in barns will save its cost in time required for chores. In the discussion on "Wiring," information is given as to the location and the size of stable lights. Poultry house lighting is discussed under "Use of Electricity in the Poultry Industry."

The Red Wing farms use a considerable amount of energy for lighting. A summary of energy used for lighting over a three-year period is given in Table XIV. The amount used has gradually increased over this period until the average is 60.2 kw. hours per month per farm. This shows that these farmers have real lighting as compared with most farmers. Data in the table show that the energy used for lighting is not dependent to a large extent on the size of the family. The number

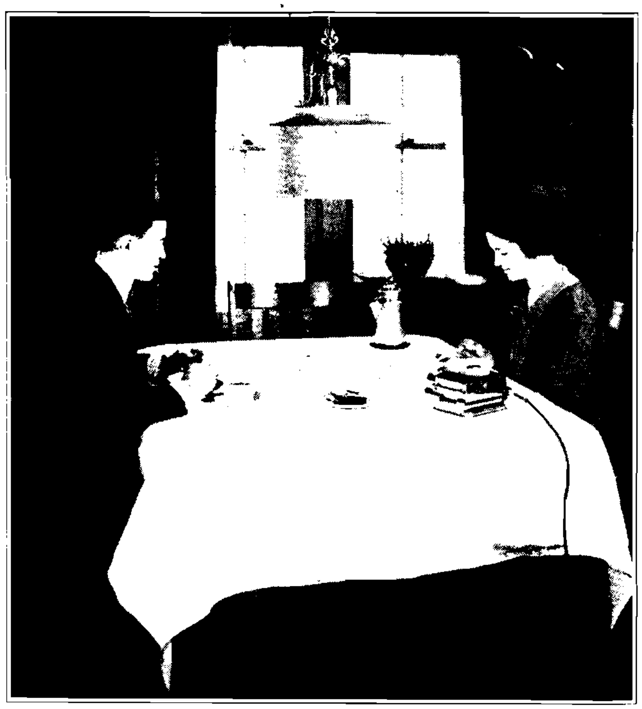

Fig. 25. Ideal type of dining-room illumination. Lights the table and not the persons at table. Not suitable in rooms used for other purposes.

TABLE XIII

ILLUMINATION IN ROOMS

Room	Condition of fixture	Directly under	Three-foot radius	Five-foot radius	Type of fixture
Kitchen	Good	7.0	3.0	2.4	Kitchen unit
Kitchen	Poor	11.0	2.8	0.3	Dome reflector
Dining-room	Good	16.0	7.0	2.5	Fig. 24
Dining-room	Fair*	5.0	4.0	3.5	4-pendant
Living-room	Good	4.5	2.9	2.5	4-pendant
Living-room	Poor	5.0	2.5	1.5	2-pendant, shaded

* Used also as a living-room.

TABLE XIV

ENERGY USED IN FARM LIGHTING, 1925-27

	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	E. Johnson
Connected lighting load, watts	1440	1140	1810	1485	2055	1465	1890	1800
No. of lights	33	16	41	30	41	33	35	43
No. in family	5	2	6	6-4	3	6-4	5	4
Kw.-hr. average monthly, 1925	29	27	50	68	58	36	59	102
Kw.-hr. average monthly, 1926	36	28	72	49	61	77	36	132
Kw.-hr. average monthly, 1927	76	25	88	57	76	69	42	98
Three-year average	44	27	70	58	65	61	46	111

Grand average, 60.2 kw. hr. per month.

TABLE XV

ILLUMINATION TESTS AT A. C. BRYAN'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Kitchen	1—75	7.0	3.0	2.4	White, closed globe
Washroom	1—75	11.0	5.0	4.0	12-inch enamel shade
Pantry	1—50	3.5	1.6	...	White open shade
Dining-room	4—25	5.0	4.0	3.5	Frosted bulbs, chandelier
Living-room	5—25	2.7	2.3	2.75	Candlestick type chandelier
Hall, second floor	1—50	3.0	1.6	1.2	Round globe
Southeast bedroom	1—50	10.0	3.0	2.5	Open, ornate shade
Northeast bedroom	1—50	6.0	2.0	1.5	Open shade
Southwest bedroom	1—75	6.0	2.7	2.0	Closed, ornate shade
Northwest bedroom	1—40	3.5	1.9	1.5	Open shade

TABLE XVI

ILLUMINATION TESTS AT W. J. BRYAN'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Kitchen	1—75	11.0	2.8	0.3	12-inch enamel shade
Dining-room	2—50	11.0	3.0	0.25	18-inch square, ornamental shade
Living-room	2—50	5.0	2.5	1.5	Drop with shades
Front hall	1—25	0.9	0.7	0.5	Closed globe
Music room	4—50	14.0	8.0	6.5	Drop with shades
Bedroom, first floor	1—50	15.0	...	...	Open shade
Pantry	1—25	0.9	0.15	0.11	Open bulb
Washroom	1—25	0.9	0.15	0.11	Open bulb
Shed	1—25	0.9	0.15	0.11	Open bulb
Hall, second floor	1—50	11.0	...	...	Open shade
Bath	1—50	2.5	1.5	1.3	Open shade
Northeast bedroom	1—50	1.4	0.51	0.45	Open shade
South bedroom	1—50	3.0	2.5	1.5	Open shade

TABLE XVII

ILLUMINATION TESTS AT W. A. CADY'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Kitchen	1—60	3.5	1.5	1.3	White shade
Washroom	1—50	4.5	2.0	1.6	White, metal shade
Dining-room	4—40	7.0	4.0	2.5	Drop with shades
Living-room	3—50	10.0	6.5	4.5	Drop without shades
Hall	1—40	3.3	0.7	0.8	White globe
Northwest bedroom	1—40	1.9	1.1	1.0	White shade
Southwest bedroom	1—40	2.5	1.5	1.25	White shade

TABLE XVIII

ILLUMINATION TESTS AT B. I. MELIN'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Dining-room	1—150	17.0	5.0	0.8	Ornamental dome shade
Living-room	4—25	4.5	2.9	2.5	4-light drop open bulb
Bedroom over living-room	1—40	6.0	3.0	2.3	Open ornamental shade
Bedroom over summer kitchen	1—50	4.5	2.0	1.75	Open shade
Back hall	1—50	4.5	...	...	Open shade
Left bedroom	1—50	5.0	...	...	Open shade
Front bedroom	1—75	4.5	...	...	Bracket
Kitchen	1—75	4.0	2.2	1.9	Closed, white globe
Summer kitchen	1—50	0.7	0.4	0.35	Open bulb
Washroom	1—75	6.5	3.0	2.75	Indirect, white cowl shade
Pantry	1—50	0.8	...	...	Open shade

TABLE XIX

ILLUMINATION TESTS AT F. A. MILLER'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Kitchen	1—75	5.0	2.0	1.7	Decorated, closed shade
Pantry	1—50	2.5	...	...	Open, white shade
Washroom	1—50	8.0	3.0	2.5	Doric reflector
Dining-room	1—75	7.0	3.25	2.5	Chandelier
Living-room	3—25	3.2	1.5	1.5	3-light chandelier, brown and gold
Bedroom, first floor	1—50	5.5	2.5	2.2	Ornate globe
Parlor	1—75	8.0	2.5	2.0	Verde antique
Hall, second floor	1—50	3.0	0.9	0.7	Closed globe
East bedroom	1—50	2.5	1.5	1.4	Open shade
Southwest bedroom	1—40	2.0	1.0	0.9	Open shade

TABLE XX

ILLUMINATION TESTS AT ARTHUR NELSON'S FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Dining-room	3—50	16.0	8.0	5.0	Antique chandelier
Living-room	1—150	7.0	4.0	2.75	Inverted bowl combination
Bedroom, first floor	1—75	7.0	3.25	0.17	Closed, ornamental shade
Kitchen	1—75	6.5	2.5	1.75	Closed, white globe
Pantry	1—50	3.25	...	...	9-inch Trojan
Hall	1—50	4.0	...	...	Round, white globe
South bedroom	1—50	5.5	3.0	1.9	Open shade
Middle west bedroom	1—50	4.0	2.25	1.6	Open shade
North bedroom	1—50	6.5	2.5	0.8	Open ornamental shade

TABLE XXI

ILLUMINATION TESTS AT NELSON BROTHERS' FARM

Room	No. of lamps and wattage	Position of meter: Directly under	3-foot radius	5-foot radius	Type of fixture
		Foot candles			
Den	1—100	7.0	2.5	2.0	White, closed shade
Kitchen	1—75	4.5	1.5	0.9	White, closed shade
Entryway	1—50	2.5	...	...	White, closed shade
Pantry	1—50	3.0	...	...	9-inch Trojan
Dining-room	1—100	16.0	7.0	2.5	Large, open shade
Hall, first floor	1—50	3.5	1.25	0.8	Closed shade
Living-room	1—200	10.0	3.5	2.5	Inverted bowl combination
Bedroom, first floor	1—50	3.75	1.25	1.0	Open, ornate shade
Hall, second floor	1—50	2.5	1.7	1.5	W. I. and frosted glass lantern
Northwest bedroom	1—50	4.5	2.5	2.0	Open shade
Middle south bedroom	1—50	4.0	2.5	2.0	Open shade
East bedroom	1—50	4.5	3.0	2.3	Open, ornamental shade
West bedroom	1—50	3.5	2.0	1.0	Closed, ornamental shade

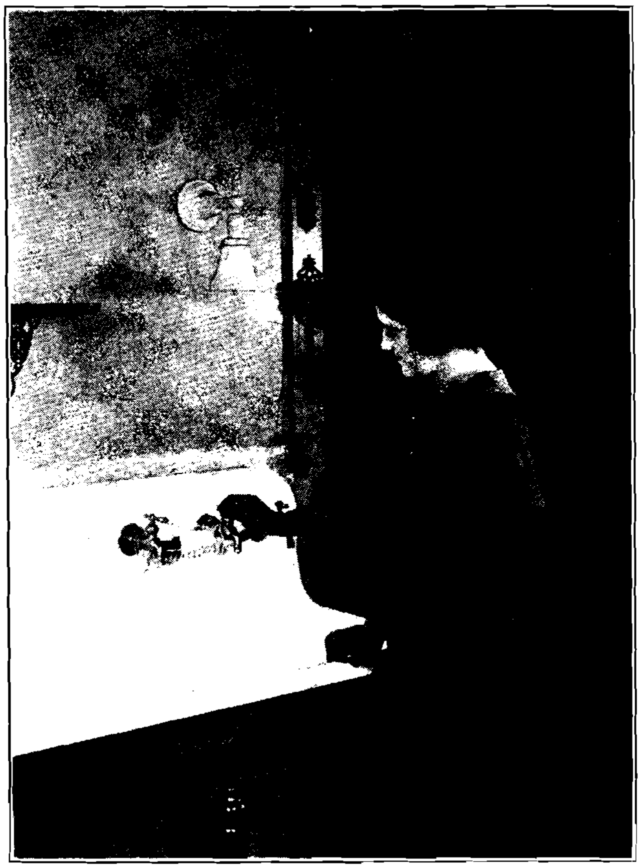

Fig. 26. Good light at the kitchen sink is highly desirable.

of lamps on these farms is large. The average size is considerably in excess of 40 watts.

The conclusions drawn from this study are:

1. Lamps larger than 25-watt are usually necessary to obtain sufficient light.
2. Single light fixtures are preferred to multiple light fixtures on account of cost and efficiency.
3. Fixtures, excepting in dining-rooms and living-rooms, should generally be placed close to the ceiling.
4. Separate lamps should be provided, in addition to the general room illumination, for writing, reading, washing dishes, sewing, etc.
5. Practically all lamps should be shaded.
6. Lamps on drop cords are very inefficient sources of light.
7. Totally enclosed shades are preferable to open top shades because of cleaning.
8. Lamps should not be removed from sockets in order to use the sockets for convenience outlets.

ACCOUNTING STUDIES ON FIVE FARMS ON THE RED WING LINE

The Farm Management Section of the Minnesota Agricultural Experiment Station in 1924 began co-operation with the farmers in keeping financial accounts.

While eight farms have received service from the original high line, continuous cost records have been kept on but five. Records on the other farms for five consecutive years are not available because of change of management or for other reasons.

In Tables XXII-XXVIII data are given for the years 1924 to 1927. The experimental line was built late in 1923, and service was started on most of the farms in January, 1924. Records of the farm business for 1923 are not available. The business for 1924 was conducted at a time when the farms were being equipped with electrical appliances. Some electrical equipment was installed during the summer and by the end of the year most of the farms had considerable electrical equipment. During the two years 1924-

Fig. 27. Proper bathroom lighting requires at least two bracket lamps which should be controlled by a wall switch.

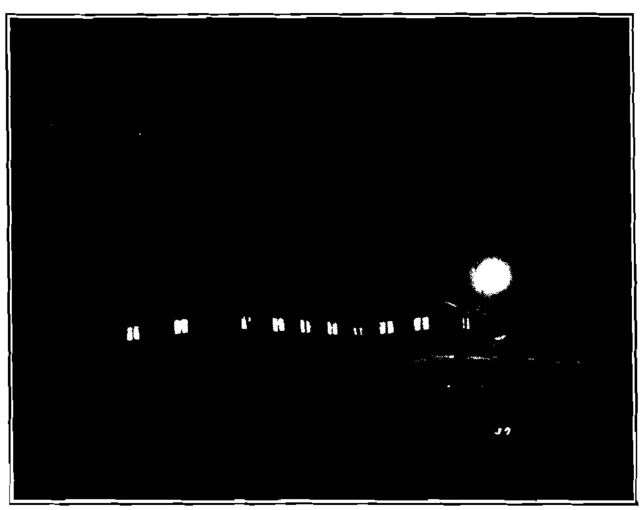

Fig. 28. Good illumination for the barn and the yard can be secured only by adequate wiring.

26, two new barns were built, and these account for a large part of the increase in investment in the two years.

Explanation of Tables

"The Consolidated Statement of Revenues and Expenses," Table XXII, gives data concerning the revenues and expenses totaled for the five farms. This statement is contained in Table XXIII to show the net labor income for the farms, and a summary of Tables XXII and XXIII is given in Tables XXIV and XXV, arranged to show the group data for all five farms and also to show the average value per farm. Details concerning investment, revenues, and expenditures for each of the farms are given in Tables XXVI, XXVII, and XXVIII. The data on investment in Tables XXII and XXVI represent probable values. There is considerable fluctuation in the revenues received from the different sources as shown in Tables XXII and XXVII. Dairy products show a consistent increase, while the revenue from cattle sales fluctuates widely. The fluctuation in cattle sales between 1926 and 1927 was probably due to the fact that some cattle were held over from one year to the next, and to some increase in the price of cattle. The fluctuation in this one item accounts largely for the small increase in revenues and net income for 1926 over 1925. The large drop in hog sales in 1925 was caused by an epidemic of hog cholera on one farm. The receipts from hogs on this farm dropped from $1405.62 in 1924 to $390.61 in 1925, and the gross revenues decreased more than $1,100 in this year.

The total expenditures given in Tables XXII and XXVII include all money paid out by the farmers. They include payments of notes, interest on debt, additions to capital, operating expenses, and personal and household expenses. The total expenditures have been classified into operating and non-operating expenses. The non-operating expenses consist of capital expenditures, livestock purchases, personal, rent, and interest expense. These non-operating expenses must be separated from the total expenditures if a comparison is to be made of operating expenses. Interest paid on mortgages or capital indebtedness is not considered as operating expense. One farmer pays a nominal rental charge of $500 a year for his farm. This is not a true rental charge, so his farm is considered as owned by him, and the investment in the farm is included in the total investment. This rental charge is considered as interest on investment and is, therefore, not an operating expense. In all other cases where land was rented, the rental is figured as an operating expense and the investment charge for farm land is not included in this statement.

Stock purchases are not an operating expense as they are additions to capital, yet they may be sold during the year, so the total stock purchases and changes in inventory must be taken into consideration in determining the net income. The stock purchases vary greatly from year to year and would cause operating expenses to fluctuate similarly if such purchases were included in operating expense.

Since the payment of some bills was deferred every year, and had to be paid during the following year, adjustments have been made to take care of such deferred payments. The true operating expenses include all operating costs for the farm and household, but do not include personal expense for clothing, recreation, and other things.

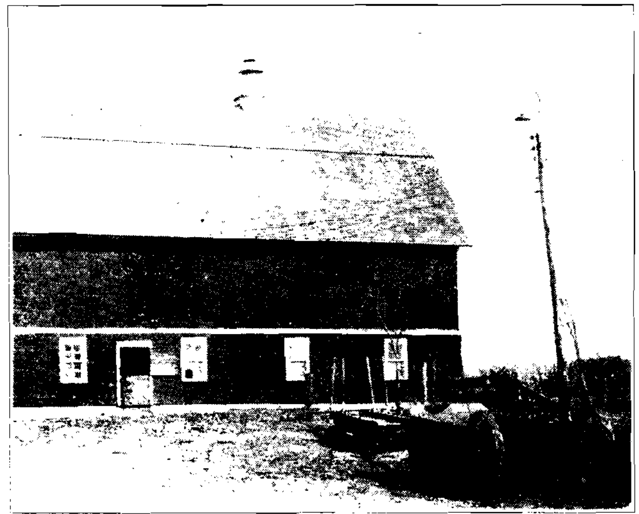

Fig. 29. A pole in the center of the yard serves for the distribution of the farmstead's wiring and as mounting for a yard light. Note the conduit entrance.

The net operating income does not present a true picture of what these farmers have earned for labor and capital, because adjustments must be made for any increase or decrease in inventories due to purchases of stock or other supplies which might be sold. Adjusting the value of the net operating income for changes in inventory of livestock and supplies and subtracting the cost of stock purchases, a net cash income is determined which includes family labor and depreciation and interest on the investment. The net cash income shows decided increase over the three years following 1924, the increase being 42.5 per cent in 1925, 54.6 per cent in 1926, and 81.0 per cent in 1927. In order to eliminate fluctuation in inventory values caused by price fluctuations, the inventories have been readjusted on the basis of the same prices at the beginning and at the end of each year, with allowance for reasonable depreciation in the case of mature animals, and appreciation in the case of young stock.

Deducting interest on the investment of these farms at 5 per cent, from the net cash income, gives the net cash income, less interest, as shown in the last line of Table XXII. The data show that the interest charge in 1924 was $6.66 greater than the net cash income before deductions for labor, interest, and depreciation were made. The net cash income exceeded the interest charges in 1925 by $2,484, in 1926 by $2,932, and in 1927 by $4,802.

In order to determine the net labor income as given in Table XXIII, several other items of expense and income must be considered. The depreciation on buildings and equipment is one of these items. When depreciation, house rent, living, etc., are taken into consideration, a value of net labor return is derived, as given in line 9 of Table XXIII.

The equipment loaned to these farmers for experimental work had retail values of approximately the following amounts: January 1, 1925, $8,520; January 1, 1926, $9,545; January 1, 1927, $13,805; and January

TABLE XXII. CONSOLIDATED STATEMENT OF REVENUES AND EXPENSES, FIVE FARMS

	1924		1925		1926		1927	
Total investment (app.)		$139,647.29		$146,254.00		$153,962.41		$152,878.85
Revenues								
Cattle	$3,256.38		$3,881.66		$1,706.22		$6,246.88	
Dairy products	4,448.80		6,375.76		7,942.81		8,724.90	
Hogs	5,204.26		3,626.04		4,025.46		3,119.56	
Poultry	304.50		436.45		579.62		560.66	
Crops and miscellaneous	4,152.47		5,727.08		6,146.36		6,164.12	
Total revenues		17,366.41		20,052.99		20,400.48		24,821.12
Expenditures								
Total		19,258.07		20,692.52		19,122.26		21,304.67
Capital expenditures	3,643.00		6,665.62		4,647.08		6,620.84	
Personal, rent and interest	2,013.62		3,589.16		4,629.02		2,973.51	
Stock purchased	3,261.37		484.50		1,130.38		1,831.50	
Non-operating expenses		9,817.99		10,739.28		10,406.48		11,425.85
Operating expenses		9,440.98		9,953.24		8,715.78		9,878.82
Adjustment for deferred bills		+ 203.66		− 397.74		+ 21.43		132.64
Operating expense		$ 9,644.64		$ 9,555.50		$ 8,737.21		$ 9,746.18
Increase over 1924, per cent				−0.9		−9.4		+1.0
Net operating income		$ 7,721.77		$ 10,497.49		$ 11,663.27		$ 15,074.94
Adj. for inventory, gain or loss in livestock and supplies		+2,415.30		− 216.14		+ 97.81		− 796.82
Total operating income		$ 10,137.07		$ 10,281.35		$ 11,761.08		$ 14,278.12
Less stock purchased		3,261.37		484.50		1,130.38		1,831.50
Net cash income, before interest, department of labor		$ 6,875.70		$ 9,796.85		$ 10,630.70		$ 12,446.62
Increase over 1924, per cent				42.5		54.6		81.0
Interest at 5 per cent		6,982.36		7,312.70		7,698.12		7,643.90
Net cash income less interest (no depreciation)		−$ 6.66		$ 2,484.15		$ 2,932.78		$ 4,802.72

TABLE XXIII. LABOR INCOME STATEMENT, FIVE FARMS

	1924	1925	1926	1927
Net cash income before labor, depreciation and interest are deducted	$ 6,875.70	$ 9,796.85	$10,630.70	$12,446.62
Housing and food	6,750.00	7,000.00	7,000.00	7,000.00
Total income before labor, depreciation and interest are deducted	$13,625.70	$16,796.85	$17,630.70	$19,446.62
Less interest at 5 per cent	6,982.36	7,312.70	7,698.12	7,643.90
Income less interest	$ 6,643.34	$ 9,484.15	$ 9,932.58	$11,802.72
Less depreciation buildings and equipment (estimated)	1,421.00	1,524.00	1,683.00	1,613.00
Farmers' labor income	$ 5,222.34	$ 7,060.15	$ 8,249.58	$10,189.72
Less depreciation and interest on loaned equipment at 12½ per cent	532.50	1,128.75	1,346.88	1,794.38
Net labor income	$ 4,689.84	$ 6,831.40	$ 6,902.70	$ 8,395.34
Average labor income per farm*	937.96	1,366.28	1,380.54	1,679.07
Increase over 1924, per cent	....	45.7	47.2	79.1

TABLE XXIV. SUMMARY OF REVENUES, EXPENSES AND INCOME, FIVE FARMS

	1924	1925	1926	1927
Gross revenues	$17,366.41	$20,052.99	$20,400.48	$24,821.12
Increase, per cent	....	15.4	17.5	42.9
Less operating expenses	$ 9,644.64	9,555.50	8,737.21	9,746.18
Increase or decrease, 1924, per cent	....	−0.9	−9.4	+1.0
Net revenues from operation of farms	$ 7,721.77	$10,497.49	$11,663.27	$15,074.94
Less adjustments for stock purchases, deferred bills, changes in inventories	846.07	700.64	1,032.57	2,628.32
Net incomes	$ 6,875.70	$ 9,796.85	$10,630.70	$12,446.62
Increase over 1924, per cent	....	42.5	54.6	81.0
Net labor incomes per farm*	$ 937.96	$ 1,366.28	$ 1,380.54	$ 1,679.07
Increase over 1924, per cent	....	45.7	47.2	79.1

* This is labor income on the average farm for two workers.

TABLE XXV

Summary of Revenues, Expenses, and Income, Five Farms, Average per Farm

	1924	1925	1926	1927
Gross revenues	$3,473.28	$4,010.60	$4,080.09	$4,964.22
Less operating expenses	1,928.93	1,911.10	1,747.44	1,949.24
Net revenues from operation of farms	$1,544.35	$2,099.50	$2,332.65	$3,014.98
Less adjustments for stock purchases, deferred bills, changes in inventories	169.01	140.13	206.51	525.66
Net incomes	$1,375.34	$1,959.37	$2,126.14	$2,489.32
Net labor incomes per farm*	936.17	1,366.28	1,380.54	1,679.07

* This is labor income on the average farm for two workers.

TABLE XXVI

Total Investment, Five Farms

Name	1924	1925	1926	1927
W. A. Cady	$32,789.04	$35,224.00	$39,704.80	$39,188.24
B. I. Melin	41,544.85	44,084.95	43,289.08	41,989.84
F. A. Miller	22,787.00	22,825.15	23,034.05	24,096.50
A. Nelson	16,353.05	16,347.30	16,234.95	15,881.25
Nelson Brothers	26,173.35	27,773.45	31,699.53	31,432.02
Totals	$139,647.29	$146,254.85	$153,962.41	$152,587.85
Increase over 1924, per cent	....	5.4	10.3	9.3

TABLE XXVII

Revenues and Expenditures, Five Farms

Name	Total Revenues				Total Expenditures			
	1924	1925	1926	1927	1924	1925	1926	1927
W. A. Cady	$ 3,310.84	$ 4,982.09	$ 4,840.98	$ 5,810.22	$ 3,417.85	$ 4,518.16	$ 5,608.27	$ 4,700.80
B. I. Melin	3,588.74	5,337.94	5,734.08	6,646.84	6,344.86	5,433.64	5,371.06	6,648.14
F. A. Miller	4,236.13	4,379.78	5,281.30	6,243.57	4,884.23	4,486.97	5,355.71	6,333.06
A. Nelson	1,696.00	1,924.05	1,820.19	1,607.76	1,427.70	1,009.33	975.08	941.75
Nelson Brothers	4,534.70	3,429.13	2,723.93	4,512.73	3,184.33	5,244.42	1,812.14	2,680.92
Totals	$17,366.41	$20,052.99	$20,400.48	$24,821.12	$19,258.97	$20,692.52	$19,122.26	$21,304.67
Increase over 1924, per cent	....	15.4	17.5	42.9	....	7.4	0.7*	16.2

* Decrease.

TABLE XXVIII

Receipts from Dairy and Poultry, Five Farms

	Dairy Products				Poultry Products			
	1924	1925	1926	1927	1924	1925	1926	1927
W. A. Cady	$ 828.31	$1,262.36	$1,456.34	$2,726.96	$ 33.06	$ 60.60	$ 32.96	$ 31.50
B. I. Melin	523.23	2,009.75	2,649.06	2,006.56	66.21	109.97	215.40	290.77
F. A. Miller	1,611.07	1,243.50	1,810.86	2,175.50	205.20	265.88	331.26	238.39
A. Nelson	633.00	734.15	667.15	588.91	.....	.....	.....	.....
Nelson Brothers	853.19	1,126.00	1,359.40	1,226.97	6.03	.....	.....	.....
Totals	$4,448.80	$6,375.76	$7,942.81	$8,724.90	$310.50	$436.45	$579.62	$560.66
Increase over 1924, per cent	....	43.3	78.5	96.1	.....	40.5	86.6	80.5

1, 1928, $14,910.75. Charging interest at 5 per cent and depreciation at 7½ per cent, the depreciation and interest charges on average values are given in Table XXIII. The data show that even when the interest and depreciation charges on the loaned electrical equipment,[2] as given in line 8 of Table XXIII, is subtracted from the Farmers' Labor Income, the net labor income shows a very decided increase over that of 1924.

In addition to the loaned equipment, the farmers purchased some equipment. The total amount of equipment of all kinds that has been bought or loaned for these five farms amounts to $16,667.97. This includes equipment for barns, bathrooms, electric wiring and fixtures, ensilage cutters, threshing machines, etc., in fact all equipment used because electricity was available. Interest and depreciation charges on all of this equipment figured as stated above, would amount to $2,083.49. If this whole charge for interest and depreciation were to be subtracted from the net cash income for any year since 1924, it would still leave net incomes in excess of that for 1924, and for 1927 it would still leave a net cash income 50 per cent greater than in 1924. The interest and depreciation charges on the electrical equipment and other equipment used with it as given in line 8 of Table XXIII are over twice as great as the yearly cost of electric service as given below. In other words, equipment costs are a more important item of electric service costs than are the monthly electric bills.

The fact that these farmers have paid heavy electric bills and yet have decreased the operating expenses may indicate that electric service may decrease other expenses more than its own cost. The five farmers paid electric bills amounting to $842.77 or $14.04 per farm per month for 188 kw. hrs. in 1926 and a total of $886.54 or $14.77 per farm per month for an average of 243 kw. hrs. per month in 1927, while in 1924 the total electric bill was $501.23 or an average of $8.35 per farm per month for 98 kw. hrs., yet the operating expenses for all five farms in 1926 were $907.43 less than in 1924, and in 1927 the total operating expenses were only $101.54 more than in 1924. In fact if taxes on these farms had not increased appreciably during these four years, the expenses for each of the last three years would have been considerably below the expenses for 1924. The taxes in 1925 were $84.74 higher than in 1924, in 1926 they were $271.25 higher and in 1927 they were $453.20 higher than in 1924. This is an increase of 43 per cent in three years and is out of proportion to increase in investment.

Analysis of Data

The increase in revenues on the farms from 1924 to 1927 was quite large and can not be attributed entirely to the use of electricity. There are some other causes for this increase. The index figures for prices as given in Table XXIX are taken from the United States Department of Agriculture Yearbook. The index figure of prices for farm produce is 1.5 per cent higher in 1926 than in 1924, and 2.2 per cent lower in 1927 than in 1924. The value of the dairy and poultry products, which together make up approximately one third of the cash revenues of these farms, increased appreciably as shown in Table XXVIII; the value of the dairy products was 96.1 per cent greater in 1927 than in 1924 and the value of the poultry products was 88 per cent greater. The index figures given in Table XXIX show that taken together these two products did not sell at much higher prices in 1926 or 1927 than they did in 1924, being only 3.2 per cent higher in 1926 and 1.5 per cent higher in 1927. However, in 1926, dairy products were 1.5 per cent higher and poultry products were 6.1 per cent higher, while in 1927 dairy products were 3 per cent higher and poultry products were 4.1 per cent lower than in 1924. A price index for Minnesota for the same period would show that dairy products were significantly higher in 1926 and 1927 than average values for the United States, butterfat was 5 per cent higher in 1926, and 11 per cent higher in 1927 than it was in 1924. It is possible, therefore, that 11 per cent out of the 96 per cent increase in the value of dairy products for 1927 was due to higher prices. These farmers had developed their herds during this time so that they had heavier milkers than in 1924, altho none completely replaced his herd. Records would indicate that the production per cow increased as much as 30 per cent by the addition and selection of better producers, together with better feeding and care. However, even accounting for this increase, there is an increase of about 40 per cent in the value of the dairy products that was brought about by milking more cows, by having drinking cups in the barns, etc. There were 65 dairy cows on these farms at the beginning of 1924, while there were 77 at the end of 1927.

The increase in the prices of hogs may have helped to increase the revenues in 1925 and 1926 to some extent, but not much in 1927. Hogs on the Chicago market were 45 per cent higher in 1925, and 50 per cent higher in 1926, while in 1927 they were only 22 per cent higher than in 1924. Since total hog receipts in 1926 were only 20 per cent of the total revenues, this 50 per cent increase in hog prices would be only a 10 per cent increase in total receipts, and in 1927, when the hog receipts had dropped to 12½ per cent of the total receipts, the increase in hog prices would amount to less than 3 per cent of the increase in total revenues. Reorganization of the farm enterprises owing to a shifting of labor probably had considerable effect on the increase in revenues.

Discussion of Results

The question has frequently been asked, "Can farmers afford the extra expense of electricity at such a high cost?" The results indicate that electricity has not been "another expense" nor an added burden to these farmers. The operating expenses have not increased even tho the farmers paid heavy electric bills.

It is impossible to show exactly, by individual applications on each one of these five farms, just how electricity was used to increase gross and net revenues even after paying electric energy bills and overhead charges on this large amount of equipment. It would have required a great amount of work to determine the amount lost or saved by using electricity for the score or more jobs performed by electricity on each of the farms. The Experiment Station, therefore, did not attempt to get comparative data on each job on

[2] Interest and depreciation on all purchased electrical equipment is included in the interest and depreciation items given above.

every farm. Studies were made of many different jobs on different farms to determine the advisability of using electricity for each job. The reports on many of these individual job tests show how the farmers decreased expenses, reduced labor, and increased revenues. Such detailed information will be given in another section of the report.

The electrically operated water system saved many hours of time over hand pumping. In the average farm home, the pumping and carrying of water by hand for household use requires about thirty days of eight hours each every year. Turning the cream separator on the average daily farm requires another month of thirty days of eight hours each per year, and the caring for kerosene lamps and lanterns with cleaning and filling, requires almost another month of someone's time every year.

Two of the farmers built new barns after the project was started. Nelson Brothers have a well-equipped modern barn. The only use made of electricity in the barn is for light and ventilation service, pumping water and grinding feed are done in other buildings. Grain for feed has to be carried or hauled to the barn from the granary. Personal operation of the feed grinding is necessary. Mr. Cady built a new barn in which electricity is used for lighting, milking, feed grinding, elevating grain, and corn-shelling. Hoppers are arranged so that the feed-grinding does not require the attention of anyone. Nelson Brothers increased their dairy products output by 59 per cent, while Mr. Cady increased his by 75 per cent. The total hours of labor at Nelson Brothers increased 28 per cent, while at Mr. Cady's they increased only 29 per cent. Nelson Brothers used 157 hours per cow per year of man labor, and 157 hours per year for $100 worth of produce as each cow produced $100 of product. Mr. Cady used only 73 hours per cow per year of man labor and 88 hours per year for $100 worth of produce. A comparison of these figures with those secured by Mr. Misner in a "Study of Dairying in 149 Farms in New York State" reported in 1922 follows. Mr. Misner's study, covering 2,058 cows, showed an average of 167 hours of man labor per cow per year, or 167 hours per year for $100 worth of product. It appears that the use of the electrically operated machines and other labor saving equipment in Mr. Cady's barn is a valuable investment if we capitalize the labor saved at 35 cents per hour.

It is the utilizing of time saved in such arduous jobs on the farm that makes it possible to increase the revenues. It has been pointed out to these farmers as it has to others that time saved is of no value unless such time is used for productive enterprises.

The question may be asked, "How did these farmers live, if they didn't get any net cash income in 1924, as shown in the last line of Table XXII, and only a small amount, or some $500 per farm, in 1925 and 1926, and less than $1,000 per farm in 1927?" To put this on a basis comparable with city incomes, it must be remembered that for these farmers the entire living cost, with the exception of clothing and personal expenses, were figured in as operating expenses. If the usual values for house rental and house expense including fuel, light and food, were included about $6,750 for 1924, and about $7,000 per year thereafter would have to be added to the net incomes, as given in Table XXIII, as these farmers got their housing and food costs in addition to their net cash incomes. Someone might ask how could these farmers live in 1924, even tho they had their housing and food costs, when they had no apparent income from labor. The fact is that they lived on capital investment, which, of course, is not different from what many people in the city have to do at times.

It must be admitted that there were other contributing causes, such as better farming practices brought about by the necessity of keeping records and the causes outlined in the analysis given above, that helped these farmers to improve their revenues and incomes. But the big fact remains that these farmers, who used electricity freely, made larger labor incomes in 1925, 1926, and 1927 than in 1924, even after all costs for electricity, including interest and depreciation on all loaned and purchased equipment, were deducted.

While the data show that the farmers have benefited considerably by the use of electricity, it must not be forgotten that they have received other benefits from electric service which alone are worth a great deal. They have had better lighted homes, a happier and healthier environment, a greater satisfaction in living, and the scale of living has been raised considerably by lifting from their shoulders many arduous and back-breaking tasks.

TABLE XXIX

INDEX OF PRICES*

(1909-14 prices base = 100)

	1924	1926	Increase over 1924	1927	Increase over 1924
			Per cent		Per cent
Farm prices — produce sold	134	136	1.5	131	−2.2
Cost of living	172	176	2.3	172	0
Farm labor	166	171	3.0	170	2.4
Farm prices—dairy and poultry	137	141	3.2	139†	1.5

* Taken from the United States Department of Agriculture Yearbooks.

† This index figure given by L. H. Bean, Division of Statistical and Historical Research, United States Department of Agriculture.

Summary

1. The data show that these five farmers as a group had total cash revenues in 1927 that were 42.9 per cent greater than in 1924.

2. The operating expenses for 1927 were only 1 per cent greater than in 1924 even tho taxes were 65 per cent higher. If the taxes be deducted for each year, then other operating expenses were actually 9.9 per cent lower in 1927 than in 1924.

3. The net labor income on these farms was 47.4 per cent greater in 1926 than in 1924 and was 79.3 per cent lower in 1927 than in 1924.

4. When interest and depreciation charges on all equipment placed on these farms because of the use of electricity is subtracted from net cash incomes in 1925, 1926, and 1927, the incomes are still in excess of the income for 1924.

5. The net cash income in 1926 was 54.6 per cent more than in 1924, and in 1927 it was 81 per cent more than in 1924. Even if interest and depreciation on all equipment used on these farms with or because of electric service be subtracted from the net income of 1927, it still leaves an income 50 per cent greater than the income of 1924.

6. Electric bills for the farms in 1927 amounted to $886.54. They used an average of 243 kilowatt hours per farm per month. Interest and depreciation on the electrical and associated equipment amounted to $1,613, showing that the electric bill, even at adequate rates, is only approximately one third of the total cost of electric service.

Finally, these farmers, with a total electric service cost including equipment costs of $2,499.54 in 1927, or approximately $500 per farm, earned net incomes 50 per cent greater than they had in 1924.

EQUIPMENT ON RED WING FARMS

The Red Wing farms were equipped with a considerable amount of machinery when the experimental work was begun in 1924. Eight farmers had 16 stationary gasoline engines, and 3 tractors. There were acetylene gas lights on 2 farms, gasoline lighting on 2 farms, and a farm electric lighting plant on 1 farm. Three of the homes had water systems and bathrooms. The average investment in machinery was $1,895 on January 1, 1924. This investment was 5.1 per cent of the total investment. This value of machinery per farm is high in comparison with the average for Minnesota—$1,014 per farm, according to the 1920 United States Census.

The farmers did not have all of the farm equipment desired for use in connection with the electrical service. Water systems were installed on farms that did not have them. This included bathroom equipment, kitchen sink, and laundry tubs. The water systems are described in detail in another section of the report. A large amount of equipment, which was not electrical, was secured for these farms. This included hay hoists, barn equipment, bath tubs, milking machines, ensilage cutters, threshing machine, and feed grinders.

The farmers bought some small pieces of equipment, but most of the equipment was secured from the manufacturers of electrical equipment and of farm machinery. This equipment was placed on the farms and loaned to the University for a period of three years, or donated outright to the University. A list of the companies together with the value of the equipment secured from each company is given in Table XXX. The University of Minnesota, the people of this state, and the farmers on the Red Wing line gratefully acknowledge the assistance given by these companies.

It was not possible to secure equipment for all purposes for all of the farms, and it was not necessary for experimental purposes. It was desirable, however, that a number of the farms should have equipment

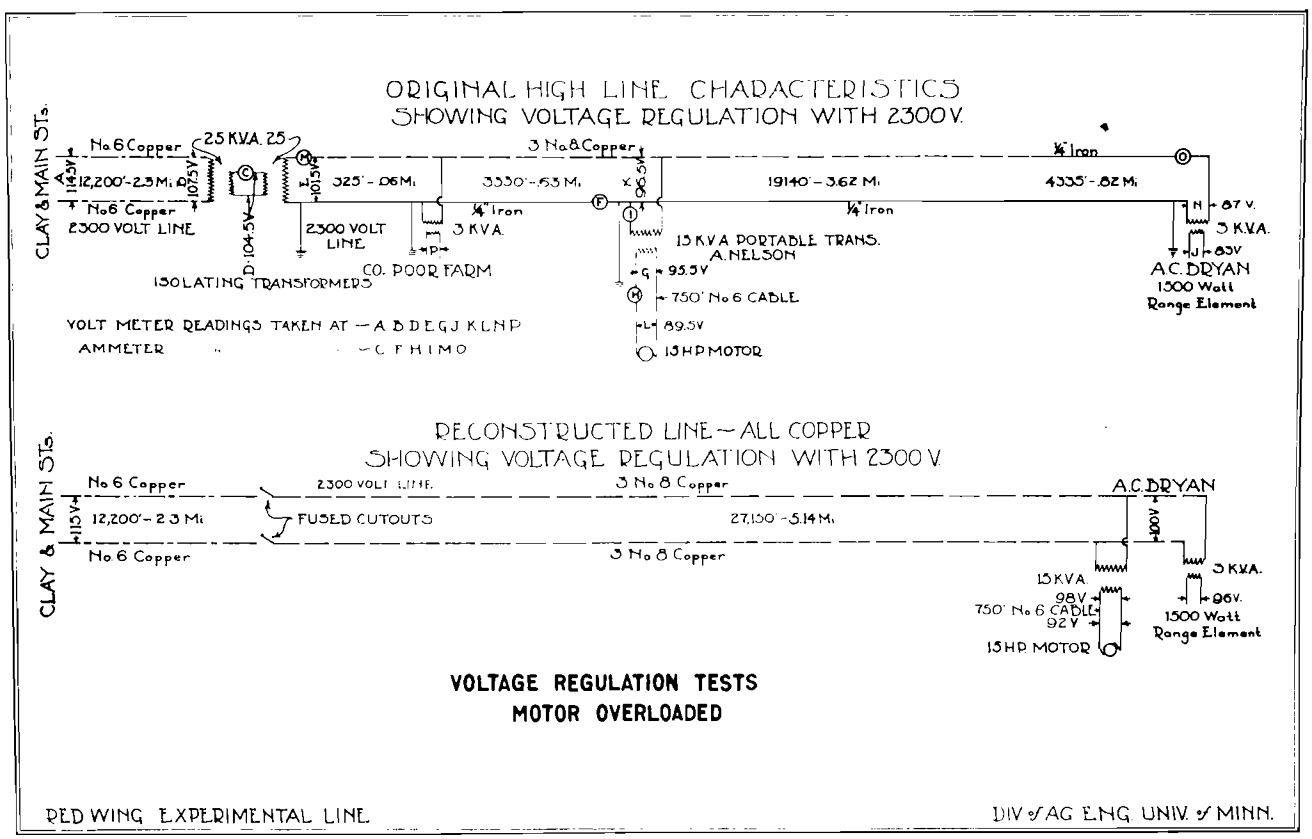

Fig. 30. Diagram showing voltages taken at different points along the high line and on some secondary lines, to show the voltage drop in each part of the circuit. Voltages are all given on the basis of 110. Other data, such as sizes of transformers and sizes of wires and amounts of load, are given. The upper diagram is for the conditions of the original 2,300-volt line. Note that the voltage drops from 114.5 volts at the city limits to 89.5 volts at the 15 h-p. motor and to 83 volts on the range at A. C. Bryan's farm. The lower diagram shows similar conditions for the reconstructed all-copper line. Note that the voltage dropped from 115 at the city limits to 96 volts at the end of the line.

TABLE XXX

Co-operating Companies Furnishing Equipment, January 1, 1928

Name of company	Value of equipment loaned or donated
Acme Machine Co.	$ 25.00
Advance Electric Co.	160.00
Allied Factories	16.50
Altorfer Bros. Co.	99.00
American Blower Co.	206.00
American Ironing Machine Co.	278.00
Anderson Implement Co.	50.00
Appleton Mfg. Co.	146.00
Associated Mfrs.	150.00
Automatic Elec. Washer Co.	110.00
Automatic Water Heater Co.	185.25
Baker Mfg. Co.	17.00
Barlow & Selig	135.00
Carter Mayhew Mfg. Co.	39.50
Century Elec. Co.	624.23
Cooper Hewitt Co.	100.00
Crane Company	175.00
Cullman Wheel Co.	81.00
Deere & Webber Co.	13.90
Delco Light Products Co.	289.00
Detroit Vapor Stove Co.	40.00
Duro Pump Co.	359.60
Edison Appliance Co.	384.00
Eggers & Tobias	16.00
Electric Controller Co.	598.30
Empire Milking Machine Co.	285.00
Estate Stove Co.	242.17
Eureka Vacuum Cleaner Co.	53.50
Excel Electric Co.	17.00
Florence Stove Co.	40.00
Gehl Bros. Mfg. Co.	320.00
General Electric Co.	1,078.80
Goulds Mfg. Co.	304.39
Hall Neal Co.	350.00
Theo. J. Helle Co.	350.00
Horton Mfg. Co.	50.00
Hudson Mfg. Co.	1,105.00
Hurley Machine Co.	467.50
Hydro-Electric Mfg. Co.	115.00
Ilg Ventilating Co.	139.50
International Harvester Co.	492.00
Kelvinator Corporation	501.00
Kenyon Pump Co.	25.00
Letz Refrigerator Co.	480.00
Louden Machine Co.	1,585.00
Mahle Auto & Wagon Co.	65.00
Malleable Iron Range Co.	215.00
Master Electric Co.	52.00
Melotte Agency	55.00
F. E. Meyers & Bros.	206.00
Michigan Stove Co.	225.00
Miller & Sons	120.00
Montgomery Ward & Co.	609.64
Nichols & Shepard	1,112.00
1900 Washer Co.	160.00
Perfection Milk Machine Co.	272.50
Pine Tree Milking Machine Co.	431.20
Portable Elevator Mfg. Co.	376.50
Prater Mfg. Co.	38.75
Puffer Hubbard Co.	365.00
Rathbone Sard & Co.	210.00
Rohne Electric Co.	14.00
Schonek Co., Inc.	22.50
Seeger Refrigerator Co.	200.00
Servel Corporation	270.00
J. Wellington Smith Co.	359.75
Standard Electric Co.	62.00
Stoughton Mfg. Co.	125.00
Stover Mfg. & Engine Co.	35.00
Superior Churn Co.	95.00
U. S. Wind Engine & Pump Co.	600.00
Vaile Kimes Co.	525.00
Wagner Electric Co.	367.00
Watson Flagg Corporation	109.00
Western Electric Co.	636.95
Westinghouse Elec. Mfg. Co.	943.64
White Lily Mfg. Co.	165.00
Woodrow Washer Co.	140.00
M. S. Wright Co.	68.00
	$21,550.57

used for the same purposes, in order that different operating conditions might be checked. The list of equipment used on each of the nine farms is given in Table XXXI. Each farm was provided with an electric range or with other electrical cooking equipment. All of the farms were provided with pump jacks and electric motors, or with deep well, electric pump heads, for pumping water. Other equipment was distributed to those farms to which it best suited for experimental work. Several of the farms could have used other pieces of electrical equipment, but no attempt was made fully to equip each farm.

In other parts of this report, details of the tests for the operation of electric motors for such jobs as feed grinding, running milking machines, pumping water, refrigeration, etc., will be given. The type and make of equipment that is used is an important factor in determining the results. In order to provide information concerning the make of machines, a list of the more important machines or pieces of equipment is given in Table XXXII.

The total value of the equipment loaned or donated to the University was $21,550.57, as given in Table XXX. The farmers purchased some equipment in addition, making a total for equipment used of $22,-469.64. The value of the equipment placed on each of nine farms and also of the equipment used for the community up to January 1, 1928, is given in Table XXXIII. The data are classified to give both electrical and non-electrical equipment. The total value of electrical equipment for the community was $14,601.02, and for the nine farms $12,264.50. This was an average of $1,362.70 worth of electrical equipment for each farm. This value does not include the cost of wiring, lighting fixtures, and lamps. A discussion of these items, including the cost, is given in the section on "Wiring the Farm Buildings." The average cost of wiring and lighting fixtures complete was $341.98. The average cost of all electrical equipment on these farms was, therefore, $1,703.68.

These data are given to encourage farmers to put in adequate wiring and lighting equipment, and to point out that considerable equipment is necessary if farmers expect to make full use of electric service. The farmer who expects to put in a wiring and lighting system for $150 is not going to get much of a job, while a job costing about $250 for the average farm will be necessary if the farmer wishes good service. The farmer will frequently spend all of his available cash for wiring and for the "high line," and will forget about equipment. Electricity for a farm is too costly for lighting alone and a farmer should plan to buy such pieces of equipment as can be operated conveniently by electric power. It is not a question of whether the farmer can afford to buy the equipment, it is rather a question of whether he can afford to pay for electric service and not have sufficient equipment to make its use profitable.

TABLE XXXI

EQUIPMENT ON FARMS, JANUARY 1, 1928

W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers
Electric range	Electric range	Combination range	Combination range	Electric range
Washing machine	Electric water heater	5 h-p. motor	Deep well pump	Washing machine
Sewing machine motor	Automatic deep well pump	Hay hoist	Automatic cistern pump	5 h-p. motor
5 h-p. motor	Washing machine	Feed grinder	Electric incubator	Automatic cistern pump
Cream separator motor	Cream separator motor	Pulleys for above	Electric brooder	Cream separator
Bathroom equipment	Bathroom equipment	Washing machine	Feed grinder	Deep well pump
Dairy barn equipment	Laundry trays	Automatic pump	Ironing machine	Refrigerator
Milking machine	5 h-p. motor	Sewing machine motor	Sewing machine motor	Electric refrig. machine
Oil burning water heater	Radiant heater	Vacuum cleaner	Vacuum cleaner	Bathroom equipment
Water softener	Electric iron	Electric incubator	Refrigerator	Laundry trays
Grain elevator	Refrigerator	Electric brooder	Electric refrig. machine	Oil burning water heater
Four ventilating fans	Brooder	Laundry trays	Washing machine	Heating plant
1½ h-p. motor	8-inch fan	¼ h-p motor	Cream separator	Milk warmer
3 h-p. motor	Hot plate	Root cutter	Bathroom equipment	Speed jack
Slide rails		½ h-p. Duro motor	Laundry trays	Silo filler
2 motor starters		Pump jack	Heating plant	Barn equipment
¼ h-p. motor		Electric iron	Electric fireless cooker	Vacuum cleaner
Threshing machine		6-inch electric fan	¼ h-p. motor	Electric iron
Hay hoist		Heating unit	5 h-p. utility truck	3 ventilating fans
Corn sheller		Radiant heater	Motor starter	Toaster
Pump jack		Curling iron	Milking machine	
Electric iron			Electric iron	
½ h-p. Paul motor				

C. H. Eckblad	F. Miller	Emory Johnson	J. B. Lokkesmoe	Community
Electric frying pan	Electric range	Electric range	Refrigerator unit	2 transformer trucks
Electric toaster	Cream separator motor	1½ h-p. pumping motor	Brooders, two 500-chick	15 h-p. motor
Electric griddle	Electric incubator	Vacuum cleaner	Incubators, five 1500-egg	Transmission cable
Automatic cistern pump	Electric brooder	Ironing machine	Poultry treater, Uviarc	2 h-p. motor
Ironing machine	Milking machine	Deep well pump	Pump jack	Motor starter
Cream separator	¾ h-p. milking machine motor	Washing machine	¼ h-p. electric motor	Washing machine
Electric brooder	Electric pump jack	Laundry trays	Hot plate	Electric dishwasher
Laundry trays	Sewing machine motor	Incubator	Vacuum cleaner	Gear base
Electric incubator	Combination feed mill	2 brooders	Electric iron	Clark selective switch
Electric fireless cooker	Washing machine	Water heater		Pump jack
Electric oven	Bathroom equipment	Sewing machine motor		2 safety switches
Refrigerator	Refrigerator	3 h-p. motor		2 15-K.V.A. transformers
¼ h-p. utility motor	7½ h-p. motor	1/6 h-p. motor		10 h-p. motor
Washing machine	Husker-shredder	Motor starter, ½ h-p.		Farm utility truck
500-chick brooder	Radiant heater	Electric iron		2 1-h-p. back geared motors
Electric iron	Electric iron	Wagon box elevator		Speed reduction pulley
Heater		Feed mill		
		Refrigerator		

TABLE XXXII

KINDS OF EQUIPMENT IN USE

	W. A. Cady	A. Nelson	A. C. Byran	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	E. Johnson	J. B. Lokkesmoe
Motor—5 h-p.	Westinghouse	Century	Gen. Elec.	Gen. Elec.	Western		Advance		
Feed grinder	New Holland	New Holland	Intern'l	Stover	Stover	Stover	Letz		
Milking machine	Empire			Pine Tree			Perfection	Pine Tree	
Ironing machine				Thor		Simplex		Simplex	
Pump or pump jack	Kenyon	Meyers	Bevan	Vaile Kimes	Duro	Wesco	Cullman	Gould	Strate-Lift
Incubator			Reed	Electro-Hatch		Petersime	Electro-Hatch	Lo-Glow	Electro-Hatch & Buffalo
Refrigerator		Frigidaire		Kelvinator	Kelvinator	Frigidaire	Lipman	Frigidaire	Servel
Ranges	Westinghouse	Monarch	Estate	Acorn	Westinghouse	Hot Point (oven)	Crawford	Hot Point (oven)	Monarch (hot plate)

TABLE XXXIII

EQUIPMENT ON FARMS, JANUARY 1, 1928

Farmer	Value of electrical equipment	Value of non-electric equipment
A. C. Bryan	$ 924.27	$ 211.45
W. A. Cady	1,344.20	3,189.85
B. I. Melin	2,353.18	655.75
F. A. Miller	1,383.15	846.25
E. Johnson	1,412.18	92.95
Nelson Brothers	1,405.70	2,559.59
A. Nelson	1,070.95	101.95
J. B. Lokkesmoe	815.00	16.00
C. H. Eckblad	1,555.87	12.85
Community	2,336.52	182.00
Totals	$14,601.02	$7,868.64
Grand total		$22,469.66
Total electrical on 9 farms		12,264.50
Average electrical per farm		1,362.70
Average non-electrical on 7 farms		276.74

OPERATING TESTS ON HIGH-LINE VOLTAGE REGULATIONS

The experimental line was originally constructed of one iron wire about No. 4 in size and three No. 8 stranded copper wires. The iron wire was grounded at each pole to serve as a grounded messenger wire. The power company did not want to connect a grounded system to the Red Wing distribution, so the farm line was isolated by the use of a one to one ratio, shop wound transformer. This transformer did not function properly and two 2300 230 volt transformers were connected together as shown at A in Figure 30. This diagram shows the details of line, wire sizes, etc. In order to test out still further the use of iron wire, one section of the line from the Erickson farm west to A. C. Bryan's was built with all iron wire. A detailed description of the line with itemized costs is given in section devoted to High-Line Construction.

Secondary Voltages

When the line was built, the transformers in most cases were located near the road, and entrance switches were generally placed in the basement or back entry room of the house. The line appeared to be satisfactory as long as lights and small appliances and small motors were the only current-consuming devices. As soon as electric ranges were installed, it was apparent that poor voltage regulation was affecting the operation of the ranges. One housewife stated that one day a sponge cake baked perfectly in one hour while a day or two later another cake was still doughy at the end of an hour's baking. This difficulty was encountered at several places. At the A. C. Bryan farm the time required to raise the oven temperature to 300 degrees Fahrenheit varied from 22 minutes to 31 minutes, on different days. Ranges at some of the homes appeared to heat much faster than those at others.

In order to determine the cause of these differences in operation, tests were conducted with all of the electric ranges to determine voltage and current conditions. It is not necessary to give data from all seven tests as three typical cases will illustrate the conditions. These tests were conducted at times of the day when very little current was being used for other purposes. The results of these tests conducted at the farms of A. C. Bryan, W. A. Cady, and W. J. Bryan are given in Tables XXXIV, XXXV, and XXXVI.

The plan of the farmstead wiring for the A. C. Bryan place is given in Figure 7 and of the W. A. Cady farmstead in Figure 9 in the section of this report devoted to "Wiring the Farmstead." In each of these cases, the transformer was fairly close to the house, altho in the A. C. Bryan home the location of the meter and entrance switch in the basement at the point of the entrance to the house necessitated a secondary run of about 130 feet from the transformer to the range. In the case of the W. J. Bryan home, the transformer was located at the roadside with the meter and entrance switch in the barn. The service wires were then run from the barn to the house. The distance was 256 feet from the transformer pole to the barn, and 224 feet from the barn to the house. Under this condition, the secondary from the transformer to the range was nearly 500 feet long. At W. A. Cady's

TABLE XXXIV

STOVE TESTS—VOLTAGE

Name—A. C. Bryan

Stove—Estate Electric

Voltage, 220-volt circuit	Voltage, 110-volt circuits		Plate tested	Switch position	Current, amperes
225	111	114	Left rear	High	7.0
226	111	115	"	Medium	4.45
228	113	115	"	Low	1.6
223	109	114	Left front	High	11.5
224	110	114	"	Medium	7.15
227	112.5	114.5	"	Low	2.8
225	111	114	Left rear	High	7.1
226	111	115	"	Medium	4.5
227	112.5	114.5	"	Low	1.75
222	108	114	Right front	High	7.05
226	112	114	"	Medium	4.5
227	113	114	"	Low	1.75
213	113	100	Oven	High	28.5
222	113.5	108.5	"	Medium	13.0

TABLE XXXV

STOVE TESTS—VOLTAGE

Name—W. A. Cady

Stove—Garland Electric

Voltage, 220-volt circuit	Voltage, 110-volt circuits		Plate tested	Switch position	Current, amperes
217	108	109	Left rear	Full	11.5
219	110	101	"	Medium	5.75
220	111	109	"	Low	2.9
217	107	110	Left front	Full	11.5
219	110	109	"	Medium	5.8
220	110	110	"	Low	2.95
217	107	110	Lower oven	Full	11.5
219	110	109	"	Medium	5.65
220	110	110	"	Low	2.9
213	105	108	Upper broiler	Full	11.0
217	107.5	109.5	"	Medium	5.4
218	111	107	"	Low	2.8
215	105.5	109.5	Right front	Full	11.0
218	107.5	110.5	"	Medium	5.7
218	108.5	109.5	"	Low	2.85
217	106	111	Right rear	Full	11.0
217	108	109	"	Medium	5.55
218	108.5	109.5	"	Low	2.85

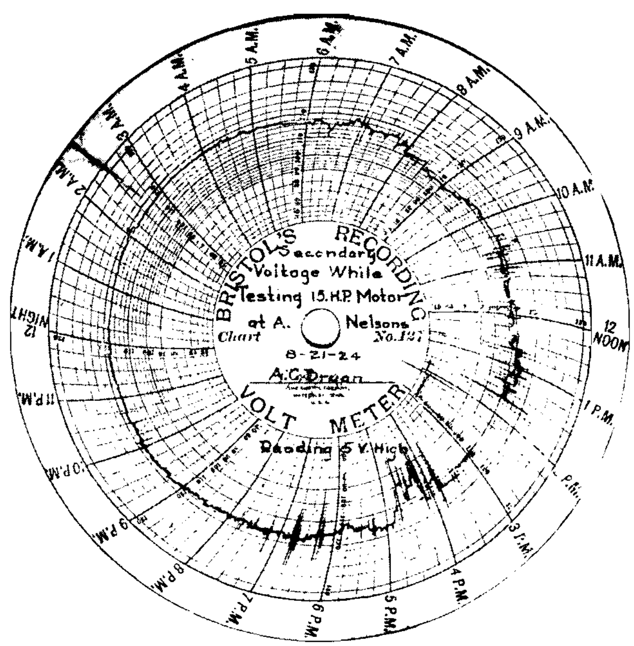

Fig. 31. Volt meter chart taken on house circuit at Bryan's farm, with one element of the range in use and with the 15 h-p. motor in operation. The voltage was pulled down when the motor was in use, with the 2,300-volt original line.

home the house was 150 feet from the transformer pole, and the total secondary run to the range was about 170 feet. All secondaries used in these tests were three No. 6 copper wires.

All of the ranges were wired for three-wire 220 110 volt service, so the voltages given in column one in Tables XXXIV, XXXV, and XXXVI were taken across the 220-volt service. Voltages are given for both 110-volt circuits, unless an element is on both circuits. In the latter case the lower voltage is the voltage of the circuit on which the element is being used. The "plate tested" column describes briefly which electric unit was being tested. The position of the switch and the amount of current in amperes is given in the two last columns.

The data in Table XXXIV show that, with the short secondary at the A. C. Bryan place, the voltage remained very good so long as only one unit was used. All of the surface units of this range were connected to one circuit, the voltages of which are given in the first column, while the two oven units were connected to the other circuit. The rear left unit using 7 amperes gave a voltage drop of 3 volts, while the large front left unit using 11.5 amperes gave a voltage drop of 5 volts. It is quite obvious that even in this case, the two units used on "high" together would pull the voltage down to about 106 volts and three units on at the same time would drop the voltage nearly to 100 volts. The two 1,600-watt oven units reduced the voltage to 100 volts. This is the maximum drop permissible and was secured with a secondary only 130 feet long.

The data in Table XXXV indicate what happens as the secondaries are made slightly longer. In most cases, when the elements were on "high" the voltage dropped to 105 or 106 volts. It is evident that two units if turned on "high" at the same time would cause the voltage to drop to approximately 100 volts.

The data in Table XXXVI, taken at the W. J. Bryan place, illustrate what happens when secondaries are 500 feet long. The larger units brought the voltage down to 100 volts or less. Two units could not be used satisfactorily at the same time on this range. The two oven units would bring the voltage down to about 92 volts.

Transformer Voltages

Tests at other farms showed similar conditions. As a result of these tests it was found necessary to improve the voltage. In order to determine whether the drop in voltage was caused by secondary drop, transformer drop, or primary drop, further tests were conducted. Tests were taken at all of the farms, in order to eliminate accidental and irrelevant differences. Tests at the Melin farm gave voltages on the 110-volt circuits as low as 85 volts and at the A. C. Bryan farm as low as 92 volts. Data from two of the tests will be given to illustrate the conditions. The voltage was taken at the transformer and on the 220-volt circuit of the secondary at the range and at the barn on the W. J. Bryan farm. The voltages were taken without any load and then with different loads up to the full range load.

The data for the test at W. A. Cady's farm are given in Table XXXVII. The house voltage dropped from 227 volts at no load to 204 volts with the full range load. At the same time the voltage at the transformer dropped from 227.5 to 211. This shows that a secondary drop of 7 volts was brought about with secondaries about 170 feet total length, with a full range load, while the transformer voltage decreased by 16 volts. Such a test indicated that this length of secondary was satisfactory, but the primary and transformer drop of 16 volts was excessive.

The data given in Table XXXVIII were taken at the W. J. Bryan farm. Voltage readings for the first part of the table were taken at the transformer and at

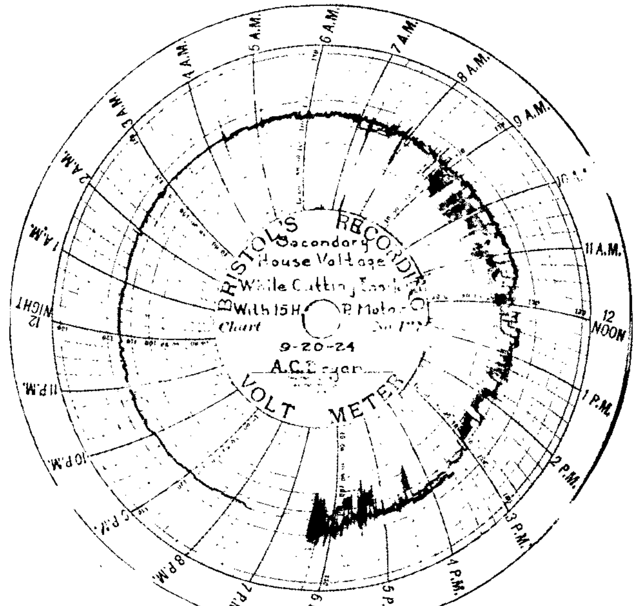

Fig. 32. Volt meter chart taken on secondary line from 7 a.m. on one day to 1 p.m. the next day. Between 9 and 12 the voltage stayed up the first day when the motor was not in use, but was pulled down to about 90 as each load of ensilage was cut the next day. This was with the original 2,300-volt line.

the barn. The voltage readings taken at the transformer and at the house are given in the second part of the table. The data show that the secondary drop from the transformer to the barn, a distance of 256 feet was only 7.5 volts with a full range load. However, at the house (second part of Table XXXVIII) the voltage dropped to 196, which gives a secondary drop of 15 volts. This is about the maximum permissible for good range operation. The transformer showed a drop of 16 volts in this case. The total voltage drop of 31 is too much, and indicated that the secondaries were too long, and that the primary voltage drop was excessive.

As a result of these tests three transformers were moved into the yards and at one other farm large No. 2 secondary wires were installed in place of the No. 6 wires. This improved conditions to some extent.

Motor Operation

In July, 1924, a 5 h-p. motor was installed at A. C. Bryan's farm to operate a hay hoist. When this motor was started it did not appear to have much power. Only small forkfuls of hay could be lifted by it. The hoist was equipped with a large belt pulley. New gears to give lower speed were installed, but still the motor could not pull up an average forkful of hay. When pulling on one forkful, the motor stalled. The fuses did not blow, and the motor was not injured. A test gave the following voltage readings with the 5 h-p. motor.

Load conditions	Voltage
No load	217
Motor idling	195
Motor medium load	170
Motor heavy load	130

High-Line Tests

This trial together with the range tests indicated that it was necessary to make some complete voltage tests on the high line. Recording voltmeters were used

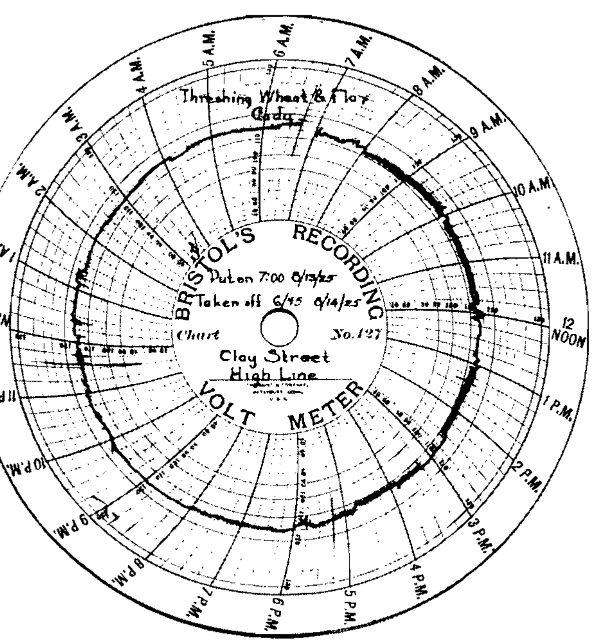

Fig. 33. Volt meter chart taken at the city limits, while a 15 h-p. motor was in use for threshing at Cady's farm, with the all-copper 2,300-volt line. The variation in voltage was small.

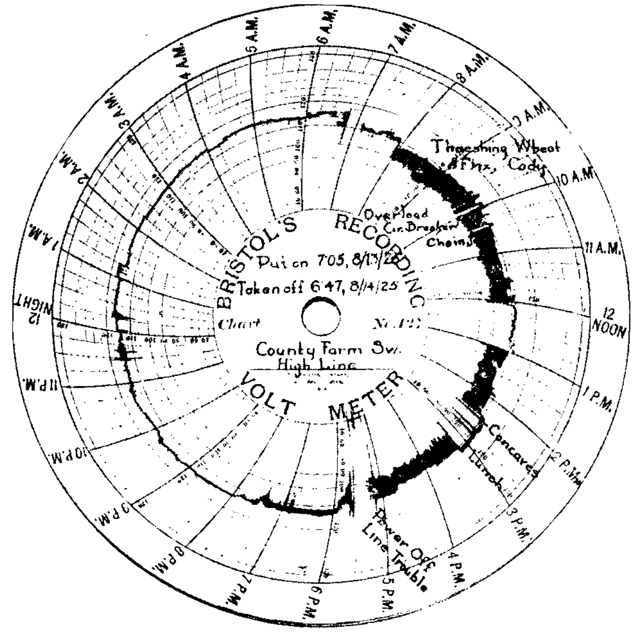

Fig. 34. Volt meter chart for the same day as that of Figure 33, at the county-farm switch. The threshing machine was about .4 mile beyond the point at which this meter was placed.

at several places. Stoves were used as loads. Voltage readings were taken at several points. These tests showed that the voltage at any one farm was changed considerably by loads at other places. In the top diagram of Figure 30 it can be seen that A. C. Bryan's farm at the end of the line, 7.44 miles from the heavy 2,300-volt circuit in Red Wing, was served through 0.82 of a mile of all iron wire, and that an iron-messenger wire was used on 4.2 miles of the line.

A portable transformer truck, described in the report on "Threshing," had been built, and a threshing machine had been equipped with a 15 h-p. 440-volt motor. This outfit was tested on August 20, 1924. The motor started very slowly and could not bring the threshing machine up to full speed. Threshing could not be done under these conditions. This motor was used as a load and several tests conducted.

The tests reported in Table XXXIX were conducted as follows: Meters were located at points marked C, D, E, K, I, H, L, and G on Figure 30. Men were stationed at these several points with watches synchronized so that they could read meters simultaneously every 15 seconds. While it was impossible to obtain all readings at exactly the same instant, and fluctuations made it difficult to get exact readings, the readings are accurate enough for the purpose. Readings were taken for several minutes, but only those from 4:14 p.m. to 4:21 p.m. are given in the first series of the table. The records for the first two minutes are complete. No readings were taken at the isolating transformer during the next minute. Just after 4:18:45 the motor became overloaded and opened the oil circuit breaker on the 2,300-volt line to the portable transformer. The motor was automatically cut off. There were some other small loads on the line but evidently not very many. When the circuit breaker was reset, the motor was not started, and the readings for 4:20 were taken without the motor load. The meters located

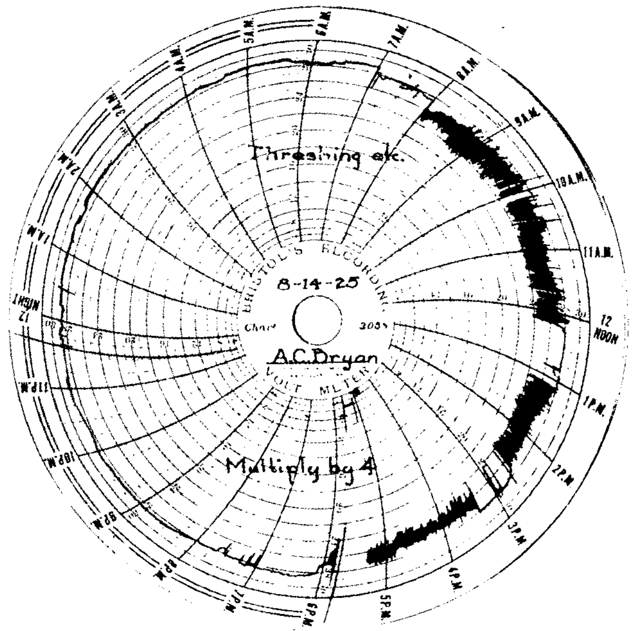

Fig. 35. Volt meter chart for the same day as those of Figures 33 and 34 on the secondary lines at the Bryan farm. Note the large variation in the voltage and check the similarity in the voltage variation between this chart and Figure 34.

at the portable transformer were not read as the ammeters and wattmeter did not register. The readings for 4:14 and 4:16, compared with those of 4:20, indicate that there was a considerable voltage drop in the No. 6 copper line and the first isolating transformer as the voltage was 216 with the motor load and 226 without the motor load at Point A. The drop through the other isolating transformer was considerable, as the voltage at 4:16 was 2060 while at 4:20 it was 2220. The voltage at the motor was very low, being only 376 at 4:16, while it was 444 at 4:20 with the motor cut off. The motor voltage (motor volt) taken at the transformer wagon varied from 386 to 394, showing that even if the voltage drop in the 750 feet of motor cable could be eliminated, the motor would not operate satisfactorily. The data in the column marked "Motor Watts" show that the motor was not overloaded as this motor takes 13.8 kw. on full load. In spite of the low voltage the motor operated at a good power factor, varying from 80.5 to 91 per cent. This proved that a low power factor was not the cause of low voltage. Other computed quantities show the very large transformer (isolating) and line voltage drop, and the very small voltage drop through the motor transformer. The drop through the cable was not excessive. In order to make a comparison, the voltage drop for transformers and line is on a 2300-volt circuit and may be divided by 20, while the cable is on a 440-volt circuit and the voltage drop may be divided by 4.

The voltages taken at different points on the line are compared on a 110-volt basis in the last five columns. Note that all of the voltages are unsatisfactory. The largest drop in voltage took place between the transformer and motor through the 750 feet of two No. 6 wire cable. Even without this drop the motor [illegible] have carried overloads.

[illegible] ther series of tests was conducted from 4:55 [illegible] 5:50 p.m. by reading only the meters at the motor transformer and motor. These indicated a higher line voltage at this hour. This gave an opportunity to see if the motor would carry any overload. With

TABLE XXXVI

STOVE TESTS—VOLTAGE

Name—W. J. Bryan
Stove—Hotpoint Electric

Voltage, 220-volt circuit	Voltage, 110-volt circuits		Plate tested	Switch position	Current, amperes
212	112	110	Left front	High	8.2
214	105	109	"	Medium	4.15
216	106.5	109.5	"	Low	2.0
215	105	110	Left rear	High	5.55
216	106	110	"	Medium	4.75
220	110	110	"	Low	0.3*
210	99.5	110.5	Right front	High	15.0
215	105	110	"	Medium	7.5
217	107	110	"	Low	3.75
217	114.5	102.5	Right rear	High	9.4
216	110	106	"	Medium	4.7
218	110	108	"	Low	2.3
212	111.5	100.5	Oven top	High	13.0
216	111	105	"	Medium	6.5
218	111	107	"	Low	3.4
213	112	101	Oven bottom	High	12.5
216	111	105	"	Medium	6.05
218	111	107	"	Low	3.3

TABLE XXXVII

VOLTAGE DROP TESTS; RANGE LOAD AT THE CADY FARM*

Time, p.m.	2:25	2:26	2:27	2:28	2:29	2:30
Stove loads........	None	Left 3	Full	Full	Right 3	None
House voltages ...	227	215	204	204	214	227
Transformer voltages	227.5	219.5	211	211	219	227.5
Sec. line drop computed	0.5	4.5	7	7	5	0.5
Primary and transformer drop ...	0.0	8.0	16	16	8.5	0.0

* Voltage drops from the transformer to the house, load supplied by the use of a Garland Electric range.

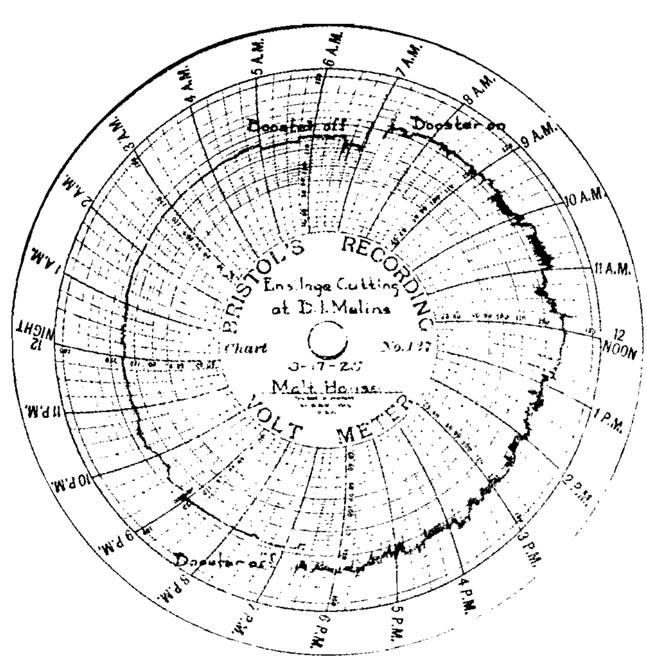

Fig. 36. Volt meter chart, taken at the city limits, showing the increase in voltage in the day time while the voltage booster was in operation. The variation in voltage is as great as, if not greater than, it was without the booster but the voltage remained higher.

two successive overloads, the voltage dropped considerably, reaching 312 volts or 79.5 volts on the 110-volt basis on the first overload, and 288 volts or 72 volts on the 110-volt basis, on the second overload. The voltage was so low that the power factor dropped rapidly and thus the effect was cumulative. The power factors dropped to 64 and 50 per cent respectively.

The higher line voltage resulted from the fact that the city load in the west end of Red Wing was taken off the line at about 4:30 p.m. Another series of tests, marked "Third Series" in Table XXXIX was made between 5:30 and 5:33 p.m. with the higher voltage on the high line. Better voltage at the motor is noticeable all through the four tests at 5:30. Between 5:31 and 5:32 the motor was being badly overloaded as shown by the readings taken at 5:32. Fifteen seconds later the circuit breaker tripped and the readings fluctuated so rapidly that only a part of the readings were obtained. Note that at 5:32 the line voltage was pulled down to 2040 volts from 2230 volts a minute earlier. The current went to the enormous value of 95 amperes (37.5 amperes normal current) while the voltage at the motor dropped to 280 volts and the power factor dropped to 55 per cent. The voltage finally dropped to 264 at the time the circuit breaker kicked out.

Completed High-Line Tests

Another series of tests was conducted on the following day, August 21, 1924, with recording voltmeters at Clay and Main streets, Red Wing (marked point A) and at A. C. Bryan's farm (marked point J), in order to determine the effect on secondary house services by the use of the large motors. The record from A. C. Bryan's farm is shown in Figure 31. (Note the low voltage between 4:00 and 5:00 p.m.) The tests were not started until the city load was taken off and the voltage improved. Additional load was secured by the use of a 1500-watt heating element at A. C. Bryan's farm. Results of this series of tests are given in Table XL. When the motor was badly overloaded, so that the voltage at the motor would fall below 360, the secondary voltages in the houses were also very low. The upper diagram in Figure 30, with the voltage marked on it, shows a typical case of motor overloading.

The data in Table XL show that the secondary voltages at Mr. Bryan's place were below 100 while the large motor was operating, even tho the high-line voltage at Red Wing (A) was fair. The line drop was excessive and when a range at A. C. Bryan's farm was turned on at 4:34 p.m. both the secondary voltage and the voltage at the motor dropped several volts. The range was turned off shortly after 4:49. The

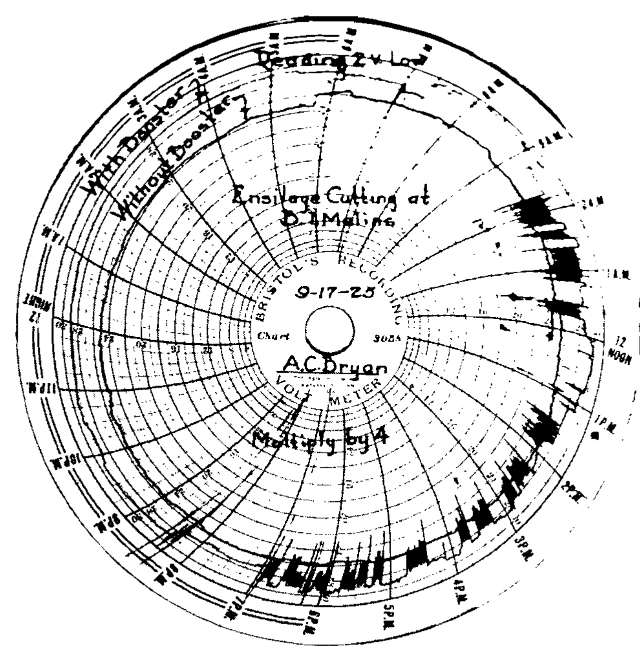

Fig. 38. Volt meter chart taken on the secondary lines at the Bryan farm on the same day as those of Figures 36 and 37. It shows the voltage for one day without the booster and without the motor in operation, and for the next with the booster and the motor both in use.

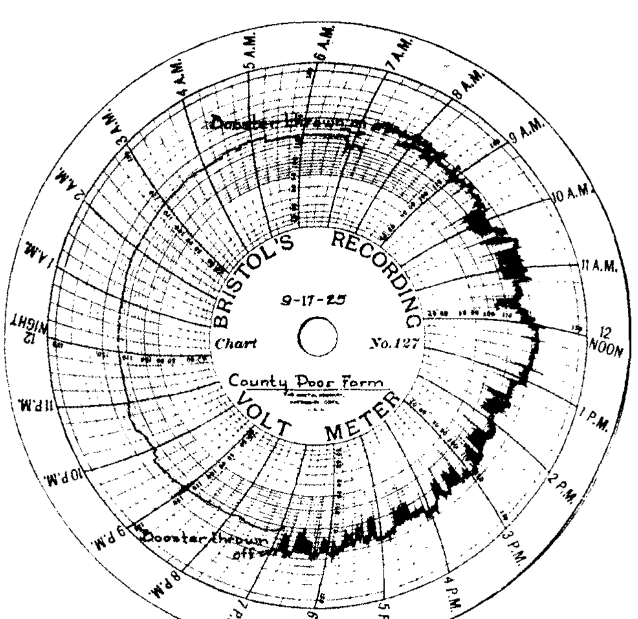

Fig. 37. Volt meter chart, taken at the county farm on same day as that in Figure 36. A higher voltage is maintained while the voltage booster is in use, but the variation is still great.

TABLE XXXVIII

Voltage Drop Tests; Range Load at the W. J. Bryan Farm

Voltage drops from transformer to barn, load supplied by use of Hotpoint Electric stove at the house.

Time, a.m.	10:06	10:08	10:10	10:11	10:13	10:15
Stove loads	None	Left 3	Full	Full	Right 3	None
Barn voltages	218.5	211	207.0	206.5	216.0	219.5
Transformer voltages	223.5	216	214.5	214.0	222.5	224.5
Sec. line drop computed	5.0	5	7.5	7.5	6.5	5.0

Voltage drops from transformer to house, load supplied by use of Hotpoint Electric stove.

Time, a.m.	10:34	10:35	10:36	10:37	10:38	10:30
Stove loads	None	Left 3	Full	Full	Right 3	None
House voltages	222	207	196	196	209	223
Transformer voltages	226	218	211	211	218	226
Sec. line drop computed	4	11	15	15	9	3
Primary and transformer drop	0	8	15	15	8	0

TABLE XXXIX

High Line Test, August 20, 1924, 15 H-p. Motor, Voltage Regulation

	Meter readings as taken									Actual Values—Readings multiplied by					
										1	20	50	20	1	4
	Line VM_0	Trans. AMM	Trans. VM	Line VM_1	Line AMM	Motor AMM	Motor VM_0	Motor watt	Motor VM_1	Trans. volt	Line volt	Trans. amp.	Line volt	Line amp.	Motor $volt_0$
Lo.F 1*	E	C	D	K	I	H	L		G	D	E	C	K	I	L
Time															
4:14									First Series						
0	103	1.90	214	98.	6.6	3.5	100	290	185	214	2,060	95	1,960	6.6	390
15	103	1.85	216	98	6.6	3.25	99	275	287	216	2,060	92.5	1,960	6.6	386
30	103	1.85	216	98.5	6.5	3.25	100	285	188	216	2,060	92.5	1,970	6.5	390
45	103	1.85	216	100	6.5	3.25	100	285	187	216	2,060	92.5	2,000	6.5	390
4:16															
0	103	1.85	216	99.5	6.4	3.1	101	280	188	216	2,060	92.5	1,990	6.4	394
15	103	1.85	216	99.5	6.4	3.2	101	280	187	216	2,060	92.5	1,990	6.4	394
30	103	1.85	216	99.5	6.35	3.2	101	275	186.5	216	2,060	92.5	1,990	6.35	394
45	103	1.85	216	99.5	6.4	3.2	100.5	280	186	216	2.060	92.5	1,990	6.4	392
4:18															
0				100	6.2	3.0	101	270	189				2,000	6.2	394
15				100.5	6.1	3.1	101	270	189.5				2,010	6.1	394
30				100.5	6.2	3.05	101	275	189				2,010	6.2	394
45				100.5	6.2	3.05	101	273	189				2,010	6.2	394
4:20															
0	111	0.55	226						222	226	2,220	27.5			
15	111	0.55	226						221.5	226	2,220	27.5			
30	111	0.55	226						222	226	2,220	27.5			
45	110	0.55	226						221.5	226	2,220	27.5			
5:30									Third Series						
0	111.5	1.8	227	109		3.60	112.5	325	221.5	227	2,230	90	2,180		450
15	112	1.8	227	109		3.65	112.5	325	221.5	227	2,240	90	2,180		450
30	111.5	1.8	227	109		4.00	113	350	221	227	2,230	90	2,180		452
45	111.5	1.75	227	109		3.70	112.5	325	221	227	2,230	87.5	2,180		450
5:32															
0	102	2.7	212	93		9.5	76	375	140	212	2,040	135	1,860		304
15	92	3.8	198	83					132	198	1,840	190	1,660		
30	112	.6	230							230	2,240	30			
45	111	.8	228						220	228	2,220	40			

* Letters indicate the location of voltmeters and ammeters at places marked by these letters on chart, Figure 30.

TABLE XL

High Line Test, August 21, 1924, 15 H-p. Motor, Voltage Regulation

	Readings as taken										Actual Values—Reading		
											20	20	50
	Line VM_0	Line VM_1	Trans. AMM	Trans. volts	Motor line AMM	Motor return AMM	Motor volt	Motor AMM	Motor watts	End 2nd volts	Line $volt_0$	Line $volt_1$	Trans. amp.
Lo.F. 1*	A	B	C	D	I	E	G	H		J	A	B	C
Time													
4:30													
0	115.5	111.0	1.90	216.0	5.8	5.8	100.0	3.00	260	98.0	2,310	2,220	95.0
30		111.0	1.85	214.0	5.9	5.8	100.0	2.85	255		2,310	2,220	92.5
60		110.5	1.90	214.0	5.9	5.8	100.0	2.80	255		2,310	2,210	95.0
4:32													
0	115.5	110.5	1.87	214.0	6.0	5.8	100.0	2.90	263	98.0	2,310	2,210	93.5
30		110.5	1.87	214.0	6.1	5.9	100.0	2.95	260		2,310	2,210	93.5
60		111.0	1.80	214.5	6.0	5.9	101.0	2.80	255		2,310	2,220	90.0
4:34													
0	115.0	108.0	2.50	208.0	6.2	6.0	94.0	2.90	255	91.0	2,300	2,160	125.0
30		108.5	2.52	210.0	6.0	6.0	96.0	2.90	255		2,300	2,170	126.0
60		108.5	2.50	210.0	6.0	6.0	95.0	2.95	255		2,300	2,170	125.0
4:45													
0	114.5	108.0	2.22	210.0	5.5	5.5	97.0	2.65	233	94.0	2,290	2,160	111.0
30		107.5	2.20	210.0	5.5	5.5	97.0	2.60	233		2,290	2,150	110.0
60		107.5	2.20	209.5	5.4	5.4	97.0	2.60	230		2,290	2,150	110.0
4:47													
0	114.5	108.0	2.17	211.0	5.5	5.4	98.0	2.65	233	94.0	2,290	2,160	108.5
30		108.0	2.15	212.0	5.4	5.4	98.0	2.60	230		2,290	2,160	107.5
60		107.5	2.30	210.0	5.4	5.4	98.0	2.60	230		2,290	2,150	115.0
4:49													
0	114.5	107.5	2.25	210.0	5.4	5.4	97.0	2.60	230	94.0	2,290	2,150	112.5
30		108.0	1.90	214.0	5.4	5.4	99.0	2.60	230	98.0	2,290	2,160	95.0
60		108.5	1.92	212.0	5.4	5.4	100.0	2.55	233		2,290	2,170	96.0

* Letters indicate the location of voltmeters and ammeters at places marked by these letters on chart, Figure 30.

TABLE XXXIX—*Continued*

rument ratios			Computed values							Voltages on 110 volt basis				
2	10	40												
Motor volt$_1$	Motor amp.	Motor watts	Motor V.A.	Pow. fact.	Line amp.	Tran. P. drop	Line P. drop	Mo. tran. P. drop	Cable P. drop	Trans. volt	Line volt$_0$	Line volt$_1$	Motor volt$_0$	Motor volt$_1$
G	H													
								First Series						
370	35	11,600	13,650	80.5	9.3	80	100	.5	20	107	103	98	97.5	92
374	32.5	11,000	12,545	88	9.24	100	100	1.5	22	108	103	98	96.5	93
376	32.5	11,400	12,675	90	9.24	100	90	1.0	14	108	103	98.5	97.5	94
374	32.5	11,400	12,675	90	9.24	100	60	2.5	16	108	103	100	97.5	94
376	31	11,200	12,214	91	9.24	100	70	1.0	18	108	103	99.5	98.5	94
374	32	11,200	12,608	89	9.24	100	70	1.0	20	108	103	99.5	98.5	94
373	32	11,000	12,608	88	9.24	100	70	1.0	21	108	103	99.5	98.5	93
372	32	11,200	12,544	87	9.24	100	70	1.0	20	108	103	99.5	98.5	93
378	30	10,800	11,820	90				1.5	16			100	98.5	94.5
379	31	10,800	12,214	88				2.0	15			100.5	98.5	94.5
378	30.5	11,000	12,017	91				1.5	16			100	98.5	94.5
378	30.5	10,920	12,017	91				1.5	16			100	98.5	94.5
444					2.68	40				113	111			111
443					2.68	40				113	111			110.7
444					2.68	40				113	111			111
443					2.68	40				113	110			110.7
								Third Series						
443	36.0	13,000	15,950	81.5	3.92	40	50			113.5	111.5	109	112.5	110.7
443	36.5	13,000	16,200	80.2	3.92	30	60			113.5	112	109	112.5	110.7
442	40.0	14,000	17,680	79.2	3.92	40	50			113.5	111.5	109	113	110.5
442	37.0	13,000	16,340	79.5	3.66	40	50			113.5	111.5	109	112.5	110.5
280	95	15,000	26,980	55	13.12	80	180			106	102	93	76	90
264					18.62	140	180			99	92	83		66
					2.64	60				115	112			
440					3.92	60				114	111			110

TABLE XL—*Continued*

ltiplied by instrument ratios					Computed Values						Voltages			
												On 110-volt basis		
	1	4	10	40										
Trans. volts	Motor line amp.	Motor volts	Motor amps.	Motor watts	Motor V.A.	P.F.	High line amp.$_1$	High line amp.$_0$	Line P. drop	Trans. P. drop	Line volt$_0$	Line volt$_1$	Trans. volt	Motor volt
D	F	G	H											
216.0	5.8	400	30.0	10,400	12,000	86.6	1.94	1.86	4.5	6.0	115.5	111.0	108	100
214.0	5.9	400	28.5	10,200	11,400	89.0	1.88	1.81	4.5	8.0		111.0	107	100
214.0	5.9	400	28.0	10,200	11,200	90.0	1.94	1.86	5.0	7.0		110.5	107	100
214.0	6.0	400	29.0	10,500	11,600	90.0	1.91	1.83	5.0	7.0	115.5	110.5	107	100
214.0	6.1	400	29.5	10,400	11,800	88.0	1.91	1.83	5.0	7.0		110.5	107	100
214.5	6.0	404	28.0	10,200	11,312	89.0	1.84	1.76	4.5	7.5		111.0	107.3	101
208.0	6.2	376	29.0	10,200	10,904	93.0	2.55	2.45	7.0	8.0	115.0	108.0	104	94
210.0	6.0	384	29.0	10,200	11,136	92.0	2.57	2.47	6.5	7.0		108.5	105	96
210.0	6.0	380	29.5	10,200	11,210	90.0	2.55	2.45	6.5	7.0		108.5	105	95
210.0	5.5	388	26.5	9,300	10,282	90.0	2.26	2.17	6.5	6.0	114.5	108.0	105	97
210.0	5.5	388	26.0	9,300	10,148	91.0	2.26	2.15	7.0	5.0		107.5	105	97
209.5	5.4	388	26.0	9,200	10,088	92.0	2.26	2.15	7.0	5.5		107.5	104.7	97
211.0	5.5	392	26.5	9,300	10,388	89.0	2.21	2.12	6.5	5.0	114.5	108.0	105.5	98
212.0	5.4	392	26.0	9,200	10,192	90.0	2.19	2.11	6.5	4.0		108.0	106	98
210.0	5.4	392	26.0	9,200	10,192	90.0	2.34	2.25	7.0	5.0		107.5	105	98
210.0	5.4	388	26.0	9,200	10,088	91.0	2.30	2.20	7.0	5.0	114.5	107.5	105	97
214.0	5.4	396	26 0	9,200	10,296	89.0	1.94	1.86	6.5	2.0		108.0	107	99
212.0	5.4	400	25.5	9,300	10,200	91.0	1.96	1.88	6.0	5.0		108.5	106	100

TABLE XLI

High Line Test, August 24, 1924, 15 H-p. Motor, Voltage Regulation

	Readings as taken										100	20
	Trans. AMM	High line V.M.	High line AMM	High line watts	Sec. V.M.	High line V.M.	High line AMM	Stove V.M.	Stove AMM	Stove watts	Trans. amps.	High line volts
Lo.F 1*	C	E	M		P	N	O	J			C	E
Time												
3:10												
0	0.58	105.5	7.1	600	106	98	2.1	180	25.5	2,400	58	2,110
30	0.6	107	7.1	600	106	98	2.1	182	25.5	2,360	60	2,140
60	0.58	107	7.1	600	106	98	2.1	184	25.2	2,350	58	2,140
3:12												
0	0.6	106	7.2	675	106	97	2.1	182	25.4	2,380	60	2,120
30	0.6	106	7.25	680	106	97	2	184	25.4	2,390	60	2,120
60	0.7	105	8.02	770	105	90	2	180	25.0	2,310	70	2,100
3:17												
0	0.79	104.5	8.85	880	105	95	2	178	24.8	2,240	79	2,090
30	0.8	104.2	8.8	860	104	94.5	2	178	24.6	2,240	80	2,084
60	0.8	104.2	8.82	865	104	94.5	2	178	24.6	2,240	80	2,084
3:19												
0	0.8	104.2	8.82	865	104	94.5	2	178	24.6	2,240	80	2,084
30	0.8	104.1	8.85	870	104	95	2	178	24.6	2,240	80	2,082
60	0.79	104	8.79	850	104	94.5	2	178	24.5	2,240	79	2,080
3:22												
0	0.6	105.2	7.25	675	106	99.5	0	200			60	2,104
30	0.59	105.3	7.25	675	106	100	0	200			59	2,106
60	0.58	105	7.22	665	106	99.5	0	200			58	2,100
3:24												
0	0.67	105	7.7	730	106	98.5	0	200			67	2,100
30	0.6	108	6.48	680	106	99	0	200			60	2,160
60	0.48	109	5.8	610	108	101.5	0	204			48	2,180

* Letters indicate the location of voltmeters and ammeters at places marked by these letters on chart, Figure 30.

variation in "Transformer Amperes," or the current through the isolating transformer secondaries, shows plainly the increase due to turning on the range.

Ground Wire

An attempt was made to determine whether the ground connections on the messenger wire were carrying any current. An ammeter was placed at point I, Figure 30, and the wire was connected directly to one of the grounds. Another ammeter was connected directly into the iron-messenger wire at point F, Figure 30. The readings from these two meters given in Table XL show that only a very small part of the current was going to the ground. The maximum amount was 0.2 amperes and most of the time there was no noticeable difference in the two readings.

Range Tests

Another series of tests was conducted on August 24 to determine the effect of electric ranges at one farm on those at other farms, the large motor not being used. The data from these tests are given in Table XLI. The test was started, and at 3:10 p.m., when the reading began, there were three ranges (at the Cady, Melin, and A. C. Bryan farms) operating. Just at 3:12:50 the range at W. J. Bryan's farm was being turned on and was on in full at 3:17. Between 3:19 and 3:22 the range at A. C. Bryan's farm (J) was turned off. The changes in transformer amperes, (C), the high-line volts (E), and, in fact, all of the measured quantities show clearly when the load was changed.

The secondary voltage at the County Farm (P) was lowered considerably during the entire test while the voltage (stove volts) at A. C. Bryan's farm (J) was too low to operate the stove for cooking purposes. Notice how the voltage at this point was affected by the range at W. J. Bryan's farm. Note also that the voltage was still only 200 volts (100 volts on the 110 volt circuits) when the range was turned off before 3:22 p.m. The other ranges were reducing the primary voltage to this amount.

The computed values for the power factor of the high line show that the added range load improved the power factor 5 or 6 per cent. The high line impedence showed a similar effect, but was not so regular.

Conclusions

The conclusions taken from these tests were as follows:

1. The iron wire line to Mr. Bryan's place was a failure when used with 2,300 volts.
2. The iron messenger wire had too much resistance to use on a 2,300-volt, single-phase circuit.
3. The grounds on the iron messenger wire did not carry an appreciable amount of current.
4. The secondaries, after moving three transformers, were satisfactory for range operation at the houses.
5. The isolating transformers were causing an appreciable voltage drop.
6. A farm line using either one or two iron wires with or without one of them grounded cannot be used for the operation of ranges and motors of 5 h-p. capacity on 2,300-volt, single-phase circuits.

TABLE XLI—*Continued*

Actual Values—Readings multiplied by instrument ratios								Computed values				
1	20	1	20	1	1	1	1					
High line amps.	High line watts	Sec. volt	High line volts	High line amps.	Stove volts	Stove amps.	Stove watts	High line V.A.	High line P.F.	High line av. amps.	High line impedence, ohms	High line P.D.
M		P	N	O	T							
7.1	13,200	106	1,960	2.1	180	25.5	2,400	14,981	88	1.6	32.6	150
7.1	13,200	106	1,960	2.1	182	25.5	2,360	15,104	87	4.6	30.0	180
7.1	13,200	106	1,960	2.1	184	25.2	2,350	15,194	87	4.6	30.0	180
7.2	13,500	106	1,940	2.1	182	25.4	2,380	15,264	88	4.65	38.0	180
7.25	13,600	106	1,940	2	184	25.4	2,390	15,370	88	4.62	38.2	180
8.02	15,400	105	1,920	2	180	25.0	2,310	16,842	91	5.01	36.0	180
8.85	17,600	105	1,900	2	178	24.8	2,240	18,466.5	95	5.42	35.0	190
8.8	17,200	104	1,890	2	178	24.6	2,240	18,339.2	94	5.40	32.0	194
8.82	17,300	104	1,890	2	178	24.6	2,240	18,380.9	94	5.41	32.0	194
8.82	17,300	104	1,860	2	178	24.6	2,240	18,380.9	94	5.41	32.0	194
8.85	17,400	104	1,900	2	178	24.6	2,240	18,425.7	94	5.42	34.0	182
8.79	17,000	104	1,860	2	178	24.5	2,240	18,283.3	90	5.40	35.0	190
7.25	13,500	106	1,990	0	200			15,254	89	3.62	32.0	114
7.25	13,500	106	2,000	0	200			15,268.5	89	3.62	29.0	106
7.22	13,300	106	1,990	0	200			15,162	86	3.61	30.0	110
7.7	14,600	106	1,970	0	200			16,170	90	3.85	34.0	130
6.48	13,600	106	1,980	0	200			13,996.8				180
5.8	12,200	108	2,030	0	204			12,644				150

The All-Copper Line

The line was changed quickly to an all-copper ungrounded line. The isolating transformers were removed. Three No. 8 copper wires were installed in place of all the iron wire, and all grounds were removed from the line. On September 11, 1924, the threshing machine was driven successfully with the 15 h-p. motor. Tests of this work are given in the section on "Threshing."

The ranges worked satisfactorily on the 2,300-volt, single-phase copper line. The large 15 h-p. motor used for threshing operated very well when near town, but caused trouble with low voltage when far out on the line. A voltage "booster" was connected in with the portable transformer as shown in the diagram of the original portable transformer outfit given in the report on "Threshing." This booster raised the voltage enough to take care of all the voltage drop in the cable. In fact the voltage on the 110-volt basis was frequently higher at the motor than on the secondary house-wiring or high line. The line drop, however, was still very large, and the voltage would frequently fall to as low as 90 when threshing was done near the end of the line. On September 20, 1924, when the motor was being used for ensilage cutting (ensilage cutting does not require such a large motor) the voltage was about 115 volts with no load on the line. A chart, showing the voltage on the secondary house circuit when the motor was in use, is shown in Figure 32. This chart is a record from 7:00 a.m. one day to 1:00 p.m. the next day. Both records are shown in the forenoon, one day without the motor (top line) and one day when the motor was in use. The voltage fluctuated between 92 and 108 while the motor was running. The motor did not operate satisfactorily. The motor would carry a full load, but would stall on overloads. A brake horse-power test made on October 9, 1924, showed that the 15 h-p. motor would carry up to 15.2 brake horse-power with the voltage at 105. When the motor was loaded to 16.38 brake horse-power, the voltage dropped to 92, and the motor stalled.

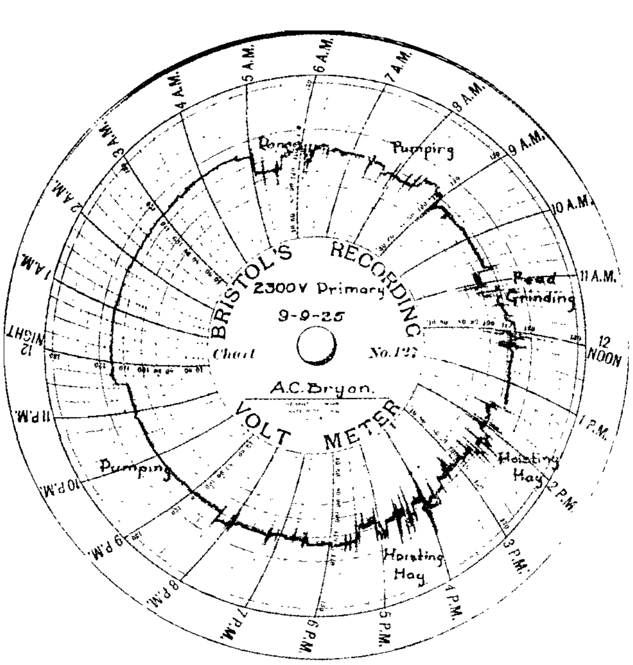

Fig. 39. Volt meter chart, showing the secondary voltage variation caused by loads of various kinds. This was taken with the all-copper 2,300-volt line and without the booster.

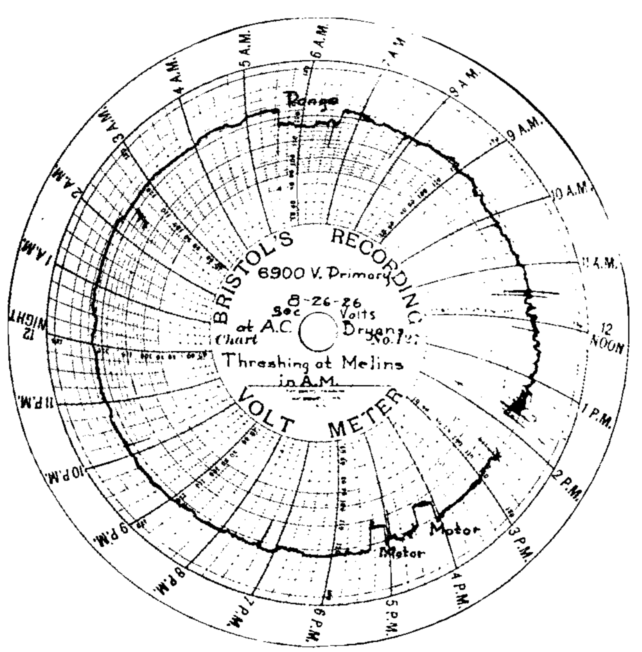

Figure 40. Volt meter chart, taken on the secondary lines at the Bryan farm with the 6,900-volt line. Various types of load are being used even at the Melin farm for threshing.

Recording Voltmeter Records

Many detailed records of tests were taken during 1924 and 1925 to determine where the trouble was. Since these tests do not show any more than can be seen on the voltage charts, the charts will be used to illustrate the conditions. Recording voltmeters were used at Red Wing (malt house), the County Farm, and at several farms on the line. Scores of such chart records were taken. One series of three records taken on the same day will be sufficient to show the results secured by the use of these records. Figure 33 is a record taken from the high line at Clay street, Red Wing; Figure 34 is the record taken from the high line at the County Farm 2.3 miles west of town; and Figure 35 is a record taken from the high line at the transformer at A. C. Bryan's farm. Threshing was being done at Cady's farm about 0.4 miles from the County Farm switch. The wheat and flax were very tough. The report on "Threshing with Electricity" shows that the motors were using 13.8 kw. during the forenoon and 15.8 kw. during the afternoon. Every change in threshing is recorded on the charts.

Conclusions from the Charts

Conclusions from the charts:

1. The voltage at Clay Street was not lowered by more than 3 or 4 volts by using the motor.
2. The voltage at Clay Street was not very high, being only 115 to 116 volts.
3. Voltage at the County Farm was reduced 22 to 25 volts and fluctuated from 92 volts to 110 volts while motor was operating.
4. Voltage at the far end of the line fluctuated from 90 to 112 volts while the motor was operating.

Booster Operation

As a result of these tests, it was decided to use a booster transformer at the beginning of the line at Red Wing to raise the high line voltage. When this was first installed, the booster was left on all the time. The off load voltage was so high that several lamps were burned out in the next two weeks. The high night time voltage can be seen in Figure 38. The booster, after this, was thrown on to the line at 7:00 a.m. and turned off in the evening.

A series of voltage charts, Figures 36, 37, and 38, taken at the same three places as given above on September 17, 1925, shows the effect of the booster. Ensilage cutting did not take as much power as threshing and so the voltage variation is not so much in this case as in Figures 33, 34, and 35. The voltage at the malt house was raised considerably by the booster, as can be noted in Figure 36. The booster was turned on when the chart was started at 7:15 a.m., September 17, but it was not on yet at 7:00 a.m., September 18, when the chart was removed. The ensilage cutting was started at 6:35 a.m., September 18, and the voltage at Clay Street dropped from 115 to 110 or 112, while on September 17, the voltage was at 120 to 125. A similar difference in voltage can be noted in Figure 37, when the booster was thrown on at 7:12 a.m. and the voltage at the County Farm jumped from 108 up to 120. Small farm loads caused the fluctuation from 7:00 a.m. to 9:45 a.m. A big fluctuation in voltage in Figures 37 and 38 took place after 9:45 a.m. when ensilage cutting was started.

The record in Figure 38 shows the voltage for one night and a Sunday without the booster and one night and the day of September 17 with the booster turned on. There was a low voltage, about 95, every time the motor was turned on when another load of corn was brought in to be cut.

These tests appeared to indicate that, altho the booster helped, the trouble was not caused by low voltage at Red Wing, but by line loss. It was stated that the 2,300 volt line might give satisfactory service for other uses even though it would not for large

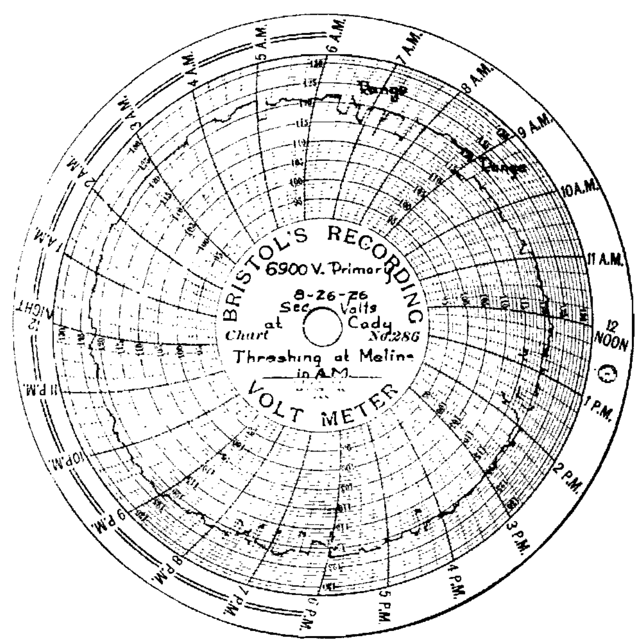

Fig. 41. Volt meter chart, showing the secondary voltage at the Cady farm, taken the same day as the chart of Figure 40. Effects caused by threshing at the Melin farm are not noticeable, and the voltage remains at about 115, even with the use of small power loads.

motors for threshing. Several tests were carried out with the use of other equipment on the line. A single chart will illustrate the results of these tests.

Small Power Loads

The chart shown in Figure 39 was taken in the house at A. C. Bryan's farm while the range and motors were being used. The booster was not used. There was a drop in voltage at 5:05 a.m. from 114 to 104, while the range was in use. The voltage was pulled down to 100 and even below several times during the day. The voltage at the motor, while being used for hay-hoisting, dropped below 90 whenever it was carrying a heavy load. (The secondaries from house to barn are too long on this farm. See the present and revised wiring plans for this farm in the section on "Wiring the Farmstead").

Conclusions from these tests:

1. The voltage variation with the booster in use was about as much as without it.
2. The high voltage secured with the booster was detrimental to equipment when heavy motors were not in use.
3. The booster did not eliminate all trouble from low voltage at the ends of the line.
4. The operation of 5 h-p. motors and ranges was not satisfactory when the line was loaded by others.
5. Ranges and motors would pull the house voltage down to 100 at far ends of line.
6. The cause of these low voltage troubles was the voltage drop on the 2,300-volt single-phase copper line, and the remedy was a change to 6,900 volts.

High Line at 6,900 Volts

The line was changed to 6,900 volts during the summer of 1926. The large motor was operated very satisfactorily after this change. All of the farmers noticed the difference in the operation of ranges and motors. One farmer stated that his "motors had a revival." A large number of chart records have been secured but two will be sufficient to show the results secured in voltage regulation by the use of 6,900 volts.

The records in charts, Figures 40 and 41, show that ranges and motors cause a drop in voltage on the secondaries of about 5 to 8 volts or about one-half as much as they did on the 2,300 volt service, and the voltage on one farm is not affected by what is being done on a neighboring farm. Even threshing, with the large motor at Melin's (far end of line) has very little effect on the voltage at A. C. Bryan's place. The maximum effect at another farm appears to be a variation of about 2 volts. This variation is shown as a broad line in the chart given in the report on "Threshing." Figures 40 and 41 show that the voltage did not at any time fall below 110. The off load voltage is rather high at 123, as the service would still be very satisfactory at 115 volts with the lowest voltage about 103.

General Conclusions

1. Secondaries of No. 6 wire for use with 3 k.v.a. transformers should not be longer than 250 feet.
2. Iron wire lines and grounded iron messenger wire lines are not adequate in capacity for high line farm service.
3. Single phase, 2,300-volt lines will not give good voltage regulation for heavy farm service on lines longer than five or six miles even with a No. 6 or larger wire.
4. Single phase, 6,900-volt, all-copper lines, appear to be the practical type of line for farm service where lines must be longer than five or six miles.

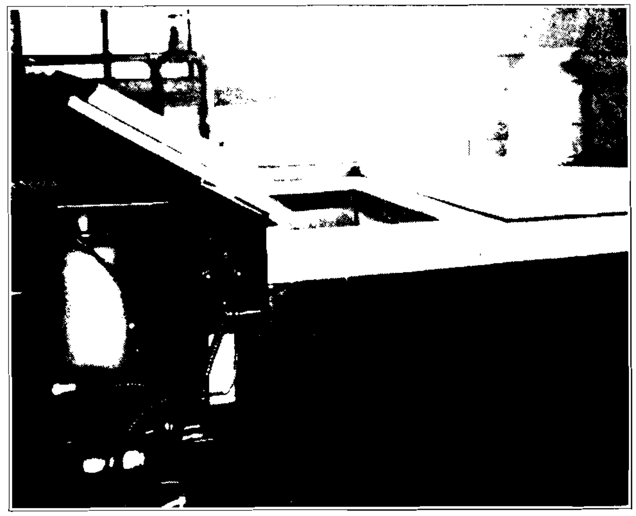

Fig. 42. Special dairy type refrigerator. This is an experimental type that has been replaced by other models.

WATER SYSTEMS AND PLUMBING

When electricity becomes available on a farm, the installation of a water system demands consideration as an outstanding improvement. Systems were provided on the eight farms which were originally in the Red Wing Project. Brief descriptions of these systems follow.

Table XLII summarizes the plumbing costs for the systems of the different farms.

Nelson Brothers' Farm

A complete hydropneumatic water system with a 120-gallon tank is installed in the basement of the house for the house water supply. This tank is connected with the kitchen sink and toilet. Water is pumped directly to the tank at the house, and branch mains from the pipe leading to the house lead to an open tank in the yard and to the barn. One-inch pipe was used for the main pipe line, and ¾-inch pipe for the branch lines.

A water system of the hydropneumatic automatic type, with a 15-gallon tank is used with the rain water cistern, from which water is available in the hot and cold water faucets at the kitchen sink, at the lavatory and the tub in the bathroom, and the laundry trays. A cross-connection was made between the soft water and the well water systems so that if the cistern is dry, water may be run in from the well water system. The soft water supply is connected to the heater pipes in the furnace and to the kerosene water heater.

B. I. Melin's Farm

The water system is a combination gravity well water supply and hydropneumatic soft water supply system. The water is pumped from the well into a 250-barrel

TABLE XLII

Summary of Plumbing Costs

	W. A. Cady	A. M. Nelson	A. C. Bryan*	B. I. Melin	Nelson Brothers	C. H. Eckblad*	F. Miller	W. J. Bryan*
Number of hours (man and helper)	97	75	25	104	108.5	18.5	78	41
Labor cost	$169.75	$131.25	$ 43.75	$182.00	$189.87	$ 32.09	$137.50	$ 71.75
Materials	139.86	101.26	21.86	114.85	107.42	16.02	110.59	25.43
Fixtures	93.55	101.95	14.45	150.75	136.45	12.85	81.25	14.70
Barn water system	146.71†	.....	.....	.....	67.04	.....	.....	.....
Total plumbing	$549.87	$334.46	$ 80.06	$447.60	$500.78	$ 60.96	$329.34	$111.88
Pumping Equipment								
Cistern water	$168.00	.....	$107.33	$118.33	$132.00	.....	.....	$ 92.00
Well water	34.00‡	206.00	25.00‡	225.00	314.60	$175.00	$ 81.00	194.73
Total water system	$751.87	$540.46	$212.39	$790.93	$947.38	$235.96	$410.34	$398.61

* Water system and bath installed previously; costs are for laundry and other additions.
† Includes cost of storage tank at $54.
‡ Pump jack only.

concrete storage cistern placed in the hillside above the buildings, from which it is piped through a one-inch pipe to the barns and the house. Water from this system at the house is supplied to the kitchen sink and the toilet, and to hot and cold water faucets in the lavatories, in bathroom and washroom. The soft water supply system is connected to the water front in the combination electric range, and to the coil in the furnace. By means of a cross-connection, water may be run into the soft water system from the well water supply tank.

A hydropneumatic automatic water system is connected with the present rain water cistern. The 15-gallon tank for the soft water is in the basement. Water from this system supplies hot and cold water for the bathtub, kitchen sink, and laundry trays.

Frank Miller's Farm

The water system is a complete gravity system so arranged that water can be supplied to the house and the barn and in the yard. A hydrant cock in the pipe underneath the platform of the well makes it possible

Fig. 43. Drinking cups should be installed in dairy barns wherever a reliable water supply can be secured.

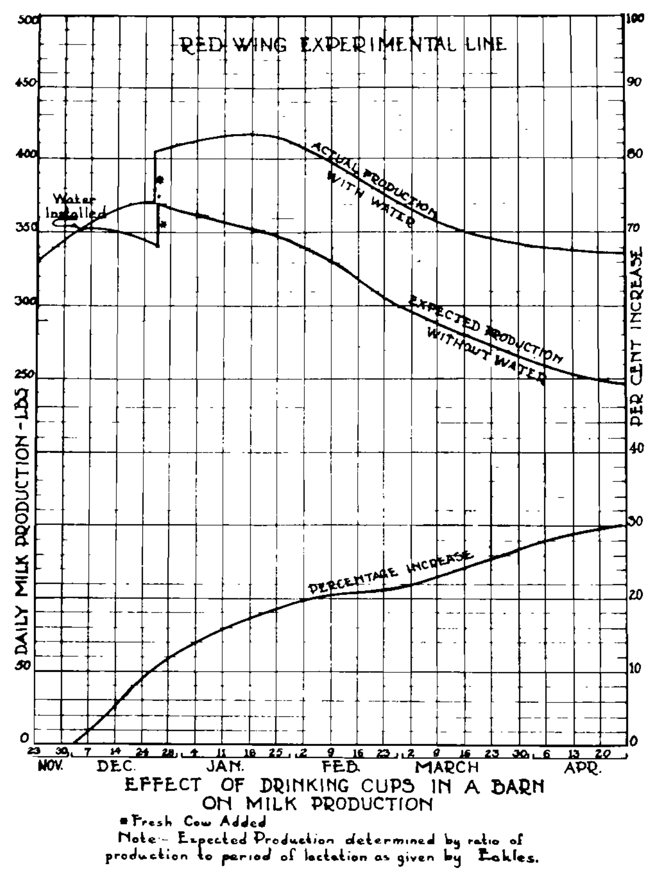

Fig. 44. Graph showing the effect of having water available in the dairy cattle barn.

to pump direct to a water tank in the yard without having to pump water into the supply tank. Water from a 25-barrel cedar tank in the barn loft supplies the drinking cups and a small tank in the barn. A 35-gallon galvanized iron tank is placed inside near the top of the larger tank to supply water for the house. Water is pumped directly through a one-inch pipe from the well to the 35-gallon tank. The pump is controlled automatically by a float switch placed in this small tank. Water may be pumped into the large storage tank, when the small tank is full, by a hand-controlled switch parallel with the automatic float switch. The overflow from the small tank runs directly into the large tank, but that from the large tank is slightly lower so that the water in the large tank can not run back into the small one. Both have tightly fitting covers and the larger storage tank is covered with hay in winter to keep the water from freezing.

The water supply for the house is taken from the pipe line that runs from the pump to the small storage tank. This system was connected to the hot water front in the wood range and supplies hot and cold water at the kitchen sink, bathtub, and lavatory; and cold water for the toilet. Hot and cold water is provided for use in the summer kitchen for washing purposes. Stop cocks with waste were provided in these two pipe lines so the water can be cut off from the faucets during cold weather. In the winter, washing is done in the kitchen. All water pipes and bathroom equipment are on inside walls to prevent freezing.

W. A. Cady's Farm

The water system for this farm is a combination hydropneumatic and gravity system. As it was impracticable to store the water at an elevation sufficient to supply water for the house, a 300-gallon tank is located in the basement of the house. Water is pumped directly from the well to this tank. A branch pipe, with a hydrant control cock underneath the well platform, supplies water to the 35-barrel galvanized iron storage tank in the barn loft. This supplies water for drinking cups for the horses and cattle.

Well water is supplied to the toilet and kitchen sink from the tank in the house. Water for the bathtub, hot water supply, and washing is taken through a water softener in the basement. Hot and cold water faucets are provided on the enclosed back porch. Pipe lines to these faucets are controlled by a stop cock and waste so the water can be cut off during freezing weather. All water pipes in the house are on inside walls to prevent freezing.

Pipes to and from the storage tank in the barn are enclosed and well insulated to prevent freezing. This tank is ordinarily covered with hay or other material to prevent excessive freezing. It is not desirable to allow air from the stable below to go up around the tank in an attempt to keep it warm, because of con-

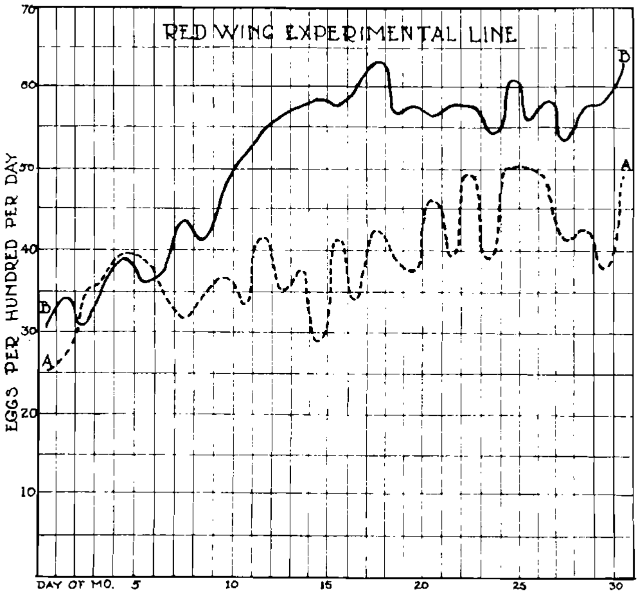

Fig. 46. Daily egg record for one month, of two pens of hens on the same farm. "A-A" egg yield of check pen without lights. "B-B" egg yield of flock with lights.

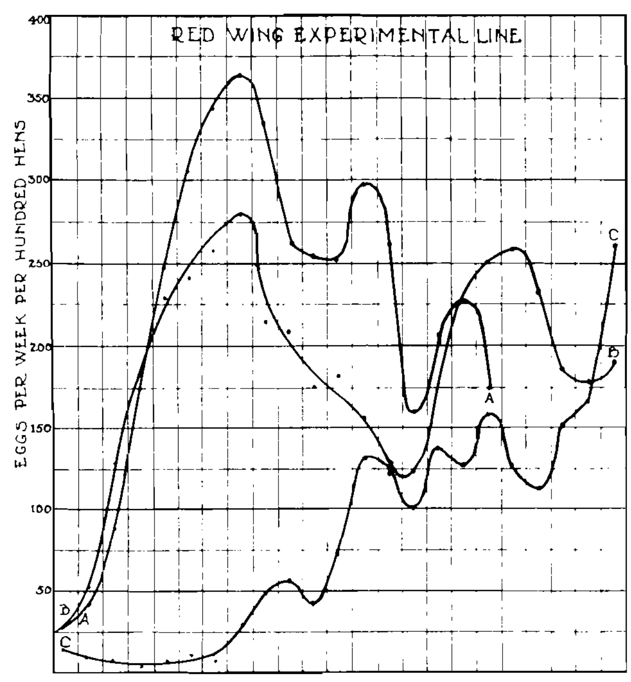

Fig. 45. Weekly egg records of three poultry flocks on different farms under different conditions. "A-A" hens in comfortable house; lights used from dark to 9:00 p.m. Nov. 1, 1925 to March 1, 1926. "B-B" hens in cold house; lights used from dark to 9:00 p.m. "C-C" hens in comfortable house; no lights used.

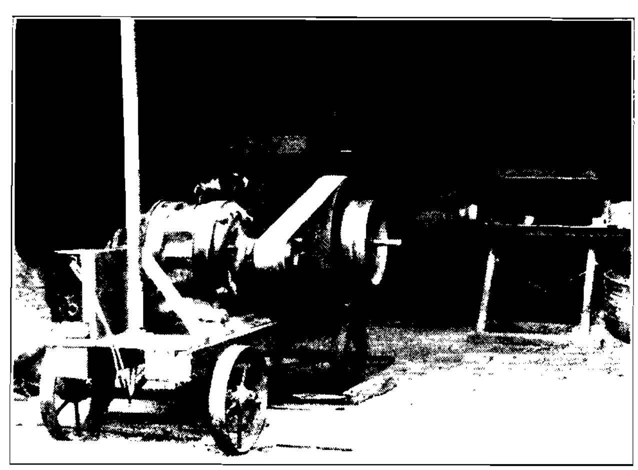

Fig. 47. By combining operations one man can do work formerly requiring two men, and have additional time for other matters.

Fig. 48. Dishwashing machines are comparatively new and may require improvements, but they reduce a hard distasteful task to a pleasant one, if properly used.

densation which takes place with a consequent running back of water into the stable below. A safety overflow was provided for the tank and is so located that water will not freeze in it.

Arthur Nelson's Farm

The water system on this farm is of the automatic hydropneumatic well water type. It is the so-called "tankless system," with a 3-gallon storage tank located on the pump in the well pit. Whenever a faucet is opened and a small amount of water is drawn from the system, the pump starts and water is drawn directly from the well. The water is not very hard and can be used for all household purposes. Both hot and cold water are supplied to the kitchen sink, laundry trays, bathtubs, and lavatory; and cold water for the toilet. Water is heated by an electric heater near the kitchen sink and the bathroom. Water is also supplied to an outdoor storage tank and to a small tank in the barn for watering livestock.

A. C. Bryan's Farm

The water supply for this farm consists of a 125-barrel, concrete storage tank mounted on a tower to provide water for both the house and the barn by gravity. A pump jack driven by an electric motor was installed to provide service in addition to that of the windmill. A hydropneumatic automatic water system with a 15-gallon storage tank in the basement of the house is connected with the cistern to supply soft water for the hot water system, the water being heated by the water front in the range. Soft water is supplied to the hot water faucets at the kitchen sink, laundry trays, bathtub, and lavatory.

W. J. Bryan's Farm

The water system on this farm is of the gravity type with a 150-barrel concrete cistern on the side of a hill. Water is provided at both house and barn. As the water is hard, a hydropneumatic system with a 20-gallon storage tank is connected to the present soft water cistern to supply hot water for the laundry trays, kitchen sink, bathtub, and lavatory. Water is heated with an automatic electric heater of small storage capacity. A hot water storage tank is connected with the hot water front of the furnace for winter use.

C. H. Eckblad's Farm

This system consisted of a 120-gallon hydropneumatic tank. Water was pumped from a cistern by a gas engine. For house use water was provided from a shallow well by a hand pump. The power pump was replaced by a tankless, hydropneumatic centrifugal pump. It operates without use of the hydropneumatic storage tank, but is so arranged that if the pump fails to operate, water can be obtained from the large tank. Water can be pumped from the shallow well if necessary. This system supplies only the house—hot and cold water at the kitchen sink, bathtub, laundry trays, and lavatory, and cold water for the toilet. Water is heated by the hot water front in both the kitchen range and the furnace.

Conclusions

1. For household purposes, a hydropneumatic automatic water system is one of the most satisfactory methods of giving adequate and dependable water.

2. In order to have water for livestock and to prevent interruptions to the supply because of repairing the well or pumping equipment, storage should be sufficient to carry the livestock at least 24 hours and a storage capacity for 48 hours is desirable.

3. Because of the possible interruptions in pumping, a hydropneumatic water supply for the barn is not always satisfactory; a gravity supply is better.

4. It is not necessary to elevate water very high for use at the barns. Low pressure is more suitable for operating drinking cups than high pressure, secured by

Fig. 49. A difficult task when the home does not have a water system.

high elevation or with hydropneumatic systems.

5. The barn loft is a suitable location for a water storage tank for the livestock.

6. Where only one pumping unit is to be used, a hand control of water pumping is satisfactory for the storage tank at the barn, leaving the automatic control for the water supplied through the hydropneumatic system at the house.

7. Where the cost of the water system must be low, a gravity system supplying both the house and the barn can be installed and will provide adequate service at a lower cost than a combined hydropneumatic and gravity system.

8. Elevation of a large amount of water on concrete towers so as to secure gravity pressure is costly and undesirable. Where the storage tank can be placed on a hill a satisfactory gravity pressure system can be provided.

PUMPING WATER WITH ELECTRIC MOTORS

Water meters were connected with some of the water systems of the Red Wing Project and electric motors with all, and tests were made to determine the costs of pumping with electric motors as compared with other means. These included tests of some of the original pumping installations using gasoline engines for power. Some of the original pump jacks were driven by electric motor though it was difficult to drive these farm pump jacks with an electric motor.

The pump jacks for gasoline engine drive are built for belt speeds of 400 feet to 750 feet per minute. A 2-inch pulley on a 1200 r.p.m. motor gives a belt speed of 600 feet per minute. Motors to be used with ordinary pump jacks should run at 1200 r.p.m., and they must be supplied with small pulleys.

Several series of tests were made and are described in the following.

FIRST SERIES OF TESTS

Tests No. 1 and No. 2 were conducted with the original gas engine and pump jack equipment. A large amount of gasoline was required in Test No. 1 to pump 1,000 gallons of water because of poor operation. The two runs reported in Test No. 2 indicate, as do several other tests, that water is pumped at a slower rate and requires more power after the first few minutes of pumping because of the gradual lowering of the water level. Note the increase in gasoline used from 4.08 pints to 4.8 pints per 1,000 gallons of water pumped. Buying gasoline at 18 cents per gallon, the cost of gasoline for water pumping was about 10 cents per 1,000 gallons.

Test No. 3 was conducted at the same farm as Test No. 1. The plunger and check valve had been repaired. An electric motor was used for power. The energy consumption was very large. A new pump head was installed on this farm and the third test is reported in the latter series of tests (Table XLIII). The energy consumption was decreased from 2.31 kw. hrs. to 1.74 kw. hrs. per 1,000 gallons of water by using a new pumping head.

Test No. 4 was conducted to determine the effect of speed on the power and energy required for pumping. The original equipment was provided with a 2½-inch pulley on the motor but as a result of the test a 2-inch pulley was used. Note how the power increased from 0.439 kw. with the 2-inch pulley to 0.60 kw. with the 2½-inch pulley. The energy required increased but slightly, as the increase in pumping speed was not enough to reduce the pumping efficiency.

Test No. 5 was conducted on the same installation as Test No. 2 to determine the effect of a line (jack) shaft on operating a pump. A motor was installed in place of the gasoline engine. The first run showed that the electric motor, using only 1.09 kw. hr. per 1,000 gallons of water, is cheaper to use than the gas engine.

TABLE XLIII
PUMPING DATA

Name	Kind of well and pump	Kind of pump jack	Size of cylinder, in.	Length of stroke, in.	Strokes per min.	Size of motor, h-p.	Total head, ft.	Gallons pumped per hr.	Kw. hr. per 1,000 gal.
W. A. Cady	6-inch cased well Force pump with underground discharge	Kenyon No. 20	3x18	5½	40	½	80 plus 65 ft. run	291	1.93
Emory Johnson	4-inch cased well Goulds No. 1697 Deep-well pumping outfit	Power head on pump	2¾x14	4	34	½	70	156	2.85
A. C. Bryan	6-inch cased well Force pump with underground discharge	Bevan heavy duty	2½	7	24	½	122	175.5	2.025
F. A. Miller	5-inch cased well Force pump with underground head for discharge	Cullman pump jack	3	6	40	¼	125 with 180 ft. run	187	1.74
Nelson Brothers	6-inch cased well Surface pump with underground head and discharge	Power head on pump	2½x16	5	..	½	129	153	2.24
A. Nelson	4-inch cased well Meyers automatic farm water system	Meyers automatic deep-well pump	2½x16	..	..	½	125	...	1.15

Fig. 50. The bath becomes easy, enjoyable, and healthful when a water system and bath equipment are installed.

A second run confirmed the test. Run No. 3 was made with the motor belted direct to the pump jack. The line shaft had been used with the gasoline engine for convenience in placing the engine and to secure proper speed. This line shaft had two heavy 18-inch wood pulleys on it and one smaller steel pulley. It was a surprise to find that more energy and more power were used when the motor was belted directly to the pump jack. An increase from 0.45 to 0.581 kw. showed that the ½-h-p. motor was now overloaded.

Test No. 6 was conducted to see if the overload on the motor or the 1½-inch pulley on the motor had caused the peculiar increase in power noted in run 3, Test No. 5. Runs 1 and 2 confirmed Test 5. An extra flywheel was added to the pump jack pulley to give the supposed flywheel effect of the line shaft, and the test is reported in Run 3. This did not solve the matter. The test watt-hour meter indicated that the line shaft smoothed out the load. The motor did not carry such heavy overloads on the up stroke nor idle so much on the down stroke. It operated at a higher efficiency. The energy consumption on run 1 is the lowest measured for farm pumping. This installation was removed and a new pump head installed before further tests could be carried out. A test on the new electric pump head is reported in the second series of tests.

Test No. 7 was conducted on a peculiar type of jack where gas engine costs for pumping had been very high. This test showed that the consumption of electricity for pumping was not excessive, yet it was higher than that of some. This outfit was replaced with an electric pump head, a test on which is reported in the second series under the name of Emory Johnson.

Test No. 1

Pumping Test at Miller's Farm, March 18, 1924

The well was 160 feet deep with 70 feet to water. It was equipped with a single-acting drop cylinder 3½ inches in diameter, connected to a 1¼-inch drop pipe with a plain pump head, with an ordinary gear-driven pump jack—11½-inch pulley on jack and driven by a belt from a 6-inch pulley on a 1½ h-p. gasoline engine.

Time of test, 37 min.
Water pumped, 142 gal.
Gasoline used, 0.8 pt.
Rate of pumping, 230 gal. per hr.
Gasoline used, 5.6 pt. per 1,000 gal.
Strokes per minute, 62.
Pump jack pulley speed, 252 r.p.m.
Engine speed, 520 r.p.m.

The plunger leathers and valve were so bad that when the speed was dropped to 32 strokes per minute the water could not be pumped. The owner stated that he had to run the engine as fast as possible to get the pump to work. Note the large amount of gasoline used per 1,000 gallons of water.

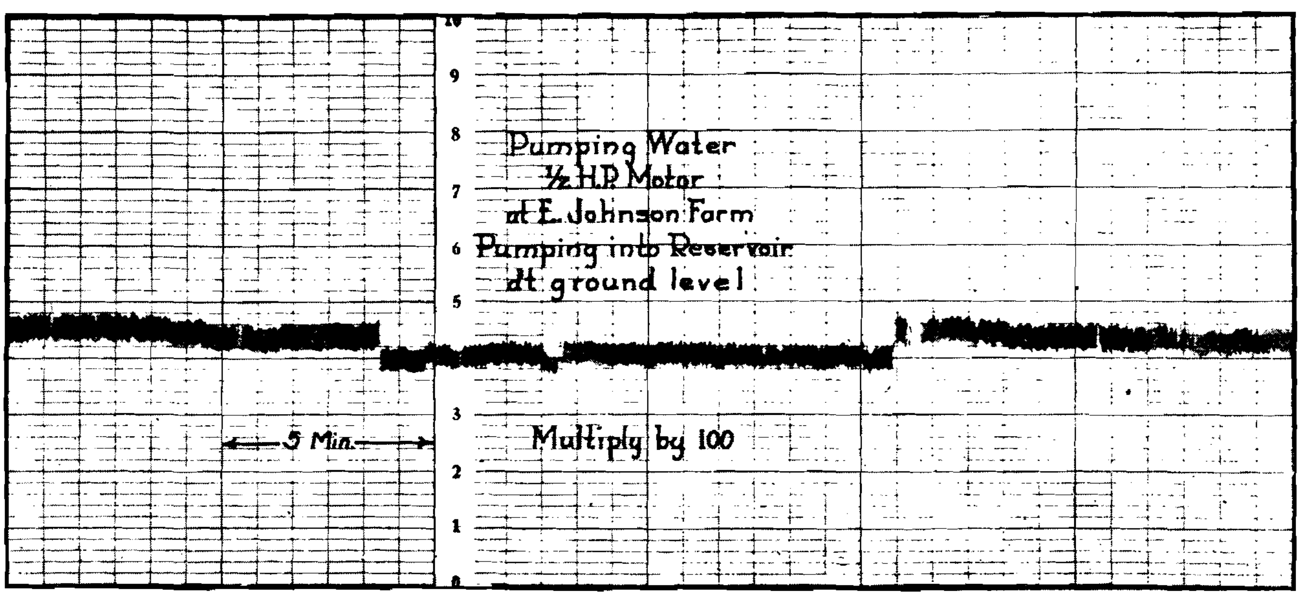

Fig. 51. Wattmeter record of pumping test at the E. Johnson farm.

Test No. 2

Pumping Test at Nelson Brothers' Farm, August 12, 1924

Pump:

The pump was an A. Y. McDonald, Figure 66V pump operated at the rate of 43 strokes per minute, using an 8-inch stroke.

Well:

Total length of pipe, ft.	152
Depth to cylinder, ft.	100
Depth to water, ft.	35
Size of cylinder, in.	2½x16
Size of pipe, in.	1¼
Size of casing, in.	4½

Reservoirs:

Two open tanks were used—one in the yard and one at the hog house.

Power used:

A 2¼ h-p. gasoline engine was used.

Jack:

The gas engine was belted to a line shaft, which was in turn belted to an ordinary geared pump jack.

Data secured:

	Run 1	Run 2	Average
Time of run, min.	39	33	36
Water pumped, gal.	245	208	227
Water pumped per hour, gal.	378	378	378
Gasoline consumed, pt.	1	1	1
Gasoline consumed per 1,000 gallons, pt.	4.08	4.80	4.44

Test No. 3

Pumping Test at F. A. Miller's Farm, August 13, 1924

Pump:

An A. Y. McDonald force pump operating at a speed of 35 strokes per minute using a 6-inch stroke.

Well:

Total length of pipe, ft.	160
Depth to cylinder, ft.	125
Depth to water, ft.	70
Size of cylinder, in.	2½x16
Size of pipe, in.	1¼
Size of casing, in.	5

Reservoir:

The water was pumped into an open tank on the ground level at the pump.

Power used:

¾ h-p., 1,200 r.p.m., 110/220-volt Wagner motor.

Jack:

An ordinary geared pump jack.

Data secured:

Time of run, min.	62
Water pumped, gal.	130
Water pumped per hour, gal.	126
Energy consumed, kw. hr.	0.30
Power input, kw.	0.29
Energy per 1,000 gallons of water, kw. hr.	2.31

Test No. 4

Pumping Test at B. I. Melin's Farm, August 14, 1924

Pump:

The pump used in this test was specially designed for motor drive as manufactured by Vaile-Kimes Co. operating at 36 strokes per minute.

Well:

Total length of pipe, ft.	98
Depth to cylinder, ft.	80
Size of cylinder, in.	2½x16
Size of pipe, in.	1¼
Size of casing, in.	6

Reservoir:

Water was pumped into a reservoir on a hillside near the pump.

Power used:

½ h-p., 110-volt, 1,750 r.p.m. electric motor mounted on pump head.

Jack:

Regular pump head as made by the manufacturers.

Data secured:

	Run 1 Using 2-inch pulley on motor	Run 2 Using 2½-inch pulley on motor
Time of run, min.	47	30
Water pumped, gal.	210	206
Water pumped per hour, gal.	268	412
Energy consumed, kw. hr.	0.30	0.30
Power input, kw.	0.439	0.60
Energy per 1,000 kw. hr.	1.43	1.451

SECOND SERIES OF TESTS

Data in Table XLIII cover six tests giving the kind of well, pump, pump jack, size of cylinder, length of stroke, number of strokes per minute, and total head, in feet, against which the water was being pumped. It will be noted that most of the installations used ½ h-p. motors; one used a ¼ h-p. motor. In general, deep well pumping can be carried out successfully with ½ h-p. motors, therefore larger motors are not recommended.

A wide range was found in the amount of energy required for pumping 1,000 gallons. This is natural, when so many factors enter into the problem as are found in pumping. Variations in depth of well, type and size of cylinders, and type of pump head or jack used, cause a variation in energy and power. The average of all tests indicates that on these farms about 2 kw. hrs. is used per 1,000 gallons of water pumped. A variation from 1.15 to 2.85 kw. hrs. per 1,000 gallons, is shown in Table XLIII.

In conducting these tests a graphic watt-meter was used to determine power requirements and to indicate changes that might take place with a variation in pumping conditions or installation.

Wattmeter records are shown in Figures 51, 52, 53, 54, and 55. All graphic records are taken from right to left. Each graph indicates a variation in power of the upstroke from that of the downstroke. This variation is much larger in some cases than in others, owing to the type of jack or pump head used. Figure

Test No. 5

Pumping Test at Nelson Brothers' Farm, August 13, 1924

Pump, well, reservoir, and jack the same as in Test No 2.

Power used:

½ h-p., 1,750 r.p.m., 110-volt electric motor connected as shown in data given below.

Data secured:

	Run 1*	Run 2†	Run 3‡
Strokes per min.	42	42	46
Time of run, min.	43	40	31
Water pumped, gal.	273	255	227
Water pumped per hr., gal.	381	382	439
Energy consumed, kw. hr.	0.30	0.30	0.30
Power input, kw.	0.42	0.45	0.58
Energy per 1,000 gallons, kw. hr.	1.09	1.17	1.32

* Motor belted to a line shaft.
† Motor connected same as Run 1.
‡ Motor belted to 18-inch pulley on pump jack.

Test No. 6

Pumping Test at Nelson Brothers' Farm, August 28, 1924

Pump, well, reservoir, and jack in this test are the same as in Tests Nos. 2 and 5.

Power used:

¾ h-p., 1,140 r.p.m., 110-volt Wagner electric motor connected to load as shown below.

Data secured:

	Run 1*	Run 2†	Run 3‡
Strokes per minute	47	47	45
Time of run, min.	30	30	30
Water pumped, gal.	212	212	212
Water pumped per hr., gal.	424	424	424
Energy consumed, kw. hr.	0.208	.218	.234
Power input, kw.	0.408	.436	.468
Energy per 1,000 gal., kw. hr.	0.98	1.05	1.10

* 3½-inch motor pulley belted to line shaft.
† 2-inch motor pulley belted to 12-inch pulley on jack.
‡ Same as Run 2 with 20-inch iron flywheel.

Test No. 7

Pumping Test at W. J. Bryan's Farm, March 17, 1925

Pump:

An A. Y. McDonald with a plain pump head, operated at 28 8-inch strokes per minute.

Well:

Drilled, ft.	150
Casing, in.	4
Diameter of pipe, in.	1¼
Depth to cylinder, ft.	100

Reservoir:

The tank is located in the ground on a hillside with the top just below the head of the pump.

Motor:

½ h-p., 1,200 r.p.m., 110-volt, single phase 60-cycle General Electric Co. motor.

Jack:

Beam type worm gear reduction.

Amount of water pumped:

Time, hr.	3¼
Water pumped, gal.	1,039
Energy used, kw. hr.	2
Energy per 1,000 gal, kw. hr.	1.92

51, taken at the Johnson Farm, shows an interesting variation in power where there is a long secondary running from the meter to the house, and shows the effect of the secondary drop in voltage. The average power requirement dropped from 440 watts where the voltage was reduced and increased again as the voltage increased. During this time the pump slowed down enough that its load and its power requirement were reduced.

In Figure 52 a peculiar harmonic increase and decrease in power can be noted. This pump was operated by a jack with a peculiar gear drive. A rhythmic change in power requirements can be noted by the

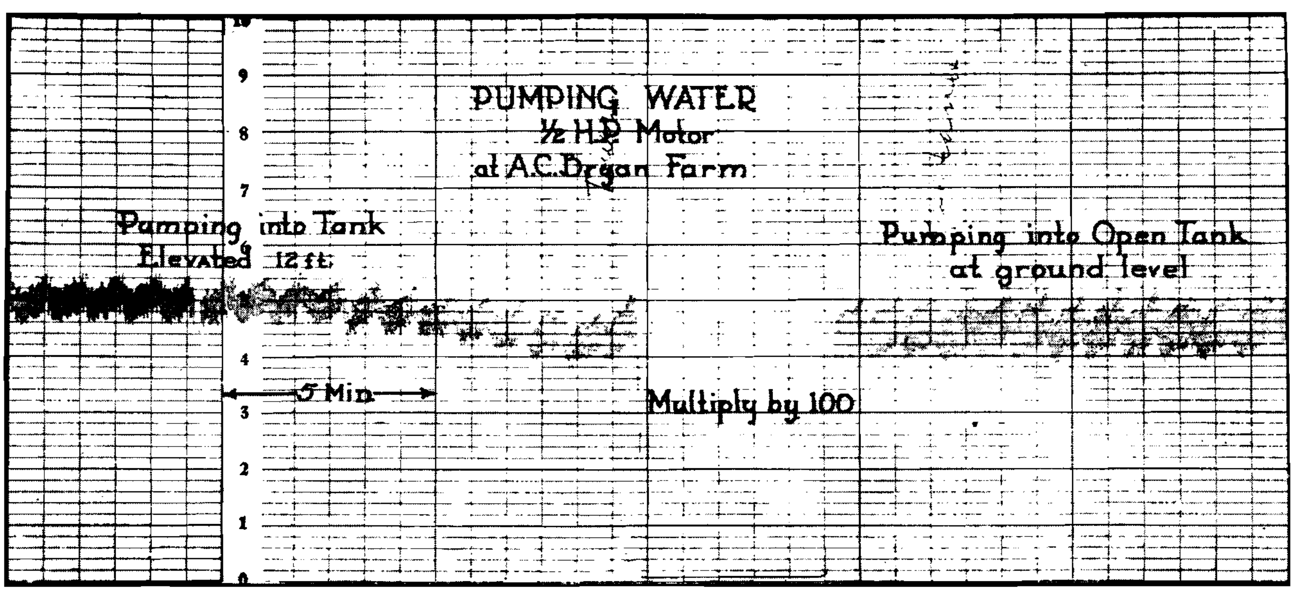

Fig. 52. Wattmeter record of pumping test at the Bryan farm.

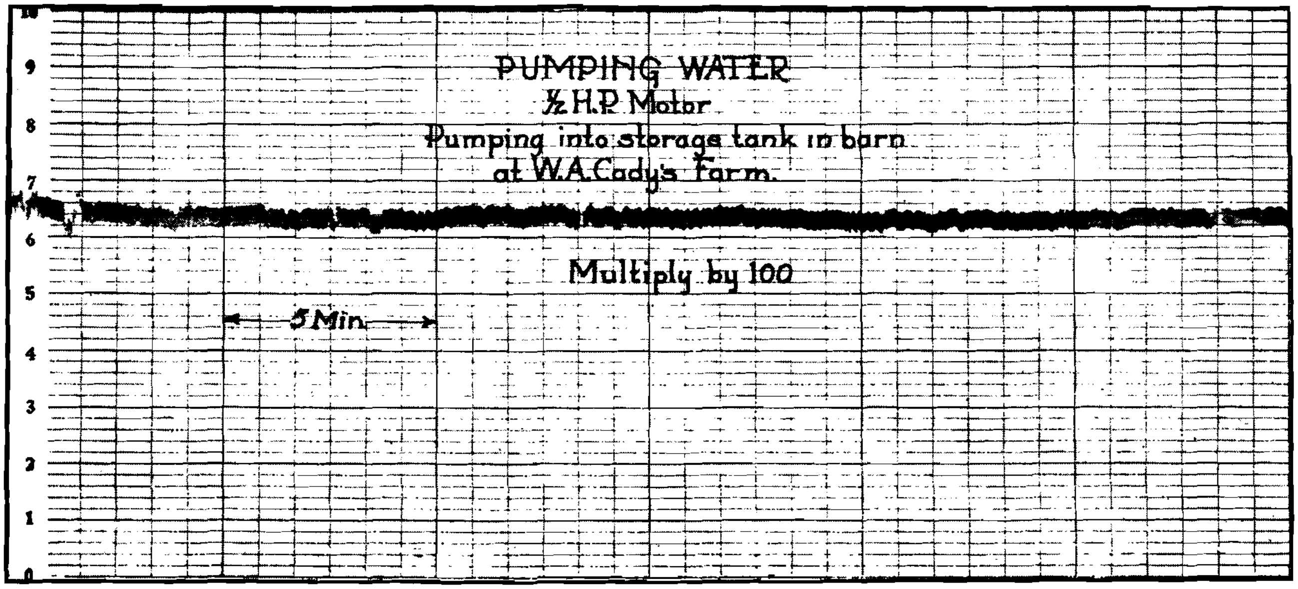

Fig. 53. Wattmeter record of pumping test at the Cady farm.

sound of the motor and by the sound of the jack when equipment is being driven by the use of the gear drive. The increase in power requirements for pumping into an open tank at ground level (right), and into an elevated tank (left), is from about 450 watts to 500 watts, or an increase of ten per cent. This shows a considerable cost for pumping the water into a storage tank elevated high enough to supply water for all purposes. It is necessary to pump water to this high elevation only for household use. The needed power gradually increased as the water in the well was lowered. About 440 watts was required when pumping into the elevated tank began. In about eight minutes the power requirement had increased to 500 watts. Pumping into the open tank started with a power requirement of less than 400 watts and gradually increased to 450 watts.

In Figure 53 are shown constant power requirements when conditions are not changing while pumping is in progress—they remain almost constant at 630 watts throughout the period. This pump was making 40 strokes per minute, which was too rapid for the size of the motor and therefore the motor was overloaded during the test. When pump jacks are not made specifically for electric drive, they frequently are run at too high a speed, because it is not practicable to use a small enough pulley on the motor and a large enough pulley on the jack to give proper pumping speed. As no electric pump jacks were available when the experimental work was started at Red Wing, several schemes for pumping water with pump jacks were tried. Now that several electric pump jacks are available, proper speeds can be secured.

Figure 54 is a record taken while a ¼ horse-power motor was used to pump water into the gravity tank in the barn loft. This system is operated with a float valve and is automatic. A 35-gallon tank, which holds approximately 28 gallons to the level at which the switch cuts off the pumping, is located inside the 25-barrel storage tank. The graph shows one period of pumping. The power increased to a very small extent while pumping was going on, owing to the slight increase in elevation as the tank filled up. The manufacturers of this outfit recommended a ¼ horse-power motor for this job, altho the data show that the motor was badly overloaded, using an input of about 425 watts. When this motor was first installed, it pumped too fast, making 40 strokes per minute. If the design were such as to reduce this rate of pumping, the ¼ horse-power motor would handle the job very well. Since this test, the 3-inch drop cylinder with a 1¼-inch pipe has been replaced with a 1¾-inch open top cylinder and 2-inch drop pipe. The ¼ horse-power motor carries its pumping load now with no apparent difficulty and the load is about 250 watts.

Figure 55 shows the type of pumping load obtained by the tankless system on the Arthur Nelson farm. The graph for this load was taken over several day periods, and that shown in the figure is for a two-hour period. During this two-hour period enough water

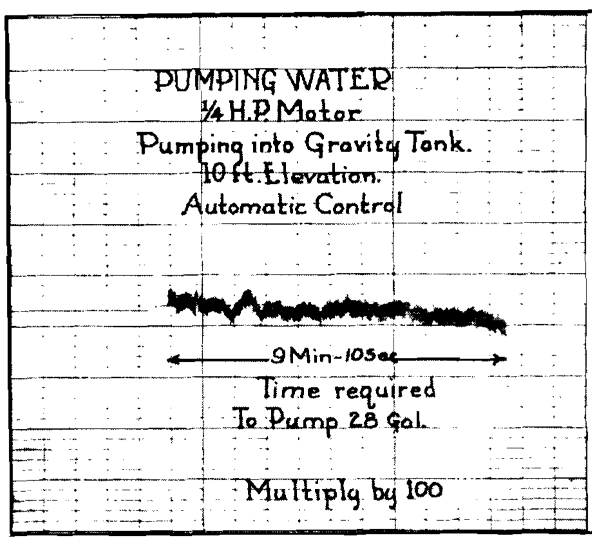

Fig. 54. Wattmeter record of pumping test at the Miller farm.

was drawn out of the 3-gallon storage tank to start the motor four different times. Evidently little water was drawn each time, as the motor ran less than a minute each time. If this water system had been provided with a storage capacity of even 30 or 40 gallons, the motor would not start so often and would run longer when started. This system has operated satisfactorily, however, and except for a little trouble owing to belt slippage and to failure of the automatic switch to operate, it must be considered satisfactory. The frequent starting appears not to have affected the motor or control equipment undesirably.

In detailed reports of the tests run on the different types of pumping equipment, which are summarized in Table XLIII, data are given concerning the type of well and of pumping equipment. In the test on the Johnson farm the large energy consumption is probably accounted for by the type of the deep-well pump head. This pump is of heavy construction and requires considerable energy for its operation. This pump installation is not of the best type for low energy consumption, consisting of a 3½-inch cylinder with a 1¼-inch drop pipe. The consumption per 1,000 gallons of water pumped is 2.85 kw. hrs.

In the test on the A. C. Bryan farm, 1.94 kw. hrs. per 1,000 gallons of water was required when pumping into an open tank at ground level; 2.025 kw. hrs. per thousand gallons was required when pumping into the elevated tank. This pumping outfit uses a smaller cylinder altho it still uses 1¼-inch drop pipe. It was more efficient than the equipment at the Johnson farm. The energy consumption in the test made on the Miller farm, 1.74 kw. hrs. per 1,000 gallons, is the lowest shown in any of the tests that are reported in detail. The low energy consumption with this installation may be due to the slow running pump head, as the type of cylinder and drop pipe are practically the same as in the other three cases.

CONCLUSIONS

1. One-half horse-power motor is large enough for pumping on most farms, if wells are properly equipped.
2. When a farmer has electric service, it will cost much less to pump with a motor than with a gasoline engine.
3. The simple pump jacks belted directly to a motor are as efficient as the more expensive pump heads, and in these tests gave higher efficiency.
4. More research is necessary to produce a highly efficient pumping outfit.

Pumping Test at A. C. Bryan's Farm, July 26, 1927

Pump:

This pump has a 3-way underground discharge head. It was operated at the rate of 24 strokes per minute, using a 7-inch stroke.

Well:

Total length of pipe, ft.	228
Depth to cylinder, ft.	160
Depth to water, ft.	114
Size of cylinder, in.	2½
Size of pipe, in.	1¼

6-inch casing drilled 14 inches into sand rock.

Reservoir:

Two tanks were used in this test. The regular storage tank is of concrete, 12 feet above the ground. A large open tank for watering cattle underneath the elevated tank was used to measure the water pumped, as there was no way to measure it in the storage tank. Two runs were made by pumping into the open tank to determine the power required and the rate of pumping; then a run was made by pumping into the elevated storage tank.

Motor:

The motor used was a ½ h-p. single phase, 60 cycle, Duro, repulsion induction motor. Speed, 1,750 r.p.m. with a 2½-inch pulley. Supplied with 220-volt circuit.

Jack:

A Bevan heavy duty jack was used. The following data were secured.

First run—Pumping into open tank

	High	Low	Average
Amperes	3.88	3.00	3.44
Watts	588	0	440 (from graph)
Volts	226 (no variation)		
Time, hr.			1
Amount of water, gal.			170
Energy used, kw. hr.			0.327
Energy used per 1,000 gal., kw. hr.			1.94

Second run—Pumping into open tank

	High	Low	Average
Amperes	3.94	3.07	3.44
Watts	602	7.5	450 (from graph)
Volts	226 (no variation)		
Time, hr.			1
Amount of water, gal.			175
Energy used, kw. hr.			0.332
Energy per 1,000 gal., kw. hr.			1.9

Third run—Pumping into elevated tank

	High	Low	Average
Amperes	4.07	3.015	3.53
Watts	653	12	490
Volts	225 (no variation)		
Time, hr.			1
Amount of water, gal.			172.5
Energy used, kw. hr.			0.3495
Energy used per 1,000 gal., kw. hr.			2.025

Pumping Test at W. A. Cady's Farm, July 25, 1927

Pump:

This pump has a 3-way head with the underground discharged about 6 feet below the surface. It was run at 40 strokes per minute, using 5½-inch strokes.

Well:

Total pipe length, ft.	150
Depth to cylinder, ft.	80
Depth to water, ft.	62
Size of cylinder, in.	3x18
Size of casing, in.	6
Size of pipe, in.	1¼

Reservoir:

The water was pumped into an open gravity tank in the hay mow of the barn, 65 feet from the pump. The water was raised to the top of the tank, which is 14 feet above ground level, or approximately 20 feet above the underground discharge pipe. The delivery pipe is 1¼ inches.

Motor:

The motor used was a Westinghouse single phase, 60 cycle, ½ h-p. motor. Speed, 1,750 r.p.m. with a 2-inch pulley, connected to a 220-volt supply.

Jack:

The pump jack is a Kenyon No. 20.

Several indicated readings of the high motor loads for both watts and amperes were taken for several strokes, and are as follows:

	High	Low	Average
Amperes	4.18	2.71	3.45
Watts	846	164	505
Volts	200 (little variation)		

Amount of water pumped:
Diameter of tank, 6 ft. (circular)

First run	
Time, hr.	1
Amount of water, gal.	291.5
Energy used, kw. hrs.	0.574
Energy per 1,000 gal., kw. hr.	1.97
Second run	
Time, hr.	1
Amount of water, gal.	296
Energy used, kw. hr.	0.571
Energy used per 1,000 gal., kw. hr.	1.93
Average energy per 1,000 gal., kw. hr.	1.95

Pumping Test at F. A. Miller's Farm, July 28, 1927

Pump:

This pump has a Cullman pump head underground and a Cullman jack on the surface. The water is discharged at the underground head where it goes to the barn through a 1¼-inch pipe. The pump was run at a speed of 40 six-inch strokes per minute.

Well:

Drilled, ft.	190
Length of pipe, ft.	180
Depth of cylinder, ft.	165
Diam. of pipe, in.	1¼
Diam. of casing, in.	5

Reservoir:

A gravity tank in the hay mow of the barn is used. A small house tank is inside the large tank. The total height above discharge head is about 20 feet.

Motor:

The motor used was a ¼-h-p. single phase, 60 cycle 110 volt, 1,750 r.p.m. Westinghouse motor.

Jack:

The jack is a Cullman electric pump jack. It is fastened to an old force pump and the discharge head is in a pit below.

Data secured:

	High	Low	Average
Amperes	5.85	4.5	5.17
Watts	782.9	92.3	438
Volts	115	111	113

Amount of water pumped	
Time, min.	9 1/3
Amount of water, gal.	28
Rate of pumping, gal. per hr.	187
Energy used, kw. hr.	0.04875
Energy used per 1,000 gal., kw. hr.	1.74

BARNS FOR USE WITH ELECTRICITY

Two of the eight farms at Red Wing were equipped with comparatively poor barns when experimental work was started. The owners had planned to build new ones in the near future and this gave an opportunity to plan and design barns suitable for the use of electricity in any way they might wish.

Mr. Cady's was designed as a general purpose barn, for housing both cattle and horses. Nelson Brothers, on the other hand, had a barn, which, with few changes, could be used readily for a horse barn, so the new barn was made to house only cattle. Mr. Cady's need of a new granary and corncrib made it possible to incorporate these in the barn and to take advantage of electricity for handling grain and feed. A combination granary and corncrib, called a "feedery," was built beside the barn and connected with it.

At Nelson Brothers, on the other hand, the horse barn and the new cow barn were separate, and at a short distance from these, as shown in Figures 5 and 6, under the article "Wiring the Farmstead," a suitable granary was located. These two farmsteads, therefore, gave an opportunity to determine the feasibility and practicability of using one building for most purposes instead of several buildings. A study of the labor involved in doing the chores at these two farmsteads has given interesting information. Mr. Cady, in addition to having his feed handy and grinding equipment so that it was not necessary to have a man present while the feed was being ground, also used a milking machine, whereas the Nelson Brothers did their milking by hand. Records for two years show that the Nelson Brothers used 157 man hours per cow per year or, on the basis of the value of the product, 157 hours per $100 worth of dairy products; whereas Mr. Cady used only 73 hours per cow per year, or 88 hours per $100 worth of products. According to these figures, buildings can be planned to eliminate travel from one building to another and handling of feed by hand when electricity is available.

Mr. Cady's barn is 36 × 82 feet with a "feedery" at one side of the barn 24 × 30 feet. The barn has room for 20 cows, 6 horses, 17 calves, a bull pen, and a cow pen, with a large amount of storage space for

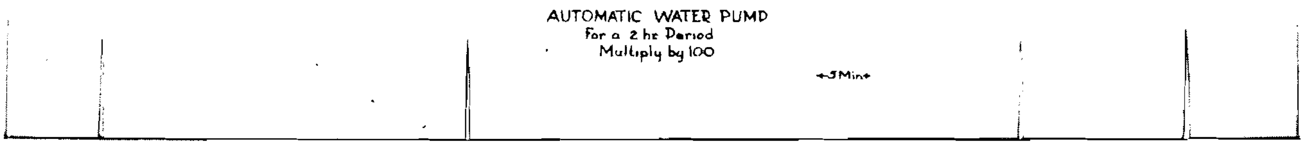

Fig. 55. Wattmeter record showing type of load produced by an automatic pump. The load factor is very low.

small grains, ground feeds, and ear corn. This large capacity on such a small floor area was accomplished by using the least possible space for alleys and arranging them in such a way that it is easy to reach all parts of the barn with the least distance to travel. The floor plan of the barn is shown in Figure 56 and an outside view of the barn and feedery in Figure 57.

The floor plan of the barn shows how the feedery, the plan of which is not detailed in the general barn plan, connects readily with the feed alley for the cow stable and calf stalls. The horse stable can be entirely shut off from the cow stable by keeping the doors closed on the feed alleys. The hay chutes are so arranged that one at the end of the barn can be used for the cattle; at the same time the chute that drops hay for the horses can be used for the cows' or calves' stable. The barn is ventilated by electric fans, details of which are given under the article on "Ventilation" and the location of the fans is shown in Figure 56. There are four electric fans, one 16-inch fan being placed on the west side of the barn, next to the feedery; two 12-inch fans on the east side of the cow stable, and one 12-inch fan on the south end of the barn to ventilate the horse stable.

The barn is well lighted. The diagram for the wiring system indicates the location of the switches and lights. Note the convenient location of the switches, also that the center-alley lights are controlled by two three-way switches, located near each of two doors by which one may enter the cow stable. The lights in the feedery also are controlled by two three-way switches, one at the door near the feedery and the cow stable and one at the outside entrance door to the feedery.

If barns are to be ventilated adequately they must be properly insulated, as the only heat provided is the animal heat. If much air is to be taken through the barn to ventilate it properly, it is necessary to retain all the heat possible in the building by good insulation. A new type of wall construction was used in these barns to keep down heat losses. The wall construction of Mr. Cady's barn is illustrated in Figure 58. The wall is 12 inches thick over all, and consists of two 4-inch, concrete walls with a 4-inch insulating space between. The insulating space is made by nailing one-inch old boards to 2 × 2 upright strips. Figure 59 shows the 4-inch insulated center section set upon the foundation wall before the outside forms for the two concrete walls were put in place. Note the 2 × 2 center piece and the two one-inch boards. The completed wall is shown in the background. Many farmers have old boards that can be used for such a purpose. The space between the two boards can be filled

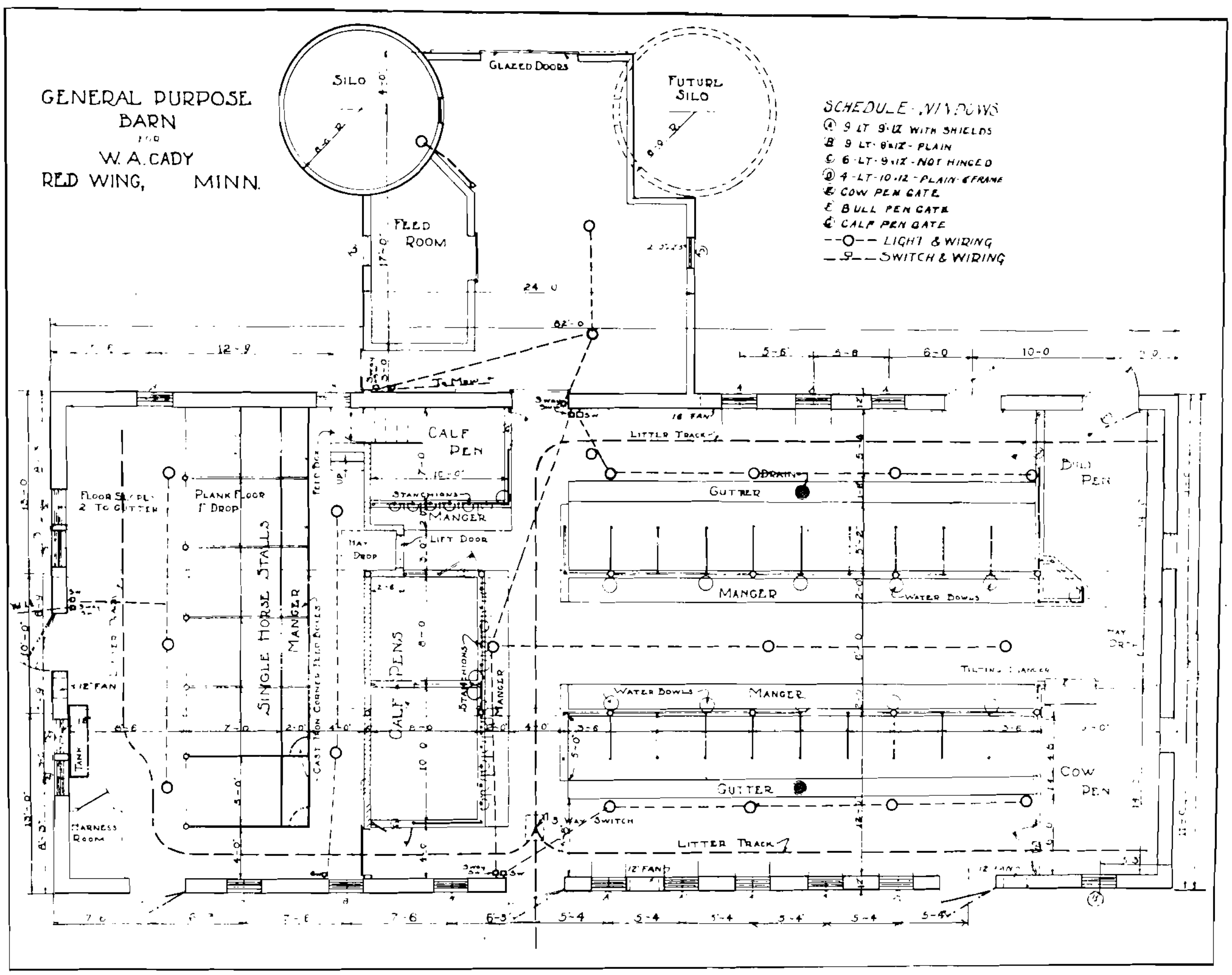

Fig. 56. Floor plan of general purpose barn for W. A. Cady. The wiring plans provide for adequate switches.

with dry coarse gravel after the rest of the wall is constructed. The gravel will help to reduce the circulation of air and the heat conductivity of the wall. A wall of this type has a coefficient of heat conductivity of about 0.165. The two 4-inch concrete walls are bonded together with iron bonds placed about 2 feet apart on centers each way.

The comparatively low conductivity of this wall when compared with walls built of other materials is shown below.

Kind of Wall	Coefficient of Conductivity
13-inch brick wall	0.31
4-inch brick and 6-inch hollow tile and plaster	.212
4-inch brick and 8-inch concrete	.30
4-inch limestone or sandstone	.65
12-inch solid concrete	.33
Studs sheathed and sided outside and plastered inside	.37
Hollow, double concrete wall (Cady's barn)	0.165

When building this barn, the workmen thought it would be difficult to use this insulation above the windows, consequently did not carry the insulation at any point in the barn above the top of the windows. This left a section at the top of the wall one foot in height all around the barn that is of solid concrete. The difficulty of placing the insulation above the windows could have been eliminated by placing the windows nearer the top of the wall. In very cold weather the difference in conductivity of the solid part and the rest of the wall is plainly seen. Frost will collect on the solid wall and if cold weather continues long it may become thick. The frost does not appear at any point on the concrete walls below this. With the type of construction used in this barn, it is possible to ventilate the barn without

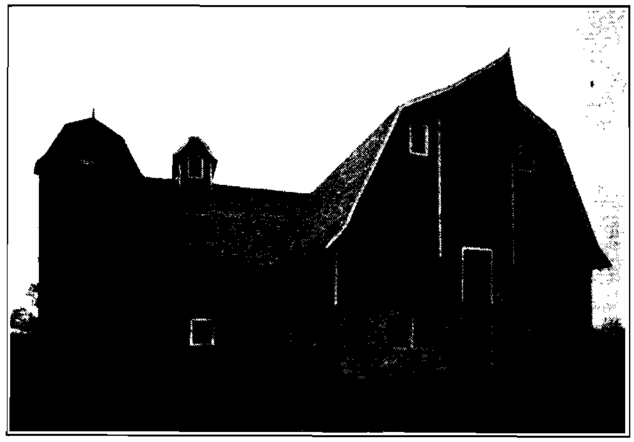

Fig. 57. Barn for W. A. Cady. Built for the use of electricity.

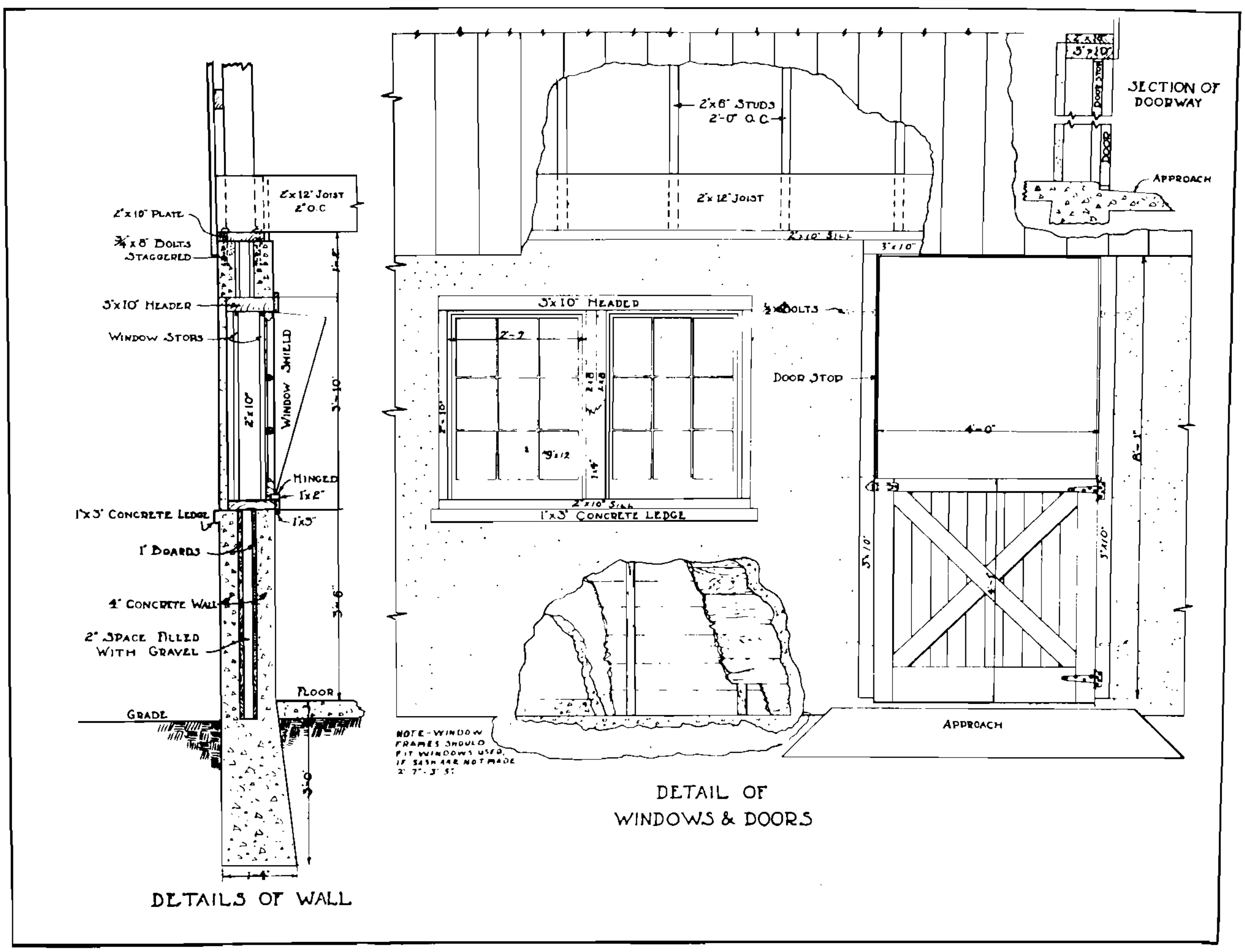

Fig. 58. Details of insulated double concrete wall for W. A. Cady. Concrete alone produces a cold barn.

cooling it to a temperature where there is danger of freezing water in the pipes or drinking cups even in the coldest weather. The compactness of the barn, whereby a large number of cattle are housed in the minimum space, contributes also to maintaining a proper temperature.

The complete detailed cost of this barn and feedery is shown on page 58. The total cost of the barn is low considering that it is equipped with steel stanchions, a water system with drinking cups, a milking machine, and electric ventilating fans. Where gravel is available and where medium priced help can be employed to do the concrete work and build the forms, such a wall can be built at a moderate cost. In this case it cost 22.7 cents per square foot, approximately 5 cents below that of any other type of masonry wall with equal heat conductivity.

In figuring the cost of this barn, it was necessary to assign a value to some of the lumber that Mr. Cady had taken from his own place. The dimension lumber and rough boards, about 20,406 board feet, were taken from his own woodlot. The cost of this lumber was taken at $45 per thousand. The total cost of materials, including plumbing, electric wiring, lights, milking machine, ventilating fan, and steel stanchions was $4,164.95. The cost of labor, figuring the help used at home at the same price as help that was hired, amounted to $1,384.20. This gives a total cost of $5,549.15.

The upper part of the wall of the new barn on the Nelson Brothers' farm was of different type from that at Mr. Cady's. The floor plan of Nelson Brothers' barn is shown in the section entitled "Wiring of Farm Buildings." The wiring plan is well designed and illustrates good farm wiring. This barn has a smaller capacity for the amount of floor area than the Cady barn because more space was needed for pens. Nelson Brothers raise dual-purpose cattle and grow out the young stock for beef. The type of wall construction, as shown in Figure 60, was made different from that of the Cady barn, to test the heat conductivity of different types of construction and also to reduce the amount of labor used in construction. The lower part of the wall is built like that of the Cady barn—two 4-inch concrete walls with a 4-inch insulated wall between. In order to do away with the solid concrete wall beneath the windows, hollow tile was used for insulation instead of the board insulation. The windows were raised, so there was no wall between the windows and the ceiling. The space between the windows was built of 2 × 8-inch studding and covered with sheathing and siding on the outside and plans were made for ceiling it on the inside. This barn has been used for two winters without using any ceiling on the inside. The lower part of the wall has low enough conductivity that frost never collects on the inside; it frequently collects on the wooden wall above it. Later the upper part of this wall will be ceiled and an attempt will be made to use different types of insulation in the wooden part. When this barn is ceiled it will be warm enough to provide fair ventilation and the lower part, being of concrete, provides a permanent construction.

This barn is built with a hay loft 8 feet high at the eaves and very similar in design to the superstructure of the Cady barn. This barn is shown in Figure 61. Note the concrete wall at the lower part of the barn wall. The cost of the materials for this barn, including the drinking cups, water systems, wiring system and lights, electric ventilating fans, and steel stanchions and pens was $3,389.64. Practically all labor was hired and the cost was $1,271.88, making a total cost of $4,661.52. The silo on both the Nelson Brothers' and the Cady farms were built before the barns and are not included in the costs given.

The cost of the Nelson Brothers' barn is slightly greater per square foot than that of the Cady barn, mostly because it is smaller. Nelson Brothers' barn cost $2.21 per square foot of floor area; the Cady barn, $1.91 per square foot.

As the Nelson Brothers' barn has only a small storage space for ground feed between it and the silo, all the feed must be transported from the granary. The cost of handling the feed, where it must be shoveled into the feed grinder by hand then transported by hand or by a wagon to the feed room at the barn largely accounts for the extra labor per cow.

In order to reduce the labor in handling feed on the Cady farm, the feedery was built in connection with the barn. It contains the corncrib, granary, and feed-grinding equipment, and is so arranged that a nominal amount of shoveling by hand is required. The feed grinding, which formerly was done by hauling grain to the feed mill in another building and grinding it by tractor power required about three hours for two men. The same amount of feed can now be ground

Fig. 59. Wall under construction showing insulating section in place. In left background, forms are in place for concrete.

with an expenditure of approximately fourteen minutes by one man.

The feedery was constructed according to floor plans shown in Figures 62 and 63. A cross-section of the feedery is shown in Figure 64. The plan for the first floor shows the location of the motor with its belt running to the line shaft and with belts from pulleys on the line shaft to the feed grinder and the elevator. The location of the mixing room and bins for ground feed, and the elevator pit are shown. Two large grain bins are located on this floor. They may be filled by the elevator through chutes from above and when they are emptied the grain can be conveniently shoveled from them into the elevator.

The feed grinder and corn sheller are located on what might be called the "mezzanine floor." The floor is dropped below the level of the second floor. This is shown in the cross-section diagram, Figure 64.

The plans for the second floor show the location of the two hopper bins used to run feed automatically into the feed grinder, placed below them. Four other grain bins are shown. The north half of the second floor of the feedery is occupied entirely by two large corn bins with the sheller located underneath and between them. The self-feeder on the sheller is so located that boards from either of the corn bins may be removed and ear corn allowed to run out on the self-feeder of the sheller. In this way fully two thirds of the grain in the bins, if they are filled to capacity, could be shelled without shoveling. Air ducts with openings are located in the floor of these two bins. Air is forced into the bins and up through the corn with a 16-inch fan that is used in the winter for ventilation. By using the fan for forced air circulation it is not necessary to leave the outside of the corn bins open to the weather and this makes it possible to incorporate them with the rest of the granary. On the second-floor plan can be noted also the hay hoist, which is driven by the motor used for grinding feed and elevating.

The alley on the first floor of the feedery is shown in Figure 65. The photograph was taken through the door at the west end of the feed alley, looking toward the stable door, in the background. The elevator, with the self-feeder raised out of the way so that the feed cart may be wheeled past it is shown. Directly above the feed cart can be seen the corn sheller, so situated that the shelled corn drops directly from the sheller into the elevator feeder, and the chute between the sheller and the elevator carries the cobs directly into a wagon-box if the wagon is backed into the feedery alley.

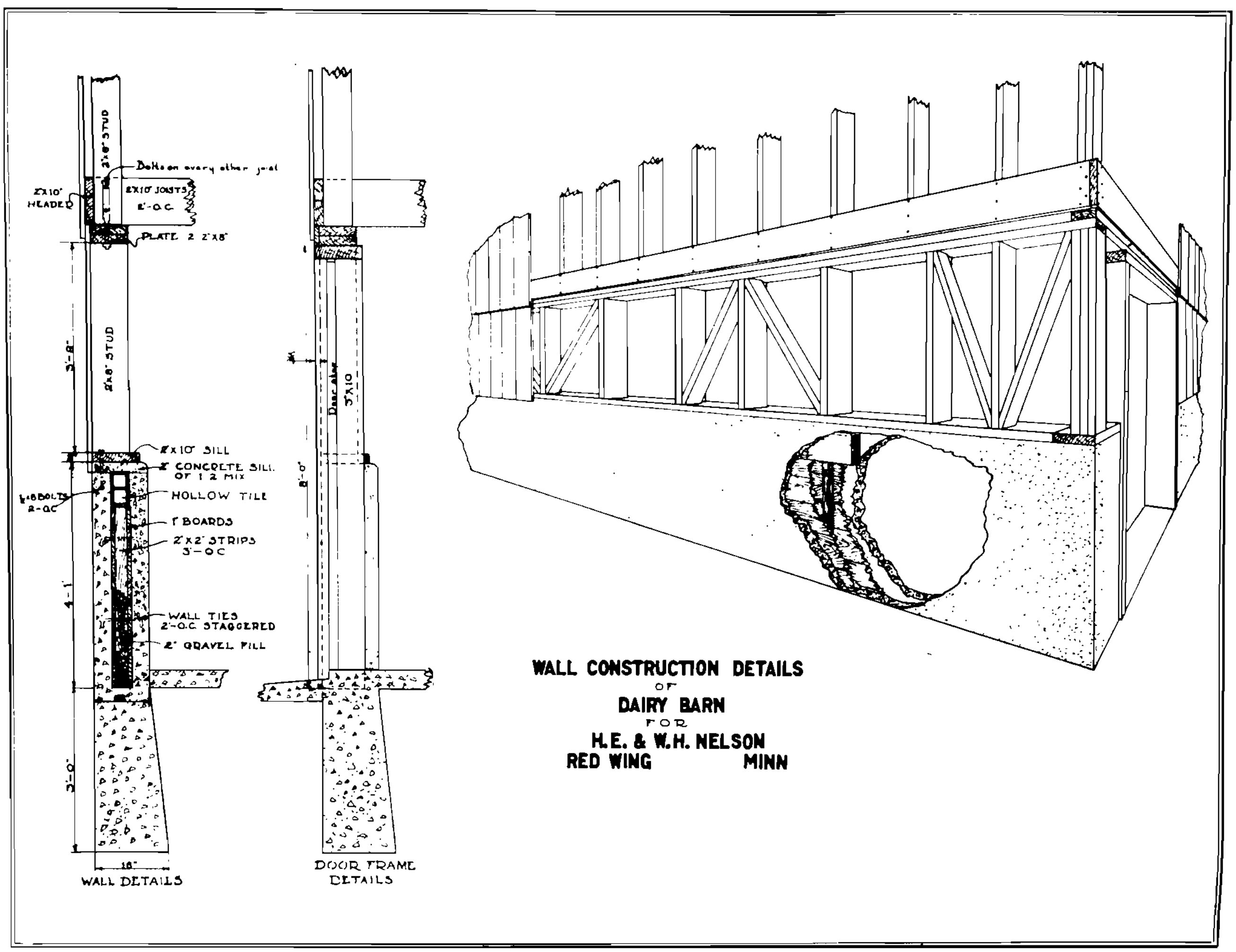

Fig. 60. Details of insulated wall construction in the Nelson brothers' barn. Note the use of hollow tile instead of solid concrete at top of the wall section.

Figure 66 shows the second floor of the feedery—the hay hoist in the foreground and the bottom of the two hopper bins immediately behind. The elevator can be seen to the right and beyond the hoist. The operation of the hay hoist is described in more detail under the heading "Hoisting Hay."

Nearly all the corn for feeding is stored in the second floor of this feedery. From there it can be run through the chutes into the boot of the elevator where the grain is carried up into the hopper bins. From the hopper bins, the feed runs by gravity through the grinder and down a spout into the bin for ground feed, shown in Figure 62, into the mixing feed bin, or directly into the feed cart. With this arrangement the elevator can conveniently be used to move grain from one bin to another if the grain should be heating or for any other reason, and can also be elevated from almost any bin to the hopper bin and ground without being handled by hand.

Fig. 61. Barn of the Nelson brothers. Note the insulated concrete wall below the windows and the frame construction above.

The two large bins on the second floor will hold about 1,200 bushels of ear corn. The corn is dried by forcing air through it with a 16-inch fan. Dampers are so arranged that the fan can be used for ventilating the stable in winter or for forcing air through the corn bins in late fall. By this method corn can be dried only on days when the air is comparatively dry and when the temperature of the corn is higher than that of the outside air. To be successful, a farmer should use the fan on all days that are suitable for drying until the corn is dry enough to keep. Tests have shown that corn containing approximately 32 per cent moisture has been dried out to 18 to 20 per cent moisture. Corn with this amount of moisture will keep in this latitude, and

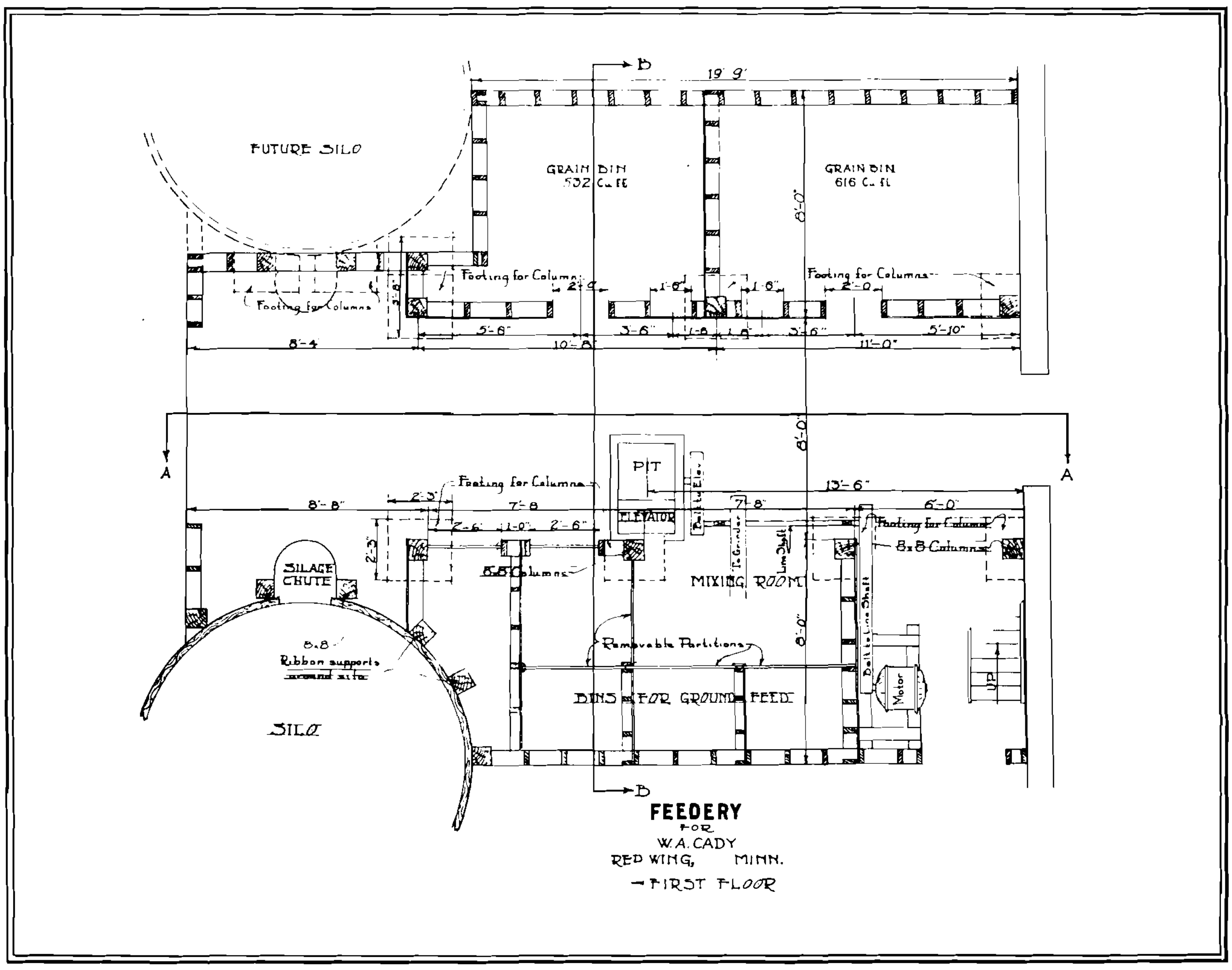

Fig. 62. First floor plan of feedery at the Cady farm. Note location of motor, line shaft, and elevator.

in the spring it will ordinarily dry sufficiently not to cause any trouble with heating. During one fall since this feedery was installed the weather was damp for a long time. The corn was very wet, in many cases containing 40 per cent moisture, and drying was not satisfactory. If the farmer had been careful to operate the fan on every day on which conditions were suitable, the corn might have been dried satisfactorily even under these most adverse conditions.

The grinding is done so slowly with a 5 h-p. motor, averaging from 17 to 30 bushels per hour, depending on the kind of grain and its condition, that it is necessary to arrange for hopper bins for feed grinding. Ear corn does not run through hopper bins like other grains. In this installation it would be almost impossible to grind ear corn, owing to the arrangement of the bins and grinder. To eliminate the necessity for grinding corn on the cob, a corn sheller was installed and all the corn can be shelled before grinding. A considerable amount of labor is saved by placing the corn sheller so that much of the corn can be shelled with the self-feeder without having to be shoveled, and the shelled corn drops directly into the elevator and can be run into the hopper bins above the feed grinder. Corn can be shelled and ground at an energy cost of less than one-half as much as to grind it on the cob. Details of these tests are given under "Feed Grinding," page 80. Altho many farmers have used corn-and-cob meal, the tendency is to get away from this, and many farmers find it to their advantage not to grind corn on the cob.

This feedery, while being complete in equipment, is not so expensive as to be burdensome when we consider the large amount of time saved in handling and grinding the feed. The cost of material, including the machinery installed, was $1,083.91. The labor cost for the building was $525, which makes the total cost $1,608.91. A good corncrib and granary each holding as much grain as this one building, would cost approximately the same and advantage could not be taken of the machinery such as we find in this feedery. If interest and depreciation are figured at 11 per cent, the annual cost for this building would be $176.98. According to data on feed grinding, results of which are given in the section on "Some Examples, Showing How Electricity Was Used on These Farms" this farmer can earn the total carrying charge on this building in his saving on grinding about 1,900 bushels of feed per year. As it would be necessary for him to have some type of storage for grain and corn, which would cost, under almost any conditions, more than half what this building cost, it can be seen that this building will earn for the farmer more than its annual

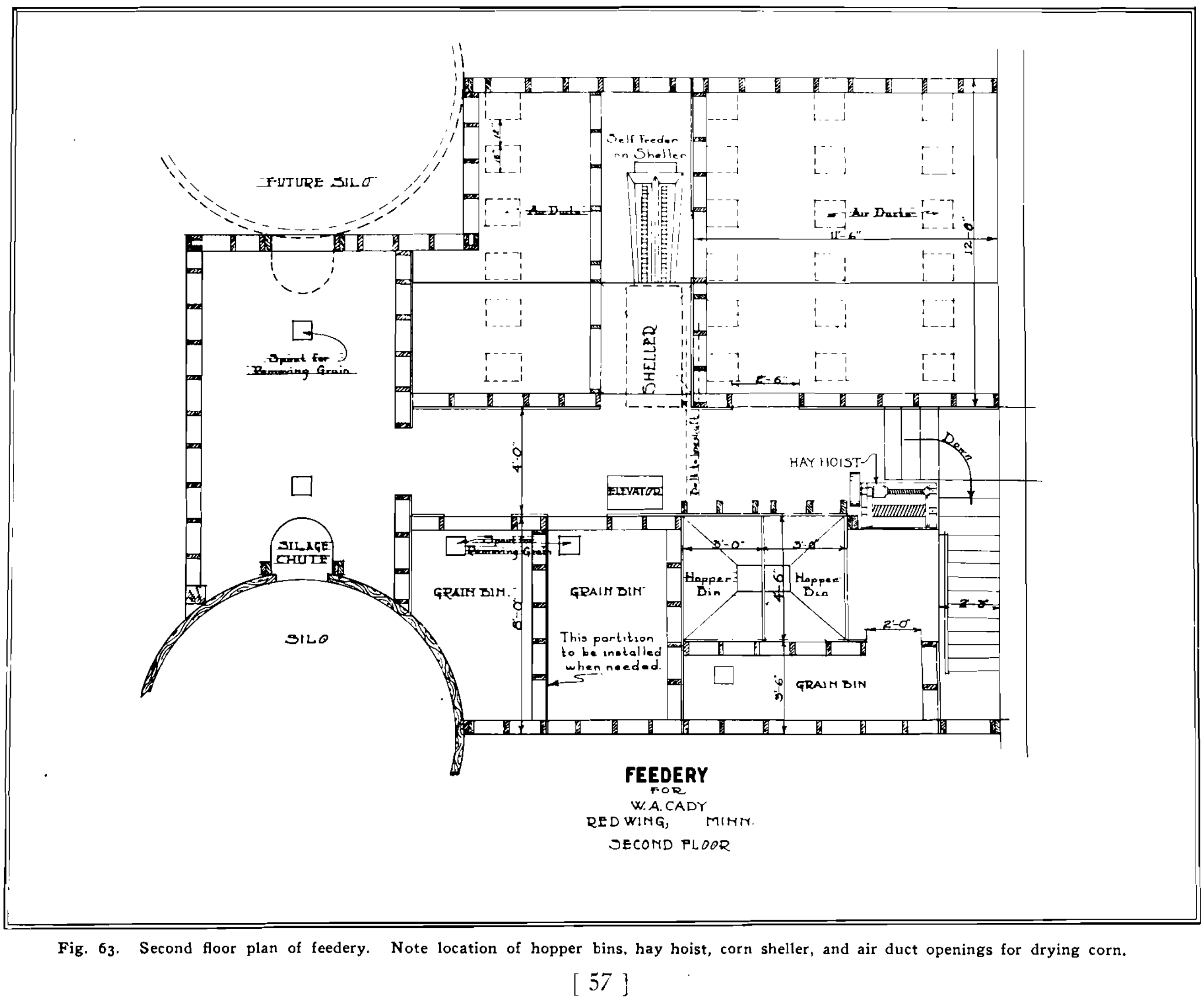

Fig. 63. Second floor plan of feedery. Note location of hopper bins, hay hoist, corn sheller, and air duct openings for drying corn.

BUILDING COSTS

W. A. Cady—Barn Cost

Cement (700 sacks)	$ 371.00
16 Window frames (single)	40.00
2 Window frames (double)	10.60
Nails	40.00
Paint and oil	40.23
Dimension material	620.92
1-inch rough material	297.38
1-inch stock boards and finish	240.35
Shiplap, doors, and frames	329.00
Battens	74.22
Shingles	134.10
Labor (walls and foundation)	125.60
Labor (floor)	159.20
Labor (other)	1,009.40
Miscellaneous hardware	38.83
Hay track and fittings	45.43
Equipment	1,105.00
Fans	139.00
Ducts for fans	19.85
Cupola	44.00
Lightning rods	60.00
Windows	49.50
Plumbing	146.71
Lights	20.00
Milking machine	285.00
Hauling equipment	11.00
Freight on equipment	2.83
	$5,549.15

20,406 board feet of home-grown lumber was used, valued at approximately $12 per 1,000 board feet standing and was valued at $45 per 1,000 feet in calculating building cost.

W. A. Cady—Feedery Cost

Cement	$ 45.00
Nails	18.31
Paint and oil	22.63
Dimension material	107.32
1-inch rough material	195.11
1-inch stock boards and finish	50.75
Shiplap	39.15
Battens	15.38
Shingles	58.15
Labor	525.00
Miscellaneous hardware	37.18
Metal duct (inside)	37.05
Metal duct (outside)	31.88
Windows	9.00
Elevator	326.00
	$1,608.91

8,500 feet of home-grown lumber was used, valued at $12 per 1,000 board feet standing and at $45 per 1,000 in calculating building costs.

Cost of Double Concrete Wall in Cady's Barn

Total wall area	1,824 sq. ft.
Window area	218 sq. ft.
Door area	192 sq. ft.
Net wall area	1,414 sq. ft.
Material wall cost	$278.60
Labor, 235.5 hours at 40 cents per hour	$ 94.00
Total concrete wall cost	$322.00
Cost per square foot	$ 0.227

Nelson Brothers—Barn Cost

Lumber and building materials	$1,585.15
Cement	362.05
Hardware	47.48
Labor	1,221.88
Painting (including paint)	110.00
Equipment	975.00
Freight on equipment	10.95
Gravel	18.50
Cost of ventilating fans (installed)	244.77
Lights	18.70
Water system	67.04
	$4,661.52

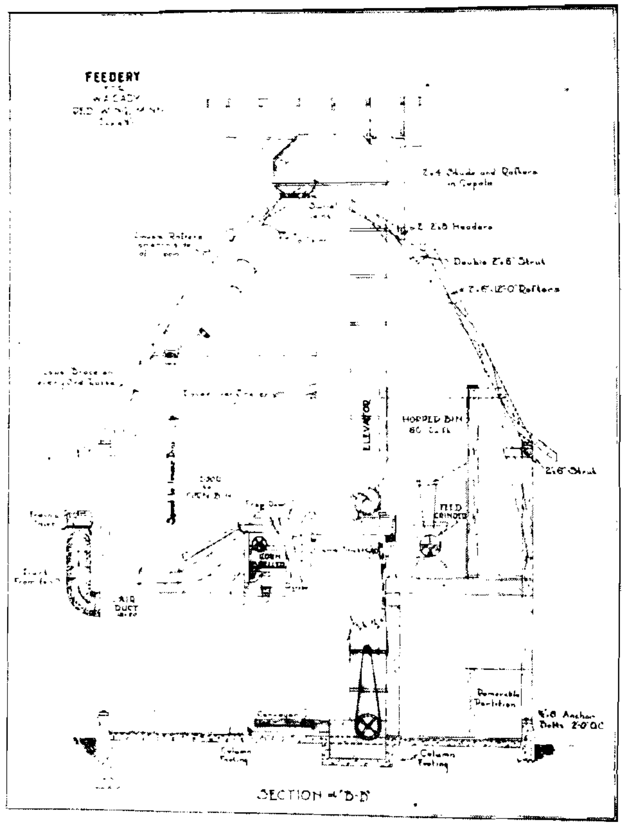

Fig. 64. Vertical section of feedery showing location of feed grinder, corn sheller, elevator and bins. Note air duct for drying corn.

Fig. 65. Interior first floor of feedery looking from west door. Note corn sheller in upper left corner.

carrying cost if the average amount of feed used is ground on the farm.

Farm buildings equipped with labor saving machinery and adequately wired so that electricity can be used to the greatest advantage, will make it possible for farmers to reduce labor costs and at the same time increase their output per man.

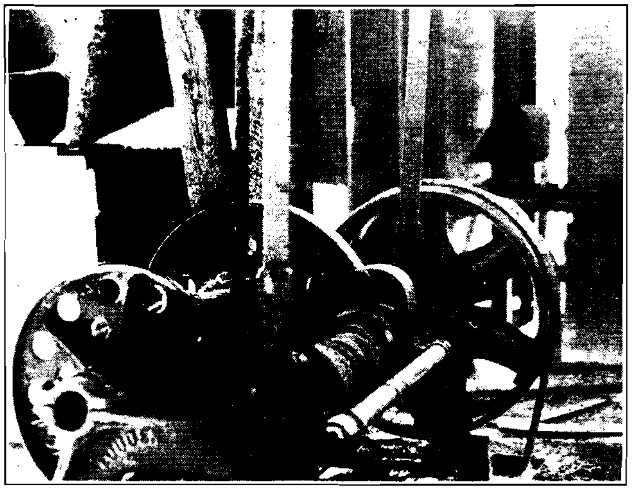

Fig. 66. Hay hoist and upper floor of feedery alley. Note hopper bottom of bin at left and bucket elevator at the rear.

ELECTRICAL ENERGY USED

Electricity was used on the Red Wing project farms principally for lights during the first four months after the service line was constructed, as it was not possible to get and install equipment until spring. As meters had not been installed, no records were available until May, 1924. By that time meters had been provided for most of the equipment, and totalizing meters were installed on each farm and meters had been placed on the high line. In addition to the eight original farms on which the project work was conducted, two other farms were connected in June, 1924, and the consolidated school was connected at the beginning of experimental work. The ninth experimental farm, that of Mr. Lokkesmoe, was not connected for service until February, 1926.

The amount of energy used on each of these farms, beginning in May, 1924, is given in Tables XLIV, XLV, XLVI, and XLVII. In these tables the total energy for each consumer for the year, the total energy used on the line each month, and the average monthly energy consumption are given.

A general increase in energy is noted throughout the first year until November. During the first few months of the summer some of the farms used a very small amount of energy. The farms showing a considerable increase in energy, like that of Mr. Miller,

TABLE XLIV

MONTHLY ENERGY CONSUMPTION, IN KILOWATT HOURS, 1924—8 MONTHS

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	W. J. Bryan	Swanson	Anderson	School	Total
January												
February												
March												
April												
May	9	11	42	79	26	*	35	21	*	*	25	248
June	52	25	195	84	21	49	102	193	3	349	†	1,073
July	46	21	144	114	109	25	127	372	10	450	†	1,418
August	50	24	134	255	102	25	116	221	13	507	†	1,447
September	155	35	276	423	67	29	110	520	24	565	35	2,239
October	145	53	348	246	133	46	211	462	36	414	19	2,113
November	115	139	371	336	137	62	90	523	57	618	25	2,473
December	120	115	286	383	74	56	115	718	61	400	30	2,358
Total (8 months)	692	423	1,796	1,920	669	292	906	3,030	204	3,303	134	13,369
Av. per month	86	53	224	240	84	42	113	379	29	472	27	152

* Service started in June.
† School closed, meters not read.

TABLE XLV

MONTHLY ENERGY CONSUMPTION, IN KILOWATT HOURS, 1925

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	W. J. Bryan	Children's Home	Anderson	School	Total
January	94	102	270	379	321	34	222	717	62	182	39	2,431
February	84	64	151	253	268	53	151	577	46	143	24	1,814
March	60	58	122	308	295	251	109	642	40	309	21	2,215
April	86	74	186	319	295	491	154	647	24	316	18	2,610
May	78	94	179	259	336	530	180	705	*	516	30	2,907
June	177	154	170	271	295	193	230	606	115	552	*	2,763
July	178	175	445	292	304	46	223	464	85	732	*	2,976
August	1,024	279	373	260	310	65	138	559	23	741	6	3,772
September	149	172	487	531	329	47	107	354	37	990	20	3,223
October	355	180	180	396	658	81	376	†	59	940	24	3,255
November	240	566	172	257	308	72	98	104	65	910	49	2,841
December	111	223	125	169	208	74	112	113	38	520	29	1,722
Totals	2,636	2,141	2,869	3,694	3,927	1,937	2,100	5,514	594	6,851	286	32,529
Av. per month	219	178	239	308	327	161	175	459	49	571	24	246

* Meters not read.
† Farm vacant most of month.

from May to June, 1924, are accounted for by the installation of either an electric range, a 5 h-p. motor, or some other equipment that used a considerable amount of energy. Only a few of these homes show a gradual increase.

In 1924 the maximum amount of energy used on any one of the project farms in a month was 718 kilowatt-hours—where an electric range and a water heater were used. Without the water heater the largest amount of energy consumed in any one month was 423 kilowatt-hours. This was on a farm where some energy had been used for threshing and an electric range was used.

The consumption by Mr. Eckblad in 1925 is characteristic of a farm that is well equipped with household appliances and is using electricity for incubating and brooding. Even tho this home had practically everything in the way of home appliances, including a refrigerator, pump, washing machine, vacuum cleaner, and several small cooking utensils, yet the energy consumption did not reach 100 kw.-hrs. during any one month when the incubator and brooder were not in use.

The large amount of energy used in August and September on some of these farms is accounted for by its use for threshing; the large amount used in October and November is accounted for by the ensilage cutters or corn huskers and shredders. The energy consumption at the home of Mr. Eckblad in 1926 and 1927 was not as low during any month as in 1925, probably because more energy was being used in winter for lighting the poultry house and in summer for the electric oven, which was installed late in 1925.

The energy consumption on the farms that use electric ranges is considerable. An electric range was used at the home of Nelson Brothers from January 1925, to October, 1926. The energy consumption on this farm is representative of the amount used when the home is equipped with electric lights, small appliances, an electric range, and a 5 h-p. motor for feed grinding, ensilage cutting, and other work. Consumption dropped off in November, 1925, but after that, again showed considerable increase until in September, 1926, it was about what it had been before the use of the range was discontinued. This can be accounted for by the greater use of electricity for pumping water, grinding feed, and other purposes.

The energy consumption at the home of Arthur Nelson is characteristic of a small home well equipped

TABLE XLVI

Monthly Energy Consumption, in Kilowatt Hours, 1926

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	Emory Johnson	Lokkes-moe	Chil-dren's Home	Anderson	School	Total
January	95	407	192	216	270	87	99	206	*	61	1,000	23	2,656
February	220	318	189	165	296	84	128	291	95	53	850	60	2,749
March	170	251	163	135	257	70	105	709	133	29	640	20	2,682
April	175	278	206	235	335	464	121	842	185	39	860	25	3,765
May	183	47	143	157	329	398	269	935	455	29	810	32	3,787
June	223	106	217	141	327	404	205	1,023	684	23	720	24	4,097
July	199	166	230	260	365	136	73	1,112	114	20	620	12	3,307
August	857	225	246	197	385	213	179	923	78	28	430	6	3,767
September	306	367	558	1,350	598	222	260	1,162	99	43	630	48	5,643
October	92	191	120	161	252	125	58	916	134	41	520	47	2,657
November	216	357	185	273	133	138	194	1.103	258	48	770	101	3,776
December	254	208	250	425	161	128	207	825	236	95†	770	76	3,635
Totals	2,990	2,921	2,699	3,715	3,708	2,469	1,898	10,047	2,471	509	8,620	474	42,521
Av. per month..	249	243	225	310	309	206	158	837	206	42	718	40	295

* Service started February 2.

† Electric pump installed.

TABLE XLVII

Monthly Energy Consumption, in Kilowatt Hours, 1927

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	C. H. Eckblad	F. A. Miller	Emory Johnson	Lokkes-moe	Chil-dren's Home	Anderson	School	Total
January	231	261	238	300	188	100	188	255	169	84	740	78	2,832
February	243	280	209	176	168	80	204	279	95	279	400	70	2,483
March	292	64	180	250	168	80	160	243	58	117	380	78	2,070
April	272	62	237	306	278	650	168	536	110	72	440	70	3,201
May	122	328	152	185	129	553	324	174	537	50	260	86	2,900
June	127	231	281	120	132	302	200	340	119	28	290	12	2,182
July	216	339	132	280	140	190	201	710	80	34	340	18	2,680
August	1,166	356	1,156	1,484	465	216	193	939	69	42	120	21	6,227
September	257	309	514	554	136	107	208	885	...	53	370	44	3,437
October	316	233	160	456	256	100	153	829	128	45	560	93	3,329
November	216	273	175	180	172	134	142	1,061	128	82	720	91	3,374
December	250	275	361	250	179	158	223	678	109	100	790	104	3,477
Totals	3,708	3,011	3,795	4,541	2,411	2,670	2,364	6,929	1,602	986	5,410	765	38,192
Av. per month..	309	251	316	379	201	223	197	577	146	82	451	64	265

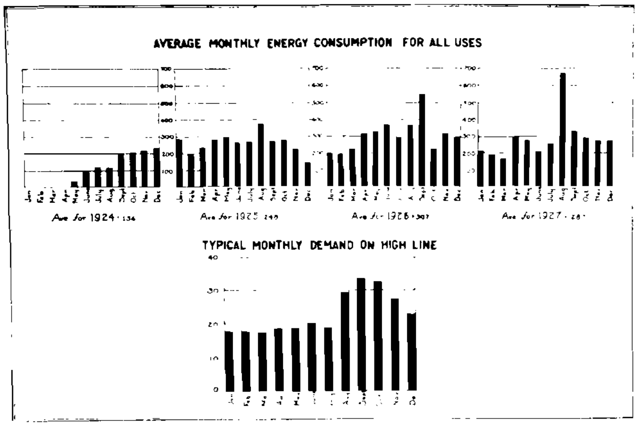

Fig. 67. Graph of energy consumption and high-line demand. High demands in August and following months caused by threshing and ensilage cutting.

with electric appliances, range for cooking in summer and a heater for heating small amounts of water.

In the last column on each table is given the total amount of energy used and also the average monthly consumption for each year. The average energy consumption gradually increased from 142 kw. hrs. per month per consumer to 246 kw. hrs. in 1925, to 295 kw. hrs. in 1926, and decreased to 265 in 1927. The averages given are for the amount of energy bought and used. In addition, a considerable amount of energy was contributed by the power company for water heating and, the first year, for threshing.

In Figure 67 the average amount of energy used for each month and each year is shown graphically. The averages given are for all uses, including energy donated. They differ slightly from those given in the tables. The total amount of energy used per farm, as shown on the chart, is 154 kw. hrs. per month in 1924; 248 in 1925; 307 in 1926; 287 in 1927. The chart shows that the energy consumption is fairly constant throughout the year except for peaks in August and September, due to threshing.

LINE CONSUMPTION DATA

The data given in Tables XLVIII, XLIX, L, and LI concern the amount of energy sold, donated, total amount used, total energy delivered to the line, efficiency of the line; average kilowatt-hour cost, and total returns from the line. The data concerning the efficiency of the line show remarkable results. It is to be regretted that so much trouble was experienced with the meters that data could not be secured throughout the experimental work. The information, however, indicates that during the first eight months when using the 2,300-volt line with a small energy consumption for the consumers, the average efficiency was 78.5 per cent. During 1925, with a larger energy consumption, the efficiency increased to 86 per cent; during 1926 to 91 per cent. This increase in efficiency shows how highly desirable it is, from the standpoint of the power company, to have farmers use large amounts of energy. When the line was changed in 1926 to 6,900-volt service, no high-line meter was installed until the following April. Data for 1927 give an efficiency of only 80 per cent, the lowest of the four years. It is remarkable how the change to 6,900 volts decreased the efficiency of transmission. To some extent this was to be expected.

The returns from the line show a gradual increase from one year to the next. In 1924 total returns were $995.33; in 1925, $1,934.13; in 1926, $2,089.38, and in 1927, $2,556.15. During the last year $443.69 was due to additional consumers; the total from original consumers being $2,112.46.

COST OF ENERGY

The cost of energy by months for each consumer is given in Tables LII, LIII, LIV, and LV. Other data in these tables are the amount paid monthly by all consumers and the amount paid yearly by each consumer together with the average monthly bill. Data in the last line on each of the tables give the average cost per kilowatt-hour for each consumer and the average for all the consumers. In 1924 the average monthly

TABLE XLVIII

ENERGY CONSUMPTION DATA, 1924—8 MONTHS

Month	Energy sold, kw. hrs.	Energy donated, kw. hrs.	Total energy used, kw. hrs.	Energy delivered, kw. hrs.	Efficiency of line, per cent	Average kw. hrs. per customer on line	Average kw. hrs. per customer on project	Average kw. hr. cost	Returns from line
January									
February									
March									
April									
May	248	0	248	437	56	31	32	$0.2672	$ 66.28
June	1,073	0	1,073	1,336	80	119	90	.0955	102.47
July	1,418	0	1,418	1,660	85	142	118	.0824	116.86
August	1,447	0	1,447	1,910	75	145	116	.0814	117.85
September	1,853	386	2,239	2,695	83	203	202	.0857	158.75
October	1,807	306	2,113	2,555	82	192	205	.0755	136.46
November	2,257	216	2,473	2,960	83	225	221	.0665	150.11
December	2,134	224	2,358	2,780	84	214	233	.0686	146.52
Totals	12,237	1,132	13,369	16,333					$995.33
Av. per month	1,530	141	1,671	2,042	78.5	151	154	$0.1028	11.31

TABLE XLIX

ENERGY CONSUMPTION DATA, 1925

Month	Energy sold, kw. hrs.	Energy donated, kw. hrs.	Total energy used, kw. hrs.	Energy delivered, kw. hrs.	Efficiency of line, per cent	Average kw. hr. per customer on line	Average kw. hr. per customer on project	Average kw. hr. cost	Returns from line
January	2,351	220	2,571	3,160	81	234	286	$0.065	$ 153.03
February	1,814	0	1,814	2,250	81	165	200	.075	136.80
March	2,132	118	2,250	2,660	85	205	235	.069	146.28
April	2,585	25	2,610	2,980	88	237	281	.062	160.44
May	2,907	0	2,907	3,290	88	264	295	.056	162.21
June	2,763	0	2,763	3,050	90	251	262	.060	164.79
July	2,976	0	2,976	3,320	89	271	266	.058	171.18
August	3,772	0	3,772	4,480	84	343	376	.052	194.92
September	3,223	0	3,223	3,500	92	293	272	.056	178.99
October	3,255	0	3,255	3,800	86	296	279	.055	179.85
November	2,477	364	2,841	3,510	81	258	227	.063	156.81
December*	1,545	177	1,722	1,990	86	157	142	.083	128.83
Totals	31,800	904	32,704	37,990					$1,934.13
Av. per month	2,650	75	2,725	3,166	86	248	260	$0.068	14.65

* The meters were read early in December and the records are for 21 days only.

TABLE L

ENERGY CONSUMPTION DATA, 1926

Month	Energy sold, kw. hrs.	Energy donated, kw. hrs.	Total energy used, kw. hrs.	Energy delivered, kw. hrs.	Efficiency of line, per cent	Average kw. hr. per customer on line	Average kw. hr. per customer on project	Average kw. hr. cost	Returns from line
January	2,290	366	2,656	3,170	83	241	197	$0.066	$ 151.06
February	2,398	351	2,749	3,290	84	229	198	.067	161.56
March	1,970	712	2,682	2,980	90	223	221	.075	148.48
April	3,063	702	3,765	4,300	87	314	316	.057	175.76
May	3,173	614	3,787	3,920	96	316	324	.057	181.32
June	3,430	667	4,097	4,350	94	341	370	.056	192.64
July	2,646	661	3,307	3,510	94	276	295	.064	168.82
August	3,075	692	3,767	3,920	96	314	367	.055	169.95
September*	4,636	1,007	5,643	*	*	470	547	.049	229.06
October	1,925	732	2,657	....	...	221	227	.077	147.75
November	2,771	1,005	3,776	....	...	315	317	.063	176.18
December	3,105	530	3,635	....	...	303	299	.060	186.80
Totals	34,482	8,039	42,521	29,440 (8 mos.)					$2,089.38
Av. per month	2,873	670	3,543	368	91	297	307	$0.0621	14.51

* High line meter removed because voltage changed to 6,600.

TABLE LI

ENERGY CONSUMPTION DATA, 1927

Month	Energy sold, kw. hrs.	Energy donated, kw. hrs.	Total energy used, kw. hrs.	Energy delivered, kw. hrs.	Efficiency of line, per cent	Average kw. hr. per customer on line	Average kw. hr. per customer on project	Average kw. hr. cost	Returns from line
January	2,832	0	2,832	*	...	236	214	$0.061	$ 173.03
February	2,483	0	2,483	*	...	207	193	.066	164.16
March	2,070	0	2,070	*	...	173	166	.075	155.19
April	3,201	0	3,201	3,440	93	267	291	.058	186.03
May	2,743	157	2,900	3,450	84	242	277	.064	175.64
June	2,026	156	2,182	2,730	80	182	205	.076	153.73
July	2,136	546	2,682	3,120	86	224	255	.074	157.24
August	5,468	759	6,227	7,320	85	519	671	.047	257.21
September	2,751	686	3,437	4,910	70	286	330	.061	168.58
October	2,582	747	3,329	4,756	70	277	292	.066	171.51
November	2,566	808	3,374	4,217	80	281	276	.066	170.33
December	2,882	595	3,477	4,636	75	290	276	.062	179.81
Totals	33,740	4,454	38,194	38,579					$2,112.46
Av. per month	2,812	557	3,183	4,286	80	265	287	$0.0646	176.04
New consumers added during year	5,751			5,751				.077	443.69
Grand total	39,491			44,330					$2,556.15

* High line meter not operating.

TABLE LII

MONTHLY ENERGY BILLS, 1924

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eck-blad	F. A. Miller	W. J. Bryan	Swan-son	Ander-son	School	Total
January												
February												
March												
April												
May	$ 7.35	$ 7.45	$ 8.76	$ 9.87	$ 8.20	....	$ 8.55	$ 7.95	....	....	$ 8.15	$ 66.28
June	9.06	8.15	13.35	10.02	7.95	$ 8.97	10.56	13.29	$ 4.26	$16.86	*	102.47
July	8.88	7.95	11.82	10.92	10.77	8.15	11.31	18.66	7.40	21.00	*	116.86
August	9.00	8.10	11.52	15.15	10.56	8.15	10.98	14.13	7.55	22.71	*	117.85
September	9.75	8.55	11.79	15.00	9.51	8.35	10.80	23.10	8.10	24.45	29.35*	158.75
October	11.85	9.09	11.70	14.88	11.49	8.88	10.89	21.36	8.58	19.92	7.85	136.49
November	10.95	11.67	13.11	17.58	11.61	9.36	10.20	22.23	9.21	26.04	8.15	150.11
December	11.10	10.95	13.08	18.99	9.72	9.18	10.95	25.32	9.33	19.50	8.40	146.52
Totals	$77.94	$71.91	$95.13	$112.41	$79.81	$61.04	$84.24	$146.04	$54.43	$150.48	$61.90	$995.33
Av. per month.....	9.74	8.99	11.89	14.05	9.98	8.72	10.53	18.26	7.77	21.50	7.74	11.31
Per kw. hr.	0.127	0.17	0.081	0.058	0.119	0.209	0.104	0.051	0.266	0.046	0.461	0.082

* Includes fixed charge for four months.

TABLE LIII

MONTHLY ENERGY BILLS, 1925

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eck-blad	F. A. Miller	W. J. Bryan	Children's Home	Ander-son	School	Total
January	$ 10.32	$ 10.56	$ 15.87	$ 18.87	$ 17.13	$ 8.52	$ 11.76	$ 29.01	$ 9.36	$ 12.96	$ 8.67	$ 153.03
February	10.02	9.42	12.03	15.09	15.54	9.09	12.03	24.81	8.88	11.79	8.10	146.80
March	9.30	9.24	11.16	16.74	16.35	15.03	10.77	24.27	8.70	16.77	7.95	146.28
April	10.08	9.72	13.08	17.07	16.35	22.23	12.12	26.91	8.10	16.98	7.80	160.44
May	9.84	10.32	12.87	15.27	17.58	23.40	12.00	28.65	....	22.98	8.40	162.21
June	12.81	12.12	12.60	15.63	16.35	13.29	14.40	25.68	10.95	24.06	6.90	164.79
July	12.84	12.75	20.85	16.26	16.62	8.88	14.19	20.82	10.05	29.46	8.46	171.18
August	38.22	15.87	18.69	15.30	16.80	9.45	11.64	24.27	8.05	29.73	6.90	194.92
September	11.97	12.66	22.11	23.43	17.37	8.91	10.71	18.12	8.61	37.20	7.90	178.99
October	17.55	12.90	12.90	19.38	27.24	9.03	18.78	8.10	9.27	35.70	8.10	179.85
November	14.70	13.56	12.66	15.21	16.74	9.66	10.44	10.62	9.45	34.80	8.97	156.81
December	10.83	8.88	11.25	12.57	13.74	9.72	10.86	10.89	8.64	23.10	8.35	128.83
Totals	$168.48	$138.00	$176.07	$200.82	$207.81	$148.11	$150.60	$252.15	$100.06	$295.53	$96.50	$1,934.13
Av. per month.....	14.04	11.50	14.67	16.74	17.32	12.34	12.55	21.01	8.34	24.63	8.04	14.65
Per kw. hr.	0.064	0.086	0.061	0.054	0.053	0.076	0.075	0.047	0.168	0.043	0.337	0.059

TABLE LIV

MONTHLY ENERGY BILLS, 1926

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Broth-ers	Eck-blad	F. A. Miller	Emory Johnson	Lokkes-moe	Chil-dren's Home	Ander-son	School	Total
January ...	$ 10.35	$ 9.63	$ 13.26	$ 13.98	$ 15.60	$ 10.11	$ 10.47	$ 12.78	*	$ 9.33	$ 37.50	$ 8.05	$ 151.06
February ..	14.10	9.66	13.17	12.45	16.36	10.02	11.34	13.02	$ 10.05	9.09	33.00	9.30	161.56
March	12.60	9.45	12.29	11.55	15.21	9.60	10.65	12.09	11.19	8.35	26.70	7.90	148.48
April	12.75	9.54	13.68	14.55	17.49	21.42	11.13	12.03	13.05	8.67	33.30	8.15	175.76
May	12.59	8.91	11.79	12.21	17.37	19.44	15.57	17.13	17.70	8.35	31.80	8.46	181.32
June	14.19	9.90	14.01	11.73	17.31	19.62	13.65	18.96	28.02	8.05	29.10	8.10	192.64
July	13.47	12.48	14.40	15.30	18.45	11.58	9.69	21.03	10.92	7.90	26.10	7.50	168.82
August ...	21.43	12.45	14.88	13.41	19.05	13.89	12.87	16.23	9.84	8.30	20.40	7.20	169.95
September..	16.68	11.91	24.24	48.00	25.44	14.14	15.30	18.75	10.47	8.79	26.40	8.94	229.06
October ...	10.26	9.06	11.10	12.33	15.06	11.25	9.24	17.19	11.52	8.73	23.10	8.91	147.75
November..	13.98	10.53	13.05	15.69	11.49	11.64	13.32	18.12	15.24	8.64	33.95	10.53	176.18
December ..	15.12	11.88	15.00	20.55	12.33	11.34	13.71	18.21	14.58	10.35	33.95	9.78	186.80
Totals	$167.52	$125.40	$170.87	$201.75	$201.16	$164.05	$146.94	$196.44	$152.58	$104.55	$355.30	$102.82	$2.089.38
Av. per month ..	13.96	10.45	14.24	16.81	16.76	13.67	12.25	16.37	12.72	8.71	29.61	8.57	14.51
Per kw. hr...	0.056	0.106	0.063	0.054	0.054	0.066	0.077	0.055	0.062	0.205	0.041	0.217	0.061

* Service started February 2.

TABLE LV

Monthly Energy Bills, 1927

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eckblad	F. A. Miller	Emory Johnson	Lokkesmoe	Children's Home	Anderson	School	Total
January	$ 14.43	$ 14.64	$ 10.05	$ 16.50	$ 13.14	$ 10.50	$ 13.14	$ 15.15	$ 12.57	$ 10.02	$ 33.05	$ 9.84	$ 173.03
February	14.79	9.75	13.77	12.78	12.54	9.90	13.62	15.87	10.35	18.24	22.95	9.60	164.16
March	16.26	8.55	12.90	15.00	12.54	9.90	12.30	14.79	9.24	10.02	22.35	11.34	155.19
April	15.66	9.36	14.61	16.68	15.84	27.00	12.54	23.58	10.80	9.66	20.70	9.60	186.03
May	11.16	12.63	12.06	13.05	11.37	24.09	17.22	12.72	23.61	9.00	18.65	10.08	175.64
June	11.31	9.75	15.93	11.10	11.46	16.56	13.50	17.70	11.07	8.30	19.55	7.50	153.73
July	13.93	11.95	11.46	15.90	11.70	13.20	13.53	18.30	9.90	8.52	21.05	7.80	157.24
August	42.48	13.86	42.18	52.02	21.45	13.98	13.29	17.22	9.57	8.76	14.45	7.95	257.21
September	15.41	12.24	22.92	24.12	11.58	10.71	13.74	18.00	....	9.09	21.95	8.82	168.58
October	10.98	9.54	12.30	21.18	15.18	10.50	12.09	14.91	9.04	8.85	27.65	10.29	171.51
November	13.98	10.05	12.75	12.90	12.66	11.52	11.76	20.73	11.34	9.96	32.45	10.23	170.33
December	15.00	10.35	18.33	15.00	12.87	12.24	14.19	15.39	10.77	10.50	34.55	10.62	179.81
Totals	$204.39	$132.67	$199.26	$226.23	$162.33	$170.10	$160.92	$204.36	$128.26	$120.92	$289.35	$113.67	$2,112.46
Av. per month	17.03	11.06	16.61	18.85	13.53	14.18	13.41	17.03	11.66	10.08	24.11	9.47	14.67
Per kw. hr.	0.055	0.071	0.053	0.05	0.067	0.064	0.068	0.048	0.08	0.122	0.053	0.15	0.061

electric bill was $11.31. In 1925 it was $14.65; in 1926, $14.51, and in 1927, $14.67. This indicates that the amount of energy used became fairly well stabilized in 1925; also that the large amount of energy used in 1926 did not necessarily increase the average bill because more energy was used by the smaller consumers and less than half as much by the larger consumers.

The cost per kilowatt-hour shows a big variation between farms. In 1924 energy used by Mr. Swanson averaged more than 26 cents per kw. hr.; that used by B. I. Melin even during his first year, cost little more than 5.8 cents per kw. hr., that used by W. J. Bryan cost but a little more than 5 cents, and that used by Mr. Anderson cost less than 5 cents. During 1925 the amount of energy used by each of the consumers increased so that the highest average price on the project was that paid by Arthur Nelson, 8.6 cents per kw. hr. Mr. Nelson's farm is small and there is little use for electricity. On the other hand, the energy at the W. J. Bryan farm cost but 4.7 cents per kw. hr. In 1927 the amount of energy used by some of the smaller users increased so that the highest average price was 8 cents per kw. hr.

The average cost for all consumers on the line is only 8.2 cents per kw. hr. during the first year and 6.1 cents during each of the three following years.

ENERGY USES

Electric meters were installed on most of the equipment so that data are available for the energy used for practically all purposes. Not all the farms had all kinds of equipment, but similar types, used for the same purpose, were installed on some farms so that energy consumption could be obtained under different conditions.

In Table LVI is given the amount of energy used in the refrigerators, in some cases for three years; in one case for one year only. One refrigerator was used throughout the year; most of the refrigerators were used from April to November. The yearly energy consumption for these refrigerators varies from 212 kw. hrs. for the smallest, used for 6 months of the year, to 811 kw. hrs. for the largest, used all the year.

The data in Table LVII show the amount of energy used in operating ironing machines. The consumption varies from month to month because of the large varia-

TABLE LVI

Energy Used in Refrigerators

	Lokkesmoe		Nelson Brothers			Eckblad	Melin		
Size of refrigerator	5.14 cu. ft.		5.88 cu. ft.			6.39 cu. ft.	8.76 cu. ft.		
	1926	1927	1925	1926	1927	1927	1925	1926	1927
January	0	0	0	0	0	0	60	26	48
February	0	0	0	0	0	0	73	0	0
March	0	0	0	0	0	0	47	10	0
April	0	0	37	25	5	0	61	58	0
May	38	21	70	63	54	23	74	89	0
June	45	39	62	68	67	65	81	108	15
July	42	47	56	71	75	73	84	92	63
August	43	41	62	71	66	86	87	68	53
September	37	40	63	60	98	0	80	77	59
October	30	24	31	40	69	1	79	66	56
November	22	0	0	0	17	1	77	62	46
December	0	0	0	0	0	0	8	59	28
Total	257	212	381	398	451	249	811	715	368

TABLE LVII

Energy Used in Ironing Machines

	E. Johnson		Eckblad		Melin		
	1926	1927	1926	1927	1925	1926	1927
January	2	9	5	4	29	12	7
February	2	9	6	5	23	4	4
March	11	14	3	8	24	7	15
April	2	10	9	7	19	10	18
May	7	11	9	12	22	14	2
June	19	16	13	10	23	11	31
July	9	10	9	7	23	14	18
August	4	8	14	6	26	29	30
September	6	11	8	5	31	6	11
October	10	13	12	6	29	10	18
November	9	14	8	7	16	8	15
December	10	12	6	15	9	17	5
Total	91	137	102	92	274	142	174
Average	8	11	9	8	23	12	15

tion in the amount of ironing done. The average per month varies from 8 kw. hrs. with a small ironing machine, to 23 kw. hrs. with a large machine used in a larger family.

In Table LVIII is given the amount of energy used for heating water. The water heater on the farm of Arthur Nelson was operated manually in 1925 until October. After that it was operated automatically and the temperature of the water was kept at 184° F. This served a family of two with an occasional extra person. The family was very saving in the amount of water used. Other data are given in the section entitled "Water Heating." The data for water heating in the rest of this table, at the home of E. Johnson, are for an automatic water heater, used in a large family where they were not very saving of the amount of water used. The two conditions are extreme and represent the minimum and maximum of what might be expected.

TABLE LVIII

ENERGY USED FOR WATER HEATER

	A. Nelson			E. Johnson		
	1925	1926	1927	1925	1926	1927
January	17	167	185	...	425	438
February	22	252	205	...	369	333
March	19	188	188	...	675	369
April	26	167	167	...	424	380
May	24	178	178	...	658	542
June	20	160	156	...	681	524
July	7	185	194	...	564	626
August	7	129	145	...	628	615
September	7	92	151	...	720	555
October	184	173	165	...	703	583
November	248	244	188	...	644	620
December	342	...	180	...	525	415
Total	923	1,935	2,102	...	7,016	6,000

The amount of energy used for milking machines on three farms is given in Table LIX. In one case this is given for one year, as the milking machine was not used throughout any other year. On one of these farms the milking machine was not used during the fall months because many of the cows were not giving milk and those that were being milked were strippers. The energy consumption for milking is low and on a rate of 3 or 4 cents per kw. hr. the cost is small for the amount of service received. The lowest average energy consumption per month is 18 kw. hrs. where the milking machine was used on 16 cows. The highest is 45 kw. hrs. where the machine was used for 22 cows, milking some of them three times a day.

TABLE LIX

ENERGY USED FOR MILKING MACHINES

	Cady		E. Johnson			Miller
	1926	1927	1925	1926	1927	1927
January	0	0	38	54	41	18
February	34	34	41	55	43	20
March	23	37	32	56	36	16
April	23	37	31	63	48	17
May	26	19	39	57	46	17
June	25	28	46	57	47	19
July	17	44	58	37	41	21
August	0	17	44	29	38	17
September	0	0	20	31	37	15
October	0	0	29	30	36	18
November	4	0	35	35	34	17
December	6	0	20	37	32	16
Total	158	216	433	541	479	211
Average	...	...	36	45	40	18

The use of electric ranges has been studied. Seven of the project farms used electric ranges, and Tables LX, LXI, and LXII give the total amount of energy used by months for the last three years of project work; the total amount used, by months, by all the ranges, the total amount used yearly by each family, and the total amount used by all the ranges for each year.

In order to understand readily the variation in the amount of energy used on one farm, from the amount used on the next for the range, the following statements, No. 1 to 8, give the methods in which each range was used.

No. 1, Mr. Cady—An electric range was used to supplement a wood range. During the winter it was used mainly to start the breakfast and the oven was used some for baking. The large amount of energy used in the summer is typical of what can be expected of an electric range used to supplement a wood range.

No. 2, Arthur Nelson—The electric range was used in a way similar to that on the Cady farm, with the exception that it was usually disconnected and not used during the winter. Otherwise its use is typical of what may be expected where the range is used to supplement a wood range.

TABLE LX

ENERGY USED IN ELECTRIC RANGES, 1925

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	F. A. Miller	W. J. Bryan	Totals
January	12	....	0	80	186	5	227	510
February	19	....	0	56	149	2	301	527
March	10	....	0	48	176	5	220	459
April	29	23	10	31	166	11	327	597
May	38	29	1	16	195	16	366	661
June	132	92	156	55	163	83	267	948
July	134	139	265	50	177	60	272	1,097
August	90	135	233	43	180	30	355	1,066
September	89	120	180	50	184	0	190	813
October	55	33	17	72	236	0	*	413
November	7	0	2	65	204	0	1	279
December	16	0	0	73	141	0	11	241
Totals	631	571	864	639	2,157	212	2,537	7,611

* No one living in house; E. Johnson moved in, in November.

No. 3, A. C. Bryan—The range was used only to supplement the wood range. It was used much more than either No. 1 or No. 2, consequently the amount of energy used in the summer was larger in 1925. During 1926 and 1927 hired help did the cooking. The help was not familiar with an electric range, consequently it was used but little.

No. 4, B. I. Melin—The range at the home of Mr. Melin was a combination wood and electric range. The oven was not heated by the wood-burning part, hence electric heating was used for the oven throughout the winter, even tho wood was burned to heat the kitchen. This is probably a typical case of the use of a combination range.

No. 5, Nelson Brothers—This family used an electric range for all cooking purposes until October, 1926. The amount of energy used is typical of what can be expected in a family of three with occasional help. The consumption is larger than in most city homes, but is accounted for by the fact that more dishes are washed and more cooking is done in the farm home.

No. 6, Mr. Miller—An electric range was used to supplement a wood range. It was not used in 1926 and only a little in 1927.

No. 7, W. J. Bryan—An electric range was used for all cooking in 1925, until October. The family was large and a considerable amount of water was heated on the range. This represents the maximum energy consumption to be expected from the use of an electric range. When another family, that of E. Johnson, moved to this place the range was used less, supplementing a wood range. The consumption by this range in 1927 is representative of what can be expected in a large family.

No. 8, C. H. Eckblad—An electric oven was installed in 1926. It took the homemaker a long time to get accustomed to its use. It has been used mainly to supplement the oven in the wood range; therefore it requires more energy during the summer.

Large Energy Consuming Appliances

It is interesting to determine the total amount of energy used each month by large energy-consuming appliances. Data in Table LXIII show the amount of energy used on all the farms by water heaters, large motors, ranges, and incubators. Two water heaters were in use, two large motors for ensilage cutting, seven electric ranges, and four incubators. The yearly consumption by these appliances brings a considerable revenue to the power company. The load of water heaters and ranges is fairly constant throughout the year; that of large motors and incubators is seasonal. As most of the homes will not soon have water heaters, 15 h-p. motors will be little used. As few ranges will be installed, it was deemed desirable to determine what would be the average energy consumption on these farms if large energy consuming appliances were not used.

In the first column in Tables LXIV, LXV, and LXVI is given the average amount of energy consumed for all uses, by months, for each of the three years,

TABLE LXI

Energy Used in Electric Ranges, 1926

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	E. Johnson	C. H. Eckblad*	Totals
January	10	0	0	47	191	19	1	268
February	82	0	0	33	211	6	0	332
March	69	0	1	46	200	5	0	321
April	108	0	9	23	176	17	0	333
May	130	0	30	29	177	67	10	443
June	103	152	71	56	185	101	23	691
July	137	168	70	62	169	97	36	739
August	147	159	69	36	246	96	32	785
September	170	112	27	26	247	7	33	622
October	72	59	1	43	†	38	23	236
November	77	3	0	34	....	110	10	234
December	44	0	0	81	....	14	12	151
Totals	1,149	653	278	516	1,802	577	180	5,155

*Electric oven only.
† Electric range removed in October.

TABLE LXII

Energy Used in Electric Ranges, 1927

Month	W. A. Cady	A. Nelson	A. C. Bryan	B. I. Melin	F. Miller	E. Johnson	C. H. Eckblad*	Totals
January	53	0	0	107	0	5	7	172
February	72	0	0	56	5	11	9	153
March	55	0	0	105	0	28	5	193
April	40	20	0	165	1	33	7	266
May	37	23	1	87	2	29	17	196
June	76	118	25	95	11	37	16	378
July	159	179	50	154	20	105	51	718
August	164	166	7	73	6	92	27	535
September	113	125	1	83	3	49	6	380
October	133	88	0	26	0	20	37	304
November	48	9	0	54	0	62	23	196
December	87	0	0	108	0	6	38	239
Totals	1,037	728	84	1,113	48	477	243	3,730

* Electric oven only.

TABLE LXIII

ENERGY USED FOR VARIOUS PURPOSES ON PROJECT FARMS, KW. HRS.

Month	Water heaters 1925	Water heaters 1926	Water heaters 1927	Large motors 1925	Large motors 1926	Large motors 1927	Ranges 1925	Ranges 1926	Ranges 1927	Incubators 1925	Incubators 1926	Incubators 1927
January	11	366	176	80	0	0	510	268	177	0	0	0
February	48	351	205	0	0	0	527	332	159	0	0	0
March	59	712	9	83	0	0	459	320	221	0	192	152
April	100	902	0	25	0	0	597	333	348	351	585	661
May	162	614	157	0	0	0	661	475	344	393	740	591
June	291	667	156	0	0	204	948	590	579	169	363	97
July	15	661	544	0	0	0	1,097	739	977	14	21	0
August	71	692	759	993	320	3,554	1,066	787	808	0	91	0
September	200	1,007	686	510	2,033	646	813	622	508	0	0	0
October	0	732	747	984	0	400	413	236	354	0	0	0
November	364	1,005	808	160	0	0	279	233	257	0	0	0
December	177	532	595	104	48	144	241	150	244	0	0	0
Totals	1,498	8,241	4,842	2,939	2,401	4,948	7,611	5,085	4,976	927	1,992	1,501

TABLE LXIV

AVERAGE MONTHLY ENERGY CONSUMPTION DATA PROJECT FARMS, KW. HRS., 1925

Month	All uses	Without water heaters	Without water heaters and large motors	Without water heaters and ranges	Without water heaters large motors, and ranges	Without water heaters, large motors, ranges and incubators
January	286	285	275	239	232	232
February	200	194	194	128	128	128
March	235	228	217	170	160	160
April	281	269	266	194	191	147
May	295	275	275	192	192	141
June	262	226	226	107	107	86
July	266	264	264	127	127	125
August	376	367	243	234	110	110
September	272	247	184	145	81	81
October	279	279	156	227	104	104
November	227	182	162	147	127	127
December	142	120	107	90	77	77
Average	260	245	214	167	136	126

TABLE LXV

AVERAGE MONTHLY ENERGY CONSUMPTION DATA PROJECT FARMS, KW. HRS., 1926

Month	All uses	Without water heaters	Without water heaters and large motors	Without water heaters and ranges	Without water heaters large motors, and ranges	Without water heaters, large motors, ranges and incubators
January	197	151	151	118	118	118
February	198	159	159	122	122	122
March	221	142	142	106	106	85
April	316	216	216	179	179	113
May	324	256	256	203	203	121
June	370	296	296	230	230	190
July	295	222	122	139	139	137
August	367	290	255	203	178	157
September	547	435	209	366	140	140
October	227	146	146	120	120	120
November	317	205	205	180	180	180
December	299	240	235	223	229	229
Average	307	230	199	182	162	142

TABLE LXVI

AVERAGE MONTHLY ENERGY CONSUMPTION DATA PROJECT FARMS, KW. HRS., 1927

Month	All uses	Without water heaters	Without water heaters and large motors	Without water heaters and ranges	Without water heaters large motors, and ranges	Without water heaters, large motors, ranges and incubators
January	214	194	194	174	174	174
February	193	170	170	153	153	153
March	166	165	165	141	141	124
April	291	291	291	252	252	179
May	277	260	260	222	222	166
June	205	188	165	125	101	90
July	255	195	195	86	86	86
August	671	587	202	497	102	102
September	330	254	182	197	125	125
October	292	209	165	170	126	126
November	276	186	186	158	158	158
December	276	210	194	184	166	166
Average	287	243	197	197	151	138

1925 to 1927. Other data give the average energy consumption for each month and the average for each year for all uses except water heaters; without water heaters and large motors; without water heaters and ranges; without water heaters, large motors, and ranges; and without water heaters, large motors, ranges, and incubators. These tables show that the average energy consumption on the Red Wing Experimental Line has been considerably increased by these large appliances. In 1925 the average consumption was 260 kw. hrs. for all uses; without the large energy consuming appliances the average was 126 kw. hrs. per farm, per month. In 1926 the average for all uses was 307 kw. hrs.; without these large energy consuming appliances it was 142; in 1927 the average for all uses was 287 kw. hrs.; without these devices it was 138. The data indicate that energy consumption above 200 kw. hrs. per month will ordinarily not be expected unless electric ranges or some other large energy-consuming appliances like incubators or water heaters are used. On the other hand, the data show that energy consumption can be considerably above 100 kw. hrs. per month without the use of large units.

Lighting and Small Appliances

As many farmers feel that all they can afford to have installed when they first install electricity is lighting and small appliances, information concerning the energy used for these purposes was thought desirable. Tables LXVII, LXVIII, and LXIX show the amount used by each of the farms for each month; also the amount used yearly by each farm, the average monthly consumption for each, and the average per month of all farms.

It is interesting to observe that the average for all farms, per month, gradually increased from 53.5 kw. hrs. in 1925 to 61 kw. hrs. in 1926, and 66.3 kw. hrs. in 1927. This increase can be accounted for largely by greater use of the lights. When people once realize that the use of the lights cost but little they will make greater use of their lighting facilities.

Data given in the above mentioned tables show that the minimum energy consumption in 1925 for this purpose was an average of 27 kw. hrs. per month while the maximum was 68 kw. hrs. per month. In 1926 the minimum was 28 kw. hrs. per month while the maximum was 77. In 1927 the minimum was 25 kw. hrs. per month and the maximum was 88. The minima occurred each year on the same farm, where there were two people and where there was a small house and a small barn. The average energy consumption on this farm, however, of 27 to 28 kw. hrs. per month for lighting and small appliances shows that, even on small farms if the energy is used for nothing else but for these two purposes, more can be used profitably than has been used by many farmers in the past. A summary of Tables LXVII, LXVIII and LXIX given in Table LXX gives the average energy consumption for all farms, for lighting and small appliances for each month during the three years. Some of these data are shown graphically in Figure 68.

The chart in Figure 68, the energy consumption for lighting and small appliances, shows that during 1925 energy for this use gradually decreased and reached its minimum in October. This can be accounted for by the fact that the use of electricity was somewhat new on these farms and its use had not become stabilized. The graph for 1926 and 1927 shows a very stabilized condition in the use of electric energy for lighting and small appliances. In the same figure a chart is given showing the amount of energy used in refrigerators under three different conditions. Two of the refrigerators were used during the summer months only, and one was used throughout the year. The size of the refrigerator box is given on the chart. The larger box required in general a larger amount of electricity. The amount of electricity used by three of the ranges is given in this same chart and is characteristic of what may be expected in the way of energy consumption by electric ranges.

Average Amount of Energy Used per Year

While it is important to know something concerning the amount of energy used for various purposes by months, from the standpoint of the power company and as well from the standpoint of the farmer, it is highly desirable to know what can be expected in the way of energy to be used for different purposes for a year. The data given in Table LXXI and shown graphically in Figure 69 show the amount of energy used for various uses by the year for twenty different

TABLE LXVII

ENERGY USED FOR LIGHTING AND SMALL APPLIANCES, KW. HRS. 1925

Month	Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eckblad	Miller	W. J. Bryan
January	54	56	36	70	80	17	60	123
February	42	45	27	55	94	28	72	137
March	31	36	36	63	102	32	50	105
April	28	30	45	158*	69	34	70*	137
May	20	19	67*	78*	46	28	74*	102
June	20	20	80*	52	48	26	51	105
July	20	17	47*	86	49	31	57	79
August	20	14	42	54	41	46	21	117
September	25	15	49	21	46	28	56	120
October	24	15	45	43	36	60	65	†
November	31	21	60	77	57	46	59	53
December	27	32	56	56	30	53	77	41
Totals	342	320	590	813	698	429	712	1,119
Average	29	27	49	68	58	36	59	102
Grand average	53.5 kw. hrs. per farm per month.							

* Includes use of small brooder.

† House vacant.

TABLE LXVIII

ENERGY USED FOR LIGHTING AND SMALL APPLIANCES, KW. HRS. 1926

Month	Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eckblad	Miller	Johnson
January	19	47	95	64	49	67	45	62
February	22	34	71	54	47	65	46	86
March	22	35	49	65	40	40	52	78
April	25	38	86	50	45	82	30	88
May	28	29	50	32	54	78	21	117
June	29	16	25	22	35	80	22	147
July	26	15	79	18	40	75	27	150
August	30	14	66	33	48	87	30	170
September	32	15	62	34	68	82	35	184
October	42	28	65	38	102	76	30	154
November	55	30	115	80	108	106	50	164
December	97	32	95	96	91	84	40	185
Totals	427	333	858	586	727	922	428	1,585
Average	36	28	72	49	61	77	36	132
Grand average	61 kw. hrs. per farm per month.							

TABLE LXIX

ENERGY USED FOR LIGHTING AND SMALL APPLIANCES, KW. HRS. 1927

Month	Cady	A. Nelson	A. C. Bryan	B. I. Melin	Nelson Brothers	Eckblad	Miller	Johnson
January	86	28	135	74	82	76	58	116
February	80	34	90	64	76	59	39	104
March	71	26	82	98	71	45	47	115
April	92	16	103	93	118	60	36	86
May	70	28	96	53	67	70	30	92
June	35	15	77	35	51	76	27	83
July	46	16	60	35	60	67	22	60
August	44	19	53	27	57	73	34	73
September	87	28	45	42	67	81	29	87
October	81	32	88	51	88	58	49	98
November	90	27	76	44	82	72	53	141
December	125	36	154	63	92	87	84	122
Totals	907	305	1,059	679	911	824	508	1,177
Average	76	25	88	57	76	69	42	98
Grand average	66.3 kw. hrs. per farm per month.							

uses of electricity starting with a minimum of 13.1 kw. hrs. per year for churning.

Some of the readers of this bulletin may be interested in knowing the amount of energy used monthly on each of these farms for the various uses. Data were kept on each of these farms for the three years—1925, 1926 and 1927. Such energy consumption data for each of the farms and for each use that was made of electricity on each of these farms are given in twenty-six tables in the Appendix, pages 145-53. A discussion will not be given of each of the tables as the data given are self-explanatory.

TABLE LXX

MONTHLY AVERAGE ENERGY USED FOR LIGHTING AND SMALL APPLIANCES, KW. HRS.

Month	1925	1926	1927
January	62	56	82
February	63	53	68
March	57	42	69
April*	71	56	76
May	54	51	63
June	50	47	50
July	48	54	46
August	44	60	48
September	45	64	58
October	36	67	68
November	51	89	73
December	47	90	95

* Small brooders used on two farms.

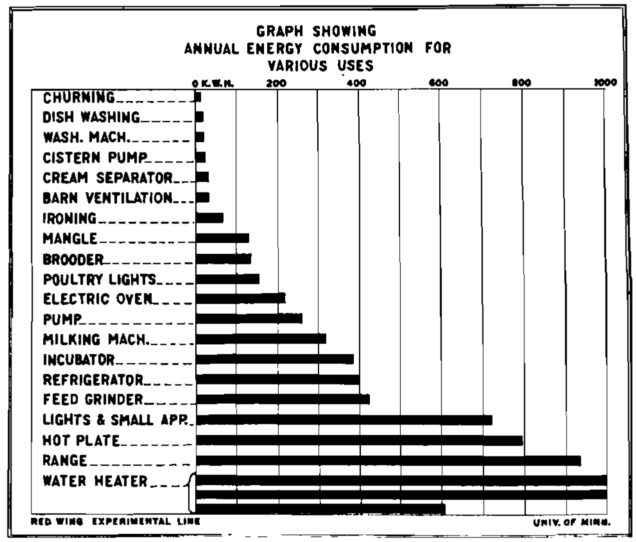

Fig. 69. Comparative amount of electricity used for various purposes. Some jobs like milking, refrigeration, and feed-grinding are necessary if much energy is going to be used.

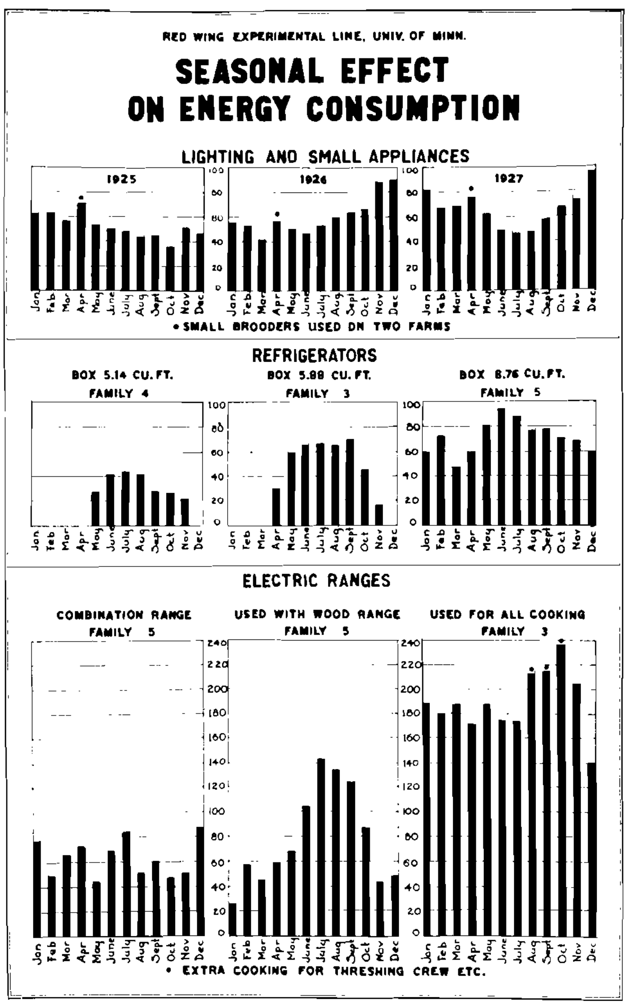

Fig. 68. Seasonal effect on the use of electricity for various purposes.

TABLE LXXI

ENERGY USED PER YEAR

	Uses	Kw. Hrs.
1	Churning	13.1
2	Dishwashing	18.0
3	Washing Machine	19.7
4	Cistern Pump	22.7
5	Cream Separator	31.4
6	Barn Ventilator	31.5
7	Ironing	66.6
8	Mangle	125.4
9	Brooding	132.0
10	Poultry Lights	153.2
11	Electric Ovens	217.0
12	Pumping	258.9
13	Milking Machines	316.0
14	Incubating	384.0
15	Refrigerating	397.6
16	Feed Grinding	421.9
17	Lights and small appliances	723.6
18	Hot Plate	796.0
19	Ranges	936.8
20	Water Heating	2,608.0

DEMAND AND CONNECTED LOAD

In discussions of the size of transformer to give adequate farm service it has often been brought out that the size of the transformer is related to the amount of load connected. When the work at Red Wing was started, it was decided that three-kva. transformers would be installed on all the farms except two, on which a five-kva. was installed. One of the five-kva. transformers was installed at the home of Mr. Anderson. No experimental work was to be done, but we knew the maximum demand would be relatively high.

The use of three-kva. transformers on other installations had shown that this size was large enough to carry a 5 h-p. motor and the electric range. As all other devices placed on these transformers had a smaller rated capacity than either the range or the motor, it appeared that the maximum demand would be caused by the range and the motor being in use at the same time as small equipment. As it is impossible for a farmer to use many pieces of equipment at the same time, it seemed reasonable to assume that little additional demand would be created when the range or the motor was in use. In order to prevent an excessive demand, the original installations provided a double-throw switch in the power circuit so that the range and the portable motor could not be used at the same time. No data were available as to what would happen if both these loads were used at the same time.

Early records of the demand created at different farms indicated that it might be possible to use the range and motor at the same time and yet not create higher demands than had been created by keeping them off the line at the same time. Consequently, two of the installations were changed so that the range and the motor could be used simultaneously. The demands under this condition differed little from those created before this change was made. As a result, all installations except one were finally changed so that the range and the motor could be used at the same time.

Surprisingly large connected loads can be carried on three-kva. transformers, because a farmer has a large diversity factor in the use of his equipment. In addition, the transformers can carry more than 100 per cent overload in this climate without serious difficulties. The data given in Table LXXII show the size of transformers and the connected load for each of the farms at the end of 1927. The connected load is given for lighting, power, and heating. The connected load on the three-kva. transformers ranged from 8.4 to 24.8 kw., while the connected load on the two five-kva. transformers was 19.9 and 58.8 kw. The average connected load on the experimental farms was 15.7 kw. From these data it appears that a transformer can carry a connected load from four to eight times the rated capacity of the transformer.

Maximum Demand

Demand meter attachments were placed on each of the farm totalizing meters, and records of these demands extended over most of the period of experimental work. A maximum demand meter was also placed on the line that served the group of farms, and readings were taken from this meter during part of the experimental period. A great deal of difficulty was experienced in keeping this meter in operation and complete records of maximum demands are not available. Maximum demand meter readings are given in Tables LXXIII, LXXIV, LXXV and LXXVI for 1924 to 1927. In 1924 a small amount of equipment was in use. The demands that were registered were not high, the average demand being 4.2 kw. On some farms, however, where the five horse-power motor was used for such jobs as husking corn and grinding feed, high demands during certain months were established even during the first year. One high demand of 8.8 kw. was established in September at the home of A. M. Nelson. This was when the 5 h-p. motor was being used for grinding feed and at the same time the pump motor and the water heater were being used. An electric range was installed on this farm, but during 1924 it was not possible to use this range simultaneously with the electric motor.

One of the farmers on the Red Wing Line, C. H. Eckblad, has never used a 5 h-p. motor. The demand meter readings for his farm throughout 1924 and 1925 do not exceed 2 kw. except for a short time during four months in the spring, while he was using an incubator and brooders. In May, 1926, an electrically heated oven was installed and the readings from then on show a considerable increase. About this time an electrically heated mangle was installed. The total connected load in 1926 and 1927 was a little more than twice that for 1925, about 5.2 kw. in 1925 and 11.7 kw. in 1926 and 1927. This shows that a high connected load of small appliances can be used without creating large demands.

The average monthly demand for 1925 on the group of farms did not increase much over that for 1924, being 4.4 kw. in 1924 and 4.48 kw. in 1925. The average demand on each farm in 1925 varied from 2 to 5.75 kw. The monthly maximum demand varies from 1.5 to 7.4 kw. In 1926 a change in wiring was made on most of the farms so that the electric range could be operated at the same time as the 5 h-p. motor. The first change was made at the home of A. C. Bryan, in July. Nelson Brothers' was changed in September, A. M. Nelson's in October, B. I. Melin's and W. J. Bryan's in November, and W. A. Cady's in December. At the home of Frank Miller a 7.5 h-p. motor was used and the electric range was used very infrequently so no change was made on this farm.

TABLE LXXII

Connected Load—Lighting, Power, Heating, 1927

	Transformer	Lighting	Power	Heating	Total
	kva.	Watts	Watts	Watts	Kw.
W. A. Cady	3	1,440	11,290	6,550	19.3
A. Nelson	3	1,140	6,270	6,750	14.2
A. C. Bryan	3	1,810	6,515	8,735	17.1
B. I. Melin	3	1,485	10,790	12,475	24.8
Nelson Brothers	3	2,055	7,270	1,230	10.6
C. H. Eckblad	3	1,465	1,520	8,800	11.8
Frank Miller	5	1,880	9,540	8,475	19.9
E. Johnson	3	1,805	1,480	12,075	15.4
J. B. Lokkesmoe	3	2,055	600	5,755	8.4
A. P. Anderson	5	16,425	28,285	14,100	58.8
School	3	1,340	2,000	.....	3.3
Community		.....	32,125	.....	32.1
Total		32,900	85,560	84,945	203.6
Total (farms only)		15,135	55,275	70,845	141.5
Average Farms		1,682	6,142	7,872	15.7

TABLE LXXIII

Monthly Demand Meter Readings, Kw., 1924

Name	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
W. A. Cady	1.2	3.1	2.6	3.4	3.2	2.7
A. M. Nelson	5.8	8.8	2.7	3.8	6.1	5.4
A. C. Bryan	3.4	4.6	4.0	5.0	6.5	4.7
B. I. Melin	5.4	5.0	6.0	6.0	5.9	5.7
Nelson Brothers	2.5	5.1	3.0	2.8	2.6	3.2
C. H. Eckblad	..	..	..	1.7	1.8	1.75
Frank Miller	2.9	5.2	5.8	1.5	8.6*	4.8
W. J. Bryan	5.6	5.0	5.8	4.6	5.0	5.2
Totals	26.8	36.8	29.9	28.8	39.7	32.4
Average	3.8	5.3	4.3	3.6	5.0	4.4

* Demand meter needle inoperative.

TABLE LXXIV

MONTHLY DEMAND METER READINGS, KW., 1925

Name	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
W. A. Cady	3.15	2.45	3.1	1.5	6.8	2.0	2.7	3.4	3.9	4.4	4.3	2.2	3.3
A. M. Nelson	5.6	4.9	5.0	5.8	4.9	6.1	4.9	4.5	4.7	5.1*	6.7	5.4	5.3
A. C. Bryan	6.5	6.35	5.95	5.1	5.6	5.1	6.5*	6.3	7.4	5.5	4.1	4.6	5.75
B. I. Melin	8.0	3.7	6.4	5.4	4.2	4.5	4.7	4.3	4.7	4.5	3.9*	5.4	4.97
Nelson Brothers	5.7	5.2	5.2	4.9	4.7	4.6	4.2	3.6	3.7*	6.5	6.2	7.9	5.2
C. H. Eckblad	1.5	1.7	2.4	2.3	2.2	2.3	1.8	2.1	1.9	1.9	2.1	2.0	2.0
Frank Miller	3.5	7.1	1.9	2.2	3.0	5.3	4.7	8.1*	7.2	6.5	4.7	5.3	4.96
W. J. Bryan	6.3	5.7	5.9	5.8	4.7	5.1	4.6	6.5	5.6	1.8	1.5*	4.3	4.81
Consolidated School§	..	..	..	..	..	..	..	..	1.2	1.5	1.6	1.4	1.42
Vasa Orphans' Home§	..	..	..	..	..	..	..	..	1.0	1.0	1.1	0.8	0.97
A. P. Anderson§	..	..	..	..	..	..	..	6.0	9.3	9.2	9.0	8.8	8.46
Totals	40.25	37.10	35.85	33.0	36.1	35.0	34.1	44.8	50.6	47.9	45.2	48.1	40.67
Average	5.03	4.63	4.48	4.1	4.51	4.37	4.26	4.98	4.6	4.35	4.1	4.37	4.48
Maximum line demand	..	..	17.2	18.4	18.6	19.8	18.6	29.4*	33.6†	32.4+	27.6‡	22.8	23.84
Diversity factor	..	..	..	..	..	..	..	..	1.5	1.4	1.6	2.1	1.6

* Using 7½ h-p. motor for husking corn.
† Threshing with 15 h-p. motor.
‡ Husking corn with 15 h-p. motor.
§ Blank spaces denote no demand meters installed.

TABLE LXXV

MONTHLY DEMAND METER READINGS, KW., 1926

Name	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
W A. Cady	3.1	2.2	2.1	2.0	1.8	4.3	5.0	4.8	5.2	4.5	4.9	5.6	3.79
A. M. Nelson	4.8	5.0	5.4	4.9	4.2	4.9	4.7	5.1	4.8	4.9	7.2	6.8	5.22
A. C. Bryan	5.4	5.8	6.3	4.8	4.3	5.0	6.0	6.9	6.8	6.3	6.4	5.4	5.78
B. I. Melin	4.5	4.2	4.3	4.5	4.2	1.6	3.5	5.1	3.5	3.9	3.7	4.0	3.91
Nelson Brothers	4.0	3.5	4.4	6.0	6.5	5.5	4.9	4.5	6.7	4.0	3.4	4.6	4.83
C. H. Eckblad	2.1	2.0	1.8	2.2	2.6	4.5	3.6	3.7	3.7	3.5	3.4	3.8	3.07
F. Miller	4.4	4.9	5.0	6.5	6.4	6.5	7.0	7.4	7.5	7.4	8.2	7.1	6.52
E. A. Johnson	2.9	3.0	2.7	4.6	6.4	5.1	5.4	4.7	7.3	3.7	4.4	5.5	4.64
School	1.4	1.4	1.8	1.5	1.7	8.1	8.2	8.2	8.2	8.2	8.1	8.2	5.41
Children's Home	1.0	0.8	0.6	1.6	1.4	7.0	6.9	6.9	7.0	6.9	6.9	6.9	4.49
Anderson	9.0	7.6	6.5	8.6	8.8	8.9	9.5	6.8	8.6	7.6	8.9	7.2	8.16
Totals	42.6	40.4	40.9	47.2	48.3	61.4	64.7	64.1	69.3	60.9	65.5	65.1	55.82
Average	3.87	3.67	3.71	4.29	4.39	5 58	5.88	5.82	6.3	5.53	5.95	5.91	5.08
Maximum Line Demand	18.0	18.0	14.8	17.4	18.7	21.0	19.2	23.4					18.81
Diversity Factor	2.3	2.2	2.7	2.7	2.6	2.9	3.3	2.7					2.67

TABLE LXXVI

MONTHLY DEMAND METER READINGS, KW., 1927

Name	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
W. A. Cady	6.7	6.5	5.9	7.1	5.4	4.7	5.2	5.1	7.7	6.1	5.8	6.5	6.05
A. M. Nelson	5.9	6.2	5.4	5.4	5.5	5.8	5.5	6.3	6.1	6.1	6.6	6.1	5.9
A. C. Bryan	5.4	5.0	4.1	4.7	4.9	5.0	7.1	6.1	6.4	6.7	6.7	7.2	5.77
B. I Melin	4.0	4.2	6.4	6.4	5.3	3.7	5.5	5.3	4.7	4.0	4.0	3.5	4.75
Nelson Brothers	4.4	4.8	4.2	4.6	3.5	3.8	4.0	3.8	2.8	6.9	5.0	5.0	4.4
C. H. Eckblad	3.0	3.8	3.9	4.0	4.0	4.0	4.0	3.9	3.7	3.8	4.9	3.8	3.9
F. Miller	7.1	7.2	7.1	7.9	8.0	7.2	8.1	6.5	7.1	6.2	6.8	7.3	7.2
E. A. Johnson	4.5	6.0	4.8	7.4	7.2	6.7	6.5	7.5	8.5	6.0	8.2	6.7	6.66
School	8.2	8.2	8.1	8.3	8.2	8.2	8.1	8.2	8.1	8.1	8.1	8.1	8.15
Children's Home Lights	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.8	6.8	6.9	6.9	6.88
Children's Home Power		3.0	2.5	2.6	3.0	2.3	3.0	3.2	3.2	3.2	3.0	3.0	2.66
Anderson	7.0	5.5	4.0	3.4	4.8	8.5	7.4	2.0	5.2	8.0	7.4	6.8	5.83
H. Bryan		6.1	4.1	0.7	1.1	7.3							3.86
Totals	63.1	73.4	67.4	69.4	67.8	74.1	71.3	64.8	70.3	71.9	73.4	70.9	
Average	5.73	5.64	5.18	5.33	5.21	5.70	5.94	5.40	5.85	5.99	6.11	5.90	

TABLE LXXVII

CONNECTED LOADS, KW.

Month	All uses	Without water heaters	Without water heaters and large motors	Without water heaters and ranges	Without water heaters large motors, and ranges	Without water heaters, large motors, ranges, and incubators
1924	127.29	125.29	110.295	78.945	63.94	63.44
1925	141.26	138.26	123.26	91.91	76.91	75.89
1926	168.12	166.12	141.12	119.77	94.77	92.20
1927	176.72	171.72	146.72	133.37	108.37	105.80

The maximum demand for 1926 increased considerably over that of 1924 and 1925, the average being 5.08 kw. It may be assumed that this increase was due to the use of the motor and the range at the same time. A study of the monthly maximum demands for the separate farms does not indicate that this was the cause of the increase in the average maximum demand.

A study made of the demands before and after this change in the operation of these two large devices shows that at the home of W. A. Cady a maximum of 6.8 kw. was established before the change was made, and the highest demands in the two years following were 7.1 and 7.7 kw.; during the other 22 months the maximum was less than 6.8 kw. At the home of A. M. Nelson the maximum demand before the change was made was 8.8 kw.; the highest in the following two years was 7.2 kw. At the home of A. C. Bryan the highest demand before the change was 6.5 kw.; the highest after the change was one month of 7.4 kw., one of 6.8 kw., one of 6.9 kw.; during the other 29 months it was less than 6.5 kw. Therefore the maximum demand was not appreciably larger when two pieces of equipment were used at the same time. The increase in the average maximum demand for all the farms was brought about not because of an increase in the highest maximum demand, but rather an increase in the lower monthly demands. In 1924 and 1925 maximum demands of less than 3 kw. were recorded on different farms—about twenty times; in 1926 the maximum fell below 3 kw. only half as many times. The larger connected load on these farms in 1926 and 1927 accounted for the increase in the lower maximum demands.

Table LXXVIII shows the connected load for each farm by years. On most of the farms the connected load increased considerably in 1925 and 1926. A summary is given in Table LXXVII. The connected load increased from 127.29 kw. in 1924 to 141.26 in 1925; 168.12 in 1926; 176.72 in 1927. In the section on "Energy Uses" data were given to show the energy consumption on these farms without taking into consideration some of the large consuming devices. In order to make possible a comparison between the amount of energy consumed and the connected load, the connected load was separated on the same basis. The figures are given in Table LXXVII. When water heaters, 10 and 15 h-p. motors, electric ranges, and incubators are omitted, the other connected load amounted to 63.44 kw. in 1924; 75.89 in 1925; 92.20 in 1926; and 105.80 in 1927, indicating a considerable increase in the use of small appliances. The use of small appliances has raised considerably the minimum figures for monthly maximum demands.

Referring again to the monthly demand readings given in Tables LXXIII to LXXVI, the rather gradual increase in the totals for each month is quite noticeable. In 1926 the total for all demands started at 42.6 kw. in January and increased to 65.1 kw. in December; in 1927 it started at 63.1 kw. in January and increased to 73.4 kw. in November.

High-Line Demand

During most of 1925 and a part of 1926, the maximum demand meter on the high line was operating. Readings from this meter are given in Tables LXXIV and LXXV. During part of 1925 demand meters were not installed on all consumers' meters so it was impossible to get a diversity factor between maximum line demand and total individual demands. From September, 1925, until August, 1926, however, or during one complete year, data show the maximum demand for all farms and for the high line. Except in the months in which threshing was being done, line demand never exceeded 23.4 kw.; the sum of the individual farm demands reached a maximum of 64.7 kw. High demands on the high line were established in September, October, and November, as noted in Table LXXIV, because of threshing and husking. It is reasonable to assume a diversity factor of between two and three for the type of installation used at Red Wing. During 1926 the connected load without the large motors was approximately 145 kw. The average maximum line demand was 18.81 kw. This shows a diversity between connected load and line demand of approximately 8.

Maximum Line Demand

A study of the maximum high line demands for several days was made from the demand meter charts to determine the relation between the hours of the day, the days of the week, and the maximum demands. (See Figures 70, 71, 72, and 73.)

The daily maximum demands, plotted in Figure 70, show a wide distribution from 7:00 a.m. to 6:00 p.m. The demand occurs most frequently between the hours of 11:00 and 12:00 a.m. More information concerning the frequency of the demand at different hours is shown in Figure 71. The upper graph shows the maximum demand at each hour on any day throughout the period; the lower, the number of days that the demand occurred in each hour of the day. Note that the maximum demand occurs near the middle of the day, with a distinct drop at noon. Note also, from the lower curve, that the maximum demand occurs more frequently between 11:00 and 12:00 a.m. than at any other hour.

There were several days when the demand in any particular hour might not be the maximum for that day, yet it might be higher than had ever been established as a daily maximum at that hour. Figure 72 gives the maximum demand during each hour of the day throughout the period under study. This curve

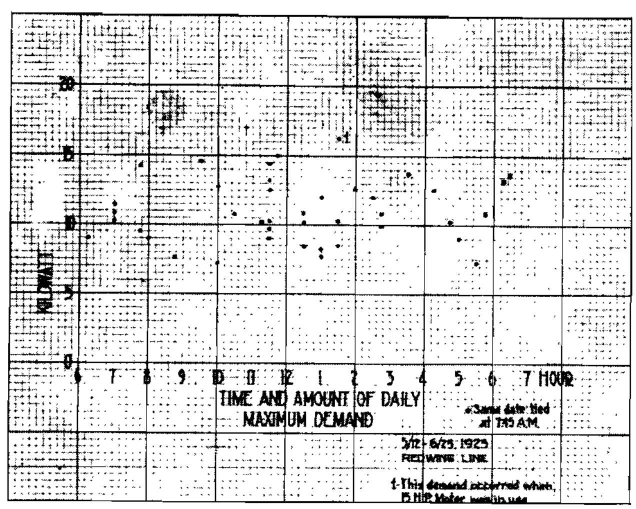

Fig. 70. Plot showing the occurrence of daily maximum demands. Note the wide distribution.

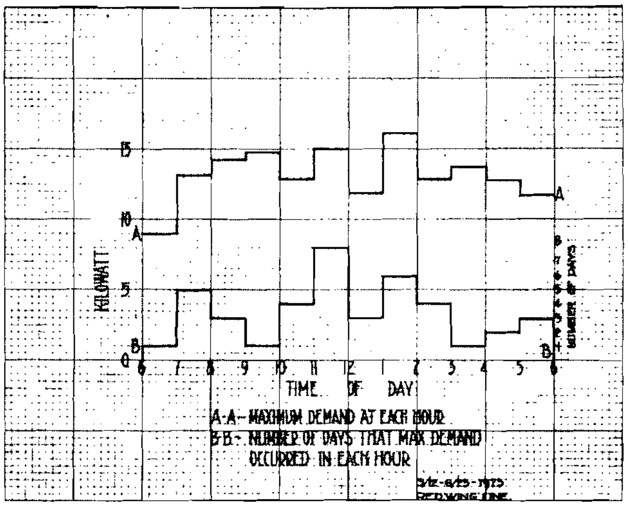

Fig. 71. Graph showing the relation of time of day and maximum demand.

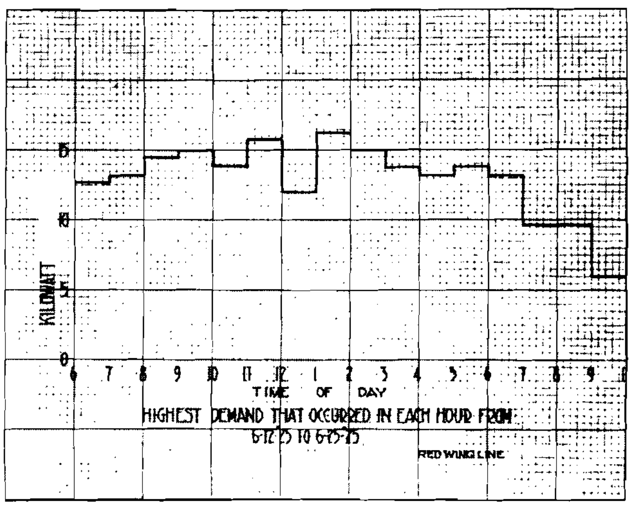

Fig. 72. Graph showing hourly highest demand, regardless of whether it was the daily maximum.

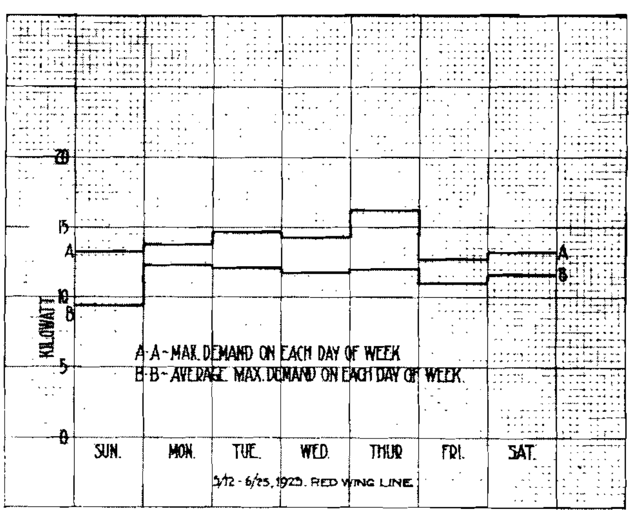

Fig. 73. Graph showing relation of days of week to maximum demand.

lies above the upper curve in Figure 71 at several hours of the day. This graph represents more accurately the relation of the demands that may be expected. Note how the highest demands occur in the middle of the day.

A further study was made to determine how the days of the week affect the maximum demands (Figure 73). The maximum demand is slightly higher in the middle of the week. The average of maximum demands for each day of the week shows a different relation. The demand is not to any great extent dependent upon the day of the week.

CONNECTED LOAD AND ENERGY CONSUMPTION

In the section headed "Energy Uses," the amount of energy used for lighting and small appliances has been separated from that for other uses. In order to determine what factors may influence the amount of energy used for lighting and small appliances, data concerning the connected lighting load, number of lights, number in the family, and the monthly average are given in Table XIV for each of the farm homes. A minimum monthly average energy consumption of 27 kw-hrs. was used at the home of A. M. Nelson. This home also had the smallest connected load, the fewest lights, and the smallest family. The next lowest average monthly energy consumption, 41 kw-hrs. per month, occurred at the home of Mr. Cady, where the connected lighting load was next lowest, in a family of five. The largest energy consumption, 111 kw-hrs. per month, occurred at a home where the connected lighting load is one of the four highest, where they had the largest number of lights, and with four in the family. The largest connected lighting load occurred where there was a family of three. Owing to the smaller family, this home did not have the largest energy consumption. It appears, therefore, that the connected lighting load, the number of lights, and the number in the family directly influence the energy consumption for lighting and small appliances.

A graphic comparison of monthly energy consumption and connected loads by years, is shown in Figure 74 for each of the experimental farms on the Red Wing Line. On the two farms where there are electric water heaters, the energy consumption for heating water and for other uses is given separately. Where the connected load has had a normal increase, and where there has been a real attempt to use electricity as much as possible, the relation between connected load and energy consumption is very close. This is illustrated on the farms of C. H. Eckblad, W. A. Cady, and B. I. Melin. The decrease in energy consumption on the farm of Mr. Johnson for all uses, with the exception of water heating, has been brought about by decreased use of the electric range. The same thing is true at the home of Nelson Brothers. The electric range was used for practically all cooking in 1925 and most of 1926, but was not used in 1924 or 1927. In general, all these farms show an increase in energy consumption from 1924 to 1927, except the two on which the use of the electric range had been discontinued, or nearly so, in 1927. If data were to be secured from these farms for several years, there would probably be less variation from year to year than in these first four years.

The uses would become more or less standardized and the amount of energy used would vary less.

Farm Connected Loads

The connected load for each of the farms classified according to lighting, power, and heating, the size of the equipment, name of the equipment, and also by years, is given in Table LXXVIII. The connected load, as will be seen, increased from 1924 to 1927. In some cases, where equipment was changed from one farm to another, or where use of some piece of equipment was discontinued, the amount in use may have been slightly less in 1926 and 1927 than in 1925.

Data given in Table LXXVIII show how well equipped these farms were. The connected load at the home of A. Anderson, amounting to 58.8 kw., has been carried successfully on a five-kva. transformer. It is surprising that such an enormous load can be operated successfully. This is possibly because larger motors were used than were necessary. It can also be noted in looking at the connected load on B. I. Melin's farm that a total load of 27.7 kw. has been carried on a three-kva. transformer.

Conclusions

1. The maximum demand established on any farm depends more on the use of the maximum connected load than on the total connected load.

2. Individual pieces of equipment with twice the capacity of the transformer may safely be used on farm installations.

3. A total connected load of from six to ten times the capacity of the transformer may be used without injury to the transformer, if several large pieces of equipment are not to be used at the same time.

4. It can reasonably be assumed that a diversity factor from 2 to 3 can be established on the average farm line between the sum of the individual farm demands and the line demand.

5. The maximum demand will not increase as the connected load increases, but the average monthly maximum demand and the line demand will increase.

6. Energy consumption increases with an increase in connected load.

TABLE LXXVIII

Connected Load at A. P. Anderson's, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
	Lighting				
25	152			3,800	3,800
50	140			7,000	7,000
75	9			675	675
100	3			300	300
500	2			1,000	1,000
1,000	2			2 000	2,000
1,650	1 arc lamp			1,650	1,650
	Power				
Use	Size				
Utility motor	1.8 amp., 110 v.			200	200
Picture projector	1/8 h-p.			125	125
Ventilating fan	4.7 amp., 110 v.			520	520
Drying rack	.8 amp., 110 v.			100	100
Pump	1/4 h-p.			250	250
Mangle	1/4 h-p.			250	250
Churn	1/4 h-p.			250	250
Vacuum cleaner	3/4 h-p.			750	750
Washing machine	1/2 h-p.			500	500
Line shaft	10 h-p.			10,000	10,000
Line shaft	7½ h-p.			7,500	7,500
Pump	7½ h-p.			7,500	7,500
Cream separator	1/6 h-p.			170	170
Pump	1/6 h-p.			170	170
	Heating				
Range				7,000	7,000
Iron				1,100	1,100
Water heater				6,000	6,000
				58,810	58,810

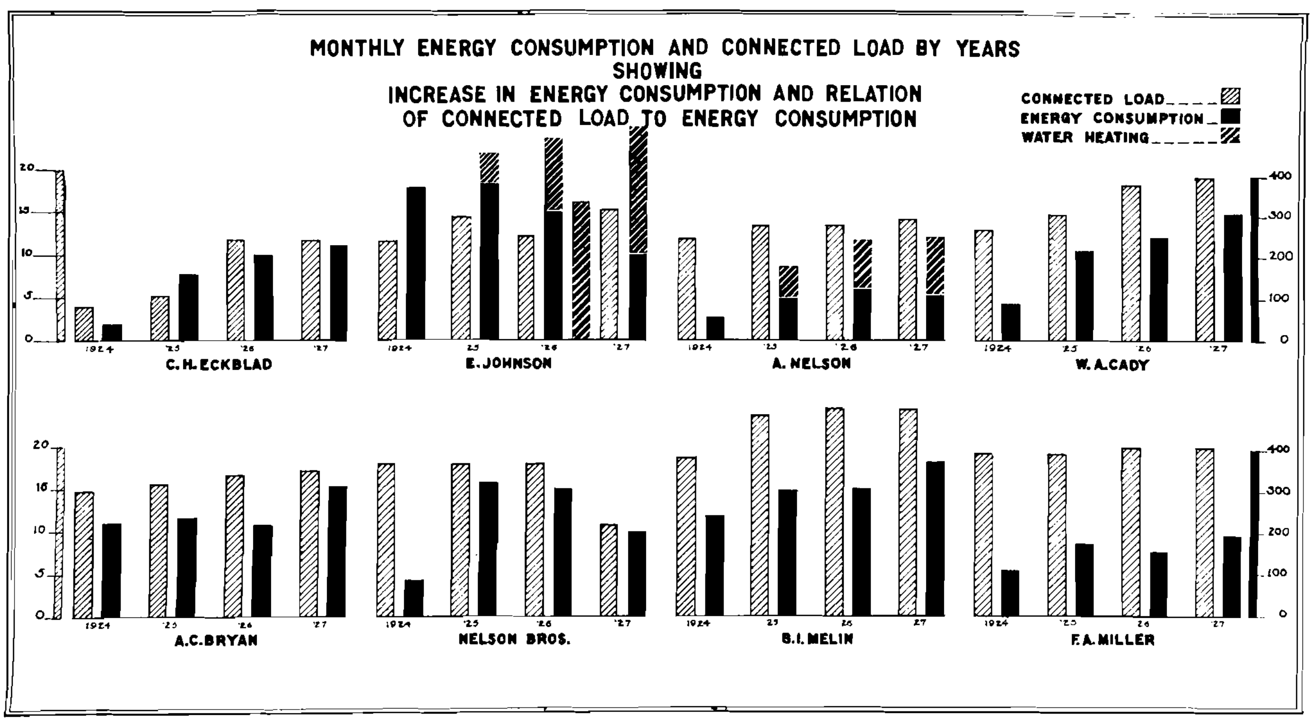

Fig. 74. Relation of load to energy used.

TABLE LXXVIII—Continued

Connected Load at A. C. Bryan's, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
Lighting					
25	11	275	275	275	275
40	14	560	560	560	560
50	12	600	600	600	600
75	3	225	225	225	225
150	1	150	150	150	150
Power					
Use	Size				
General utility motor	5 h-p.	5,000	5,000	5,000	5,000
Washing machine	¼ h-p.	250	250	250	250
Sewing machine	⅛ h-p.	125	125	125	125
Vacuum cleaner		100	100	100	100
Cistern pump	¼ h-p.		250	250	250
Pump	½ h-p.		500	500	500
Root cutter	¼ h-p.		250	250	250
Fan for chicken coop				40	40
Heating					
Range	6.5 amps.	6,600	6,600	6,600	6,600
Iron	550	550	550	550	550
100 chicken brooder*		150	150	300	300
100 chicken incubator		125	125	125	125
Curling iron				50	50
Fireless cooker				660	660
Hog heater					450
		14,710	15,710	16,610	17,060

* Two brooders in 1926.

TABLE LXXVIII—Continued

Connected Load at W. J. Bryan's 1924-25, Emory Johnson's 1926-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
Lighting					
25	11	275	275	275	275
40	17	680	680	680	680
50	14	700	700	700	700
100	0				
150	1	150	150	150	150
Power					
Use	Size				
Pump	½ h-p.	500	500	500	500
Vacuum cleaner		100	100	100	100
Mangle	1/6 h-p.	175	170	170	170
Washing machine	¼ h-p.	250	250	250	250
Cistern pump	1/6 h-p.	170	170	170	170
Portable motor	¼ h-p.	250	250		
Milking machine	2 h-p.		2,000	2,000	2,000
Sewing machine	1/20 h-p.		2,000	40	40
Refrigerator	¼ h-p.				250
Heating					
Range		7,000	7,000	7,000	7,000
Mangle		1,300	1,300	1,300	1,300
Water heater			1,000		3,000
Incubator				125	125
Brooders (two)				300	300
Iron				350	350
		11,550	14,545	14,110	17,360

TABLE LXXVIII—Continued

Connected Load at W. A. Cady's, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
Lighting					
25	5	125	125	125	125
40	21	840	840	840	840
50	5	250	250	250	250
75	1	75	75	75	75
150	1	150	150	150	150
Power					
Use	Size				
General utility motor	5 h-p.	5,000	5,000	5,000	5,000
Washing machine	¼ h-p.	250	250	250	250
Sewing machine		40	40	40	40
Cream separator	1/6 h-p.	170	170	170	170
Milking machine	½ h-p.		500	500	500
Threshing (fan and shoe)	½ h-p.		1,500	1,500	1,500
Ventilators*			80	80	80
Thresher blower	3 h-p.			3,000	3,000
Utility motor	¼ h-p.			250	250
Pump	½ h-p.				500
Heating					
Range		6,000	6,000	6,000	6,000
Iron					550
		12,900	14,980	18,230	19,280

* Three fans 1/40 h-p., one fan 1/20 h-p.

TABLE LXXVIII—Continued

Connected Load at C. H. Eckblad's, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
Lighting					
25	13	325	325	325	325
40	2	80	80	80	80
50	12	600	600	600	600
60	1	60	60	60	60
75	4	300	300	300	300
100	1	100	100	100	100
Power					
Use	Size				
Washing machine	¼ h-p.	250	250	250	250
Cream separator	1/6 h-p.	170	170	170	170
Dishwasher	⅛ h-p.		125		
Vacuum cleaner			100	100	100
Portable motor	¼ h-p.			250	250
Pump	¼ h-p.			250	250
Mangle motor	⅛ h-p.			125	125
Refrigerator	¼ h-p.			250	250
Incubator	⅛ h-p.		125	125	125
Heating					
Incubator*		125	520	520	520
Brooder†		180	180	360	360
Frying pan		550	550	550	550
Griddle		550	550	550	550
Toaster		550	550	550	550
Fireless cooker			660	660	660
Mangle	26 h-p.			1,300	1,300
Iron				650	650
Oven				3,000	3,000
Heater				660	660
		3,840	5,245	11,785	11,785

* 1,400-egg capacity in 1926. † Two brooders in 1926-27.

TABLE LXXVIII—Continued

CONNECTED LOAD AT J. B. LOKKESMOE'S, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
25	11			275	275
40	12			480	480
50	16			800	800
Uviarc	1			500	500
		Power			
Use	Size				
Refrigerator	¼ h-p.			250	250
Vacuum cleaner				100	100
Pump	¼ h-p.			250	250
		Heating			
13 incubators	1 amp. each			1,430	1,430
2 brooders				300	300
Iron				525	525
Hot plate					3,500
				4,910	8,410

TABLE LXXVIII—Continued

CONNECTED LOAD AT B. I. MELIN'S, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
25	5	125	125	125	125
40	4	160	160	160	160
50	16	800	800	800	800
75	4	300	300	300	300
100	1	100	100	100	100
		Power			
Use	Size				
General utility motor	3 h-p.	3,000	3,000	3,000	3,000
Hard-water pump	¾ h-p.	750	750	750	750
Cistern pump	¼ h-p.	250	250	250	250
Mangle	1/6 h-p.	170	170	170	170
Sewing machine		100	100	100	100
Vacuum cleaner		100	100	100	100
Refrigerator	¼ h-p.	250	250	250	250
Washing machine	½ h-p.	500	500	500	500
Cream separator	1/6 h-p.	170	170	170	170
Utility motor	5 h-p.		5,000	5,000	5,000
Milking machine	½ h-p.			500	500
		Heating			
Range		8,500	8,500	8,500	8,500
Incubator		125	125	125	125
Brooder		150	150	150	150
Mangle		2,600	2,600	2,600	2,600
Fireless cooker		550	550	550	550
Iron				550	550
		18,700	23,700	24,750	24,750

TABLE LXXVIII—Continued

CONNECTED LOAD AT F. A. MILLER'S, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
25	3	75	75	75	75
40	2	80	80	80	80
50	24	1,200	1,200	1,200	1,200
75	5	375	375	375	375
150	1	150	150	150	150
		Power			
Use	Size				
Cream separator	¼ h-p.	250	250	250	250
Milking machine	¾ h-p.	750	750	750	750
Pump	¼ h-p.	250	250	250	250
Sewing machine		40	40	40	40
Washing machine	¼ h-p.	250	250	250	250
Refrigerator	½ h-p.	500	500	500	500
General utility motor	1/27 h-p.	7,500	7,500	7,500	7,500
		Heating			
Range		7,000	7,000	7,000	7,000
Incubator		125	125	125	125
Brooder*		150	150	300	300
Iron		550	550	550	550
Heater				500	500
		19,245	19,245	19,895	19,895

* Two brooders in 1926 and 1927.

TABLE LXXVIII—Continued

CONNECTED LOAD AT ARTHUR NELSON'S, 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
40	1	40	40	40	40
50	10	500	500	500	500
75	2	150	150	150	150
150	3	450	450	450	450
		Power			
Use	Size				
Cream separator	1/6 h-p.	170	170	170	170
General utility motor	5 h-p.	5,000	5,000	5,000	5,000
Washing machine	¼ h-p.	250	250	250	250
Pump	½ h-p.		500	500	500
Fan, 8-inch			100	100	100
Refrigerator					250
		Heating			
Range		3,250	3,250	3,250	3,250
Water heater		3,250	3,250	3,250	3,250
Iron			550	550	550
Glow heater			450	450	450
Hot plate					500
		13,060	14,660	14,660	15,410

TABLE LXXVIII—Continued

Connected Load at Nelson Brothers', 1924-27

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
25	15	375	375	375	375
40	2	80	80	80	80
50	16	800	800	800	800
75	4	300	300	300	300
100	3	300	300	300	300
200	1	200	200	200	209
		Power			
Use	Size				
Washing machine	¼ h-p.	250	250	250	250
General utility motor	5 h-p.	5,000	5,000	5,000	5,000
Hard-water pump	½ h-p.	500	500	500	500
Cistern pump	¼ h-p.	250	250	250	250
Cream separator	¼ h-p.	250	250	250	250
Refrigerator	¼ h-p.	250	250	250	250
Vacuum cleaner	1/6 h-p.	170	170	170	170
Ventilating fans—3 small motors					600
		Heating			
Range		8,000	8,000	8,000	
Milk warmer		75	75	75	75
Toaster	5.5 amp.	605	605	605	605
Iron		550	550	550	550
		17,955	17,955	17,955	10,555

TABLE LXXVIII—Continued

Connected Load, 1924-27

Use	Size	Total watts 1924	1925	1926	1927
		Community			
		Power			
Threshing, silo filling, etc.	15 h-p.	15,000	15,000	15,000	15,000
Dish washer	⅛ h-p.		125	125	125
Threshing, etc.	10 h-p.			10,000	10,000
Utility motor	5 h-p.				5,000
Utility motor	1 h-p.				1,000
Utility motor	1 h-p.				1,000
		15,000	15,125	25,125	32,125

School

Wattage	No. of lights	Total watts 1924	1925	1926	1927
		Lighting			
		1,340	1,340	1,340	1,340
		Power			
Use	Size				
Washing machine	¼ h-p.	250	250		
Pump	2 h-p.			2,000	2,000
		1,590	1,590	3,340	3,340

FEED GRINDING

Farmers on the Red Wing line had been using tractors and stationary engines as sources of power in grinding feed, or else had been hauling their grain to commercial grinders in town. W. A. Cady, for example, had been grinding his feed at home. His costs for grinding 50 bushels were: For getting out team and tractor, grinding and cleaning up, 2 men, 3 hours each, at 30 cents an hour, $1.80; 6 gallons of kerosene, 78 cents. This made a total of $2.58, to which should be added depreciation on equipment and use of team and wagon. Another farmer, who had been hauling his grain to town for grinding was paying a total of about $3.70 for grinding 50 bushels of grain, plus the cost of team and wagon for 4 hours. The expenses involved in these methods suggested a study of the possible advantages in using electric power for the work. The farmers on the Red Wing line were provided with utility motors such as could be used for the kind of work involved. Nearly all of these were 5 h-p. The substitution of 5 h-p. motors for 20 or 30 h-p. tractors necessitated other changes in equipment and also changes in methods, the aim being to reduce man labor to a minimum by eliminating the necessity of continuous attention. In other words, it was sought to make feed grinding as nearly automatic as possible.

With these objects in view, a building called a "Feedery" was added to W. A. Cady's barn. This feedery (Figs. 65 to 75) is arranged to hold all the small grain and corn that is raised, whether for sale or for feeding. The feed-grinding equipment is so arranged that the feed does not have to be shoveled into the feed-grinder or shoveled away from the grinder. A diagram of the feed-grinding arrangement is shown in Figure 64. A double hopper bin is located on the second floor above the feed grinder. The feed grinder is on a balcony. The feed after being ground can be run directly into the feed cart beneath, or on to a mixing floor, or into bins on the ground floor.

In order to grind feed by use of a hopper bin and without an attendant it is necessary to include other equipment. An elevator must be provided for elevating the grain. The elevator can be used for other purposes than getting the grain into the hopper bins. All grain stored in the feedery can be transferred from wagons to the bins at the time of threshing, thereby saving considerable man labor. An elevator is shown in Figures 65 and 75. The conveyor boot is lifted off the floor when not in use. When the conveyor is down, grain can be run directly into it from bins on the second floor, or grain from bins on the ground floor can be shoveled into it. By changing the position of the distributor pipe at the top of the elevator, grain can be delivered to any bin.

Ear corn can not be satisfactorily passed to the mill through a hopper bin. Where corn on the cob is to be ground, a man must be on hand to feed the grinder. Since there is little food value in the cob, and since tests show that it costs less to shell the corn and then grind shelled corn, than to grind corn on the cob, a corn sheller was installed in the feedery. This is shown in Figure 65 at the upper left corner. It is shown diagrammatically in Figure 64. The shelled corn can be run directly into the conveyor boot and elevated to the hopper bins, to any other bin, or run back into a wagon.

The cobs can be run through a conveyor pipe, shown in Figure 65, into a wagon box. In order to eliminate the shoveling of corn, the corn-sheller was equipped with a self-feeder. The installation was so arranged that the corn-sheller is located between the two corn bins. Removeable boards, which form a door into the corn bins, can be taken out and a large part of the corn in each bin will run by gravity to the self-feeder.

The storing of corn in a building of this character requires special equipment for drying the corn. The adjoining barn is ventilated with electric fans and it was decided to use one of these (an 18-inch fan) for forcing air through the ear corn. The fan is so arranged that outdoor air can be forced through a system of air ducts under the bins and up through the corn. This method of drying the corn is not entirely satisfactory. If the corn is harvested early in the fall, enough dry days with air above freezing are available for drying the corn. If, on the other hand, the corn is harvested late, the corn may be frozen before it is dried sufficiently to keep well.

All of the feedery equipment is driven by a 5 h-p. motor connected to the line shaft (Fig. 65). A hay hoist mounted on the second floor (Fig. 66), is run by the same motor. The motor is mounted on skids to facilitate moving it for use in ensilage cutting, wood sawing, and other work not done at the feedery. Motors for such uses can now be purchased that are mounted on portable trucks.

Tests on Feed Grinding

On the farm of A. C. Bryan 4 to 6 tons of grain per month are ground during the winter and spring. From 30 to 40 tons of grain are ground per year, requiring from 600 to 800 kw-hrs. of energy. Records for representative months were as follows:

Month	Grain	Time required	Weight of feed ground	Kw. hrs. used	Energy rate per cwt.
		Hrs.	Tons		Kw. hrs.
March	Corn and oats	23.2	3.83	44.7	0.59
April	Oats and wheat	11.6	2.51	30.5	0.61
	Corn	19.8	2.43	55.6	1.18

The average grinding rate during April was 243 pounds of corn on the cob or 300 pounds of oats or other small grain per hour. Twenty to thirty hours of man labor per month were required for grinding the feed, because there was no hopper bin. At Mr. Cady's, with the elevator and hopper bin about 1½ or 2 man-

TABLE LXXIX

DATA ON FEED GRINDING

Tests on 6-inch Burr Mill

Grain ground	Speed, r.p.m.	Lbs. grain per hr.	Average power, kw.	Kw. hrs. per cwt.
Shelled corn (old burrs)	586	663	3.9	0.597
Shelled corn (new burrs)	586	700	2.5	0.367
Oats (old burrs)	586	475	3.8	0.808
Oats (new burrs)	586	740	3.8	0.520
Oats (new burrs)	500	663	4.2	0.635
Corn on cob	586	283	2.9	1.025
Corn on cob	500	252	3.3	1.310
Barley (old burrs)	500	793	4.2	0.525

Fig. 75. Feedery alley from barn door. Note feed spout from feed grinder on second floor to feed cart or bin.

hours would be required for the same amount of feed grinding. Mr. Bryan now has a hopper bin.

Test data, Table LXXIX, is taken from a 6-inch burr mill run by a 5 h-p. motor. The feed grinder is provided with a hopper bin. The motor runs a line shaft, and the feed mill and elevator are run from the line shaft. The power requirements and the energy consumption is that put into the motor, in other words, it is the amount that the farmer pays for.

The small grains were ground with a fineness modulus of about 2.5, the shelled corn a fineness of 2.7, and corn on the cob with a fineness of 3.2.

Several other tests were made with various types of mills and with different grains. A few of the tests are reported in Table LXXX. The tests show the desirability of using new burrs in place of old, badly worn burrs. New burrs require from 20 per cent to 40 per cent less energy than old ones. Shelled corn and barley require less energy for grinding than does oats or corn on the cob. The tests indicate that a 5 h-p. motor has plenty of power to operate a 6-inch burr mill up to a speed of 600 r.p.m. A three h-p. motor was used for some time on one of these mills.

Grinding Shelled Corn

The energy consumed per bushel in shelling corn, and in elevating and grinding the shelled corn was less than the energy required to grind corn.

	Kw. hrs. per bu.
Shelling corn (246 r.p.m)	.0195
Elevating corn	.0467
Grinding shelled corn (586 r.p.m.)	.2100
Total (shelling, elevating, and grinding)	.2762
Grinding corn on the cob (580 r.p.m.)	.7400

It took about two and one-half times as much energy to grind ear corn as it did to shell, elevate, and grind shelled corn. The labor required in each case was about the same, altho grinding ear corn required more attention than grinding shelled corn. Two men were required to shell the corn, and two men were required to shovel the ear corn up into the bin near the grinder.

The power required for just the grinding operation is much smaller than that given in the tables, as power is used to run the motor, the line shaft, and the empty feed grinder. These values are as follows:

	Kw.
5 h-p. motor idling	0.96
Motor and line shaft	1.84
Motor, line shaft, and grinder	2.00

Tests at Cady's

This feed mill installation appears to be most conveniently handled by the use of a line shaft. Pulleys on the line shaft can be used to drive other machinery.

TABLE LXXX

DATA ON FEED GRINDING

Make of grinder	Size of burr	Kind of grain	Amt. of grain	Duration of test	Bu. per hr.	Lbs. per hr.	Fineness	Energy consumed	Kw. hrs. per bu.	Kw. hrs. per cwt.
	in.		lbs.	hrs.				kw. hrs.		
Stover	6 (new)	Oats	941	2	14.7	470.5	2.3	5.9	.200	0.63
Stover	6 (old)	Oats	722	2	11.3	361.0	2.4	6.0	.265	0.83
Stover	6 (new)	Ear corn	337	2	2.34	168.5	3.5	3.9	.830	1.16
Fairbanks Morse	8	Oats	1,015	2	15.8	507.5	2.7	5.2	.164	0.51
Fairbanks Morse	8	Shelled corn	1,513	2 1/6	9.66	698.3	4.0	8.9	.460	0.59
Holland	8	Oats	999	2	15.6	499.5	2.5	9.4	.301	0.94
Stover	6 (new)	Oats	166	5/12	13.9	398.4	2.2	1.1	.212	0.66

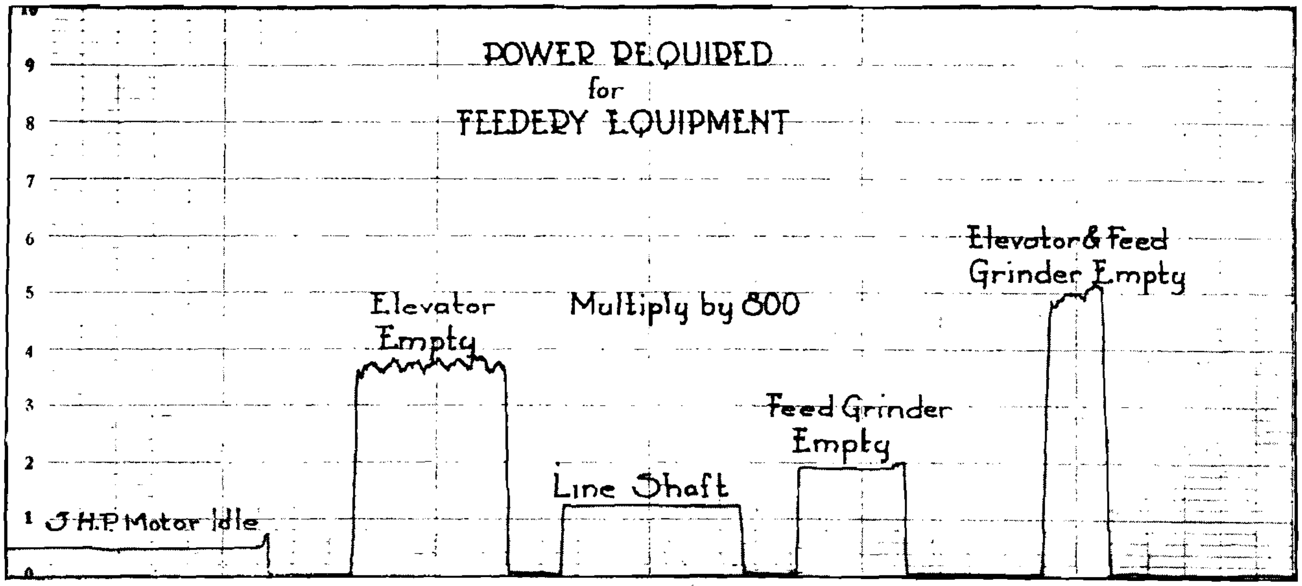

Fig. 76. Wattmeter record showing power required by motor to drive feedery equipment empty.

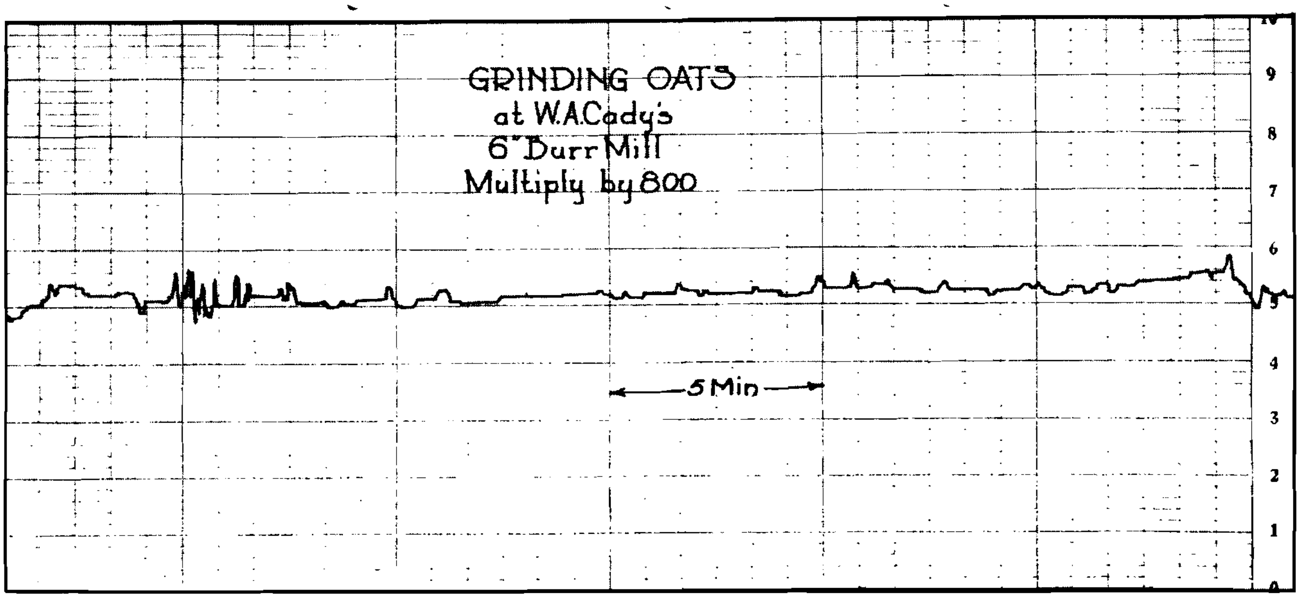

Fig. 77. Wattmeter record showing a load of about 4,200 watts for grinding oats—6-inch burr.

In Mr. Cady's barn the same motor and line shaft are used to drive the elevator, feed mill, corn-sheller, and hay-hoist. If suitable arrangements could be made to drive the equipment without the use of the line shaft, a saving in power and energy could be made. No load data on the equipment in use at Mr. Cady's are given below. Two readings have been given in all cases to show the variation that may be expected in measurements of this type.

A number of feed-grinding tests were made with this equipment. In all of the tests the power and energy used for feed grinding or elevating includes the power and energy used to drive the equipment as given opposite. Figure 76 shows the amount of power in watts required to drive the equipment, under the different conditions, as stated on the graph.

	Volts	Amps.	Watts	Power factor, per cent
Line voltage	234	..	....	...
Second reading	237	..	....	...
Motor idle	223	12	400	14.9
Second reading	227	12	456	17.0
Motor and line shaft	224	12.8	1,024	35.7
Second reading	221	12.8	1,120	39.4
Motor, line shaft, and grinder, empty	221	14	1,560	50.4
Second reading	218	15	1,840	56.3
Motor, line shaft, grinder and elevator empty	208	24.8	4,000	77.5
Second reading	206	23.2	3,760	78.7
Motor and line shaft elevator empty	214	10.2	3,200	78.0
Second reading	211	20	3,320	78.5

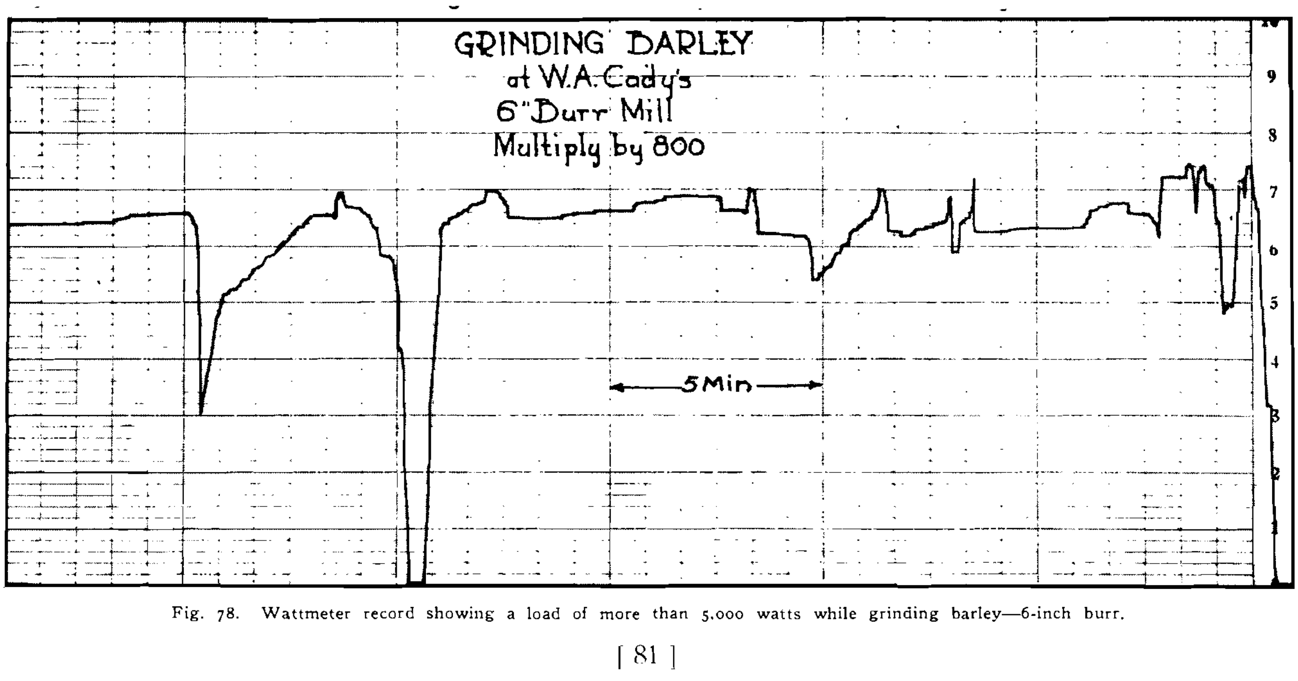

Fig. 78. Wattmeter record showing a load of more than 5,000 watts while grinding barley—6-inch burr.

Reports of the Two Tests on the Feed Grinding Equipment

Grain	Speed	Wt. of grain	Time	Rate of grinding per hr.	Power	Kw. hrs. per cwt.	Power factor
	r.p.m.	lbs.	min.	lbs.	kw.		per cent
Oats.....	567	771.5	90	482	4.2	.83	81.6
Barley...	580	1,015.0	35 70 10	870	5.1	.304	82.2

Graphical records of these two tests are given in Figures 77 and 78. The power required for this grinding is greater than that reported in the other tests. This is because of the power required to drive the line shaft and other equipment. When grinding at a high rate, as with the barley, the power fluctuates noticeably owing to variation in the grinding rate. In general, the power for feed grinding fluctuates only slightly as shown in Fig. 77.

Conclusions

1. A 5 h-p. motor is large enough to grind feed satisfactorily with a 6- or 8-inch burr mill.
2. A 3 h-p. motor can be used with a 6-inch burr mill if the speed is reduced to about 450 r.p.m. or less.
3. A hopper bin arrangement and a feed mill located above a ground-feed bin are necessary for satisfactory operation of a small power unit.
4. Barley and shelled corn require the least amount of power and can be ground at the highest rate, usually more than 20 bushels per hour.
5. Oats can be ground at from 12 to 18 bushels per hour with a 5 h-p. motor and a burr mill.
6. Corn on the cob is ground so slowly and requires so much attention that it is desirable to shell the corn first and then grind it.
7. Corn can be shelled and then ground at much lower cost for power than grinding corn on the cob.

SHELLING CORN

A limited amount of experimental work was done in corn shelling. In one set of tests an International 2-hole corn-sheller was driven by a ½ h-p. motor. The results of two tests are given:

Test	Amt. of corn, lbs.	Time	Kw. hrs. per cwt.	Kw. hrs. per bu.	Speed, r.p.m.	Shelling rate per hr., lbs.	Power, watts
1	1,921 (34.3 bu.)	2 hrs.	.0572	0.321	300	960	600-1,000
2	576 (10.3 bu.)	23 min.	.0348	.0195	246	1,536	600-1,000

These two tests indicate that corn shelling can be done with motors of ½ h-p. or more. The energy consumption for such work is very small, approximately one kilowatt hour per ton, and does not mean much from the standpoint of load-building. The tests indicated that lower speed operation was more efficient as the machine could be fed to larger capacity. The problem that the farmer encounters in corn shelling with the small sheller is a labor problem similar to that in grinding corn on the cob. The rate of shelling is much higher, however, than is the rate of grinding corn on the cob with small mills. Whenever a self-feeder can be used as at Cady's farm the labor problem is reduced. Dry corn requires less energy for grinding than moist corn. The corn in test 1 given above contained 30.5 per cent moisture and required .057 kw. hr. per cwt. Drier corn which contained 22 per cent moisture required .050 kw. hr. per cwt.

ELEVATING GRAIN

Three types of elevators were used in elevating grain: Belt conveyor type, inclined portable with chain conveyors, and a chainless bucket type. The latter type is the only one that will elevate ear corn as well as small grain.

A 5 h-p. motor was used to drive one elevator by the use of a line shaft. The elevator was one using metal cups on an 8-inch belt. The cups hold about 2 quarts each. This system was not efficient, but it enabled the farmer to use the same 5 h-p. motor which was used for other purposes. The efficiency of the elevator is low. For this elevator the power was 3 kws. to run the elevator when empty and 3.6 kws. when loaded. The tests with the three types of elevators show that the power required to run them empty is nearly as great as when loaded.

When elevating shelled corn, the energy used was a total of .083 kw. hr. per cwt. or .0467 kw. hr. per bushel. The grain was elevated at the rate of 6,620 pounds per hour.

With this same elevator oats were elevated with a power requirement of the same amount (3.6 kws.) and an energy requirement of. 035 kw. hr. per cwt. of grain. Another test showed that a 70-bushel load of oats was elevated in 16 minutes, or at the rate of 4 tons per hour. Tests show that driving the elevator directly from the motor, if that could be done, would reduce the power requirement about 25 per cent. This can not be done because of speed reduction.

The portable type of elevator, elevating wheat, required .035 kw hr. per bushel or .059 kw. hr. per cwt. This elevator was driven by use of a countershaft mounted on the motor truck, and used a 3 h-p. motor. With this equipment Nelson Brothers elevated 710 bushels of barley and 1,260 bushels of oats and used a total of 18 kw. hrs. at the rate of .6 kw. hr. per ton of grain.

Another type of elevator using a track system, with metal buckets holding a peck, a chainless bucket elevator, required power as follows: 5 h-p. motor idling, .43 kw.; motor and elevator empty, 3.26 kws.; motor and elevator loaded, 3.5 kws.

The elevator was loaded to about one-half its capacity, but it was elevating barley at a rate of 6,060 pounds per hour. The energy required was .0577 kw hr. per cwt. This farmer uses the elevator for unloading all grain at time of threshing, all of his corn, and feed grain to the hopper bins for grinding. He uses only about 100 kw. hrs. per year for elevating over 80 tons of grain.

Grain may be elevated by the use of a portable outside elevator or by the use of a permanent inside elevator. In either case, the elevator costs do not have to be charged altogether to elevating the grain. If a portable elevator is used, it may serve three or more farmers. If an inside elevator is used, it will be used for other elevating during the year. One third of the elevator charge may be assessed against taking care of grain at threshing time. The cost of electricity for elevating grain on one farm was 1.4 cents per hundred bushels; on another farm it was 1.6 cents per hundred bushels. Most of the farmers had about 3,000 bushels of grain per year. The energy cost for elevating would be about 50 cents. Depreciation and interest charge on the elevator would be about $1.60, and on the motor about 50 cents. The total elevating cost would be $2.60. On other farms where an elevator was not used, two extra men were usually required to handle the grain. The cost for these two men was not less than 50 cents per hundred bushels. It usually cost more than that because of delays in getting grain to the machine and because of the time consumed in setting. The cost for hand operation, therefore, would be $15. A grain elevator operated by a motor may make a saving of about $12.40 for the average farmer on this line.

CUTTING ENSILAGE

Gasoline engines or tractors have generally been used for cutting ensilage. In a few instances small ensilage cutters have been run with eight- to ten-horse-power gasoline engines, but farmers have not been satisfied with this type of outfit as they frequently had to cut the bands on the bundles of corn in order to keep from overloading the engine. Fifteen horse-power or more has been considered the requirement for ensilage cutting, and ensilage cutters have usually been run at speeds from 700 to 900 r.p.m.

The first ensilage cutting with motors that was done in the Red Wing experimental work in 1924 was with the 15 h-p. motor, using 16-inch ensilage cutters. The 15 h-p. motor was mounted on skids as shown in Figure 79. Tests were conducted on three farms. The use of skids for such motors was found to be very unsatisfactory. At a later date the motor was mounted

Fig. 79. A 15 h-p. motor used first year for ensilage cutting. The skid mounting is cumbersome and unsatisfactory.

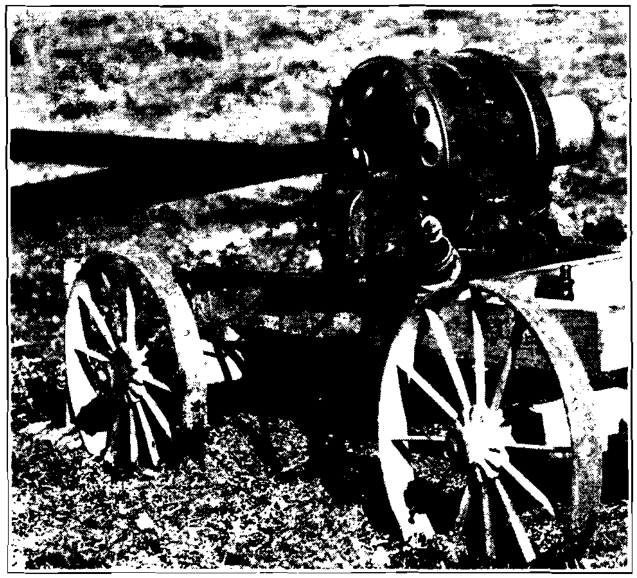

Fig. 80. A much better way of mounting motors like a 15 h-p. Note the heavy duty plug and cord.

on a truck. This method of handling the large motors was very convenient. The motor mounted on a truck is shown in Figure 80. A good heavy cable with heavy-duty plugs and receptacles is necessary for portable motors. Note the cable and good type of plug and receptacle. The practice of operating the ensilage cutters at high speed was followed in these tests. When run at speeds of 750-800 r.p.m. the 15 h-p. motor was loaded to as high as 26 h-p. The silo where one test was conducted held about 170 tons of ensilage. Eighty tons were cut with the motor and required 192 kw. hrs. of electricity. This is an energy consumption of 2.4 kw. hrs. per ton. With electricity at 3 cents per kw. hr. the energy cost was 7.2 cents per ton for electricity. The other 90 tons were cut by the use of a tractor at a cost of 9.2 cents per ton for kerosene and oil. At another farm 150 tons of ensilage were cut with the motor operating the ensilage cutter at about 700 r.p.m. At this farm 300 kw. hrs. were used, or at the rate of 2 kw. hrs. per ton.

These tests showed that a motor was practicable. They also showed that high-speed operation of the cutter was unnecessary and expensive.

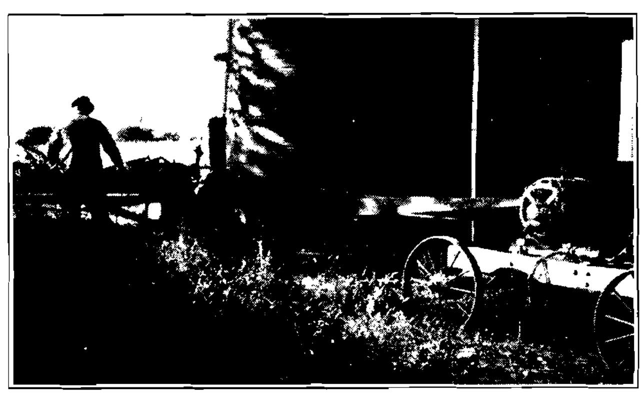

Fig. 81. A 10 h-p. portable motor driving the 13-inch ensilage cutter. This size of motor is not necessary.

TABLE LXXXI

TESTS ON ENSILAGE CUTTING, OCTOBER 1, 1927

Cutter	Size	Length of cut	Cutter pulley	No. of knives	Motor	Size	Motor pulley	Height of silo	Speed No load	Speed Loaded	Weight per bundle	No. of bundles	Weight of load	Time	Rate, per hour	Power	Kw-hrs. energy	Kw-hrs. per ton
	In.	In.	In.			H-p.	In.	Ft.	r.p.m.	r.p.m.	Lbs.		Lbs.		Tons	Kw.		
Papec	16	3/8	24	2	Wagner	5	5½	32	425	390	26	65	1,690	7'-30"	6.71	4.82	.602	.717
Gehl	13	"	24	2	Westinghouse	"	6	27	456	426	16+	79	1,310	6'-15"	6.29	3.90	.406	.619
"	"	"	"	"	"	"	"	"	"	"	19	111	2,080	8'-10"	7.80	4.39	.585	.562
"	"	"	"	"	"	"	"	"	"	440	19	122	2,320	9'-0"	7.72	4.58	.686	.591
"	"	"	"	"	"	"	"	"	"	"	20+	77	1,560	5'-40"	8.27	4.77	.450	.577
"	"	"	"	"	"	"	5½	"	420	390	20+	99	2,005	8'-10"	7.36	4.13	.564	.563
"	"	"	"	"	"	"	"	"	"	"	22	89	1,960	8'-20"	7.06	3.98	.553	.563
"	"	"	"	"	"	"	5	"	380	348	19	64	1,215	4'-40"	7.77	4.22	.330	.492
"	"	"	"	"	"	"	"	"	"	"	19	84	1,590	5'-30"	8.53	4.70	.436	.548
"*	"	"	"	"	"	"	"	"	"	336	20	67	1,340	5'-10"	7.72	4.45	.384	.573
"*	"	"	"	"	"	"	5½	"	421	363	17+	100	1,725	8'-20"	6.21	4.54	.630	.733
"*	15	"	"	"	"	"	"	"	418	389	17	108	1,830	10'-50"	5.04	4.57	.830	.902
"*	"	"	"	"	"	"	5	"	383	349	16−	92	1,430	7'-30"	5.72	4.40	.550	.765
"	"	"	"	"	"	"	"	"	382	350	15	114	1,710	7'-30"	6.84	4.56	.570	.722
"	"	"	"	"	"	"	5½	"	419	388	16	65	1,040	5'-0"	6.24	4.99	.416	.800
Papec	16	"	"	"	Wagner	"	"	32	425	400	17	165	2,805	10'-45"	7.84	5.21	.930	.664
"	"	"	"	"	"	"	"	"	400	"	17	130	2,210	7'-45"	8.60	5.68	.734	.661
"†	"	"	"	"	"	"	5	"	"	365	16	137	2,190	12'-0"	5.97	5.40	1.080	.982
"†	"	"	"	"	"	"	"	"	"	"	17	140	2,380	12'-10"	5.83	5.49	1.121	.942
"‡	"	"	"	"	"	"	"	"	"	"	18−	143	2,540	10'-0"	7.62	4.79	.798	.628
"	"	"	"	"	"	"	"	"	"	"	18−	137	2,450	9'-0"	8.16	4.90	.735	.600
"	"	"	"	"	"	"	"	"	"	"	17	104	1,770	8'-0"	6.65	4.31	.574	.649
"	"	"	"	"	"	"	"	"	"	"	17	98	1,670	6'-30"	7.66	4.80	.522	.625
"	"	"	"	"	"	"	"	"	"	"	18	97	1,740	7'-0"	7.50	4.12	.474	.545
Gehl	15	3/8	20	"	Advance	7½	"	27	480	437	18+	86	1,570	8'-20"	6.15	5.35	.743	.946
"	"	"	"	"	"	"	"	"	"	"	21+	93	1,980	9'-10"	6.43	5.45	.838	.840
"	"	"	"	"	"	"	"	"	"	"	18+	89	1,640	7'-50"	6.31	5.54	.720	.878
"	"	"	"	"	"	"	"	"	"	"	19+	96	1,830	7'-30"	7.32	5.63	.714	.785
"	"	"	"	"	"	"	"	"	"	"	19+	92	1,770	6'-40"	7.86	5.45	.606	.688
"	"	"	"	"	"	"	"	"	"	"	20	78	1,569	6'-50"	6.81	5.28	.600	.771
"	"	"	"	"	"	"	"	"	"	443¶	20	82	1,640	7'-30"	6.56	5.26	.657	.801
"	"	"	"	"	"	"	"	"	"	"	20	86	1,720	7'-40"	6.72	5.32	.681	.793
"	"	"	"	"	"	"	"	"	"	"	19+	87	1,660	7'-30"	6.64	5.79	.724	.872
"	"	"	"	"	"	"	"	"	"	"	19	83	1,590	8'-40"	5.44	4.60	.666	.843
"	"	"	"	"	"	"	"	"	"	"	19+	84	1,610	7'-30"	6.44	5.09	.636	.795
Papec	13	1/3	18	3	Wagner	"	"	32	495	470	Nct satisfactory with poor voltage							
"§	"	"	"	"	"	"	4½	"	446	425	16+	184	3,000	17'-0"	5.30	6.48	1.836	1.224
"§	"	"	"	"	"	"	"	"	"	"	16	203	3,140	13'-30"	6.92	8.40	1.908	1.215
"‖	"	"	"	"	"	"	"	"	"	"	16	164	2,630	13'-0"	5.54	4.83	1.050	.795
"**	"	"	"	"	"	"	"	"	"	"	18	170	3,060	16'-15"	5.66	5.68	1.536	1.000
"	"	"	"	"	"	"	"	"	"	"	18	172	3,300	9'-20"	10.56	7.06	1.104	.667
"	"	"	"	"	"	"	"	"	"	"	17	158	2,690	10'-30"	7.66	6.26	1.098	.887
"	"	"	"	"	"	"	"	"	"	"	18	206	3,710	12'-15"	9.10	5.97	1,219	.658
"	"	"	"	"	"	"	"	"	"	"	17	156	2,650	9'-20"	8.48	6.93	1.082	.814
"	"	"	"	"	"	"	"	"	"	"	18	150	2,700	10'-0"	8.10	7.34	1.224	.907
Gehl	16	3/8	20	2	Advance	"	5	27	430	416	17+	74	1,280	6'-55"	5.45	5.16	.600	.937
"	"	"	"	"	"	"	"	"	"	"	18.5	79	1,460	7'-40"	6.57	5.72	.624	.855
"	"	"	"	"	"	"	"	"	"	410	19	66	1,260	6'-40"	5.67	4.99	.554	.880
"	15	"	24	"	Century	10	6	32	466	440	27	73	1,970	9'-20"	6.34	5.81	.907	.921
"	"	"	"	"	"	"	"	"	"	"	24	107	2,570	6'-10"	12.52	9.31	.960	.745
"	"	"	"	"	"	"	"	"	"	"	24	107	2,570	7'-5"	10.87	8.53	1.003	.777
"	"	"	"	"	"	"	7½	"	565	544	27	85	2,300	5'-40"	12.18	11.37	1.073	.933
"	"	"	"	"	"	"	"	"	"	"	25	110	2,750	11'-30"	7.17	6.74	1.294	.944
"	"	"	"	"	"	"	"	"	"	"	24	83	1,990	5'-15"	11.40	11.43	.981	.986
"	"	"	22	"	"	"	"	"	621	580	26	108	2,810	8'-0"	10.57	13.21	1,762	1.255
"	"	"	"	"	"	"	"	"	"	"	26	116	3,020	7'-15"	12.50	13.60	1.645	1.090
"	"	"	"	"	"	"	"	"	"	"	24	115	2,760	7'-30"	11.05	12.57	1.570	1.138
"	"	"	"	"	"	"	6	"	507	490	36	55	1,980	5'-10"	11.55	12.35	1.060	1.070
"	"	"	"	"	"	"	"	"	"	500	26	93	2,420	8'-0"	9.06	7.56	1.009	.834
"	"	"	"	"	"	"	"	"	"	"	24	38	910	3'-0"	9.10	9.60	.480	1.065
"	"	"	"	"	"	"	"	"	"	"	21	94	1,970	5'-30"	10.78	10.33	.948	.963
Papec	16	½	16	3	"	15	7	30	740	725	20.5	108	2,220	6'-20"	10.50	14.76	1.558	1.405
"	"	"	"	"	"	"	5½	"	610	571	20.5	86	1,770	6'-10"	8.62	11.60	1.192	1.405

* Corn drying rapidly.
† Grassy corn, dull knives.
‡ Sharp knives.
¶ Belt tightened
§ Dull knives.
‖ New knives.
** Large corn.

During the ensilage cutting season the following year, a 10 h-p. motor for the most of the work was used, tho the 15 h-p. motor was used at the farm of B. I. Melin. The ensilage cutting outfit shown in Figure 81 is the 13-inch cutter with the 10 h-p. motor mounted on a truck. The plug and receptacle on this outfit was of smaller capacity and cheaper than the one shown in Figure 80, but it was very satisfactory. The cutters used were a 13-inch Gehl and a 16-inch Papec. These were run at about 650 r.p.m. and 570 r.p.m. respectively. The saving in energy consumption by using the smaller motor and operating the cutter at a lower speed, is shown in Table LXXXI. Again the 15 h-p. motor operating the cutter at the higher speed used nearly 2 kw. hrs. (1.79 kw. hrs.) per ton, while the 10 h-p. motor driving the cutter at 570 r.p.m. operated at less than 1.5 kw. hrs. per ton. At times the 10 h-p. motor carried as much as 18 h-p. when driving the Gehl cutter at 550 r.p.m.

The results of these tests indicate that smaller motors could be used and that lower speeds of the cutter were desirable. During the season of 1927, a large number of tests on different farms were conducted with different makes of cutters and with different makes of motors varying in power from 5 h-p. to 15 h-p. The results of some of these tests are given in Table LXXXII. One of the ensilage cutters being operated by a 5 h-p. motor is shown in Figure 82. This is a one-man job when operated in this manner.

A glance at Table LXXXII shows clearly that very low energy consumption can be secured by using small-power motors with low-speed operation of the cutters. A summary of the table gives the following average values.

TABLE LXXXII

SUMMARY

Size of motor	Rate of cutting per hr.	Speed of cutter	Power used	Kw. hrs. per ton
H-p.	Tons	r.p.m.	Kw.	
5	7.13	336-440	4.65	.667
7½	7.55	410-443	5.81	.862
10	10.39	440-580	10.17	.978
15	9.56	570-725	13.18	1.405

A further summary of Table LXXXII in reference to the 5 h-p. motor shows the energy consumption under different conditions to be as follows:

SUMMARY FOR 5 H-P. MOTOR (1750 R.P.M.) 2½ PER CENT BELT SLIP

Size of cutter	Cutter pulley	Motor pulley	Kw. hrs. per ton
In.	In.	In.	
13	24	5	.503
16	24	5	.586
13	24	5½	.620
16	24	5½	.747

Operation of the machine at or near the capacity of the motor gives a low energy rate. With the 7½ h-p. motor, one man would seldom feed it up to the capacity of the motor. The average rate of cutting with the 7½ h-p. motor is but little more than for the 5 h-p. motor and the power required is only about 6½ h-p. In practically all tests, the feeding was done by one

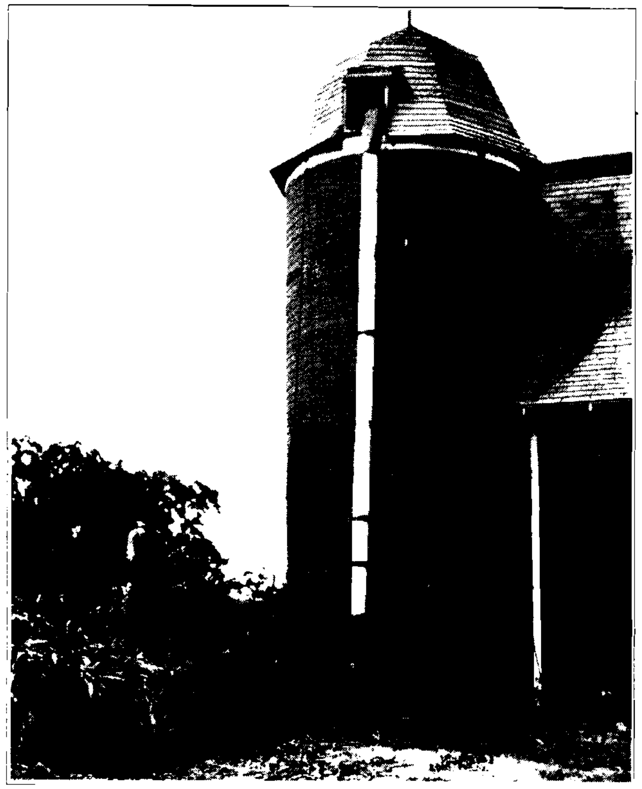

Fig. 82. A 5 h-p. motor on skids driving a 15-inch ensilage cutter. This is a very satisfactory motor when the machine is fed evenly.

man. One man can feed at a higher rate than 7.55 tons per hour, but if he is not urged to do so, ordinarily he will not, with bundles weighing 20 pounds each or less. There was another factor, however, which held down the capacity of the machine operating with the 7½ h-p. motor. With the 15-inch cutter running at a speed of 440 r.p.m. the capacity, with one man throwing off and no one feeding, was limited to about 8 tons per hour with short corn. The maximum capacity for a full load was 7.86 tons per hour. When a faster rate was attempted, the butts of the bundles would double over at the feed rolls, frequently stopping the feed. When this happened, enough time was lost to cut down the rate of cutting to less than 7 tons per hour.

The entire ensilage-cutting job at the farm where the 7½ h-p. motor was used with the 15-inch cutter required a total elapsed time of 14.5 hours. Ninety-two loads, totaling 78.2 tons, were cut with an energy consumption of 66 kw. hrs. This gives an average energy consumption of .844 kw.hr. per ton, which is very close to the average given above for the 7½ h-p. motor tests. Of the 14.5 hours, 1.3 hours were wasted in waiting for corn. The machine was stopped for about two thirds of this time and allowed to run idle for the remainder of the time. On a basis of 13.2 hours running time, which includes the time for changing wagons, removing plugs in pipe, etc., the average rate of cutting was 5.92 tons per hour. While the machine was in operation without any interference from our tests, 75 loads were sent in and trouble with a plugged pipe occurred but four times. The cutting was handled with four men and four teams. This job required only .75 man-hour per ton of ensilage cut.

The cost of energy at 3 cents per kw-hr. was only 2.5 cents per ton. These costs are low as compared to 1.83 man hours per ton and a fuel cost of 7 cents per ton as given in the *Wisconsin Bulletin* No. 386 for 282 farms in Wisconsin.

Graphical records have been made of the amount of power required in a very large number of tests. Only a few of these charts can be given here.

The graph shown in Figure 83 is a record of the test in 1927. The 5 h-p. motor when thrown directly on to the line at starting does not take anywhere near as much power as the motor does when operating the ensilage cutter loaded. The graphical record shows a maximum of 4.4 kw. at the time of starting. When starting the apron, the power increased from 2 kw. to 3.5 kw., but as soon as the apron was started the amount of power required to run the machine with the apron moving differed little from the power required to run the blower alone, being but 2.1 kw. in either case. The graph shows how the power fluctuates as the bundles are passed into the cutter, varying from about 3 kw. to a maximum of 8.5 kw. the average being 5.5 kw. for one entire load.

The tests conducted with the 10 h-p. motor indicate that a capacity equal to what one man can feed can be secured with the 16-inch cutter driven at a speed of about 400 r.p.m. The average man will not keep the motor loaded. With heavy bundles of large corn, one of the best men, working very hard, fed at the rate of 10.87 tons per hour and the motor required 8.53 kw. power input. A man would not want to work at this rate for even one hour. With two men feeding and at the same speed, the rate of cutting was 12.52 tons per hour and required about 10.3 h-p. Working under this condition of full load on the motor and at a minimum speed for this capacity, the energy consumption was only .745 kw. hr. per ton, which is less than the average for the 7½ h-p. motor on all runs. This capacity cannot ordinarily be secured at this speed. It was obtained in this case by using a man at the feed table and by cutting large bundles. At a higher speed of 580 r.p.m. two men fed at the rate of 12.5 tons per hour without having a man at the feed table. At this speed the power required was 13.6 kws. with the motor overloaded nearly 50 per cent and the energy required jumping to 1.09 kw. hrs. per ton, or an increase of 46 per cent. With one man feeding, using large bundles and working at higher than average speed, the rate of cutting was about 9 tons per hour to utilize the full power of the motor.

Tests were conducted with a 5 h-p. motor in order to determine the effect of voltage regulation upon the operating characteristics of the motor and upon the power requirements. A graphical record for the power required to cut three loads of ensilage is given in Figure 84. All of these graphical records read from right to left. The first part of the record on this chart, therefore, is the one when the machine was operating at 350 r.p.m. with poor voltage regulation. The transformer was located at a distance of about 200 feet from the motor, using No. 6 copper wire conductors. The graph indicates that the maximum power which could be secured was 6 kw. The flat top on the peak loads indicates that the motor had reached its maximum available power. This characteristic of the graph is always noticeable whenever conditions are such that the motor cannot get any more power from the line. The resistance drop in voltage is so great that whenever the amount of current increases the voltage decreases proportionately, and consequently the power remains stationary. Under this condition, the power required is even greater than with the proper voltage regulation and yet the ensilage cutting is not satisfactory because the machine will plug very frequently on slight overloads.

Later the transformer was moved up close to the motor and the record, which is shown in the middle part of the graph in Figure 84, was taken. The speed was the same, but the average horse-power dropped from 4.53 kw. to 4.11 kw. altho the maximum power required increased from 6 kw. to 7.9 kw. In other words, under this condition when the motor was given

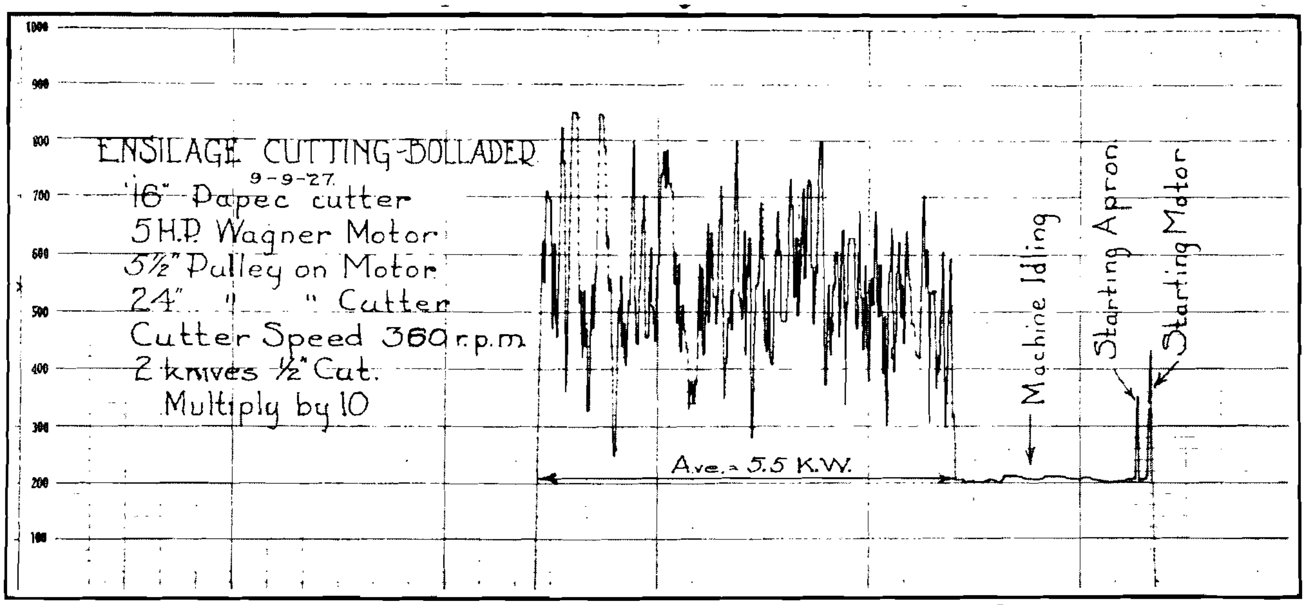

Fig. 83. Wattmeter record of ensilage cutting—one load.

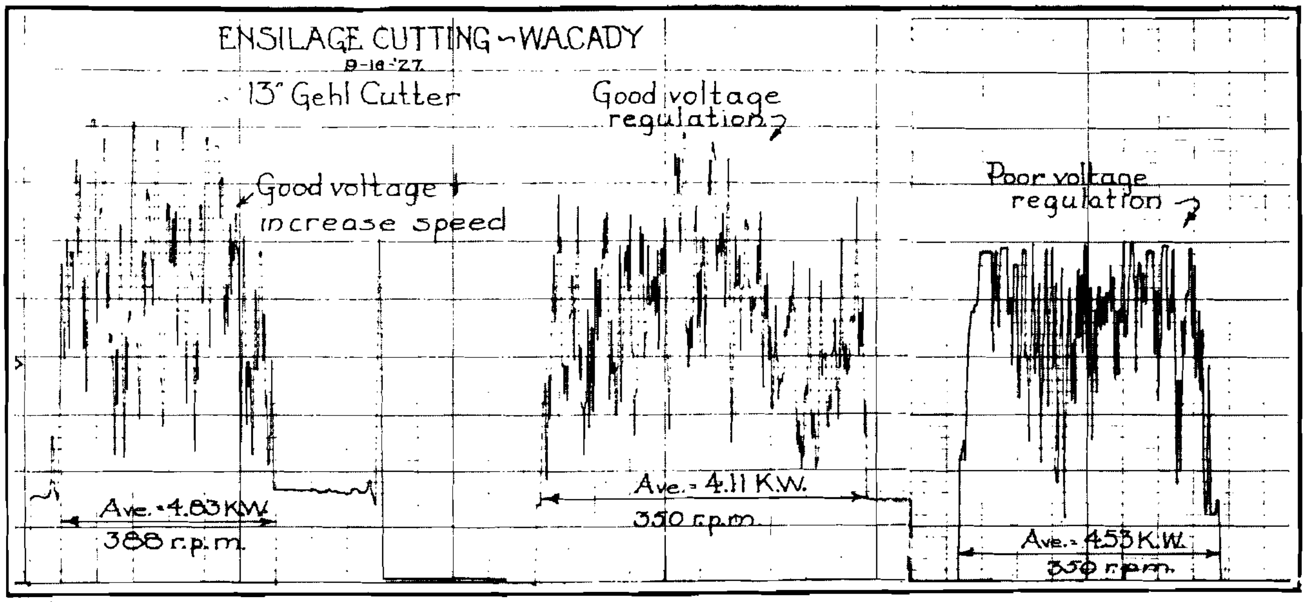

Fig. 84. Wattmeter record of ensilage cutting—three loads.

an overload it carried the overload, but owing to the better voltage, less power was actually required to do the cutting. The cutting was also handled at a higher rate of speed than in the case with poor voltage regulation when the rate of cutting was 5.72 tons per hour. With good voltage regulation, the cutting was done at the rate of 6.84 tons per hour.

Another test on good voltage regulation was conducted when the cutter was being driven at a higher speed of 388 r.p.m. The maximum power in this case went as high as 8.1 kw. The average power required, however, was only 4.83 kw. while the rate of cutting was 6.24 tons per hour. A very small increase in speed increased the power requirements even tho the rate of cutting was lower than in the test conducted at 350 r.p.m.

The amount of power required to run the machine idle is considerably less for the 13-inch cutter as shown in Figure 84, than for the 16-inch cutter as shown in Figure 83. You will note also that there is an increase in the amount of power required to run the machine empty at higher speeds, as shown in the middle diagram in Figure 84 and the left diagram in Figure 84. At a speed of 350 r.p.m. the power required was but 2.42 kw. while at 388 r.p.m. the power required was 2.62 kw.

Tests were made to show the amount of power required to run the motor and blower alone and also to run the motor, blower, and apron. On one test the power was 2 kw. for the motor and blower and 2.16 kw. for the motor, blower, and apron.

The two tests reported at the bottom of Table LXXXI with the 15 h-p. motor are given just to show

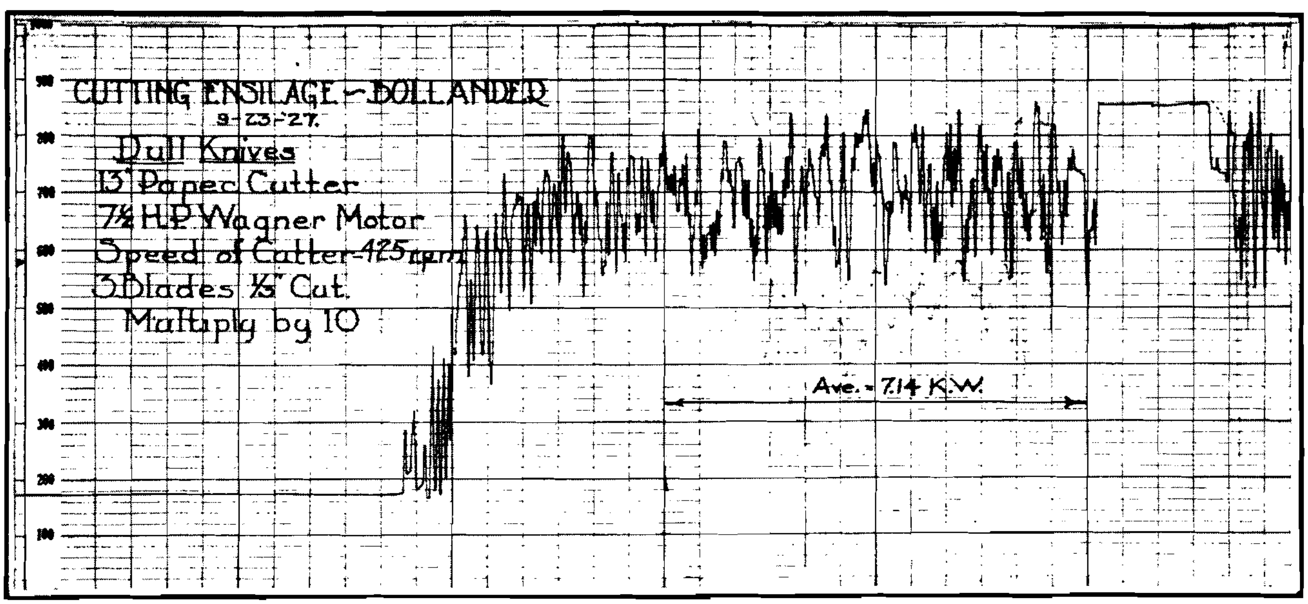

Fig. 85. Wattmeter record of ensilage cutting—one load.

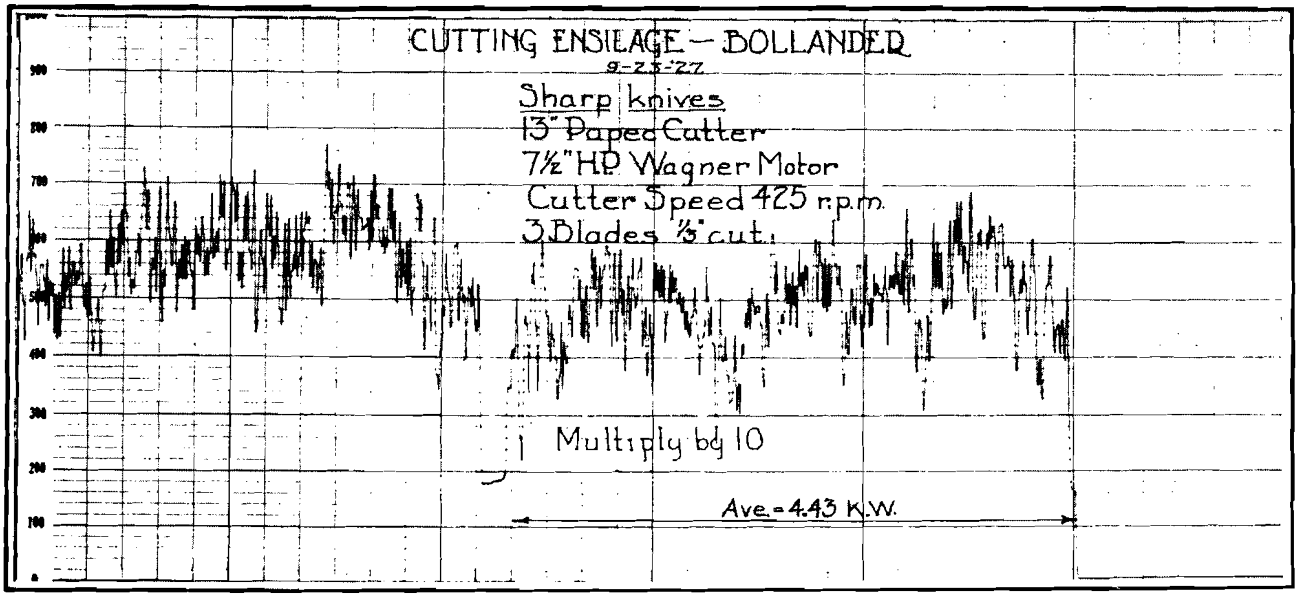

Fig. 86. Wattmeter record of ensilage cutting—two loads.

what the power and energy requirements are at the higher speed. The rate of cutting is not any higher than was secured in certain cases with the 7½ h-p. motor, as the rate of cutting depended upon the men. The results do show, however, that it is unprofitable to run the cutter at high speeds with a large motor and using only one or two men for feeding. In general, the results show that it is not economical to use two men for feeding, as the increase in cutting rate is only about 50 per cent more for two men than for one man.

The sixth run with the 7½ h-p. Wagner motor driving the 13-inch cutter at a speed of 425 r.p.m. (Table LXXXI) was conducted with two men throwing corn into the feeding apron and one man at the feeding table. The rate of cutting was 10.56 tons per hour, and required a power of only 7.06 kw. (7.6 h-p.) and the energy requirement dropped to .667 kw. hr. per ton. This shows how important it is to operate the cutter at a lower speed, and yet to load the motor to its capacity. The floating feed roll was held tight against the top of the guide for intervals of more than a minute at a time, and was near the top the whole time. This indicates that a larger feed capacity in these machines is required when they are operating at low speed with motor of 7½ h-p. or larger.

The value of sharp knives can be seen in two parts of Table LXXXI, both with a 5 h-p. and with a 7½ h-p. motor. The dull knives had been used but one-half day. The saving with sharp knives is more than 35 per cent in the energy used and a saving of 30 per cent in time, owing to increased capacity.

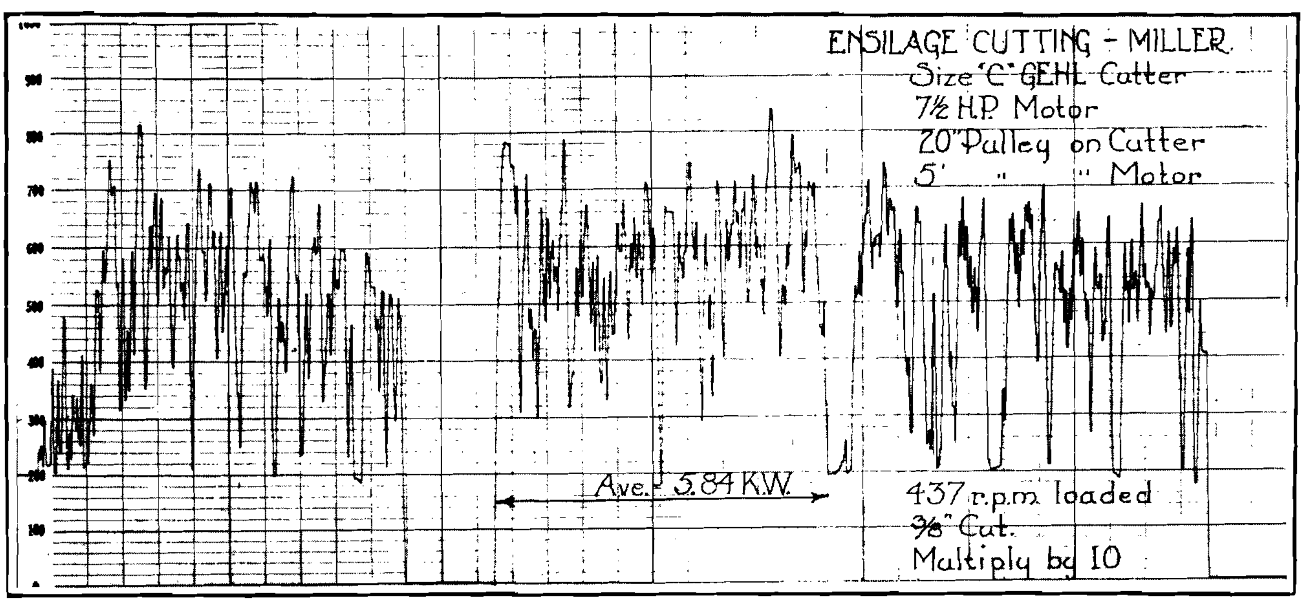

Fig. 87. Wattmeter record of ensilage cutting—three loads.

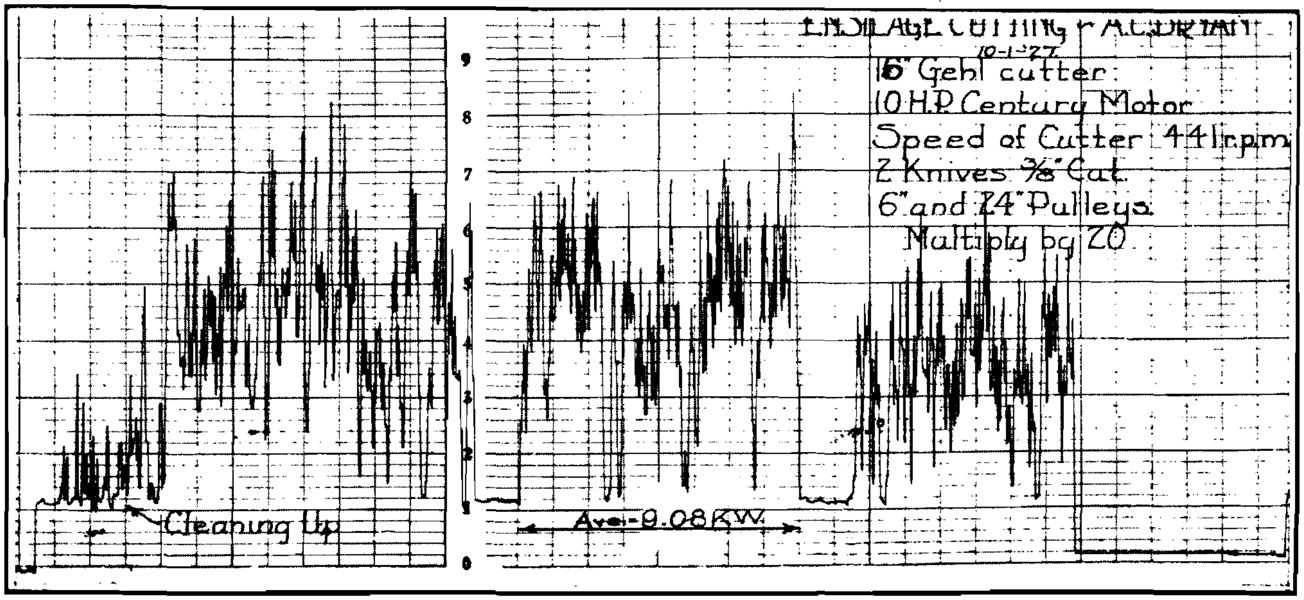

Fig. 88. Wattmeter record of ensilage cutting—three loads.

Knife condition	Rate of cutting	Kw. hrs. per ton
	Tons	
5 horse-power—		
Dull	5.90	.962
Sharp	7.52	.609
7½ horse-power—		
Dull	6.10	1.220
Sharp	8.24	.810

The two tests with the 7½ h-p. motor, as reported in Table LXXXI, are shown graphically in Figures 85 and 86. The power required, as shown by these two graphical records, differs to some extent with the power requirements as given in the table. This is perhaps because of some variation in the zero point on the recording meters, as the values given in the table are correct values, determined from test watt-hour meters.

The record shown in Figure 85 was taken when ensilage was cut at the rate of 5.3 tons per hour, and required approximately 7 kw. The knives were sharpened and the record shown in Figure 86 was taken. This record is for cutting two loads. Ensilage was then cut at the rate of 5.54 tons per hour (record at right part of Figure 86 and the power required dropped from 7.14 kw. as shown in Figure 85 to 4.43 kw. The rate of cutting for the next load was then increased to 10.56 tons per hour and with sharpened knives the power increased to slightly over 7 kw. With sharpened knives the power required to cut 10.56 tons per hour was just about the same as the power required to cut 5.3 tons per hour with dull knives.

Figure 87 shows the power required for cutting three loads of ensilage with a 7½ h-p. motor and one

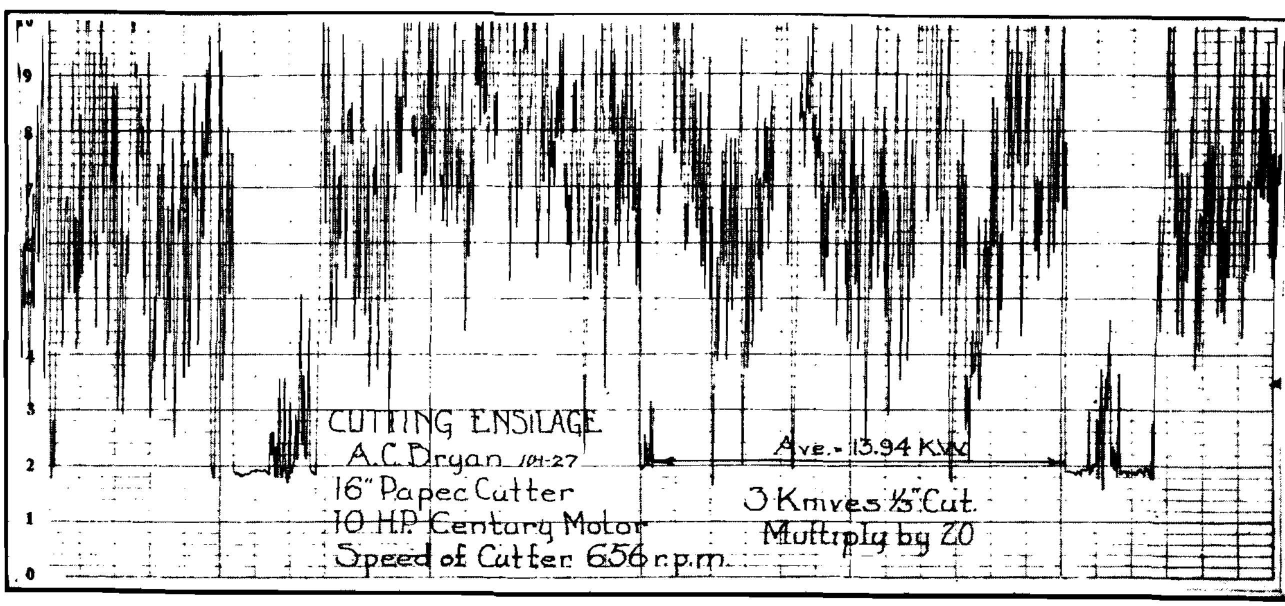

Fig. 89. Wattmeter record of ensilage cutting—three loads.

man feeding. The tests shown in this graph are the third, fourth, and fifth reported in Table LXXXI. This shows that the 7½ h-p. motor was not loaded nearly to its capacity with one man feeding, even tho the average rate of feeding was between six and eight tons an hour, being as high as 7.86 tons an hour for the load as shown at the left of the diagram in Figure 87.

Of the several tests with the 10 h-p. motor, graphical records for only two are given. Figure 88 is a record of the first three tests reported in Table LXXXI with a 10 h-p. motor. An average power of about 9.08 kw. (second test) was required when cutting the ensilage at the rate of about 12.52 tons an hour. The records for the three loads indicate a wide variation in power even from one load to another.

When the speed of the cutter was increased with an attempt to increase the capacity of the machine and the rate of cutting, the power increased very rapidly as shown in Figure 89. The cutter was run at a speed of 656 r.p.m. The power required during one of these loads was 13.94 kw. while the rate of cutting was only about 12.5 tons an hour; almost exactly the same rate of cutting as recorded for the test shown in Figure 88, yet the power required was about 50 per cent greater. Running a cutter at high speed may not mean cutting ensilage any faster but it does mean enormously increased use of power. The maximum power required increased to such a great extent that the motor at times was very badly overloaded, taking power in excess of 20 kw., as can be seen in the diagram in Figure 89, while at the lower speed (Figure 88) the maximum power required very seldom reached 16 kw.

The success of using a 5 h-p. motor for filling the silo depends upon three things: (1) the speed of the cutter, (2) condition of the knives, (3) voltage regulation at the motor. If the ensilage cutter is driven at a speed of 400 r.p.m. or less, with sharp knives properly adjusted with not more than ⅛-inch clearance between the fan blades and the housing, and with the voltage so regulated that at the motor it does not drop below 200 on overloads, the 5 h-p. motor will handle ensilage-cutting satisfactorily. Good voltage regulation can be secured only by having the transformer within 100 feet of the motor or else by using No. 2 or heavier wire for the secondaries.

Tests with secondaries of 400 feet of No. 6 copper wire, from transformer to motor, and with 418 feet of the same sized wire at another farm, show that a 5 h-p. motor can not pull its full overload so as to carry through the heavy slugs. The voltage in such cases drops to as low as 153 and the motor can not get more than about 6.5 kw. or 30 per cent overload. On the first of these farms, 345 feet of the secondary (transformer to meter) was changed from a No. 6 to a No. 2, and when a 7½ h-p. motor was used, the voltage still dropped to 153 volts (normal voltage no load was 222 volts), with 10.4 kw. input or about 30 per cent overload. The transformer was then changed to one with variable taps and the no-load voltage stepped up to 239 volts. Starting with this voltage the motor would carry a load up to 10.6 kw., or about 50 per cent overload, and the voltage would drop to only 206. Under this condition, the motor would not slow down when overloaded and the cutter pipe would not plug. Tests indicate that the 5 h-p. motors should not be used with secondaries longer than 200 feet of No. 6, unless the no load voltage can be stepped up to about 235 volts. The 7½ h-p. motors should not be used with more than 150 feet of No. 6 for secondaries unless the voltage is high. The use of larger wire is not economical for runs of more than about 300 feet. It is usually better to move the transformer closer to the job. A 3-kva. transformer has been very satisfactory for the 5 h-p. motors and a 5-kva. transformer for the 7½ h-p. motors.

Feeding Troubles

The use of the 5 h-p. motor for ensilage-cutting requires a machine that can be fed by one man standing on the load. In many of the tests, trouble with stoppage at the feed rolls, or with overloading of the machine with a heavy slug of corn, was encountered. This trouble was caused by cornstalks hanging out over the sides of the feeder and twisting or doubling back when the bundle entered the feed rolls. An extender feeder, with high sloping sides to prevent this trouble and to eliminate a man for feeding the machine, was recommended. Late in 1927, a cutter feeder of this type was made and tried out by one of the manufacturers co-operating. The cutter used is shown in Figure 90. With this type of apron there is less difficulty with the plugging of the feed rolls. No tests were conducted on this type until 1928.

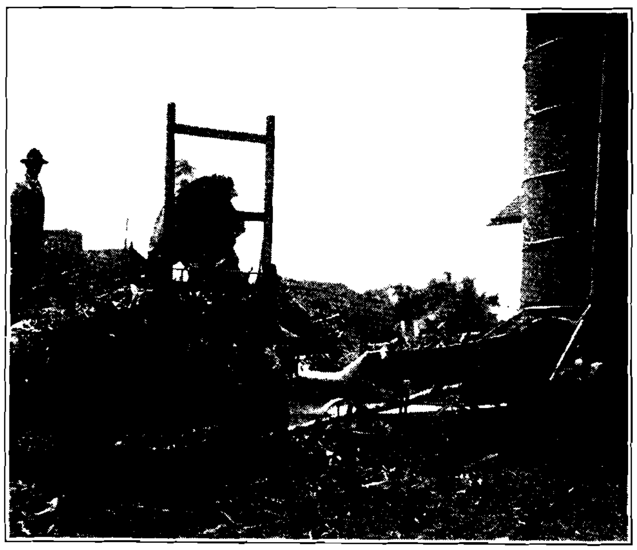

Fig. 90. Ensilage cutter with large feeder sides to assist man on load so that a man on the ground is not necessary.

Ensilage Cutting Tests—1928

The results of previous tests had shown that low speeds of about 350 to 400 r.p.m. were desirable in order to reduce power and energy requirements. When operating at a speed of 360 r.p.m. the 15-inch or 16-inch cutters could not be fed at a rate which would utilize much more than 5 h-p. unless someone assisted the feeding. In other words, in order to use a 7½ h-p. motor at its full capacity, it was necessary to operate the cutter at a higher speed than was necessary for elevation or else trouble with feeding was experienced. The solution of this trouble appeared to be the use of a 10-inch cutter with a large throat or else the redesign-

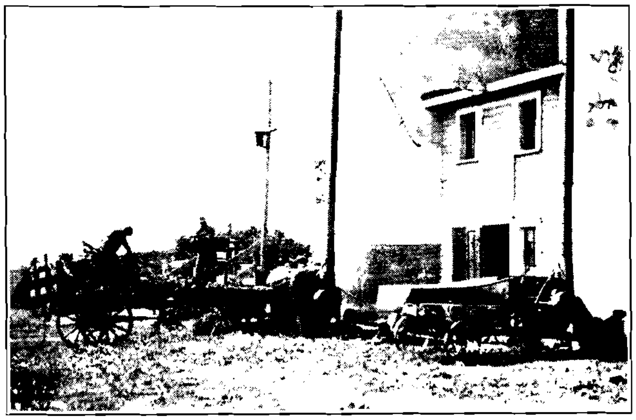

Fig. 91. Ensilage cutters used in 1928 tests. Note the proper location of transformer in order to secure good voltage.

ing of the gears of a machine so that the cutter could be operated with two knives making a ½-inch cut with the 5 h-p. motor. By speeding up the apron and using three knives for the same length of cut, a 7½ h-p. motor could be used at the same speed. The two cutters are shown in Figure 91. The 16-inch cutter with the new type of feeder is in the foreground while the 19-inch cutter with the regular feeder is in operation at the far silo. Note the favorable location of the transformer for this work.

On the farm where these tests were conducted, there were two silos both 36 feet in height above the ground. One of the cutters was placed at each silo. One cutter was the No. 127, which has a 16-inch throat; and the other the No. 158 with a 19-inch throat. This gave identical conditions for the two machines. Motors of 3, 5, 7½, and 10 h-p. were used.

Pulleys of various diameters were used on these motors to give varying speeds to the cutters. The 19-inch cutter was equipped with a 26-inch pulley and the 16-inch cutter with a 24-inch pulley. Thirty feet of 6-inch belting was used. The tests are reported in Table No. LXXXIII.

The first series of runs was made with the 19-inch cutter using the 5 h-p. motor. A 5½-inch pulley was used at first which gave the results as shown in Section I of Table LXXXIII. This was followed up by changing the pulley on the motor to 5 inches in diameter and then 4½ inches.

As will be noticed from Table LXXXIII, the rate of cutting was reduced as the speed was reduced, the average in each case being 7.34 tons per hour with the 5½-inch pulley (I), 7.09 tons per hour with the 5-inch pulley (II), and 6.77 tons per hour with the 4½-inch pulley (III). Likewise the power required in kw. and the energy in kw-hrs. per ton were reduced. From this it is conclusively shown that the faster the cutter is run the greater is the cost per ton. This is partly due to the increased power required to run the cutter at the higher speed, which is shown by the following figures:

Size of pulley	Watts input to motor
4½ inches	1,450
5 inches	1,600
5½ inches	1,820

Motor only 800 watts.

In all the tests made with the 5 h-p. motor only one man was pitching into the cutter.

The most surprising thing of all was the tremendous rate at which the 19-inch cutter would handle the corn when equipped with three knives and operated with a 7½ h-p. motor. It was necessary to have two men do the unloading, as one man could not feed fast enough to keep the motor loaded. The conveyor moved rapidly enough with three knives on the cutter and cutting .47-inch lengths so that it would not pile up as high on the cutter as it did when only two knives were used. This increased the capacity and made the feeding easier. The throat of the cutter was the limiting factor at times as the corn would raise the feed rollers up to their limit and keep them there for the greater part of a minute.

From Table LXXXIII it can be seen that the lowest cost of filling in any of these tests was secured with the 7½ h-p. motor cutting the ½-inch cut and using the 19-inch cutter. (See Sections IV and V of Table LXXXIII.) The motor was able to take a 100 per cent overload for a considerable period, and this avoided to a large extent any chances of the cutter's slowing down to where the pipe would be plugged.

When the 7½ h-p. motor was used with the 19-inch cutter, such a high ratio existed between the pulleys of the cutter and motor that 100 r.p.m. drop in motor speed meant only 21 r.p.m. drop in the cutter speed. This was a sufficient drop in the motor speed to increase greatly the power input to the motor without affecting the operation of the cutter. This also aided to a large extent in securing the very high rate of cutting and the low cost per ton. The fact that the 19-inch cutter has such a large throat also increased the capacity very much.

The next set-up (No. VI) consisted of the 19-inch cutter equipped with six knives and gears of ratios to cut ⅜-inch lengths. The cutter was operated with a 10 h-p. motor.

At first a 6-inch pulley was used on the motor, which gave the empty cutter a speed of 425 r.p.m. This set-up did not give as high a rate in tons per hour as was obtained with the 7½ h-p. motor at the highest speed. The amount of energy used per ton was also increased about 50 per cent. Several things contributed to this increase in power. The corn was being cut into ⅜-inch lengths. Considerable trouble was found in elevating the silage when cut so fine even tho the speed was increased. There was also difficulty in feeding the machine. When the feeding mechanism was running fast it did not take hold of the bundles nearly so well. It was almost impossible to operate the cutter without having someone watch it. The bundles would carry one another along when the feeder ran slowly, but at higher speeds there would be times when the cutter was empty. A single bundle in the feeder was likely to catch on the sides and the whole process would have to be stopped and the feeder reversed to get out the bundle that was caught. This happened sometimes when the feeder was operated at a slow speed but not nearly so often.

Three knives were then taken off and the 10 h-p. motor was used on a set-up similar to that used with the 7½ h-p. motor. This gave about the same results as were obtained with the six knives. (See Test VII.) A good deal less trouble was encountered in feeding.

TABLE LXXXIII
Tests on Ensilage Cutting, 1928

Cutter	Size	Length of cut	Cutter pulley	No. of knives	Motor	Size	Motor pulley	Height of silo	Speed No load	Speed Loaded	Weight per bundle	No. of bundles	Weight of load	Time	Rate per hour	Power	Kw-hrs. energy	Kw-hrs. per ton
	In.	In.	In.			H-p.	In.	Ft.	r.p.m.	r.p.m.	Lbs.		Lbs.		Tons	Kw.		
										I								
Papec	19	.375	26	2	Wagner	5	5½	36	385	375	19.5	115	2,240	10'-15"	6.6	5.7	.975	.870
"	"	"	"	"	"	"	"	"	"	"	23.4	105	2,460	9'-25"	7.8	6.3	.996	.810
"	"	"	"	"	"	"	"	"	"	"	19.3	96	1,852	9'-10"	6.1	6.2	.945	1.000
"	"	"	"	"	"	"	"	"	"	"	21.1	92	1,941	9'-15"	6.3	5.9	.915	.940
"	"	"	"	"	"	"	"	"	"	"	30.0	84	2,520	8'-20"	9.3	6.5	.909	.722
"	"	"	"	"	"	"	"	"	"	"	24.2	95	2,300	9'-15"	7.5	6.1	.945	.820
"	"	"	"	"	"	"	"	"	"	"	24.0	108	2,592	10'- 0"	7.8	5.9	.986	.760
										Averages	23.07	99.2	2,272	9'-21"	7.34	6.1	.953	.846
										II								
Papec	19	.375	26	2	Wagner	5	5	36	355	342	22.5	81	1,820	7'-50"	6.96	5.62	.735	.812
"	"	"	"	"	"	"	"	"	"	"	22.5	76	1,710	7'-30"	6.84	5.76	.720	.842
"	"	"	"	"	"	"	"	"	"	"	26.0	92	2,392	8'-20"	8.60	5.62	.780	.735
"	"	"	"	"	"	"	"	"	"	"	21.4	90	1,926	8'-30"	6.80	5.46	.774	.803
"	"	"	"	"	"	"	"	"	"	"	20.6	87	1,792	8'-20"	6.45	5.43	.753	.840
										Averages	22.6	85.2	1,928	8'- 6"	7.13	5.58	.752	.806
										III								
Papec	19	.375	26	2	Wagner	5	4½	36	322	310	22.5	85	1,912	7'-30"	7.65	5.53	.690	.721
"	"	"	"	"	"	"	"	"	"	"	22.5	85	1,912	9'-10"	6.26	4.44	.678	.710
"	"	"	"	"	"	"	"	"	"	"	22.5	82	1,845	7'-50"	7.38	4.82	.630	.684
"	"	"	"	"	"	"	"	"	"	"	22.5	68	1,527	7'-55"	5.80	4.77	.630	.825
										Averages	22.5	80	1,799	8'- 6"	6.77	4.89	.657	.735
										IV								
Papec	19	.47	26	3	Wagner	7½	5½	36	385	370	22.5	90	2,025	4'-10"	14.55	9.09	.630	.622
"	"	"	"	"	"	"	"	"	"	"	22.5	116	2,610	5'-20"	14.7	9.13	.812	.622
"	"	"	"	"	"	"	"	"	"	"	17.9	118	2,115	4'-35"	14.6	8.57	.654	.619
"	"	"	"	"	"	"	"	"	"	"	22.5	96	2,160	5'- 0"	12.95	8.27	.690	.640
"	"	"	"	"	"	"	"	"	"	"	22.5	113	2,542	4'-45"	16.05	9.48	.750	.591
										Averages	21.6	107	2,290	4'-45"	14.57	8.90	.707	.618
										V								
Papec	19	.47	26	3	Wagner	7½	5	36	358	345	22.5	94	2,108	5'-30"	11.52	6.80	.624	.591
"	"	"	"	"	"	"	"	"	"	"	24.0	114	2,736	6'-40"	12.30	7.15	.794	.580
"	"	"	"	"	"	"	"	"	"	"	22.5	130	2,925	8'-45"	10.05	5.77	.840	.574
"	"	"	"	"	"	"	"	"	"	"	22.5	108	2,430	6'-15"	11.40	6.69	.696	.573
"	"	"	"	"	"	"	"	"	"	"	22.5	134	3,015	10'-25"	8.66	5.68	.990	.657
"	"	"	"	"	"	"	"	"	"	"	22.5	107	2,407	7'-30"	9.74	6.00	.750	.624
"	"	"	"	"	"	"	"	"	"	"	22.5	92	2,024	4'-50"	12.58	7.30	.588	.582
"	"	"	"	"	"	"	"	"	"	"	22.0	86	1,935	5'- 0"	11.54	6.48	.540	.589
										Averages	22.6	108	2,447	6'-50"	10.97	6.48	.727	.596
										VI								
Papec	19	.38	26	6	Century	10	6	36	425	415	22.5	90	2,025	4'-40"	13.05	9.18	.714	.705
"	"	"	"	"	"	"	"	"	"	"	22.5	93	2,092	5'-15"	11.95	8.91	.780	.745
"	"	"	"	"	"	"	"	"	"	"	23.0	83	1,912	6'- 0"	9.56	9.12	.912	.954
"	"	"	"	"	"	"	"	"	"	"	22.5	83	1,867	3'-40"	15.32	11.43	.696	.746
"	"	"	"	"	"	"	"	"	"	"	22.5	68	1,530	3'-20"	13.8	12.68	.708	.927
"	"	"	"	"	"	"	"	"	"	"	22.5	47	1,057	3'-20"	9.51	12.20	.677	1.280
"	"	"	"	"	"	"	"	"	"	"	22.5	92	2,070	4'-35"	13.6	14.15	1.080	1.042
"	"	"	"	"	"	"	"	"	"	"	22.0	97	2,134	4'-35"	14.0	9.8	.750	.703
										Averages	22.5	82	1,835	4'-25"	12.5	10.93	.789	.887

TABLE LXXXIII—Continued

Cutter	Size	Length of cut	Cutter pulley	No. of knives	Motor	Size	Motor pulley	Height of silo	Speed No load	Speed Loaded	Weight per bundle	No. of bundles	Weight of load	Time	Rate, per hour	Power	Kw-hrs. energy	Kw-hrs. per ton
	In.	In.	In.			H-p.	In.	Ft.	r.p.m.	r.p.m.	Lbs.		Lbs.		Tons	Kw.		
									VII									
Papec	19	.38	26	3	Century	10	5½	36	385	370	22.0	105	2,310	5′- 0″	13.9	12.95	1.080	.945
"	"	"	"	"	"	"	"	"	"	"	22.0	81	1,780	5′- 0″	10.7	9.37	.780	.877
"	"	"	"	"	"	"	"	"	"	"	22.0	115	2,530	6′-40″	11.4	10.8	1.200	.950
"	"	"	"	"	"	"	"	"	"	"	22.0	85	1,870	4′-10″	13.5	10.65	.738	.790
"	"	"	"	"	"	"	"	"	"	"	22.0	89	1,958	5′-10″	11.32	10.5	.900	.925
"	"	"	"	"	"	"	"	"	"	"	22.0	77	1,694	4′-35″	11.1	10.2	.780	.921
									Averages		22.0	92	2,024	5′- 6″	12.0	10.74	.913	.901
									VIII									
Papec	16	.38	24	2	Wagner	5	5	36	380	360	20.0	122	2,440	10′- 0″	7.34	5.76	.960	.786
"	"	"	"	"	"	"	"	"	"	"	25.0	93	2,325	8′-40″	8.05	5.82	.840	.722
"	"	"	"	"	"	"	"	"	"	"	25.0	98	2,450	9′-10″	8.02	5.11	.780	.637
"	"	"	"	"	"	"	"	"	"	"	26.0	99	2,574	8′-45″	8.80	6.17	.900	.700
"	"	"	"	"	"	"	"	"	"	"	25.0	110	2,750	10′-30″	7.85	5.82	1.020	.742
"	"	"	"	"	"	"	"	"	"	"	24.0	88	2,112	8′-10″	7.74	6.70	.910	.865
									Averages		24.1	101	2,441	9′-12″	7.96	5.89	.901	.742
									IX									
Papec	16	.47	24	2	Wagner	5	5	36	380	360	22.0	43	946	3′-20″	8.53	5.40	.300	.634
"	"	"	"	"	"	"	"	"	"	"	23.0	73	1,679	6′-40″	7.55	5.57	.618	.737
"	"	"	"	"	"	"	"	"	"	"	25.0	104	2,600	9′- 0″	8.68	6.12	.918	.706
"	"	"	"	"	"	"	"	"	"	"	24.0	60	1,440	6′-40″	6.50	5.03	.558	.775
									Averages		23.5	70	1,666	6′-40″	7.81	5.53	.598	.713
									X									
Papec	16	.47	24	2	Wagner	5	4½	36	345	338	22.0	74	1,628	7′-30″	6.52	5.13	.642	.789
"	"	"	"	"	"	"	"	"	"	"	22.0	62	1,364	5′-25″	7.55	6.32	.570	.834
									Averages		22.0	68	1,496	6′-23″	7.03	5.72	.606	.811
									XI									
Papec	16	.38	24	3	Wagner	7½	5	36	380	365	20.0	104	2,080	9′-10″	6.80	6.29	.960	922
"*	"	"	"	"	"	"	"	"	"	"	20 0	95	1,900	8′-20″	6.84	6.04	.840	.885
"	"	"	"	"	"	"	"	"	"	"	20.0	102	2,040	7′- 0″	8.74	6.18	.720	.706
									Averages		20.0	100	2,006	8′-10″	7.46	6.14	.840	.837
									XII									
Papec	16	.38	24	3	Wagner	7½	5	36	380	365	22.0	86	1,892	5′- 0″	11.38	7.92	.660	.698
"†	"	"	"	"	"	"	"	"	"	"	20.0	119	2,380	7′-30″	9.53	6.71	.840	.706
									Averages		21.0	102	2,136	6′-15″	10.46	7.32	.750	.702
									XIII									
Papec	16	.47	40¼	3	G.E., 3600 r.p.m.	3	4	36	382	365	22.0	35	770	3′-45″	6.15	4.33	.270	.720
"	"	"	"	"	"	"	"	"	"	"	21.0	23	483	2′-30″	5.78	3.60	.150	.622
									Averages		21.5	29	627	3′- 8″	5.96	3.97	.210	.671
									XIV									
Papec	16	.47	40¼	2	G.E., 3600 r.p.m.	3	4	36	382	365	15.5	50	775	5′-40″	4.10	4.20	.396	1.023
"	"	"	"	"	"	"	"	"	"	"	15.5	142	2,210	14′-10″	4.68	4.12	.972	.880
"	"	"	"	"	"	"	"	"	"	"	15.5	115	1,780	10′-23″	5.12	4.21	.732	.822
									Averages		15.5	102	1,583	10′- 9″	4.63	4.18	.700	.908

* One man unloading.
† Two men unloading.

The remaining tests were made with the No. 127 cutter, which has a 16-inch throat. It was first used with two knives and geared to cut ⅜-inch lengths. (See Test VIII.) The cutter was run with a 5 h-p. motor at 380 r.p.m. empty and 360 r.p.m. loaded. A very good rate of cutting was obtained, without overloading the motor. The corn that was cut was much more mature than that of the previous tests. The throat of the cutter was filled to the limit, and this was to a certain extent a limiting factor in the capacity obtained

The cutter was then changed to cut ½-inch lengths in corn that was a little drier and riper. (See Test IX.) This gave about the same results. It was found necessary to add water to the silage in order to pack it. A stream of water at the rate of two gallons per minute was poured into the cutter so this meant a small addition of power.

A third condition (Test X) was set up in which a 4½-inch pulley was used on the motor, which gave the cutter a speed of 345 r.p.m. with no load and 338 r.p.m. when loaded. With dry corn and water added, this gave considerable trouble in elevating. The speed was apparently a little too low for the 16-inch cutter and the height of the silo. In this case the rate of cutting was reduced again by the slow apron speed and the overhead load was nearly the same, which resulted in the increased amount of energy per ton.

Test XI was made with the same cutter, using three knives and cutting the ⅜-inch lengths. At first only one man did the feeding. He could not handle the corn fast enough to load the 7½ h-p. motor to its rated capacity. This all resulted in an increased cost of energy per ton because the motor was not working at its maximum efficiency, and the overhead power was a big factor in increasing the cost per ton. It was hardly possible to get any more corn through this cutter because of the size of the feeding throat. The cutter would handle it very well until the bundles were piled on so thick that they would wedge in the narrow part of the feeder.

As far as the feeding of the two cutters is concerned, the 19-inch gave much less trouble because of the wider throat and less wedging. The 19-inch was very easily fed until the higher speeds were tried.

In conclusion:

1. High speeds are not at all necessary for satisfactory operation. When the 19-inch cutter was used, it never gave any trouble because of low speeds. When the 4½-inch pulley on the 5 h-p. motor was used, the no-load speed was 322 r.p.m. and the average loaded speed was 310 r.p.m. However, the cutter would sometimes run at 290 r.p.m. for a considerable length of time and in one instance the speed went as low as 280 r.p.m. and the cutter still raised the silage into the 36-foot silo.

2. Large capacities can be secured without dangerously overloading the motors.

3. It is not practical to use more than a 5 h-p. motor when only one man is to do the unloading because one man cannot unload fast enough to give efficient operation with a 7½ h-p. motor or larger. The larger motors will keep two men busy.

4. Ensilage can be cut very economically when electric power is used and the cutter is properly adjusted and run at the proper speed.

5. There is nothing gained by using six knives rather than three on the cutter; in fact, it means a less efficient operation.

6. Less power is required and fewer kilowatt hours per ton are used by running the cutters at the lower speeds for each size of motor, and to increase the capacity of the machine for the 7½ h-p. motor by running the apron faster and by using three knives.

Ensilage Cutting with a 3 H-P. Motor

Following the several tests described, it was surmised that a 3 h-p. motor ought to be able to do the job.

The Papec Machine Company made a special mounting for the motor, which was attached to the frame of the 16-inch cutter. This was a very novel arrangement, as shown in Figure 92. There is an angle iron frame to which is fastened a tilting base which makes the motor sit slightly at an angle. As the motor turns, the pulley has a tendency to run down along the belt and as it goes downward, the motor tends to tip into the belt. A 3 h-p. type of S.C.R. 3,600 r.p.m. General Electric motor was used, a 40-inch pulley on the cutter, and a 4-inch pulley on the motor, and an endless 4½-inch leather belt. The cutter had a no-load speed of 380 r.p.m. and an average of 365 r.p.m. when loaded.

The results found while using three knives on the cutter are given in Section XIII of Table LXXXIII. Section XIV show the results with only 2 knives. There is not much difference in the results. The tests were made so late in the season that the corn had been in the shock for over three weeks.

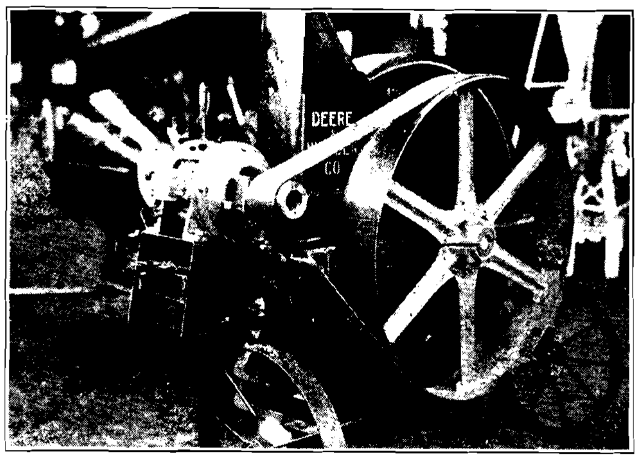

Fig. 92. A 3 h-p. motor mounted on a 16-inch ensilage cutter. Note the unique manner of mounting so that weight of motor plus its pull into the belt provides the tension.

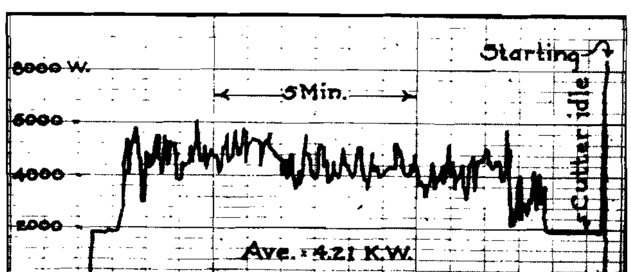

Fig. 93. Wattmeter record of cutting ensilage with a 3 h-p. motor.

In all of the tests run with this motor it was overloaded from 20 per cent to 43 per cent. A graph showing the power required is given in Figure 93. There were times when the motor was overloaded 100 per cent but for only a short period. The motor showed no indications whatever of suffering from overload. Even with the pulleys as close together as they were in this hook-up there appeared to be no belt slippage.

The cutter idle required 1,950 watts. This was nearly half of the average total load while cutting. A cutter at a slow speed, therefore, requires little power to cut and elevate the corn.

While this may not be an advisable method for the average farmer in filling his silo, it shows that a large power unit is not required, since it is possible to get a cutting rate of over 5 tons per hour with a 3 h-p. motor. A farmer could keep three or four teams busy, depending on the distance of the haul.

A Discussion of Elevation—Theory and Practice

When an ensilage cutter is operated at a very low speed it is a familiar fact that the ensilage has a tendency to clog in the pipe. This tendency is also noted when an ensilage cutter is run at a fairly high speed.

The data given in Table LXXXIV were taken from some of the tests. The first four columns are data that were measured. Data in the fifth column, that of the power required for elevating the silage, were calculated from the rate of cutting, the size of flywheel, and the speed at which the ensilage left the flywheel. The velocity with which the silage left the flywheel is given in Table LXXXV. Some attempt to measure the velocity of discharge at the point of discharge was made, but after several trials it was decided that to use the peripheral speed based upon a diameter two inches less than the diameter of the fan blades would not be far wrong. This figure was used in determining the minimum amount of power that was necessary to bring the cut ensilage up to the discharge velocity. No friction losses were considered in this calculation. Data in the sixth column in Table LXXXIV were calculated in a similar way for the air. The same velocity, or approximately the same velocity, for the air as that of the silage was assumed. The velocity of the air as determined from the velocity head measurements is given in Table LXXXV. Data in the eighth column in Table LXXXIV were taken from actual measurements of the power used to run the machine when idle. The last column in Table LXXXIV gives the maximum efficiency of elevation. These figures are based upon a 6½-inch pipe, 30 feet long, using the minimum power requirement for elevating the silage as given in column 7. The efficiency of elevation is determined by dividing the theoretical power required to elevate 10.5 tons per hour a height of 30 feet as compared with the power given in column 7. These power values are minimum values, and, therefore, the efficiency is the maximum value. In actual practice, when friction is taken into consideration the elevating efficiency would be less than the percentages given in column 10. The amount of power available to use for other purposes outside of running the machine idle and elevating the silage and the air that goes with it represents the amount of power used in cutting the ensilage and in overcoming air and silage friction in the blower. The air friction may be slightly greater than for idling, so that the figure given as that of the power remaining may include some small amount to overcome the friction of the air in the blower. There undoubedly is also a small amount of power used to maintain the pressure in the blower pipe.

The first three tests, as shown in the first three rows of figures in Table LXXXIV, are based upon a very similar rate of cutting. The power requirements, however, differ considerably owing to the difference in speed. Almost all of the difference is that required for elevation. In fact, the second and third tests both show more power remaining after subtracting the power for elevating and for running the machine idle than remained in the first test. At the lower speed a

TABLE LXXXIV

TESTS WITH 16-INCH ENSILAGE CUTTER, 30-FOOT PIPE

Speed	Rate per hour	Kw-hrs. per ton	Power	Calculated minimum power for elevating: Silage	Air	Total	Power idling	Power remaining	Maximum efficiency of elevation, 30 ft.
r.p.m.	Tons		H-p.	H-p.	H-p.	H-p.	H-p.	H-p.	Per cent
725	10.5	1.405	16.00	5.88	1.54	7.42	1.62	5.06	4.2
580	10.57	1.255	12.30	3.77	0.81	4.58	1.43	6.29	6.9
440	10.87	0.777	9.50	2.23	0.35	2.58	0.85	6.07	12.7
365	8.16	0.600	4.96	1.15	0.19	1.34	0.67	2.95	18.4
348	8.53	0.548	4.75	1.09	0.16	1.25	0.62	2.88	20.6

TABLE LXXXV

VELOCITY AND AIR PRESSURE (INCHES OF WATER) IN 6½-INCH PIPE, 30 FEET LONG—16-INCH CUTTER

Speed	Velocity of silage per minute	Velocity of air per minute	Velocity head	Static air pressure at bottom, measured	Friction loss, calculated	Pressure required at discharge, calculated	Total pressure
r.p.m.	Ft.	Ft.					
725	7,975	7,944 ± 40	4.0	1.05	5.51	4.15	9.66
580	6,380	6,316 ± 40	2.55	0.60	3.54	2.65	6.19
440	4,840	4,885 ± 50	1.5	0.35	2.54	1.52	4.06
365	4,015	3,975 ± 60	1.0	0.20	1.40	1.05	2.45
348	3,830	3,779 ± 60	0.9	0.22	1.26	0.95	2.21

very much smaller amount of power was required for elevating the silage and the air than at the higher speed. Undoubtedly, this is the point where most of the gain is made in running ensilage cutters at low speed. Efficiency in elevation, also, increases at the lower speed. The ensilage cutter was operated for a short time at a speed below 348 r.p.m., but the other records which are necessary for computing the data given in the two tables for the low speed of 336 r.p.m. were not taken. It is probable that the ensilage cutters can be operated satisfactorily at speeds even below those recorded in this test.

Table LXXXV refers to the same series of tests as reported in Table LXXXIII and are only a continuation of Table LXXXIV. The velocity of the silage as given in column 2 is computed as the peripheral velocity at a diameter of two inches less than that of the fan blades on the flywheel. A consideration of the volume of the ensilage that is thrown by each paddle brings the conclusion that the ensilage does not ordinarily occupy a width on the fan blade of more than two inches. Under such a condition, the velocity at one inch from the outer edge of the fan blade would about represent the average velocity of the ensilage as it left the flywheel. The velocities of the air as determined from the velocity head measurements taken at the inner side of the housing at the opening of the blower are very comparable with the velocities of the silage. The accuracy of measurement, of course, is not very great and the values for the velocity of the air may vary considerably from those given in the table.

In order to determine whether much of the air or of the ensilage was being blown through the delivery pipe, it seemed of interest to determine the quantities given in the last three columns of Table LXXXV. The friction loss is calculated upon the air velocity as given in the third column and the pressure required at discharge is also calculated from the same velocity. The total pressure required to overcome the friction loss and to give a sufficient static pressure to cause at the end of the pipe a discharge of the velocity as given in column 3 is very many times larger than the air pressure as measured at the bottom of the pipe. In the first case, it is nine times as much and in the last case ten times as much. The average is somewhere between ten and eleven times as great. This would indicate that the air is thrown out in very much the same way as the ensilage is, rather than being blown out.

An attempt has been made to picture, theoretically at least, what happens to the ensilage and the air as it passes up through the delivery pipe. Two conditions have been represented: the actual operating speed of 365 r.p.m. and the minimum limiting speed for 30-foot elevation of 234 r.p.m. The velocity of discharge at the higher speed is 4,015 feet per minute where the ensilage leaves the blade. The velocity of discharge in the limiting case is 2,580 feet per minute. This is just the velocity for a free throw lifting a body 30 feet in the air. A velocity of 4,015 feet per minute would lift a body 70 feet in the air. The velocity of discharge together with the speed in r.p.m. and the free throw height is given in Table LXXXVI. Very low velocities and very low speeds are required for elevation to a height of 60 or 70 feet if under conditions of a free throw. It is very evident that the air in the pipe or else the resistance of the silage in passing through the pipe has a very high retarding effect.

TABLE LXXXVI

FREE THROW HEIGHT AT DIFFERENT SPEEDS

Speed	Velocity	Height
r.p.m.	ft. per min.	ft.
234	2,580	30
276	3,034	40
299	3,379	50
338	3,715	60
365	4,015	70
378	4,166	75

An attempt has been made to show diagrammatically in Figure 94 what would happen to bunches of ensilage passing up through a blower pipe, providing they kept distinct and separate from one another. While they undoubtedly do not remain as distinct as shown, it is noticeable that they do retain somewhat their bunch identity. They go from one side of the pipe to the other and this is shown also in the figure. In the figure for the limiting speed the bunches of ensilage come together as they near the top of the pipe. This is not so noticeable at the higher velocity of 365 r.p.m., as at the lower velocity. While 365 r.p.m. is considered a low velocity, under the average operating conditions of 600 to 700 r.p.m. the bunches of ensilage as they pass up through the pipe would not come much closer together at the top than at the bottom. The fact that they do come much nearer in the lower velocities is one of the things which undoubtedly causes some interference in elevation at very low speeds.

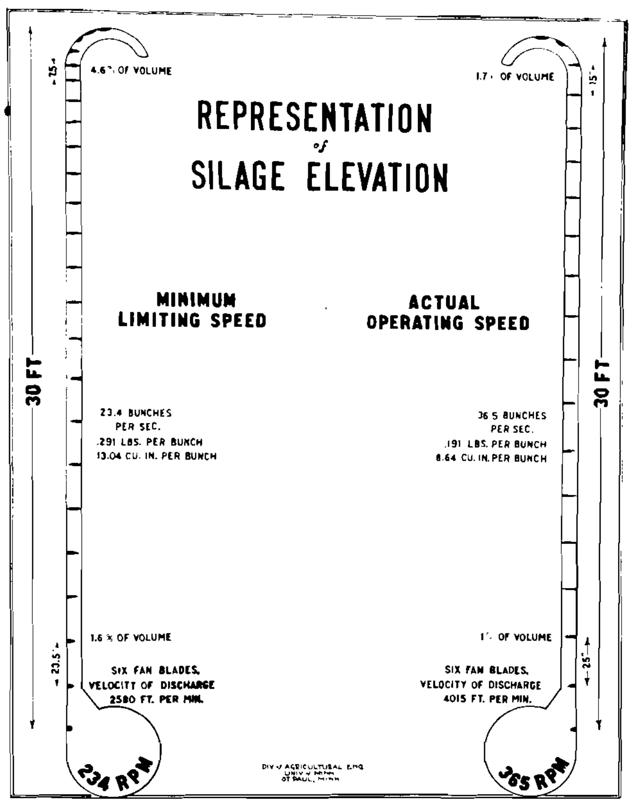

Fig. 94. Illustration of conditions of ensilage behavior in passing through delivery pipes at two speeds.

The figures show also that for the minimum limiting speed the bunches are about 23½ inches apart as they leave the blower, while at the top, in a free throw, they would be about 7½ inches apart. On the other hand, at the higher speed of 365 r.p.m. the bunches would be 25 inches apart at the lower end of the pipe and they would still be 15 inches apart at the top.

It has sometimes been stated that the small pipes do not have large enough capacity for elevating the ensilage at low speeds when cutting at a fairly high capacity. The fallacy of this is probably shown in the figures as given in Figure 94. When operating at a speed of 365 r.p.m. with six fan blades there will be 36½ bunches per second. Each bunch, when cut at the rate of 8.16 tons per hour, which was the actual rate cut at 365 r.p.m. would weigh 0.191 of a pound and would occupy approximately 8.64 cubic inches. At the lower end of the pipe the corn would occupy just 1 per cent of the volume and at the top of the pipe it would occupy 1.7 per cent of the volume. On the other hand, if cutting were done at the same rate at the lower speed of 234 r.p.m. there would be 23.4 bunches per second, each one weighing 0.291 of a pound and occupying approximately 13.04 cubic inches per bunch. These bunches would occupy 1.6 per cent of the volume of the pipe at the bottom and 4.6 per cent of the volume of the pipe at the top under the conditions of a free throw. In either case a small percentage of the volume is actually occupied by the corn, showing that the pipes certainly do have large enough capacity even in a 6½ inch size when operating at fairly high rates of cutting with low velocity, but the percentage increases at the top of the pipe at low speeds.

What happens to the air in the pipe as the silage passes through? The air must have a uniform velocity throughout the pipe. If this velocity is equal to that of the silage at the top of the pipe, then the air will exert a very retarding effect on the ensilage below this. On the other hand, if the air is moving at a velocity which is equal to that of the corn in the lower part of the pipe, then it would assist very materially in clearing the corn out of the top of the pipe. Actual operating conditions, however, do not show that the air is traveling with an average velocity equal to the higher velocity of the ensilage at the bottom of the pipe. On the other hand, if the air travels at a velocity which is that of the ensilage at some other part of the pipe, then the air will assist somewhat in carrying the ensilage out of the top of the pipe but will retard the passage of the ensilage in the lower part of the pipe.

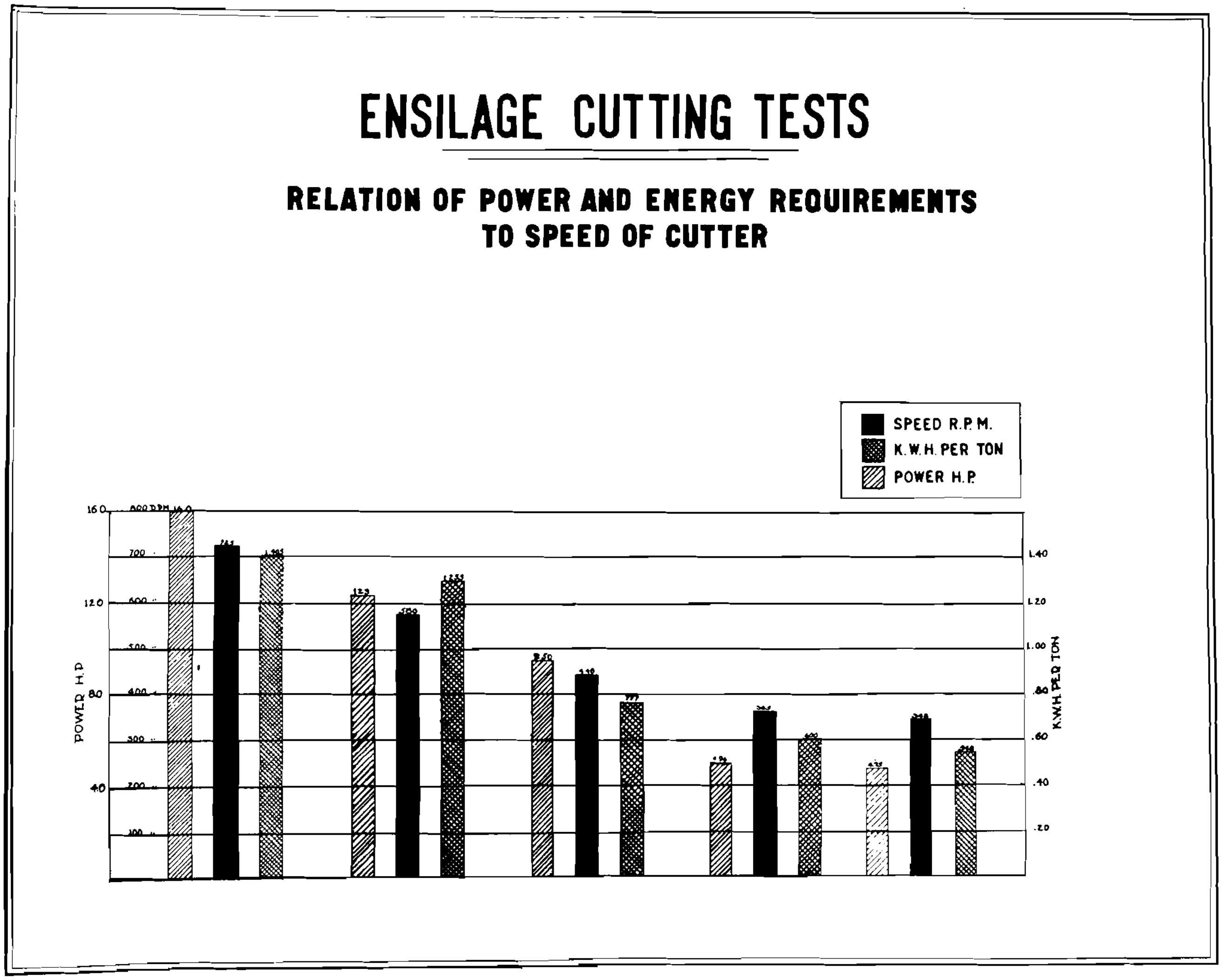

Fig. 95. Graphic illustration that shows both power and energy required for ensilage cutting are nearly directly proportional to the speed.

This is probably the condition that is met with in practice and accounts for the plugging of silage in the lower part of the elevating pipe.

Since the results of the tests show very decidedly that a decrease in speed means a decrease in cost of operating as well as a decrease in the power requirement, and since this fact has also been shown by investigations that have been carried on by Mr. Duffee in Wisconsin and by other investigators, it appears that it would be worth a good deal to find out what can be done to secure proper elevation at as low a speed as possible. It may be that the use of a pipe of nonuniform cross-section or of a pipe so arranged as to relieve the air pressure at the lower end, or some other such arrangement, might make it possible to elevate silage more efficiently at lower speeds. If some arrangement could be made to take advantage of the air movement to help carry out the ensilage it would undoubtedly increase the efficiency of elevation. At lower speeds it may be found that it is possible actually to blow the ensilage through the pipe rather than to throw it through the pipe.

Those investigations have shown that lower operating speeds mean lower cost for the power used in cutting and also that a small amount of power can be used to cut the ensilage at fairly high rates. The graph given in Figure 95 shows this very conclusively. At the higher speed of 725 r.p.m. 16 h-p. were required to drive a 16-inch cutter, cutting approximately 10 tons of ensilage an hour. The cost at this high rate of speed was 1.4 kw. hrs. per ton for cutting. Both the power required to run the cutter and the amount of energy required to cut each ton decreases in a very nearly direct ratio with the decrease in speed. In fact, the power requirement and the energy requirement decrease at a slightly greater rate than the decrease in speed as shown by the chart. At the lower speed of 348 r.p.m. it required but 4.75 h-p. to cut the ensilage at the rate of 8.53 tons per hour, and only 0.548 kw. hr. per ton.

THRESHING WITH ELECTRIC MOTORS

The equipment for threshing was built in June, 1924. The electrical equipment consisted of a portable outfit, with transformer and cable reel mounted on a truck and a 15 h-p. motor mounted on the threshing machine.

The transformer was a standard Westinghouse, oil-cooled, 15-kva.—2,300 volts primary, 440/220 volts secondary, single phase, 60 cycles. This was connected to the high line through type F—10 oil circuit breaker, with under-voltage release, and overload, automatic inverse time limit attachment. The contact to the line was made through No. 6 solid copper wire with "tree insulation." The contact to the high line was made by use of a ground clamp. The handle was made of pine and fitted with a socket which was detachable from the ground clamp. A ground wire connected to the pole above the handle was used for a while. Since there never was found to be any potential between this and the ground it was later discarded. The secondaries of the transformer were connected to a fused (75 amp.) switch. Connections from the dead end of the switch were carried to the meter transformers and to the Oliver heavy duty socket for connection to the cable. A current transformer with a 10 to 1 ratio and a potential transformer with a 4 to 1 ratio were used with a standard 5 ampere, 110-volt, watt-hour meter. The long length of secondary cable necessary produced such a large drop in potential that a standard 1.5-kva.—2,300-volt transformer was used as a booster. This was connected on the primary side of the main transformer between the circuit-breaker and transformer. A complete diagram of the connections is given in Figure 96. A photograph of the portable transformer truck is shown in Figures 97 and 98. Two oxide-type, lightning arresters and two choke coils were connected to the high tension line ahead of the oil circuit breaker.

The portable truck was a standard steel-frame low-wheeled farm wagon. Enough space was left at the rear of the truck to allow the 15 h-p. motor, when re-

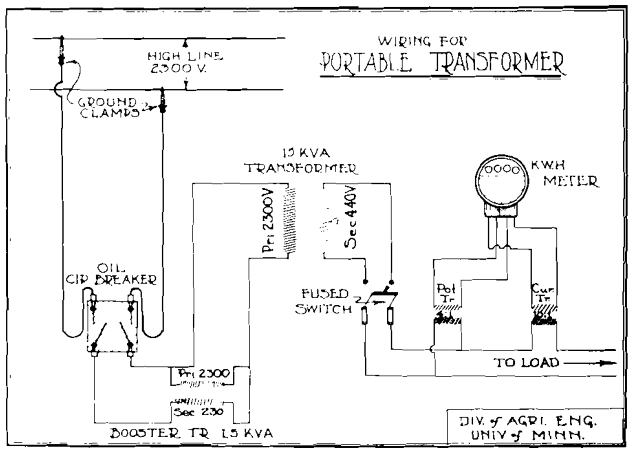

Fig. 96. Wiring diagrams of first portable transformer outfit for threshing.

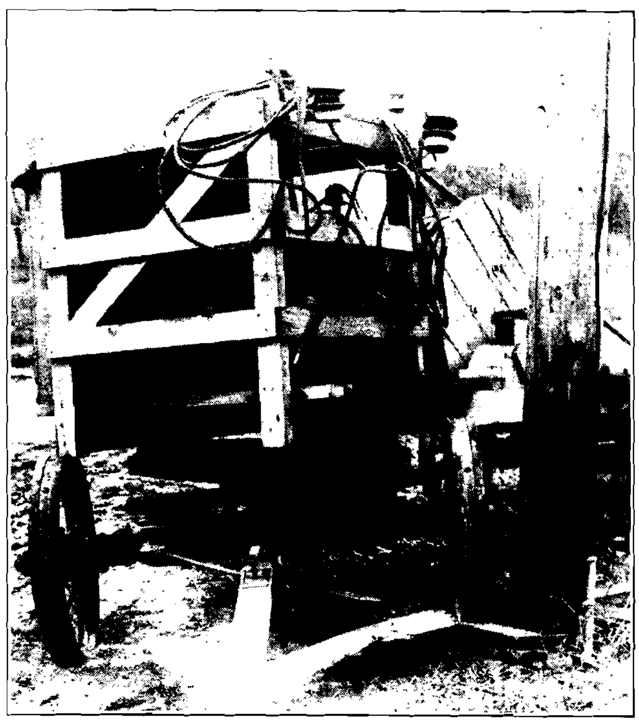

Fig. 97. First portable transformer truck. Note lightning arrestors and flexible heavily insulated conductors for connecting to the overhead wires. 750 ft. cable is wound on reel.

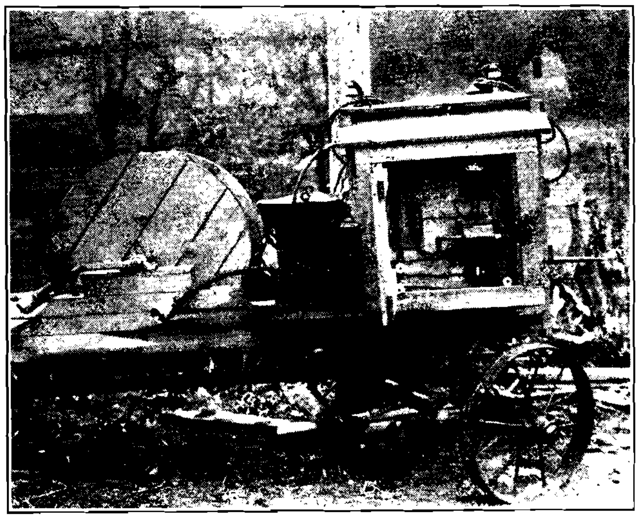

Fig. 98. Side view of transformer truck after booster transformer was added. Note the heavy duty plugs.

Fig. 99. A one-man threshing rig driven by three electric motors. One under feeder, one at left of machine and one just to the rear right of operator—1925 rig.

moved from the threshing rig, to be fastened to skids and placed on the truck. The cable was 750 feet of "Duro Cord," consisting of two No. 6 flexible conductors. This cable was connected at both ends, through Oliver charging plugs and receptacles.

The motor was a 15 h-p. single phase, 1,750 r.p.m. type RS25L Century motor for 440 volts. This motor was mounted on an angle-iron frame, fastened to the front end of the threshing machine frame and directly under the feeder. (See Figure 99.) The base was adjustable to admit of tightening the belt. The drive was an 8-inch double leather belt, with the regular 9-inch pulley on the threshing machine and a 5⅜-inch pulley on the motor. The pulleys were about 45-inch on centers. This gave a belt speed of approximately 2,400 feet per minute and a pulley speed on the threshing machine of 1,050 r.p.m. A Cutler-Hammer resistance starter was fastened to the angle iron frame. This was provided with a no-voltage release and was connected through an enclosed Square D switch. The threshing machine was a 22-inch x 36-inch Red River Special, bought in 1920. It was in excellent condition, and had been used for a week or more in 1924 with a tractor.

Improvements in 1925

The rig was started on August 29, 1924. At that time, the high line was a grounded line, consisting of a hot wire of three No. 8 copper wires twisted, and with a No. 4 iron messenger-wire, grounded at each pole. The farm line was isolated from the city distribution system by the use of two high tension transformers. When the current was turned on, the motor did not have sufficient power to pull the machine up to full speed. After several trials the machine was run empty for a while but a few bundles of grain would pull the motor down on to its brushes. Investigation showed that only 258 volts instead of 440 volts were available at the motor. Further investigation showed that if put on 110-volt basis only 96.5 volts were available across the high line, less than a mile from the County Farm high line switch, while the delivery voltage at Red Wing was 114.5 volts. It was quite plain that the trouble was in the transmission line.

The line was rebuilt within five days. The two isolating transformers were removed, the iron wire was replaced with three No. 8 copper wires twisted, and all grounds were taken off. The circuit from the city substation to the County Poor Farm still consisted of the one mile of No. 0 and 2.3 miles of No. 6 copper.

Threshing was started again on September 11, at the County Farm. It was so late in the year that there was only one job of threshing left in addition to this one. The records of the work are given in Table XCI.

The solid copper wire, used to connect to the high line, gave trouble by breaking off at the contact with the ground clamp. It was replaced with stranded cable insulated for 2,500 volts.

Tests indicated that the motor was very much overloaded at intervals. The average load was not above rated capacity while threshing oats, but it was slightly above when threshing wheat. Tests indicated an average input to the motor of 12.35 kw. on oats. The highest average found for any series of readings was 14.25 kw. input to motor while threshing wheat. Under the first condition the motor output was approximately 13.4 h-p. and under the second condition 14.5 h-p. The overload on the motor at times reached an input of 26.4 kw. or about 20 h-p. output. The motor carried a load readily and did a good job at a reasonable rate of threshing at the County Farm. This was located only 3.3 miles from the city substation. When the outfit was used at Melin's farm, over seven miles from the substation, the motor would not carry the overload, the voltage at such times would drop to 360, and the circuit breaker would open the circuit. This might happen several times in a half day.

The results obtained in the first year trials indicated that threshing by electricity was feasible, and that the costs for equipment and for energy used were comparable with costs for other types of power. But enough tests had not been conducted to establish definitely whether the voltage control on the line was adequate or not. The voltage drop on the high line appeared to be more than it should have been. When the motor would be overloaded, the potential at the motor would drop to about 370 volts.

The operator of the threshing machine, Mr. Cady, objected to the fact that the speed of the machine could not be changed. The separator was driven at the proper speed for good dry grain. When the grain was extra dry, or when they were cleaning up at the end of a threshing job some grain would be thrown over with the straw. When the grain was wet, the speed was not high enough to do good threshing. The bearings on the cylinder had given some trouble with heating, when driven either with the motor or the tractor. One bearing on the motor had "frozen" to the shaft while threshing at Melin's. Because of the cover that was used over the motor and because of the heavy overloads at a low voltage, the heating was excessive. At times, the temperature in the field windings was as high as 155° F.

Improvements in 1925

In order to improve operating conditions, many changes were made in the summer of 1925. A 7½-inch pulley was used on the motor and a 12-inch pulley on the separator. This gave a belt speed of 3,440 feet per minute and a cylinder speed of 1,095 r.p.m. A 5 h-p. Westinghouse motor was mounted on top of the threshing machine to run the blower. A 1 h-p. General Electric variable speed motor was mounted on the left side of the separator to operate the grain shoe, fan and grain auger. These last two motors were motors that could be used for other purposes during the year and were designed for 220-volt service. Note the large 15 h-p. motor below the feeder, the small 1½ h-p. motor at the left of the large motor and the 5 h-p. motor just behind Mr. Cady in Figure 99. It was necessary, therefore, to secure 220-volt service for these motors. The original cable was 2-wire, so it was necessary to use another 2-wire circuit. In order not to overload one half of the large transformer, another 5-kva. transformer was mounted on the truck and connected across the primaries of the 15-kva. transformer. The secondaries were connected through a separate switch, meter, and cable contacts to the motors on the threshing machine.

The resistance starter had given trouble because of the vibration of the machine. This was removed and the motor thrown directly on the line when starting. This motor did not draw an excessive starting current.

In order to determine the size of motor necessary to operate the fan and blower, some preliminary tests had been run as reported in Table LXXXVIII. The threshing machine had not been operated for nearly a year and all parts were a little rusty. The power required for the blower was, therefore, quite large. As a result of the tests it was decided to use a 1 h-p. motor on the fan, etc., and a 5 h-p. motor on the blower.

Threshing Operations in 1925

The first threshing was done on August 6. The operation of the machine was greatly improved by the changes. The high speed belt had relieved the trouble with belt-slippage and bearing-heating. The use of the three motors instead of one accomplished more than was expected. The cylinder could be run at a speed somewhat higher than the year before (1,095 r.p.m. as compared to 1,050 r.p.m.). This gave the machine an increased capacity on dry grain and it was fast enough to thresh grain when it was tough or wet. Mr. Cady, on the cloudy forenoon of August 13, when there had been a heavy dew the night before, stated that he could not have threshed the wheat and flax with the tractor or at the thresher speed he had formerly used. The results given in Table XCI show a large difference in power and energy requirements between the forenoon and the afternoon on this day. The variable speed motor made it possible to run the grain shoe and fan at slower speeds on dry, light grain and not throw grain over into the straw. This assisted also in not throwing grain over when cleaning up at the end of a job. Another desirable feature was that the air supply to the fan could be left on nearly full all the time, and the cleaning controlled by varying the speed. When the cleaning had to be controlled for light grain by shutting off some of the air, then uneven cleaning resulted because of poor air distribution.

The use of a separate motor on the blower was also a desirable feature. As ordinarily driven, a blower will slow down the whole machine when a slug of wet tough straw reaches it. This results in poor threshing at the cylinder, and poor separation and cleaning. By using a separate motor drive for the blower, the rest of the machine is not affected by slugging the blower. This fact coupled with the overload capacity of the motor made it possible to go through the whole 1925 season without having the cylinder speed slow down enough to stop the feeder. Mr. Cady said that he had adjusted the speed of the fan about twenty times one day while threshing clover seed so as to get good cleaning and yet not throw over any seed.

A blanket test conducted while threshing barley at Nelson brothers' farm on October 5 showed a loss of only .15 per cent of grain thrown over into the stack, and that the grain contained only 1.2 per cent of dockage. The grain had been stacked for several weeks and had been subjected to numerous heavy rains. The outer ends of bundles were matted with sprouted grain. The average loss in the straw is about 1 per cent and dockage is usually above 3 per cent.

The increase in the capacity of the machine was shown at Albert Nelson's farm where they threshed 1,604 bushels of succotash (wheat and oats) and oats in nine hours of running time. In one hour they threshed 195 bushels of oats. At Arthur Nelson's farm the machine threshed 80 bushels of oats in 18 minutes, or at the rate of 267 bushels an hour. This indicates that the rate of threshing was more dependent on getting the grain to the machine than on the type of power being used.

The 1 h-p. variable speed motor failed to operate properly after it had been used to thresh about 1,800 bushels of grain. In order to determine what could be done to get this motor to operate properly, another motor of the same size and make was secured. The results of some test runs made with this motor are given in Table LXXXIX. The motor was found to be considerably overloaded at normal speeds. This motor is so designed that its speed is controlled by balancing the torque in the motor by the resisting torque of the driven equipment. Since the torque in the motor is proportional to the square of the voltage, it is obvious that any decrease in voltage will allow the speed of the motor to drop. This motor was a six-pole machine and was rated for a speed of 550 to 1,350 r.p.m. It would maintain its full speed with normal voltage of 220 and with full load. On the other hand, when overloaded or when the voltage dropped below 220, it would not maintain full speed. It was practically impossible to maintain full voltage when the machine was operating. The normal voltage with this motor alone was about 232. When the 5 h-p. motor driving the blower was operating, the voltage at the motor was about 215, and when the 15 h-p. motor was running in addition to the 5 h-p. motor, the voltage would drop to about 206 volts. A preliminary test with no grain in the machine and with the air doors set at about normal, the speeds of the motor were respectively 1,320, 1,200, and 1,119 r.p.m. It was necessary to maintain a speed of about 1,200 r.p.m. for the proper cleaning of heavy grain. As will be noted from tests Nos. 3, 7, 8 in Table LXXXIX, the power required was approximately 1,400 watts under normal load conditions. This motor had an efficiency of approximately 75 per cent. An input of 1,400 watts indicated an output of 1.4 h-p. As a result of the tests, another variable speed motor of the same type was secured. The new motor was a four-pole machine, speed rating of 300 to 2,000 r.p.m. and a power rating of 1.5 h-p. A different pulley was used with this motor so as to require a motor speed of about 1,650 r.p.m. This motor gave perfect satisfaction and its range of speed was sufficient for all conditions.

The large motor gave trouble again as it had in 1924, because of low voltage. In order to overcome this, a transformer was connected to the high line at the city limits to serve as a booster to raise the voltage. This was used during the daytime, but was turned off at 5 p.m. so as not to give a dangerously high voltage of 130 when the large motor was not being used. The voltmeter record shown in Figure 100 shows how the voltage was raised by this "booster."

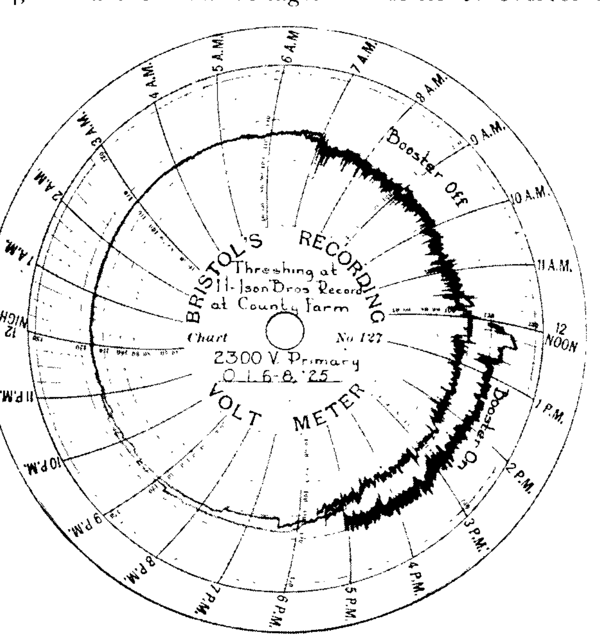

Fig. 100. Voltmeter record showing the necessity for voltage booster on line and also showing the effect of the booster while threshing.

This machine was used during 1925 with considerable success. The operator was well satisfied with the work done by the machine and with the ease of operating. The changes made in the equipment made it possible to increase the rate of threshing by 11.5 per cent, altho this necessitated a like increase in the power required. The cost of energy for threshing was slightly less per bushel and slightly more per hundredweight than for the year before. The thresherman had always sent his two sons with the threshing rig. This year it was not necessary to use the two, so one of the boys hired out and earned $71 while the electric rig was in operation.

There was still one difficulty to overcome. The voltage drop on overloads was still so great that the motor would not function properly at the end of the line. Near Red Wing, the motor had fine pick-up, the 15 h-p. motor would carry overloads up to 24 kw. input without dropping back on the brushes, without heating, and the voltage would remain around 400 at the motor. At six or seven miles from Red Wing, the motor would not carry heavy overloads without dropping back on the brushes. The voltage at the motor would drop as low as 368, and the current would be as high as 75 amperes. This would generally blow the circuit breaker or the fuses on the transformer truck and result in excessive heating of the motor.

Improvements in 1926

In order to give proper voltage regulation, the high line was changed to 6,900 volts, single phase. The change, however, was not made until August. Two of the threshing jobs were done with the outfits of 1925. The records are not available for these.

The work in 1925 was done so successfully that the Nichols and Shepard Company offered to provide a new all-steel, roller bearing, 22 x 36-inch Red River Special threshing machine for use in 1926. This rig was equipped with the motors in the St. Paul shops of the company. Records of the project indicated that a 10 h-p. motor would drive the cylinder and straw racks. The 5 h-p. motor that was used on the blower had not used its full power, so a 3 h-p. motor was placed on the new rig; also, the 1.5 h-p. variable speed motor used in 1925. These were all mounted on angle iron frames with adjustable bases for tightening the belts. The machine as equipped is shown in Figure 101. The method of mounting the large motor is shown in Figuse 102, and that for the 1½ h-p. motor in Figure 103. Switches for all three motors were mounted on the side of the machine as shown in Figure 104.

New Transformer Truck

A new transformer truck was designed and built. This was a lightweight, spring, delivery wagon, shown in Figure 105. It was covered and somewhat lighter than the other. The transformer was a Westinghouse Type SK—15-kva. 13,200/6,600 volt h-t. to 440/220

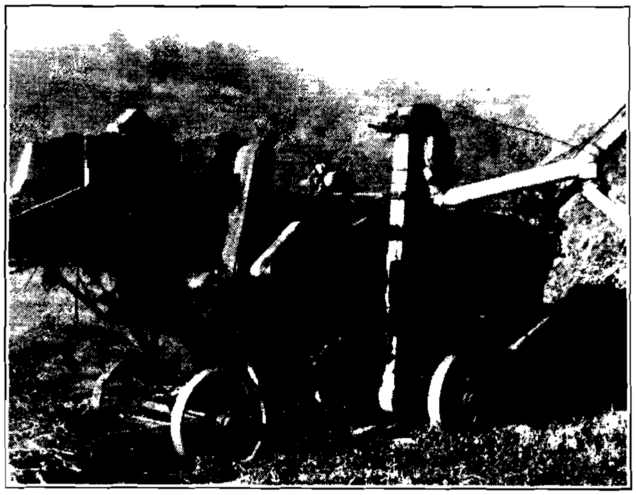

Fig. 101. The all-steel rig of 1926 with three motors. Note blower motor at the lower right.

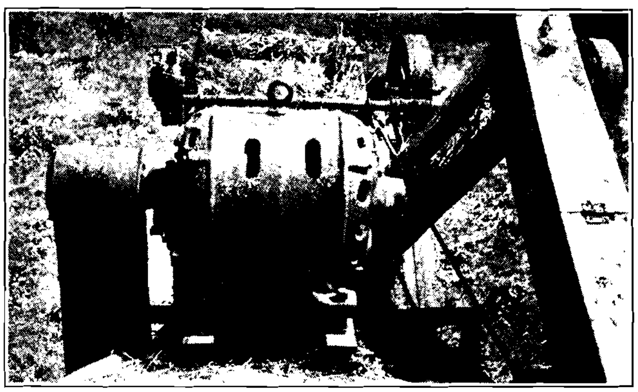

Fig. 102. Method of mounting motor on top of threshing rig with adjusters for belt tension.

volt 1-t., single phase, 60-cycle transformer. This transformer had multiple connections so that various ratios of transformation could be secured. The transformer was connected for a ratio of 5,960/440, and thus when used on a 6,600-volt circuit, an 11 per cent increase in secondary voltage to take care of the secondary drop could be obtained, and a booster transformer was not needed. To decrease the cost, a circuit-breaker was not used, and two fuse cutouts were substituted. The high-line contacts had given some difficulty, and a new type of spring contact was developed. A new type of connection plug and receptacle was also used for secondary cable connections. These were type N3, made by the Albert & J. M. Anderson Manufacturing Company. Three single wires instead of a three-wire cable was used to save expense. A three-wire cable is recommended. The secondary was connected for three-wire 440/220 volt service, through a Type WK-55, 100-ampere three-pole, 600-volt, enclosed safety switch. A diagram of the wiring is shown in Figure 106. Test connections are included for convenience.

The cable connection at the grain separator for the large motor was made at the switch. The wire was taken in conduit from there to each of the other switch ... for the other two motors. The switches, their ... and connections are shown in Figure 104.

The original (1924) transformer truck was changed by installing a 6,600/400-volt, 15-kva. transformer, and was rewired to correspond to that of the new transformer truck, with the exception that the secondary was only two-wire, with the original two-wire, secondary hook-up, as shown in Figure 95. This truck was used with the 15 h-p. motor, mounted on a cart, to run a threshing machine owned by B. I. Melin. The data for this machine are given in the last part of Table XCIII. The rebuilt truck is shown in Figure 107, and the portable motor used to operate the threshing machine is shown in Figure 108.

The new transformer truck was not available until about September 1, so that most of the threshing had been done. Only five jobs, totaling 3,773 bushels, were left for the new rig. The results of threshing with the new threshing machine and the new transformer truck are given in Table XCV.

Effect of Change in High Line

The change in the high line from 2,300 volts to 6,900 volts made a great deal of difference in the operation of the motors. The great difference in voltage regulation is shown by the charts in Figures 100 and 109. The record shown in Figure 109 was taken farther out on the line and the threshing was done farther out on the line than that in Figure 100; yet the variation in voltage is hardly noticeable in the chart made in 1926, while there was a very big drop in potential on the line while the motor was in use in 1925.

Fig. 103. Mounting of the variable speed motor.

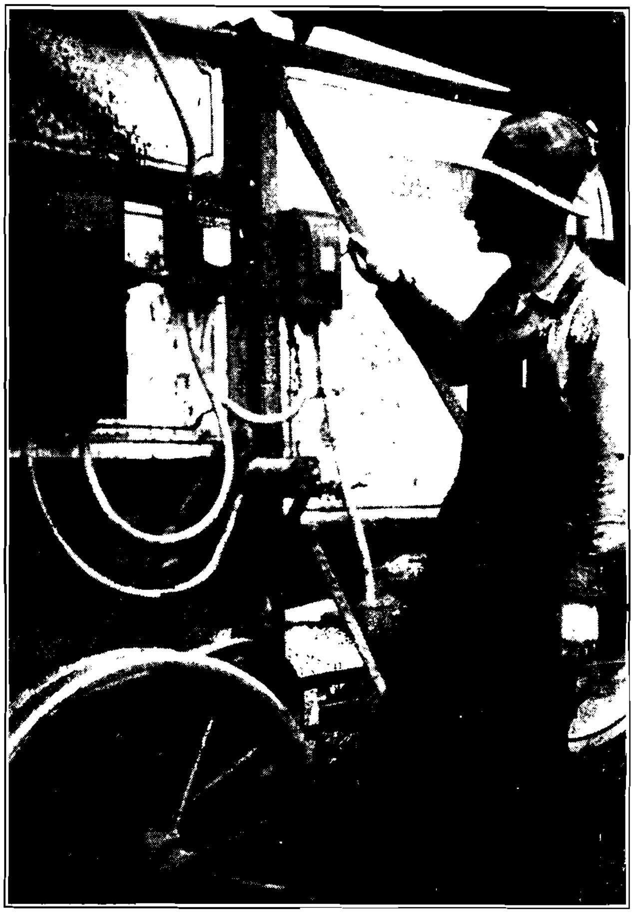

Fig. 104. Switch boxes located together to facilitate starting of machine. Flexible armored cable connections.

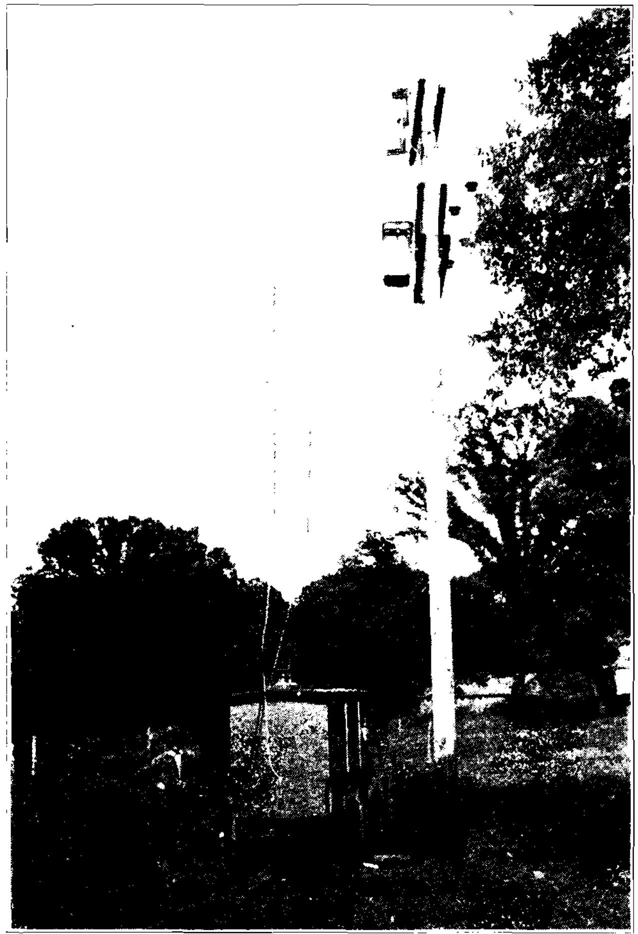

Fig. 105. New transformer truck of 1926 for 6,900 volts. Handles are left hanging to wires.

These records were taken at two farms and show secondary voltages. The normal voltage in 1925 was about 115, as shown on night-time load. When the large motor was operating, the voltage would drop to 110 as a maximum and fluctuate between that and 100, with drops as low as 90 at times of heavy overloads. The chart in Figure 100 shows how satisfactory voltage was secured by the use of a booster transformer. With the booster on, a voltage of approximately 120 was maintained when the threshing machine was in operation, but it was as high as 130 at night. This caused lamps to burn out, so the booster switch was thrown in at 7 a.m. and turned off at 5 p.m. At the time chart Figure 109 was taken, the threshing machine was operated from 7:05 to 11:45 and from 1:45 until 6:00. The two drops in voltage at 6:15 and at 8:45 were caused by starting the machine for testing purposes. The night voltage was not as high as in 1925, yet the drop caused by the large motor was only about 2 volts. The voltage did not drop below 118 except when the motor was started. Many of the charts show when the motor was started several times in the day. The drop in voltage at 5 a.m. was caused by the electric range at Mr. Bryan's farm and represents the drop in the secondary service wires and not in the high line.

Power Requirements

Tests made with indicating wattmeters in 1924 showed the output of the transformer to be about 13.1 kw. when threshing oats and 15.0 kw. when threshing wheat. The loss through the secondary cable was approximately .75 kw. The motor, therefore, had an input of approximately 12.35 kw. on oats and 14.25 kw. on wheat. The normal full load input is 13.8 kw. when the motor is developing 15 h-p. The output of the motor under the two conditions was approximately 13.4 h-p. and 15.4 h-p.

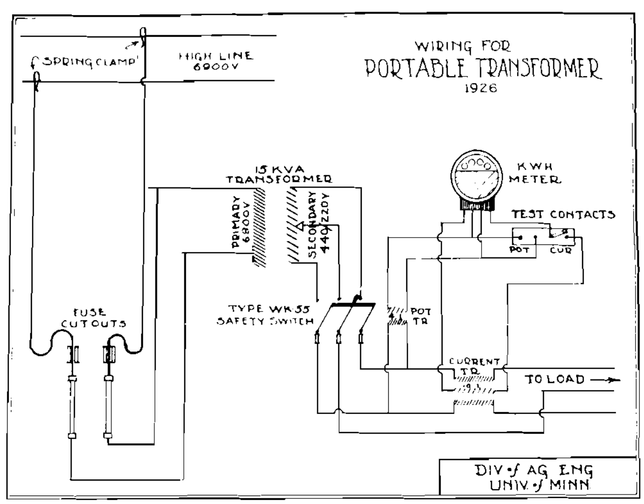

Fig. 106. Wiring diagram of portable transformer of 1926.

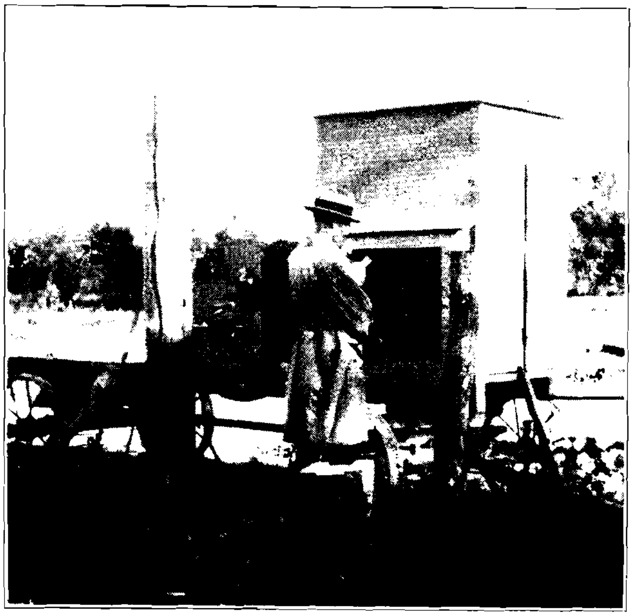

Fig. 107. The reconstructed original truck adapted to hold 6,600 volt equipment for use in 1926.

The power required for operation was measured by a recording wattmeter in 1925, 1926, and 1927. The results taken from some of those graphs are given in Table XC. This gives the power requirements for the whole load and for each of the separate motors. None of the motors was overloaded. In fact, the 5 h-p. was carrying but slightly more than a 3 h-p. load. These data together with those given in Tables XCI and XCII show that the total load in 1925 reached about 18 h-p. as a maximum, and in 1926 it seldom reached 16 h-p.

Graphical Records, 1925

The records on the graphs are made from right to left. The description of the graphs is given on each one. The speed of the chart is indicated on the first three graphs and was uniform throughout the tests. Total power requirements are shown in Figures 110 to 113. Figure 110 shows total power for threshing. The power fluctuates with nearly every bundle from 5 to 8 kw. between minimum and maximum. This large fluctuation in power is characteristic of threshing. Note that the maximum power input at times reaches 20 kw. Wet straw in the bottom of the stack required greater power than the drier grain. Fluctuations because of slow feeding were less frequent. The power required to operate the machine empty, shown just above the letter "a" in "cleaning," was about 10.4 kw.

Figure 111 shows the power required for threshing clover. It is nearly the same as for threshing oats, but did not fluctuate as much and reached a maximum of 17.6 kw. The fluctuations in power are not so regular as where the material is in bundles. The minimum power with the machine empty is shown at the right to be about 10.2 kw. The first peak of over 16.5 kw. was caused by starting the large 15 h-p. motor. The power then dropped back to 6 kw. When the 1½ h-p. motor was started, the power rose to 8 kw., and when the 5 h-p. motor was started, to nearly 16 kw., but dropped back to 10.4 kw. as soon as the machine was in full motion.

Fig. 112 shows the total power required for threshing weedy oats direct from the field. The power is considerably more than shown in Figure 110. The graph shows the power used for threshing slightly more than two loads of grain. The large fluctuation

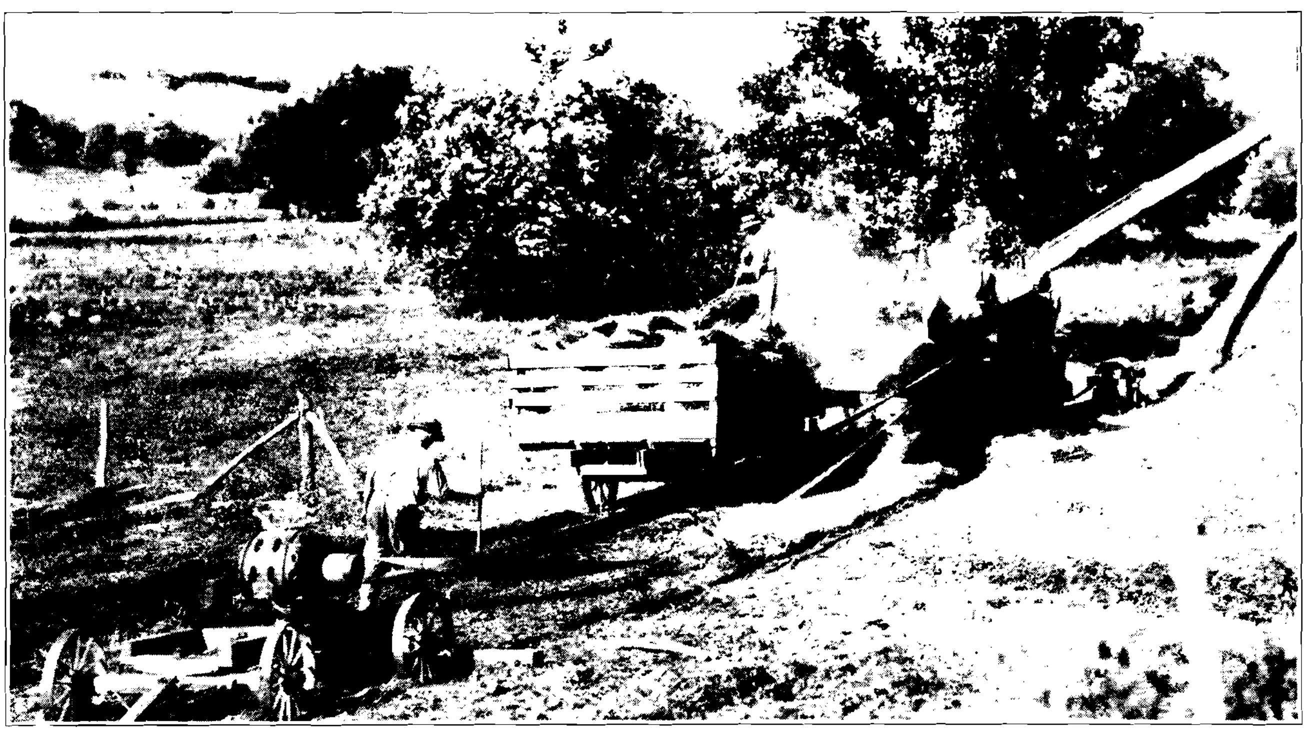

Fig. 108. A 32-inch separator driven by the 15 h-p. motor and a 5 h-p. motor driving the blower.

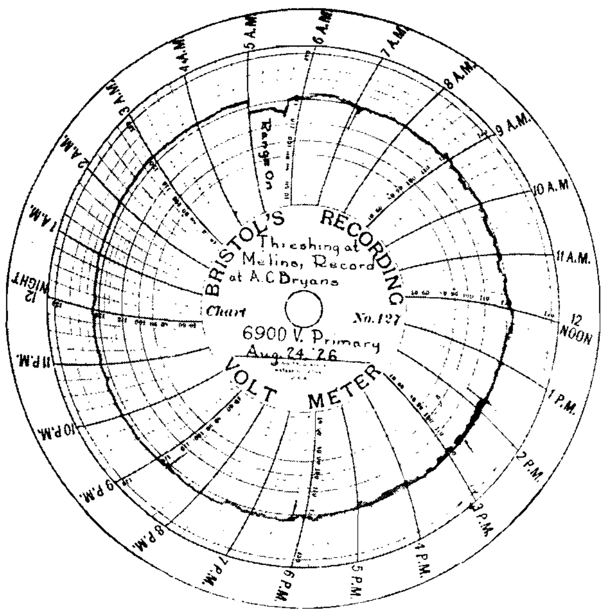

Fig. 109. Voltmeter record with 6,600-volt service showing fine voltage regulation while threshing.

was caused by the weedy condition of the grain. The maximum power at times reached 24 kw.

Figure 113 shows the total power for threshing oats from the field. This is a composite graph. The graph was run continuously for about one hour. Investigation of the graph while it was being taken, showed that the power was gradually increasing owing to the heating of the cylinder bearing. The left half of the graph was taken 45 minutes later than the right half, while threshing the same kind of grain but at a time of the day when the grain should have been getting slightly drier. Note how the average power increased from 14.9 kw. to 17.6 kw. or 18 per cent, owing to the heating of the bearing. The power to run the machine empty, as shown between loads, increased from 10.2 kw. to 12.8 kw., a rather important phase of low-belt speed operation. Higher belt speed gave less bearing trouble.

Figure 114 records were taken on each motor separately. Power records for the 15 h-p. motor, when threshing stacked barley, indicate that a smaller motor could have handled the work. The average power in this case was 10.24 kw. with a maximum of 16 kw., and a no-load minimum of 5.6 kw. The load on the cylinder motor fluctuates greatly.

Figure 115 shows the power required for the 5 h-p. motor operating the blower. The power on this motor does not fluctuate as much as the power for the 15 h-p. motor. Nearly as much power is required to run the blower empty as when straw is going through, the average being 2.8 kw. when loaded and 2.4 kw. when empty. A smaller motor could operate the blower.

Figure 116 shows the power required for the 5 h-p. motor when threshing weedy wheat. The power fluctuates more and the maximum power is greater than in Figure 115, because of the weeds. The record shown in Figure 116 enables us to measure nearly the man-power exerted in pitching off the two loads. The man pitching at the time the left half of the graph was made had been unloading for about three minutes before the part of the record shown was made, and thus took about 18 minutes to unload, with the blower taking 2.82 kw. The next man unloaded in 13½ minutes and the blower required 2.96 kw.

Figure 117 shows the power required for the 1½ h-p. motor. The power fluctuates very little, and the fluctuation, as shown, was caused mostly by changes in voltage from fluctuation of the load on the large motor. Practically all of the power is required to drive the machinery empty.

Power Requirements, 1926

Figure 118 shows the total power required for the new rig in 1926 with a 10 h-p. and a 3 h-p. motor in place of the 15 h-p. and the 5 h-p. motor used in 1925.

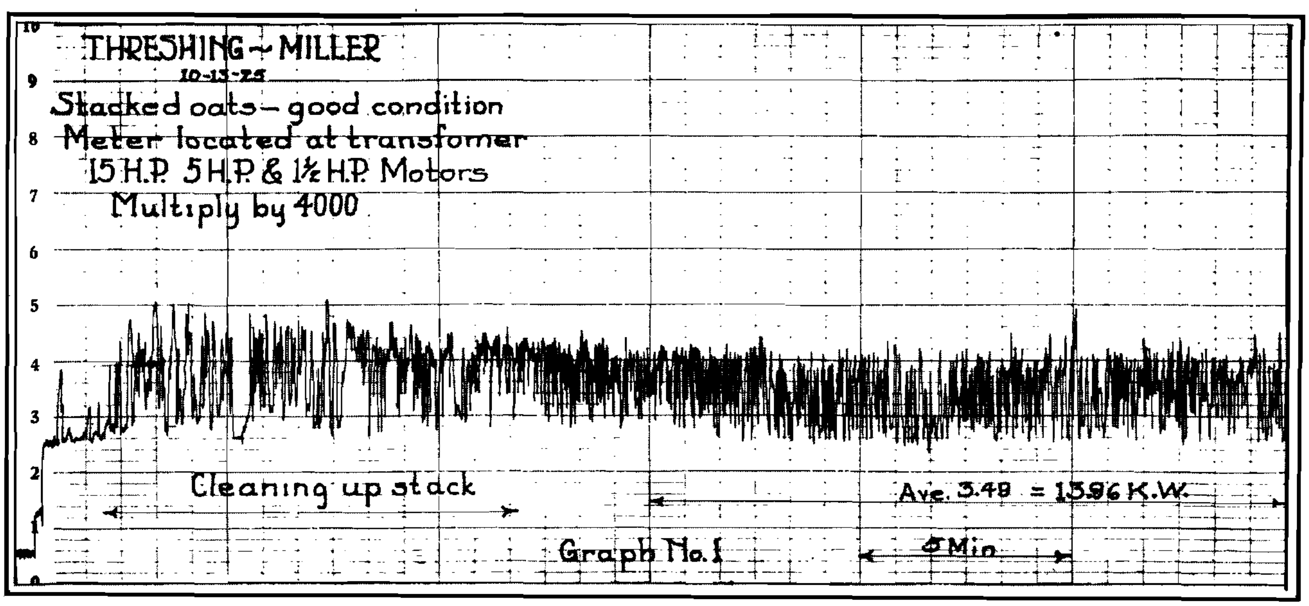

Fig. 110. Wattmeter record total load of threshing oats from stack.

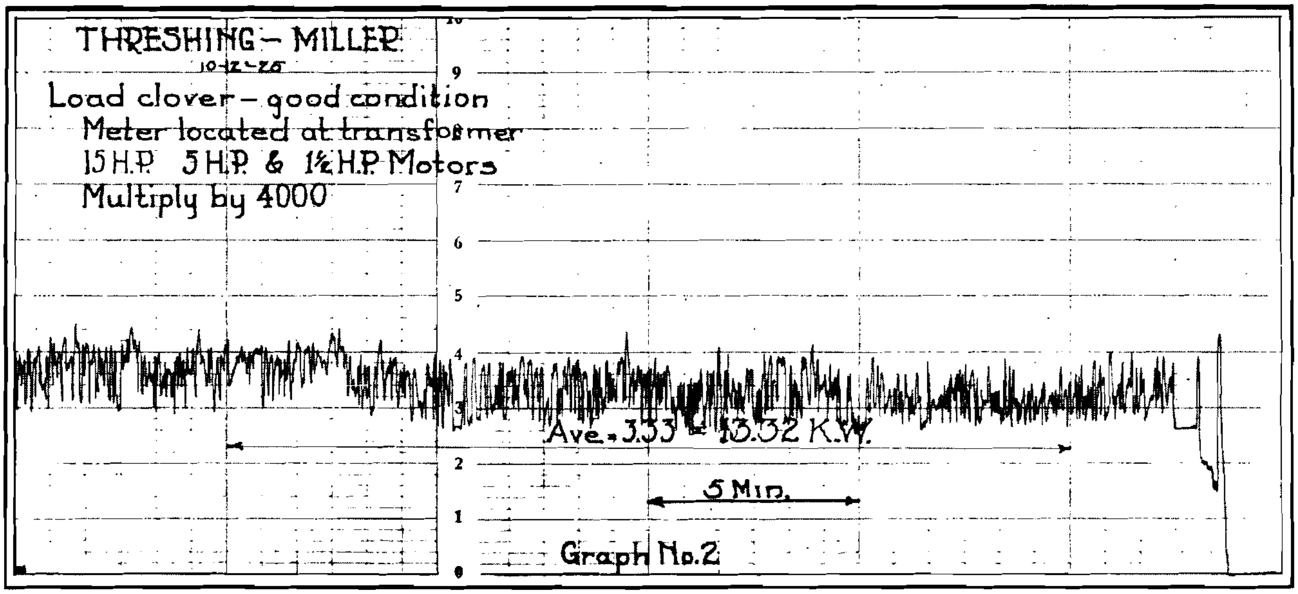

Fig. 111. Wattmeter record total load of threshing a load of clover.

The switches for the 5 h-p. motor, that for the 10 h-p. and then that for the 1½ h-p. were thrown in when starting (at the right). The average power was 14.28 kw. when threshing at full load (170 bushels per hour). The left part of diagram, with men at the far side of the stack, was taken under average threshing conditions (100 bushels per hour). The power required to run the roller-bearing machine empty was only 8 kw., or 2.4 kw. less than the power required to operate the plain-bearing machine.

Figure 119 shows the power used by the 10 h-p. motor under same conditions as in the right part of the graph in Figure 118. There were six very large fluctuations. Fluctuations were greater than with the old machine because of the roller bearings. The power required to run the machine empty was 4.2 kw., which is about 40 per cent of the average full load power. while the previous machine's no-load power was about 5.6 kw. or 50 per cent of the average full-load power.

Figure 120 shows the power required for the 3 h-p. motor under same conditions as in Figure 118 and Figure 119. The 3 h-p. motor was large enough to carry the load. Somewhat less power was required on this roller-bearing blower than for the former machine as shown in Figures 115 and 116, the no-load power being reduced from 2.4 kw. to 1.76 kw. Note the peculiar effect of smoothing out the power required when the belt began to slip.

The total power required, as shown in Figures 110, 111, 112, 113, and 118, includes the loss of power in the secondary cable which varies from .45 kw. to .85 kw. according to load conditions.

The power used on the blower in 1926 is rather low as it was being run at a low speed of 693 r.p.m. When

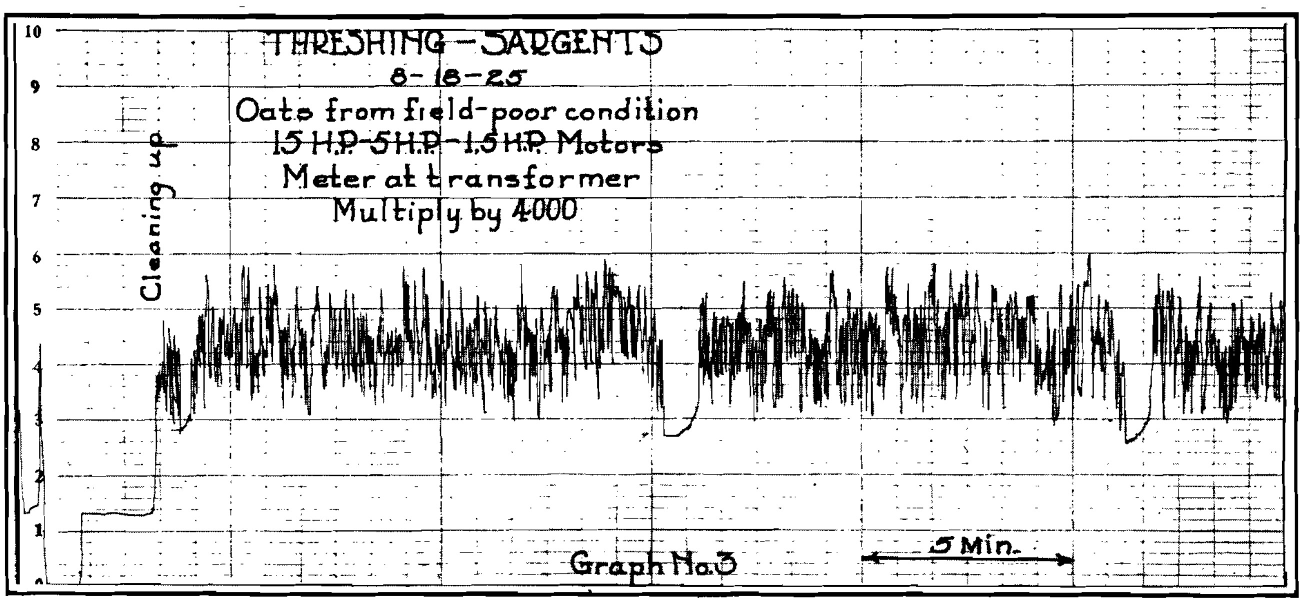

Fig. 112. Wattmeter record total load of threshing oats from the shock.

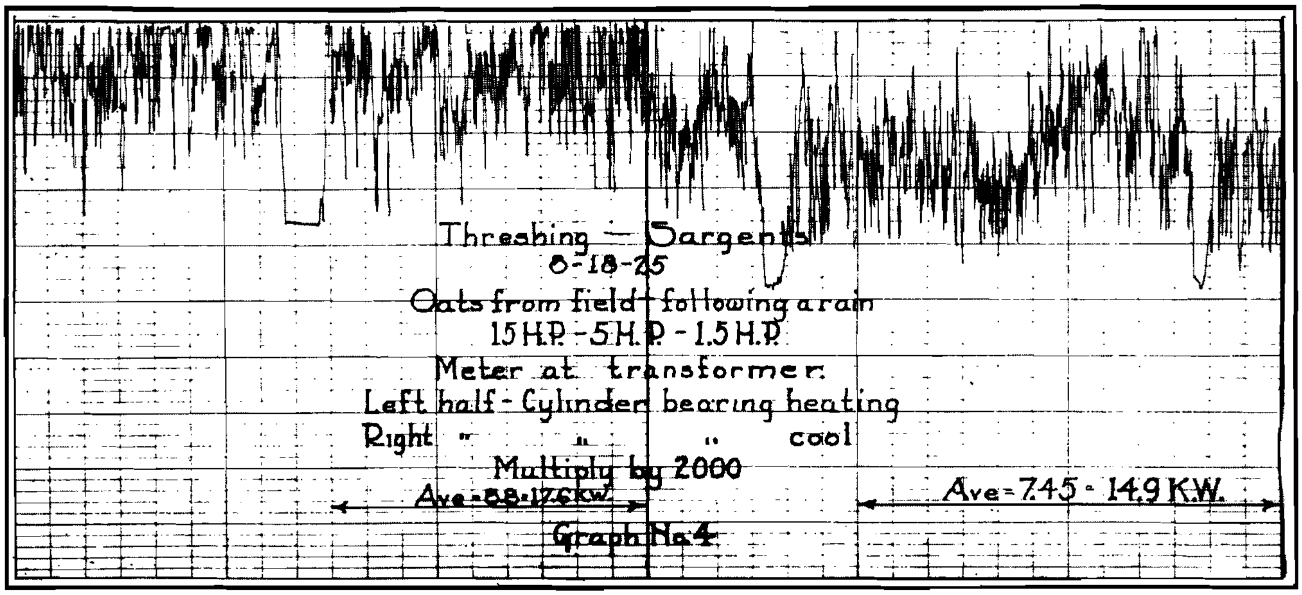

Fig. 113. Wattmeter record total load of threshing oats from the shock.

the machine was first started the blower was running at a speed of about 925 r.p.m. and was taking over 3.5 kw. of power. The blower should run at about 740 r.p.m.

Graphical Records, 1927

Some of the threshing in 1927 was done with a 15 h-p. portable motor belted to a 30-inch cylinder threshing machine, and a portable 5 h-p. motor was used to drive the blower as shown in Figure 108. Records for this rig are shown in Figures 121 to 123, and records of the new rig of 1926 are shown in Figures 124 to 129.

Figure 121 shows the power required for all of the large machine, excepting the blower. The large fluctuation is due to some tough bundles. The average power requirement was not high, being 10.94 kw., but the maximum requirements were as high as 21 kw. very frequently. Feeding had to be slow because of these high overloads.

Figure 122 shows the power requirements with the same equipment and grain three days later than shown in Figure 121. The average power required for the first load was 15.18 kw. or nearly 50 per cent larger than that shown in Figure 121, yet the maximum power seldom exceeded 20 kw. The grain was drier, the power did not fluctuate so greatly, and a heavier average load could be carried and threshing could be done at a higher speed.

Figure 123 shows the power required for operating the 5 h-p. motor belted to the blower. This was a full load for the 5 h-p. motor, but it handled the load readily as the fluctuation in power is only about 1.0 kw.

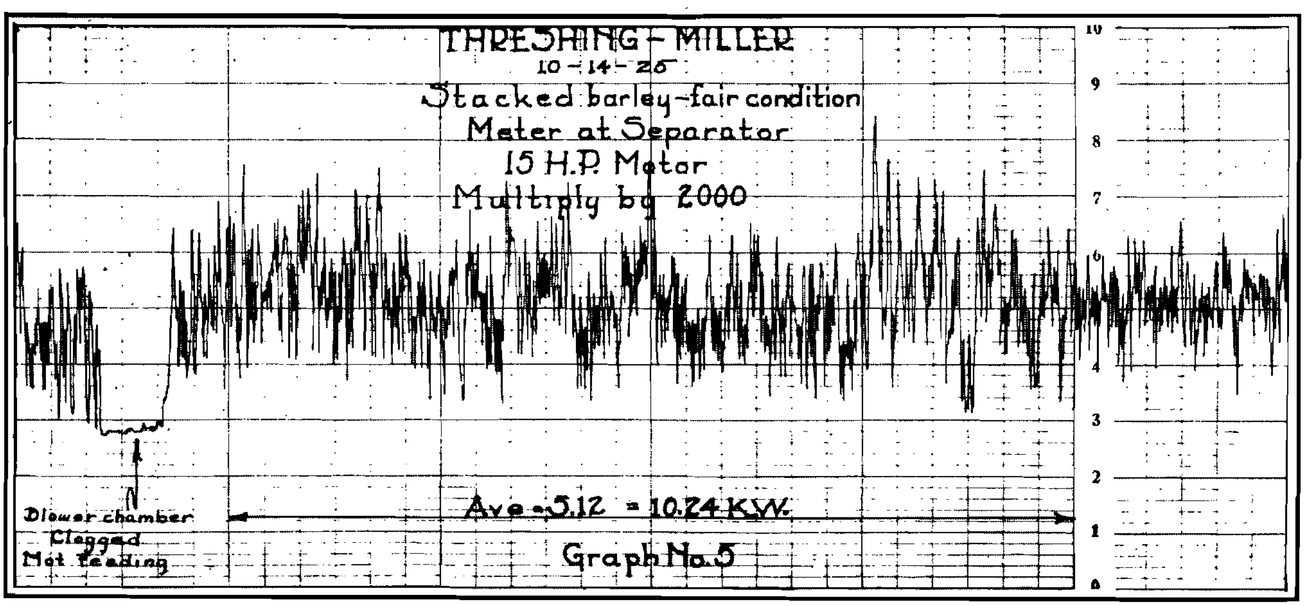

Fig. 114. Wattmeter record 15 h-p. motor of threshing barley from the stack.

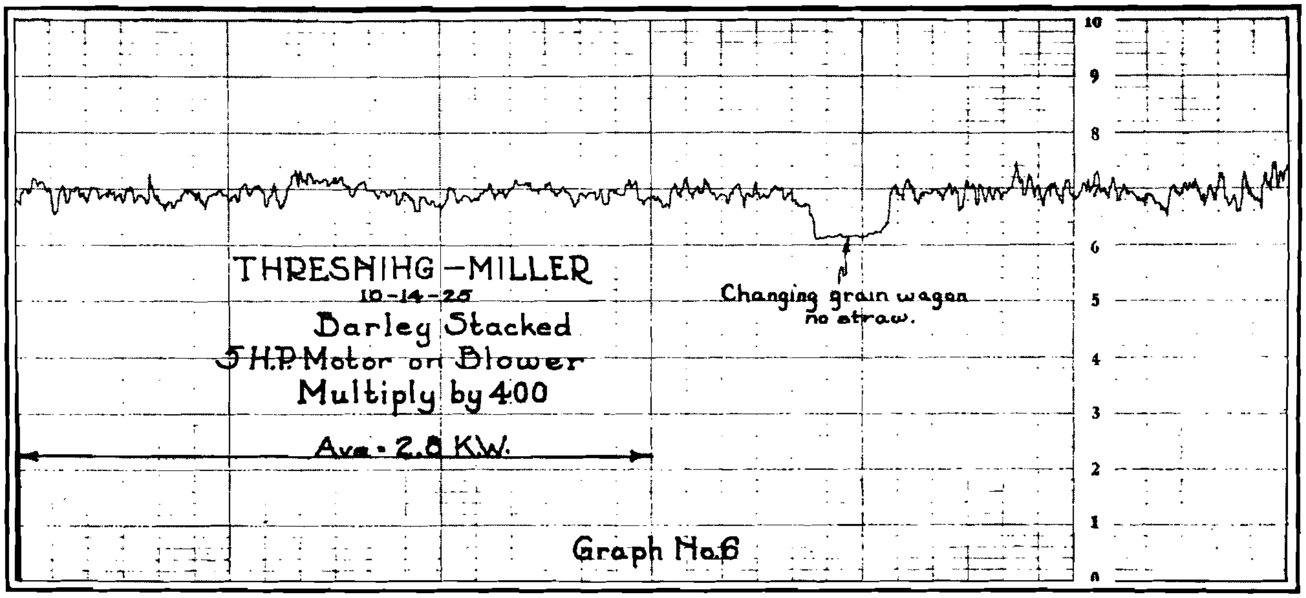

Fig. 115. Wattmeter record of power for the blower when threshing barley from stack.

Figure 124 shows the total power required to operate the new machine. When the grain is in a stack and in good condition, the power is very low, being only 10.88 kw. for the entire rig. This indicates that a rig to be used with a 7½ h-p. motor may be a possibility.

Figure 125 shows the total power required to thresh from the shock. In general, shock-threshing requires less power than stack-threshing, but wheat requires more power than any other grain. The average power required was 12.45 kw. About 18 minutes were required to thresh one load.

Figure 126 shows the power required on the 10 h-p. motor only, when threshing oats from the shock. The motor was not overloaded on the average load, but peak loads of 18 kw. were reached at times. The high peak loads show the necessity for good voltage regulation.

Figure 127 shows the power required for the 3 h-p. motor under conditions similar to those of Figure 126. This motor taking an average power of 2.1 kw. was not fully loaded. Very little power is used to handle the straw as can be seen from the power required to run the blower empty when wagons are changed.

Figure 128 shows the power required for the 1½ h-p. motor under conditions similar to those of Figures 126 and 127. When cleaning oats alone, a speed of 1,450 r.p.m. was sufficient, and required an average power of 1.249 kw. When threshing succotash (wheat and oats) a higher speed was desirable. This required a power of 1.68 kw., because of the higher speed of 1,490 r.p.m. The power increased with the speed, because the power required does not depend on the rate of threshing. This illustrates the desirability of a

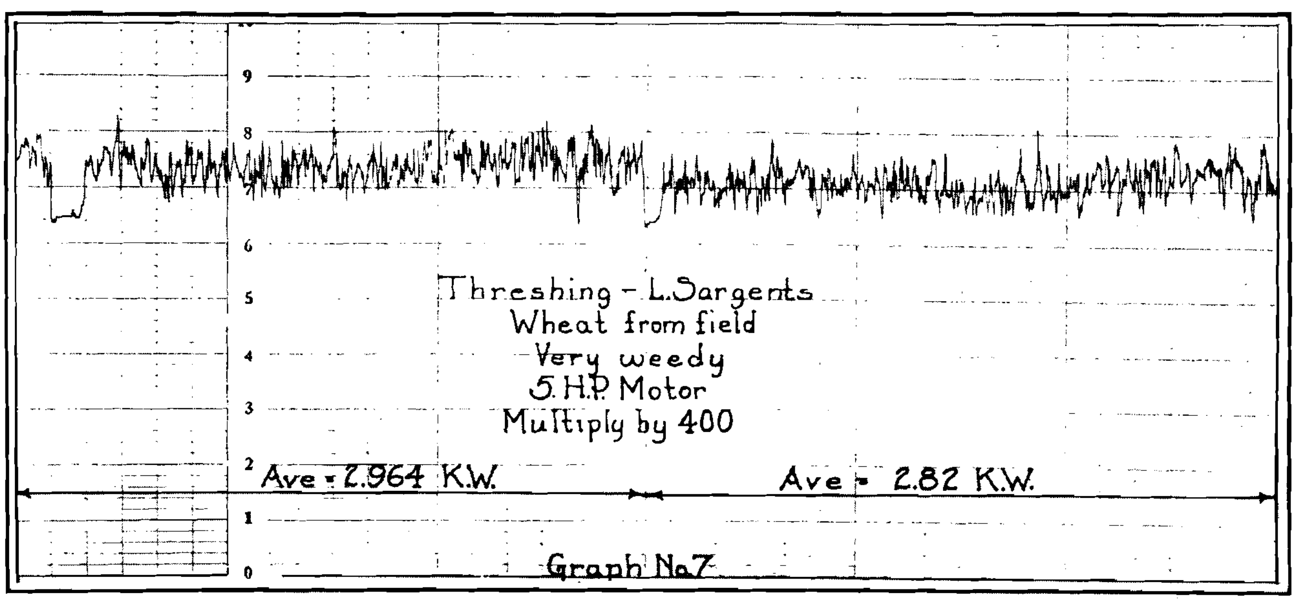

Fig. 116. Wattmeter record of 5 h-p. motor on blower when threshing wheat.

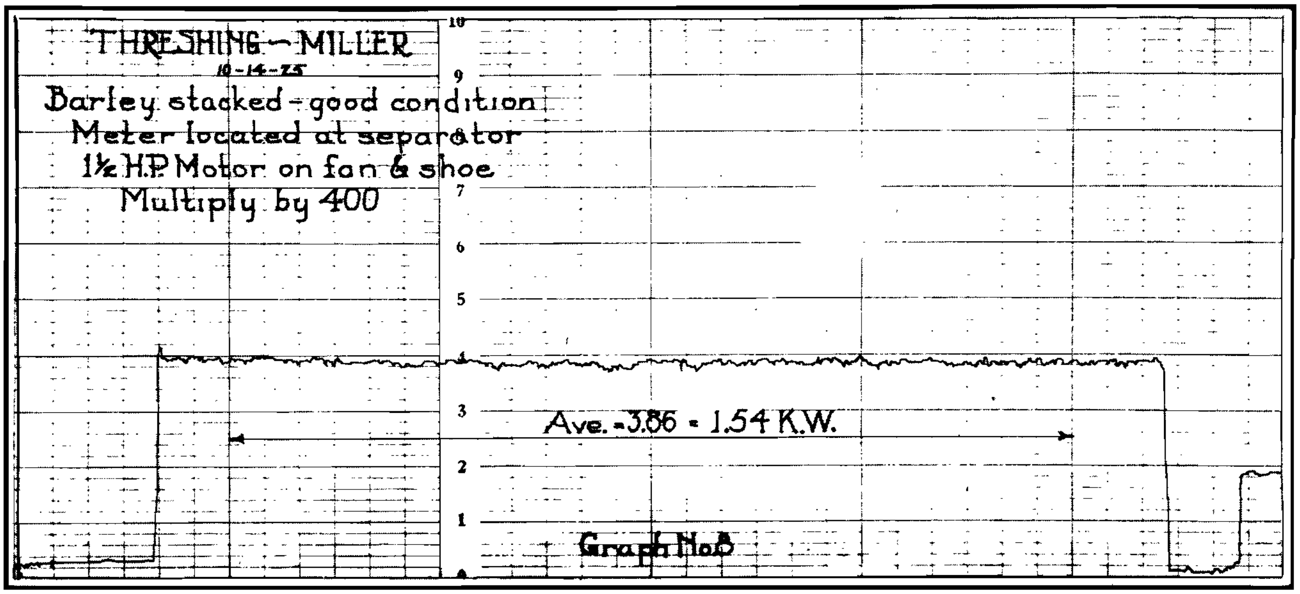

Fig. 117. Wattmeter record of $1\frac{1}{2}$ h-p. motor on fan when threshing barley.

variable speed motor for operating this part of the machine.

Figure 129 shows the power required for the 10 h-p. motor only, when threshing dry barley. With very dry grain the motor was carrying about a two-thirds load. Contrast this with the power required as shown in Figure 126. A $7\frac{1}{2}$ h-p. motor would have run the main part of the threshing machine with this kind of grain.

The records on the graphs, as well as the data given in Table LXXXVII, indicate that about two-thirds of the power to drive a threshing machine at work is required to drive it empty. This varies for the different motors, being for the 1925 rig, 50 per cent for the cylinder motor, 86 per cent for the blower motor, and about 96 per cent for the motor driving the grain pan and fan. The percentages are given in Table LXXXVII.

TABLE LXXXVII

Ratio of the Power Required for Motors Operating with No Grain and with Average Load

Motors	Average input loaded	No load input	Ratio
	Kw.	Kw.	Per cent
All three—1925	15.10	9.8	65
15 h-p.	11.12	5.56	50
5 h-p.	2.88	2.48	86
1.5 h-p.	1.54	1.48	96
All three—1926	12.70	6.84	54
10 h-p.	9.33	3.52	38
3 h-p.	2.05	1.92	95

The power required to drive the 1926 rig without grain is notably decreased by the use of roller bearings.

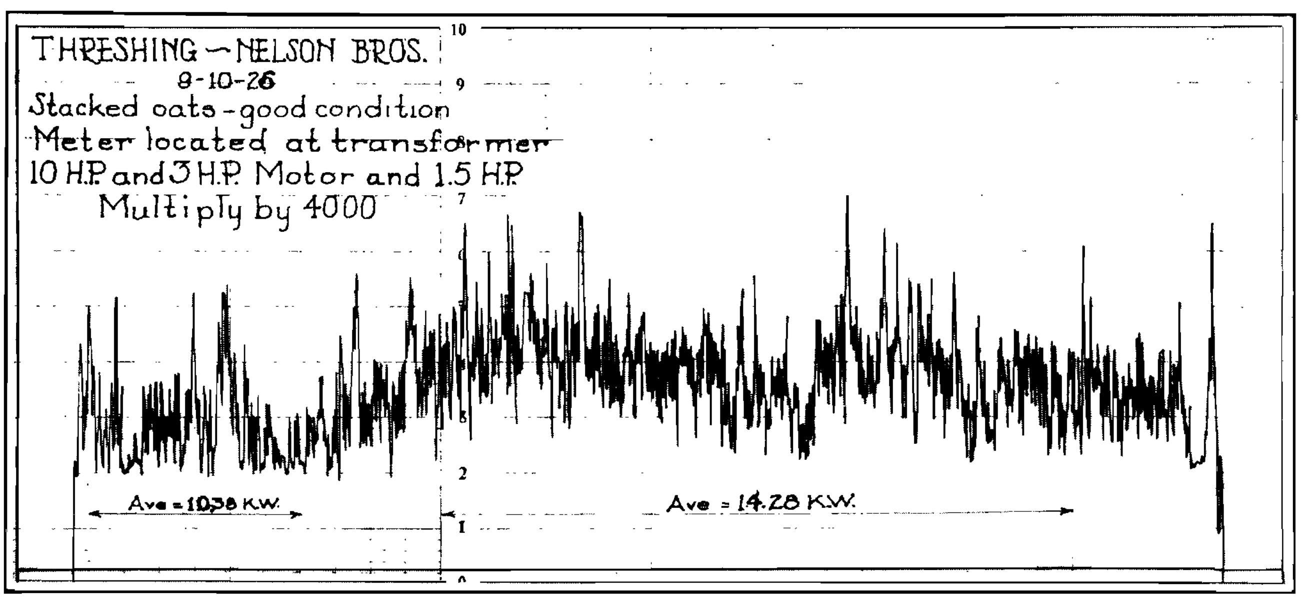

Fig. 118. Wattmeter record of total load, new rig, when threshing oats.

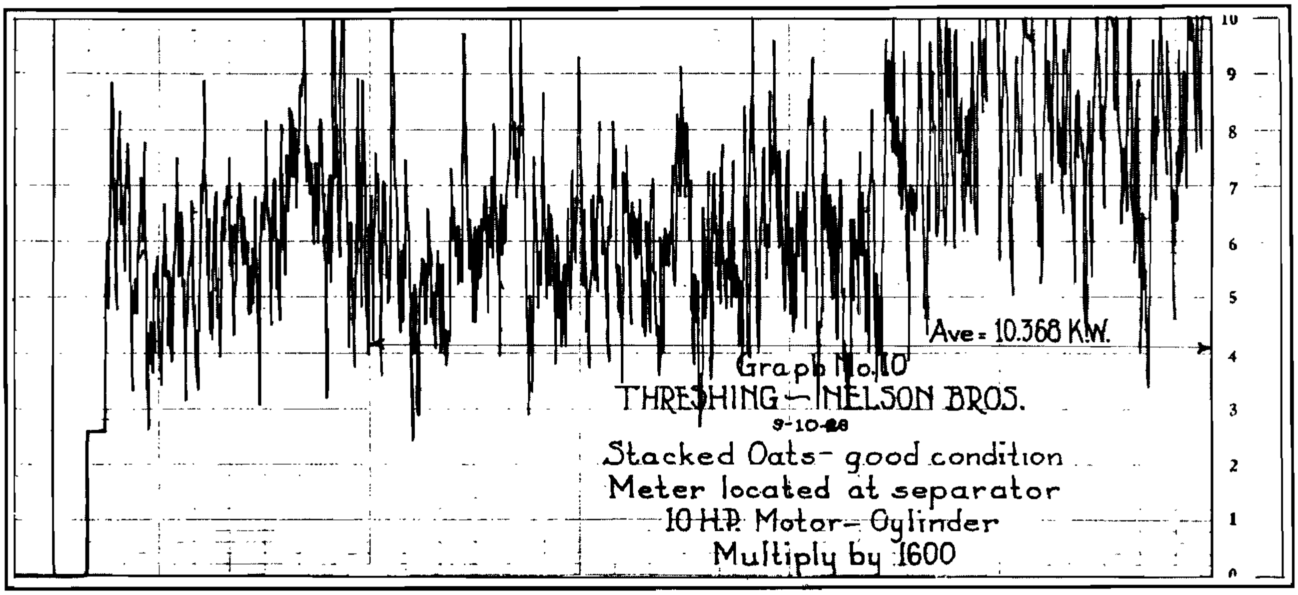

Fig. 119. Wattmeter record of 10 h-p. motor, new rig, when threshing oats.

Explanation of Tables

The data given in Table XCI covers all threshing done by the electric motor in 1924 and 1925. The average energy requirements for 1924 was .128 kw. hr. per bushel or .323 kw. hr. per cwt. of grain threshed. The amount threshed the first year was too small to give much data. It did show that the motor power and energy increased when wet grain was threshed. The average rate of energy consumption was 13.4 kw. hrs. per hour.

The results for 1925 are varied enough to give valuable data. Good dry barley was threshed at an energy requirement of .167 kw. hr. per hundredweight or with energy at 3 cents per kw. hr.; the cost was but .5 cent per hundredweight. On the other hand, wet stacked barley required .427 kw. hr. per hundredweight or over two and one-half times as much. The minimum and maximum values for wheat were respectively .269 kw. hr. and .583 kw. hr.; for oats, .212 kw. hr. and .434 kw. hr. for succotash (oats and wheat), .199 kw. hr. and .252 kw. hr. Succotash appears to thresh very easily and with little variation from place to place. Wheat is the hardest to thresh. This is shown very clearly in Table XCII in which is given the averages and totals for the season of 1925. The energy and power requirements were almost the same as in 1925.

The grain direct from the field or threshed early from stacks required less energy than did stacked grain that was threshed late in the season. Poor crops with weeds require about .5 kw. hr. per hundredweight. Clover seed requires a large energy consumption per

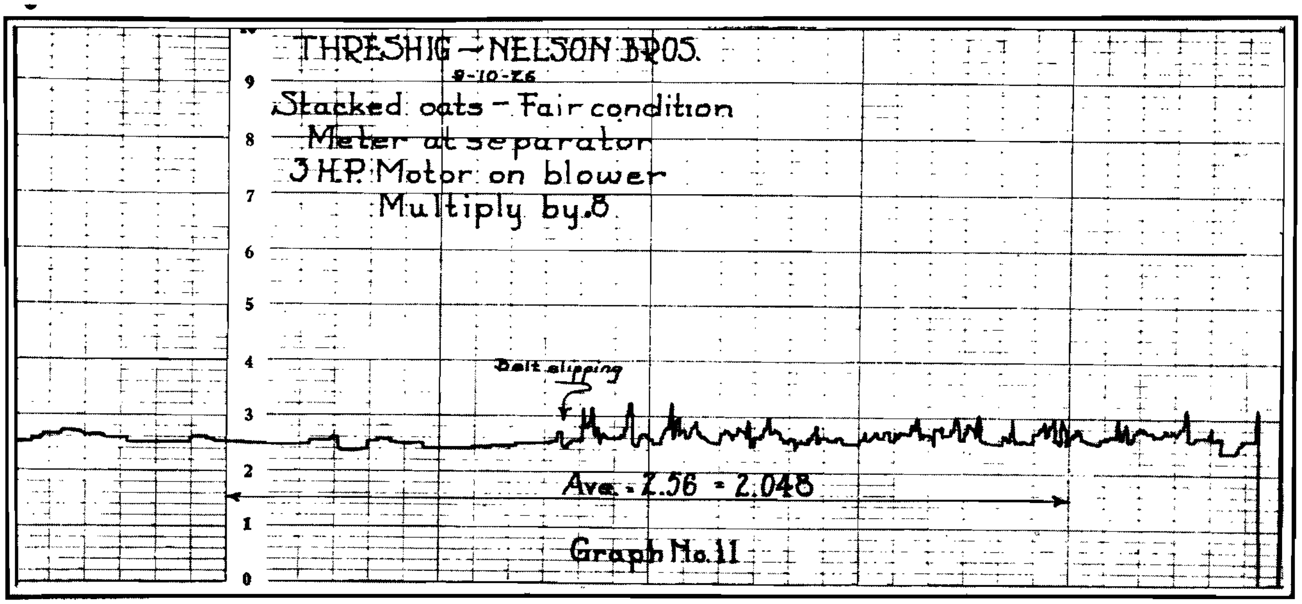

Fig. 120. Wattmeter record of 3 h-p. motor, new rig, when threshing oats.

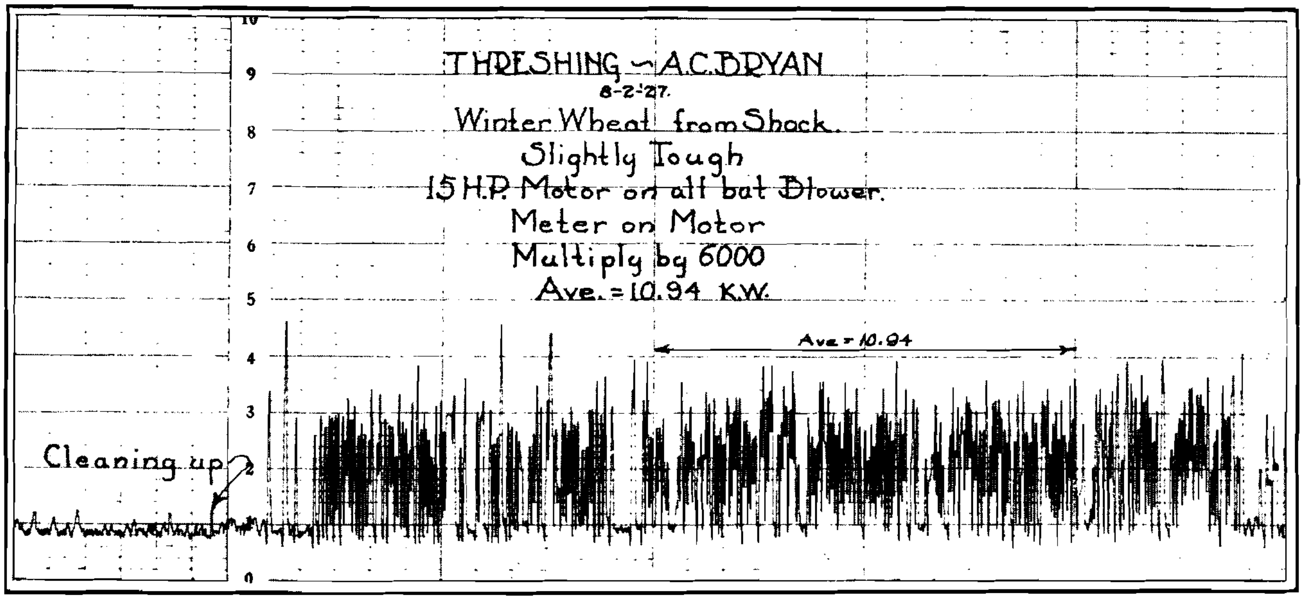

Fig. 121. Wattmeter record of 15 h-p. portable motor driving 32-inch machine threshing wheat.

hundredweight but a small amount of power, usually not more than 10 kw. Very interesting data were secured on August 13 while flax and wheat were being threshed. A heavy dew made the flax straw so tough that it pulled the concaves out twice and it continually howled in the cylinder, while the rest of the machine ran lightly. The first line of the record is for the forenoon and the second line is for the afternoon. The rate of threshing increased in the afternoon and the energy required per bushel or per hundredweight decreased in the afternoon from .632 kw. hr. per hundredweight to .538 kw. hr. per hundredweight. The peculiar thing is that the power requirement as shown by the kw. hrs. per hour was lower in the forenoon than in the afternoon. This was caused by the light running of all of the machine except the cylinder.

The kw. hrs. per hour given in Table XCI is a very accurate gauge of the kw. demand for threshing, as the time recorded in this table was determined from continuous graphs taken during the threshing season. All delays are subtracted and net time only is given.

A part of the grain in the community was not adjacent to the high line and was threshed by the same separator which was driven by a Fordson tractor. The data are given in Table XCIII. The average rate of threshing was a little slower with the tractor, in spite of the fact that all threshing done by the motor after October 6 was of wet stacked grain, while most of that threshed with the tractor was in good condition. All grain but one piece of wheat (dew on it) threshed before August 15 required less than .3 kw. hr. per hundredweight. The results given in Table XCII

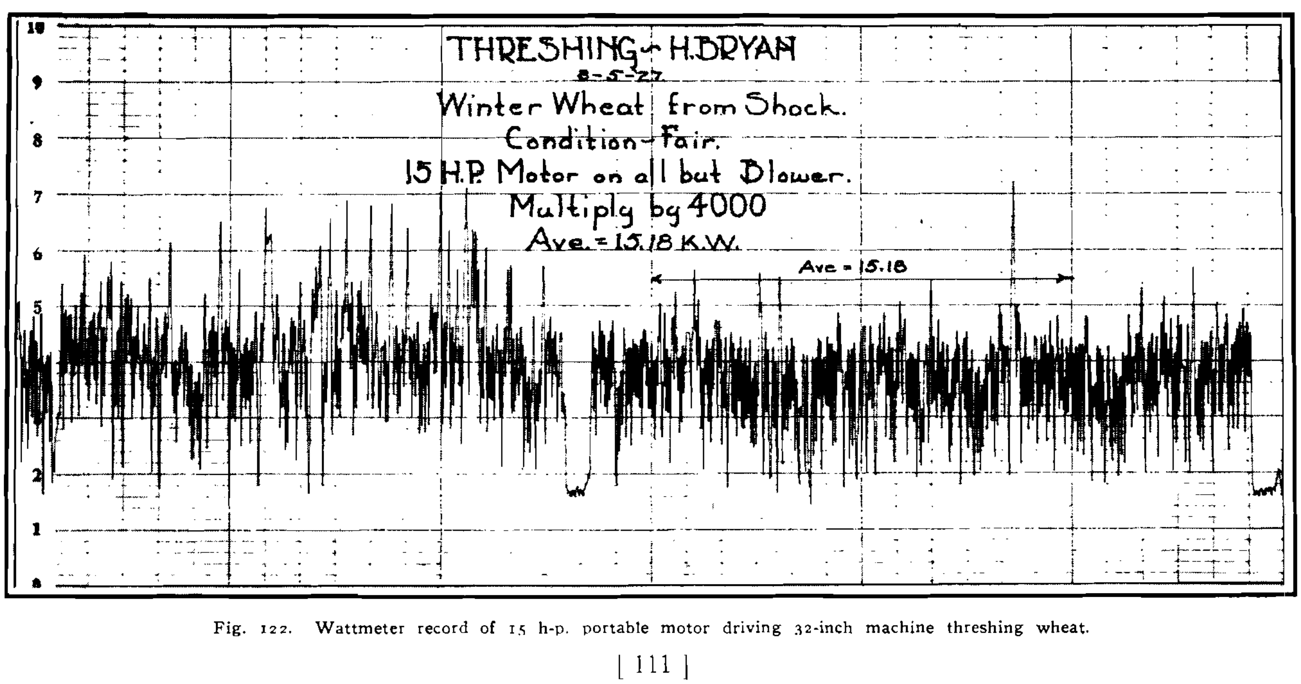

Fig. 122. Wattmeter record of 15 h-p. portable motor driving 32-inch machine threshing wheat.

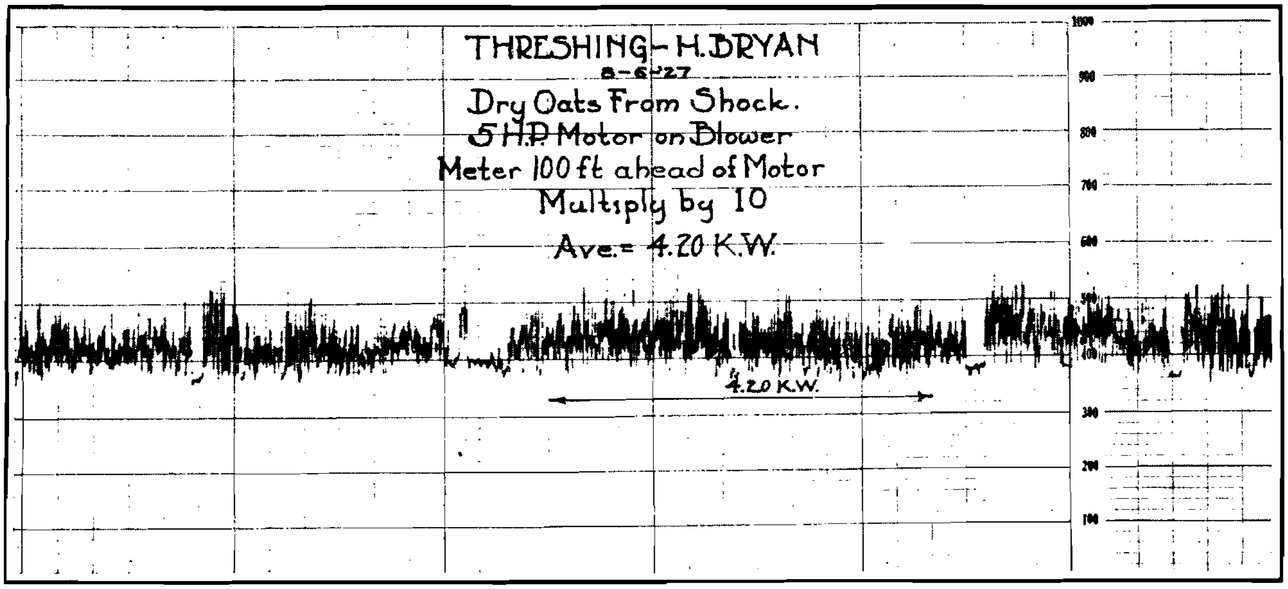

Fig. 123. Wattmeter record of 5 h-p. portable motor on blower.

show the big difference in energy requirement and cost for grain threshed direct from the field, or early from the stacks, as compared to that threshed late in the season from stacks. The costs with a tractor do not vary as much as they do with the motor. Rye appeared to be difficult to thresh. The cost per hundredweight for threshing with the tractor is not very different from that with the electric motor.

The machine was not used much in 1926, but what data are available are given in Table XCIV. The energy consumption was high again for the threshing done late in the season. However, in spite of the high consumption for the latter part of the season, the energy requirements are reduced about 11 per cent and the kw. hrs. are reduced by about 20 per cent for the new ball-bearing threshing machine under the requirements of the year preceding.

The data given in Table XCV are the threshing records for 1927 for the new rig of 1926. These are similar to data given for 1925. The results confirm those for the other machine. Power requirements in general are lower, but the energy requirements are not very different.

A chart on which is shown a summary of the cost of power for threshing as taken from the tables is given in Figure 130. The 1926 rig used less energy. The four grains require different amounts of power as shown, wheat the most, with oats, barley, and succotash following in the order named, succotash requiring slightly over one-half as much as wheat. A comparison of fuel cost for tractor threshing is shown also.

The amount of energy used with the large portable motors and portable transformers during each year is given in Tables XCVII to C. While some of the

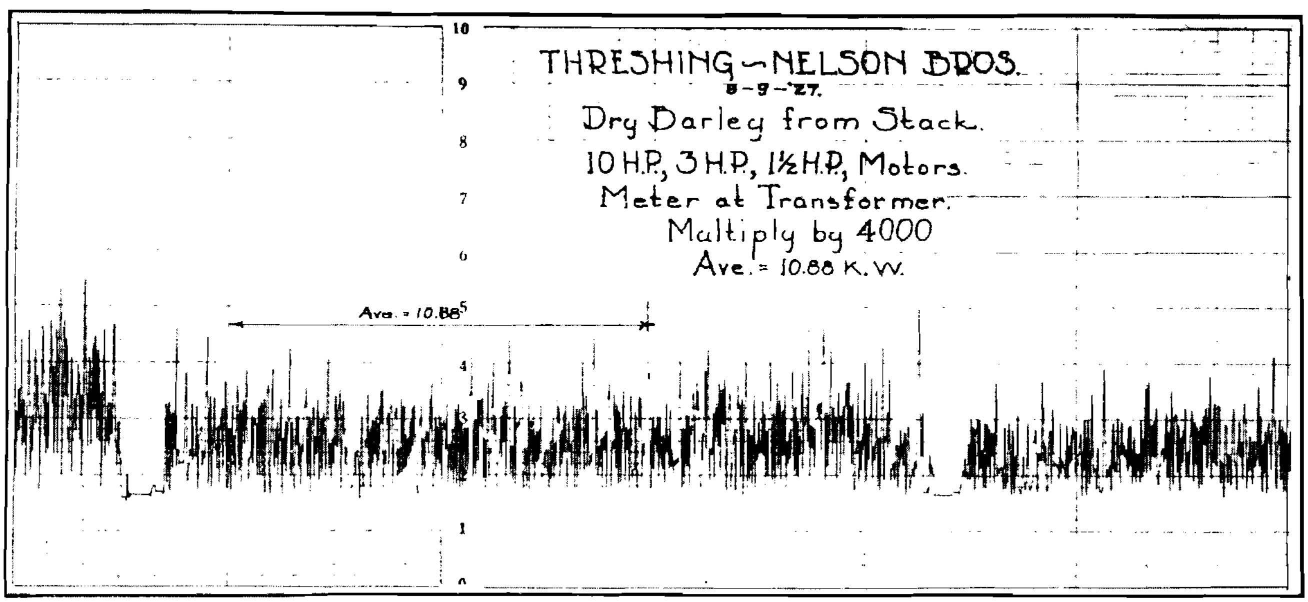

Fig. 124. Wattmeter record of total load, new rig, threshing barley.

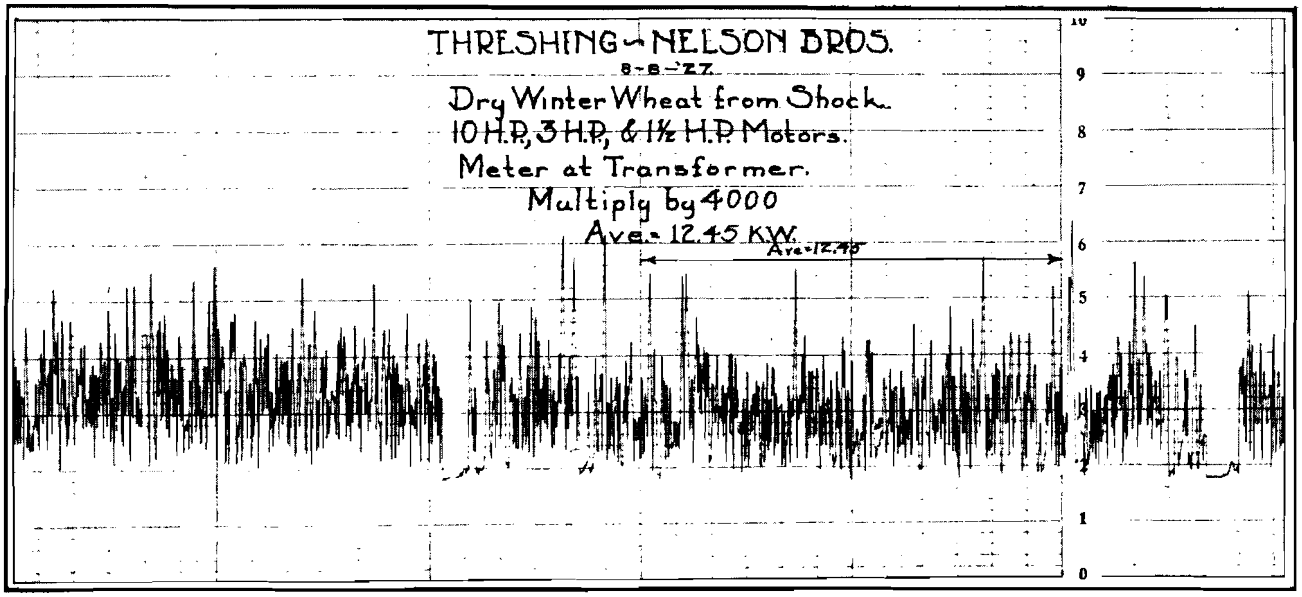

Fig. 125. Wattmeter record of total load, new rig, threshing wheat.

energy was used for ensilage cutting, most of it was used for threshing. Ensilage cutting can now be done by the use of smaller motors. The threshing load in any community represents a considerable amount, varying from 400 kw. hrs. to 2,000 kw. hrs. per farm. The threshing load will usually fit into the late summer or fall valley of the power company load and can be handled easily at that season. The graph in Figure 131 shows the distribution of the energy used through the portable transformer truck in 1925 and 1926. The threshing load may come in August, September, or

TABLE LXXXVIII

TESTS ON POWER FOR THRESHING MACHINE

W. A. Cady, August 1, 1925—Nichols & Shepard, 22 x 36-inch, 1922 Separator, Operated by G. E., 5 h-p., Farm Chore Motor, Single Phase, Type SCR

Condition	Volts	Amperes	Watts, gross	Watts, net	Speed
					r.p.m.
Motor—idling	216.3	16.5	800	....	1,840
Motor — running counter shaft	216.0	15.0	1,000	....	1,834
Driving fan, pan and auger through counter shaft..	215.0	13.3	1,300	390	451*
Driving fan, pan and auger through counter shaft..	213.0	13.0	1,570	570	600*
Driving fan, pan and auger through counter shaft..	212.5	12.6	1,980	980	886*
Driving fan, pan and auger through counter shaft with oats in machine...	212.5	12.6	2,000	1,000	886*
To start above with oats in machine	212.5	12.7	2,120	1,120	886*
Driving blower — without counter shaft	216.0	12.8	2,080	1,280	488†
Driving blower — without counter shaft	211.0	16.3	3,120	2,320	600†
Driving blower — without counter shaft with some straw	210.0	16.8	3,200	2,400	600†

Normal speed of fan is 590 r.p.m.
Normal speed of blower is 760 r.p.m.

* Fan shaft.
† Blower.

TABLE LXXXIX

TESTS ON POWER FOR FAN, GRAIN PAN AND GRAIN AUGER

Nichols & Shepard, 22 x 36-inch, 1922 Separator, Operated by a 1.0 h-p., Type BSR Motor

Test No.	Condition	Volts	Amperes	Volt-Amp.	Watts	P.F.	Speed of motor
						Percent	r.p.m.
1	No load voltage..	240	..	.....	....	...	....
2	Starting — high speed	222	16.0	3,552.0	1,200	33.8	....
3	Full speed — air all on	229	8.6	1,969.4	1,480	75.1	1,280
4	Partial speed—air all off	232	5.0	1,160.0	1,010	87.1	1,174
5	Normal load—air part on	233	4.8	1,118.4	940	84.0	1,130
6	Same as 5—blower motor on...	215	4.2	903.0	830	91.9	1,090
7	High speed — air all off	230	7.0	1,610.0	1,390	86.3	1,360
8	Full speed — air on—grain in..	225	7.2	1,620.0	1,480	91.4	1,246
9	Same as 8—blower motor on...	206	6.8	1,400.8	1,330	94.9	1,004

October or all three months, depending upon the weather conditions.

The data given in Table XCVI show how the costs of energy for threshing are dependent upon the machine, the way the threshing is handled, and the proper adjustment of the machine. The type of grain threshed is very similar in all cases. All of the grain of the first two jobs was threshed from the field and most of that of the last job. A different kind of threshing machine was used at each place. Mr. Cady's machine was in fine operating condition, while the other two may not have been. One machine was a 22 x 36-inch separator and was driven by the 15 h-p. motor. The motor was being badly overloaded but owing to the improved voltage on the line it carried an average input of 18.2 kw. The voltage was almost stationary at 480. On the third day an attempt was made to relieve the motor of its over-loading by using a 5 h-p. motor

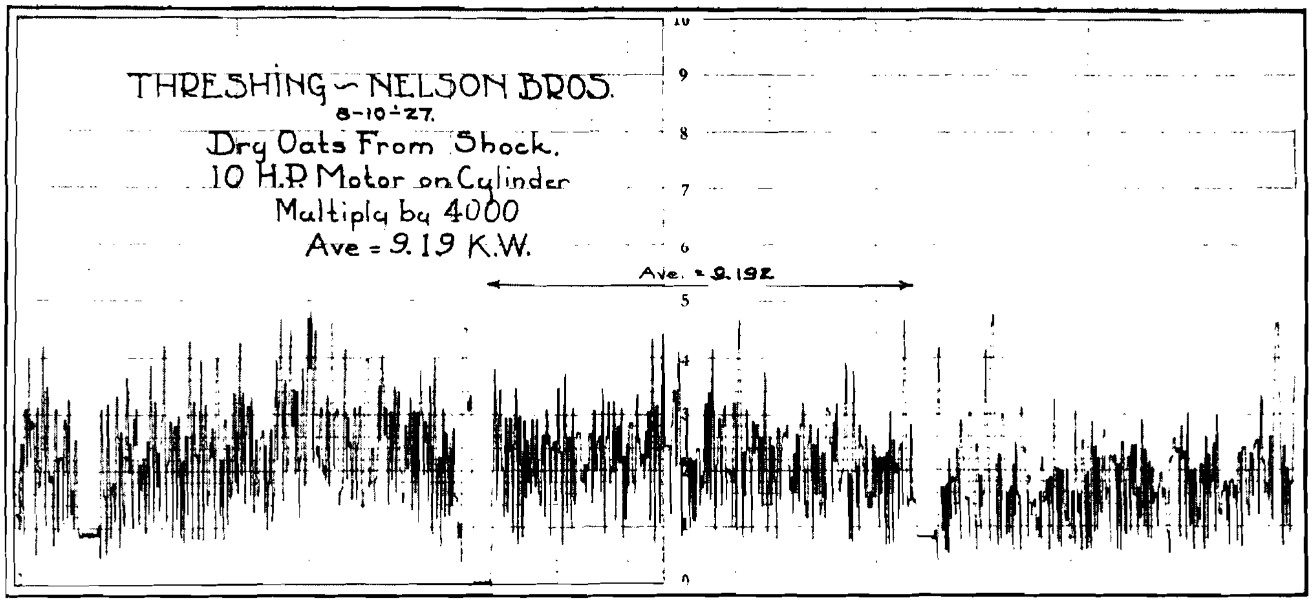

Fig. 126. Wattmeter record of 10 h-p. motor, new rig, threshing oats.

TABLE XC
POWER REQUIREMENT FOR THRESHING MACHINES

Motor	Date	Testing time	Input	Output	Grain
		Min.	Kw.	H-p.	
3 motors	10/12/25	20	13.32	13.8	Clover seed
3 motors	10/12/25	15	13.06	14.7	Oats
3 motors	8/18/25	20	14.90	15.7	Oats
3 motors	8/18/25	30	17.84	18.9	Oats
3 motors	10/12/25	..	9.80	10.3	No grain
15 h-p.	8/18/25	20	12.00	13.2	Oats
15 h-p.	10/14/25	20	10.24	11.3	Barley
15 h-p.	10/14/25	..	5.56	6.1	No grain
5 h-p.	10/14/25	20	2.80	3.1	Barley
5 h-p.	10/12/25	10	3.08	3.4	Clover seed
5 h-p.	8/17/25	20	2.80	3.1	Oats
5 h-p.	8/17/25	20	2.85	3.1	Wheat
5 h-p.	8/17/25	..	2.48	2.7	No grain
1½ h-p.	10/14/25	20	1.54	1.7	Barley
1½ h-p.	10/14/25	..	1.48	1.6	No grain
3 motors	9/10/26	5	10.38	10.7	Oats
3 motors	9/10/26	10	13.66	14.3	Oats
3 motors	9/10/26	15	14.28	14.9	Oats
3 motors	9/10/26	..	6.84	7.5	No grain
10 h-p.	9/10/26	20	8.34	9.3	Oats
10 h-p.	9/10/26	20	10.37	11.4	Oats
10 h-p.	9/10/26	..	3.52	3.9	No grain
3 h-p.	9/10/26	20	2.05	2.25	Oats
3 h-p.	9/10/26	..	1.92	2.11	No grain

on the blower. This dropped the power input to the 15 h-p. motor to 14.3 kw. The pulley on the small motor was not of the proper size and the blower did not run fast enough so the 5 h-p. motor was not used and the 15 h-p. motor was again required to drive the whole machine. An expert adjusted the separator, and a test the next day showed an input of 15.2 kw., or a decrease of 16 per cent.

Moving the Machine

Some other power, such as horses or a tractor, must be available for moving both the threshing machine and the transformer truck. Use of such power might not be practical with large rigs that cover a wide territory. The tendency in recent years, however, has been toward the smaller machine. In Europe, many small threshing machines are in use, and, where electric motors are used, a threshing machine serves but a few farmers. In many cases each farmer has a machine of his own. When the threshing machine is of small size and is used on only a few farms, it is simple enough to transport it with a team of horses. The one at Red Wing has been moved by horses or tractor. The transformer truck is moved by horses. Some time is saved by not having to line up the tractor, level it up and put on the belt. The average of seven moves when using the tractor for threshing was 1.4 hours. The average time for moves of about three-fourths mile with the electric outfit was one hour. Some time is saved when more than one setting is made at the same farm or where two farms are close enough together to leave the transformer truck in the same place for both. Resettings have been made on the same farm and threshing begun again in 18 minutes. A move of 15 rods was made at one farm and threshing started again in 17 minutes. The cable is 750 feet long, so threshing jobs not more than 45 rods from the high line can be done with the electric motors.

Conclusions

Threshing by electric motors is feasible and economical.

Three motors give better results than one motor alone.

The cost of electricity at 3 cents per kw. hr. is about the same as the cost for kerosene and oil, with good engine operation.

Time can be saved during threshing by using electricity so as to increase the total amount threshed per day.

It is highly important that grain be threshed when in good condition if the costs are to be at a minimum.

A roller-bearing threshing machine requires less power and less energy than does a plain bearing machine of the same size and make.

TABLE XCI

THRESHING, 1924

Date	Farm	Time, hrs.	Grain	Condition	Amount Bu.	Amount Cwt.	Rate per hour Bu.	Rate per hour Cwt.	Kw. hrs. Large motor	Kw. hrs. Small motor	Total kw. hrs.	Kw. hrs. per bu.	Kw. hrs. per cwt.	Cost per cwt. at 3 cents per kw. hr. Cents	Kw. hrs. per hr.
9/11	County	5.5	Oats	Moist stacked	640	205	116	37.23	Only one		65.0	.101	.317	0.951	11.81
9/24	Erickson (Melin)	4.2	Oats & wheat	Dry field	482	217	115	51.60	15 h-p.		53.0	.109	.252	.756	12.62
9/22	Melin	3.6	Oats	Wet stacked	465	149	129	41.38	motor		53.0	.114	.355	1.065	14.72
9/22	Melin	4.5	Wheat	Wet stacked	275	165	60	36.90	used		67.0	.244	.406	1.218	14.89
		17.8			1,862	736	105	41.7			238.0	.142	.332	0.997	13.51

THRESHING, 1925

Date	Farm	Time, hrs.	Grain	Condition	Amount Bu.	Amount Cwt.	Rate per hour Bu.	Rate per hour Cwt.	Kw. hrs. Large motor	Kw. hrs. Small motor	Total kw. hrs.	Kw. hrs. per bu.	Kw. hrs. per cwt.	Cost per cwt. at 3 cents per kw. hr. Cents	Kw. hrs. per hr.
8/7	Cady	3.6	Wheat	Fair field	310	186.0	86.11	51.66	41	9.0	50.0	.161	.269	0.807	13.61
8/7	Cady	1.1	Oats	Dry field	177	56.6	160.9	51.31	10	2.0	12.0	.067	.212	.636	10.91
8/7	Cady	2.2	Barley	Good dry field*	300	144.0	136.36	65.45	20	4.0	24.0	.080	.167	.501	10.91
8/8	Albert Nelson ...	3.3	Wheat	Field	285	171.0	86.36	51.81	41	9.2	50.2	.176	.294	.882	15.21
8/8	Albert Nelson ...	.3	Oats	Field	40	13.8	133.33	4.60	3	0.8	3.8	.095	.276	.828	12.67
8/10	Arthur Nelson...	3.5	Oats & wheat	Good dry field	658	210.6	188.00	60.17	43	10.0	53.0	.080	.252	.756	15.11
8/10	Arthur Nelson...	1.9	Oats	Good dry field	347	110.0	182.74	57.89	24	6.0	30.0	.086	.273	.819	15.79
8/11	Arthur Nelson...	1.4	Barley	Dry field	164	78.7	117.14	56.21	17	4.0	21.0	.128	.268	.804	15.00
8/11	Albert Nelson ...	7.5	Oats & wheat	Dry good field	1,386	543.5	184.80	72.47	88	20.0	108.0	.077	.199	.597	14.40
8/12	Albert Nelson ...	2.9	Oats	Dry field	535	171.2	184.48	59.03	32	8.0	40.0	.075	.234	.702	13.79
8/13	Gove	3.8	Flax &	Good—	136	81.6	35.80	21.5	40	11.6	51.6	.379	.632	1.896	13.60
			wheat	Very tough	178	108.8	48.10	29.4	45.5	13.1	58.6	.329	.538	1.614	15.80
8/14	Gove	1.5	Oats	Fair field	248	79.4	165.3	52.9	14.5	4.7	19.2	.077	.242	.726	13.8
8/14	Gove	3.6	Wheat	Tough field	212	127.2	58.8	35.3	52	11.0	63.0	.297	.495	1.485	17.5
8/14 8/15	County	3.4	Oats & wheat	Good field	655	209.6	192.6	61.6	40	10.0	50.0	.076	.243	.729	14.7
8/15	Cady	2.7	Oats & wheat	Good field	525	168.0	194.4	62.2	32	8.0	40.0	.076	.238	.714	14.81
8/15	Cady	1.3	Oats	Good tough field	198	63.4	152.3	48.7	18	5.0	23.0	.116	.363	1.089	17.7
8/15	Cady	.4	Timothy	Fair	8	3.6	20.0	9.0	4	1.5	5.5	.687	1.527	4.581	13.7
8/17	L. Sargent.......	6.9	Oats	Poor field	900	288.0	130.4	41.7	70	22.0	92.0	.102	.319	.957	13.3
8/17	L. Sargent.......	.5	Wheat	Poor field	25	15.0	50.0	30.0	6	1.5	7.5	.300	.500	1.500	15.0
8/18	C. Sargent.......	1.5	Wheat†	Very poor field	70	42.0	46.7	28.0	21	5.0	26.0	.383	.619	1.857	16.0
8/18	C. Sargent.......	3.9	Oats	Poor moist field	407	130.4	104.4	33.4	51	11.0	62.0	.152	.476	1.428	15.9
8/19	Tyler	3.5	Oats	Good dry stacked	665	212.8	190.0	60.8	40	10.0	50.0	.075	.235	.705	14.3
8/19	Lokkesmoe	1.2	Oats	Good dry stacked	207	66.2	172.5	55.2	12	4.0	16.0	.077	.242	.726	13.3
8/19	Lokkesmoe	1.5	Wheat	Poor stacked	75	45.0	50.0	30.0	20	5.0	25.0	.333	.556	1.668	16.7
8/19	Lokkesmoe	0.9	Barley	Fair stacked	78	37.4	86.7	41.6	10	2.5	12.5	.160	.334	1.002	13.9
10/6	Nelson Brothers..	9.0	Barley	Fair wet stacked	710	340.8	79.0	37.9	92	53.0	145.0	.204	.427	1.281	16.1
10/7	Nelson Brothers..	11.5	Oats	Fair wet stacked	1,260	403.2	109.0	35.0	112	64.0	176.0	.139	.434	1.312	15.3
10/13	Miller	10.0	Oats	Good moist stacked	1,530	489.6	153.00	48.90	112	50.0	162.0	.106	.331	.993	16.2
10/14	Miller	3.0	Barley	Fair stacked	225	108.0	75.00	36.0	28	16.0	44.0	.195	.407	1.221	14.7
10/12	Miller	8.0	Clover seed	Poor field	10	6.0	1.25	.75	48	32.0	80.0	8.0	13.3	39.9	10.0
10/14	Charlson	3.0	Oats	Fair tough stacked	370	118.4	123.00	39.4	36	15.0	51.0	.138	.431	1.293	17.0
10/15	Hedberg	4.0	Oats	Fair moist stacked	590	188.8	147.00	47.2	44	21.0	65.0	.110	.344	1.032	16.2
10/15	Hedberg	3.0	Wheat	Fair wet stacked	166	99.6	55.0	33.2	36	15.0	51.0	.307	.510	1.530	17.0
10/15	Hedberg	2.5	Barley	Good stacked	275	130.8	110.00	52.3	20	12.0	32.0	.116	.244	.732	12.8
10/15	Hedberg	3.3	Clover seed	Fair field	5	3.0	1.50	.9	24	12.0	36.0	7.2	12.0	36.0	10.9
10/16	Melin	8.0	Wheat	Fair wet stacked	360	216.0	45.00	27.0	84	42.0	126.0	.350	.583	1.749	15.7
10/17	Melin	2.3	Clover seed	Good field	5	3.0	2.10	1.3	16	9.0	25.0	5.0	8.3	24.9	10.8

† Wheat was half weeds.

* Indicates good crop, dry condition, threshed from field.

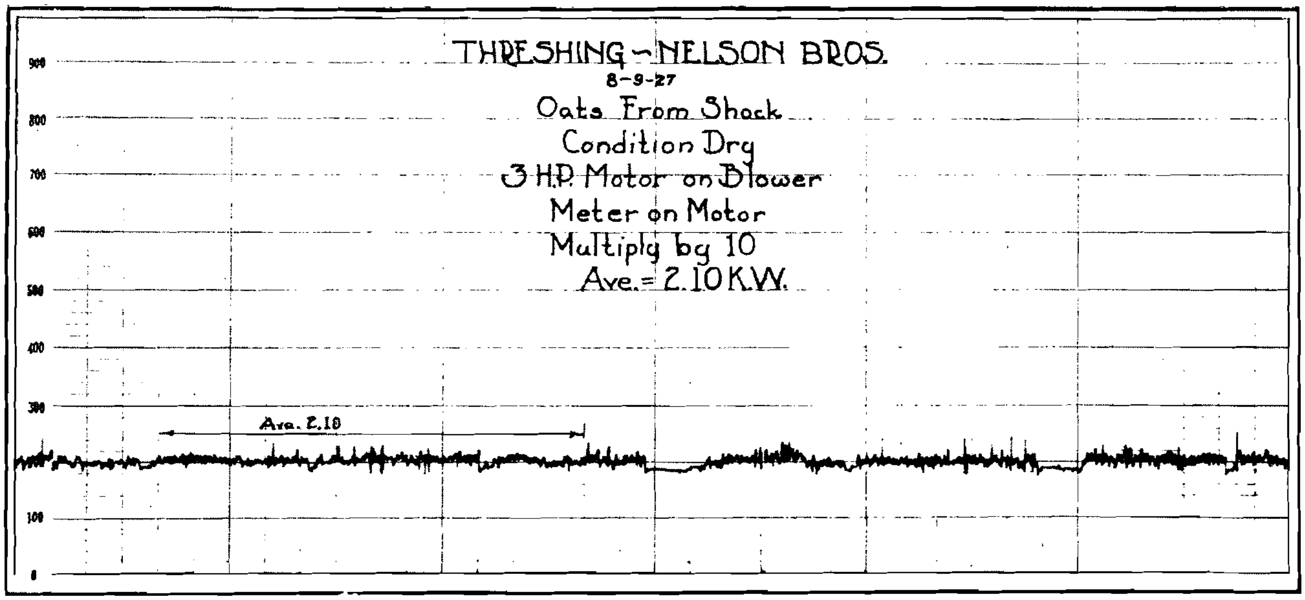

Fig. 127. Wattmeter record of 3 h-p. motor, new rig, threshing oats.

TABLE XCII

TOTALS AND AVERAGES OF THRESHING, 1925

Time, hrs.	Grain	Amount Bu.	Amount Cwt.	Rate per hour Bu.	Rate per hour Cwt.	Kw. hrs.	Kw. hrs. per bu.	Kw. hrs. per cwt.	Cost per cwt. at 3 cents per kw. hr.	Kw. hrs. per hr.
									Cents	
25.0	Wheat	1,503	901.8	60.1	36.1	398.7	.265	.441	1.323	15.9
53.0	Oats	7,474	2,491.7	142.9	47.0	836.2	.111	.346	1.038	15.7
19.0	Barley	1,752	841.0	92.2	44.2	278.5	.159	.320	.960	14.6
17.1	Oats & wheat	3,224	1,031.7	188.5	60.3	251.0	.078	.242	.726	14.6
114.1	All grain	13,953	5,266.2	122.3	46.1	1,764.4	.127	.335	1.005	15.4
53.0	Grain from field	7,442	2,808.4	140.4	52.9	808.9	.108	.288	.864	15.2
7.1	Early stacks	1,025	362.6	140.4	51.0	103.5	.100	.285	.855	14.6
54.0	Late stacks	5,486	2,095.2	101.6	38.8	852.0	.155	.406	1.218	15.8

TABLE XCIII

TRACTOR THRESHING, 1925

Date	Farm	Time, hrs.	Grain	Condition	Amount Bu.	Amount Cwt.	Rate per hr. Bu.	Rate per hr. Cwt.	Kerosene, in gals.	Oil in qts.	Total cost*	Cost per bu., in cents	Cost per cwt., in cents
9/23	Thorsteson	6.0	Oats	Good—dry stacked	883	282.6	147.2	47.1	15	2.0	$2.32	.20	.82
9/24	Stageberg	4.2	Oats	Good stacked	770	246.4	183.3	58.7	12	.7	1.73	.22	.70
9/24	Stageberg	1.1	Barley	Fair stacked	85	40.8	77.3	37.1	3	.2	.43	.50	1.05
9/24	Stageberg	.7	Buckwheat	Good	35	21.0	50.0	30.0	1	.1	.15	.43	.71
9/25	Blazer	1.0	Oats	Poor stacked	158	50.6	158.0	50.6	4	.6	.67	.42	1.33
9/25	Tyler	1.2	Rye	Fair moist stacked	88	49.3	73.3	41.1	3	.4	.47	.53	.97
9/25	Hale	3.8	Oats	Good—dry stacked	565	180.8	148.7	47.6	7	1.0	1.10	.19	.60
9/26	Benson	5.0	Oats & wheat	Fair—dry stacked	600	192.0	120.0	38.4	12	.8	1.74	.29	.85
9/26	Benson	1.8	Oats	Fair—dry stacked	260	83.2	144.0	46.2	3	.2	.44	.17	.53
9/28	Olson	2.5	Oats & wheat	Fair—dry stacked	284	90.9	113.0	36.3	4	.3	.59	.21	.65
10/2	Cady	3.0	Barley	Good—dry stacked	300	144.0	100.0	48.0	5	.4	.74	.25	.51
10/2	Cady	2.5	Oats & wheat	Fair—dry stacked	300	96.0	120.0	38.4	4	.3	.59	.20	.62
10/3	Cady	5.5	Wheat	Fair stacked	404	242.4	73.0	44.0	14	1.0	2.04	.50	.83
		38.3			4,732	1,720.0	123.0	43.8			13.01	.274	.756

* Oil, 15 cents a quart; kerosene, 13½ cents a gallon.

TABLE XCIV—Threshing, 1926

Date	Farm	Time, hrs.	Grain	Condition	Amount Bu.	Amount Cwt.	Rate per hr. Bu.	Rate per hr. Cwt.	Total kw. hrs.	Kw. hrs. per bu.	Kw. hrs. per cwt.	Cost per cwt. at 3 cents per kw. hr., cents	Kw. hrs. per hr.
8/28	C. Sargent	3.6	Oats	Dry field	375	120.0	104.1	33.3	30	.080	.250	.75	8.3
8/28	C. Sargent	1.8	Barley	Poor field	80	38.4	44.4	21.3	10	.125	.260	.78	.56‡
8/28	L. Sargent	6.3	Oats	Fair field	750	240.0	119.0	38.1	60	.080	.250	.75	9.5
9/10	Nelson Bros.	9.9	Oats	Fair—stacked	1,358*	488.8	137.2	49.4	126	.093	.258	.774	12.7
9/11	Nelson Bros.	5.4	Barley	Wet—stacked	475†	237.5	88.0	44.0	86	.181	.362	1.086	15.9
9/13	Hedberg	1.8	Oats	Fair—stacked	200	64.0	111.1	35.5	20	.100	.312	.936	11.2
9/13	Hedberg	3.2	Wheat	Tough field—stacked	235	141.0	73.4	44.1	53	.225	.375	1.125	16.5
9/13	Southwick	2.7	Oats	Fair—wet stacked	300	96.0	111.1	35.5	38	.127	.397	1.191	14.1
		34.7			3,773	1,425.7	108.7	38.2	423	.112	.296	.888	12.2

* 36 lbs. per bushel. † 50 lbs. per bushel. ‡ Reading not large enough to be accurate.

TABLE XCV—Threshing, 1927, with Nichols & Shepard Separator Equipped with 3 Motors Mounted on Machine

Farm	Time, hrs.	Grain	Condition	Amount Bu.	Amount Cwt.	Rate per hr. Bu.	Rate per hr. Cwt.	Energy, kw. hrs.	Kw. hrs. per bu.	Kw. hrs. per cwt.	Cost per bu. at 3 cents per kw. hr., cents	Cost per cwt. at 3 cents per kw. hr., cents	Kw. hrs. per hr.
Cady	4.00	Oats	Field, dry	600	192	150.0	48.0	44	.073	.229	.219	.687	11.0
Cady	1.75	Barley	Field, dry	200	96	114.0	54.8	24	.120	.250	.360	.750	13.7
Cady	2.25	Winter wheat	Field, dry	160	96	71.2	42.7	32	.200	.333	.600	.999	14.2
County Farm	6	Oats	Field, tough & weedy	650	208	108.3	34.6	80	.123	.231	.369	.693	13.3
Nelson Bros.	9.75	Winter wheat	Field, very dry	514	308.4	52.7	31.6	124	.241	.403	.723	1.209	12.7
Nelson Bros.	10.5	Barley	Field, very dry	790	380	75.2	36.2	112	.142	.295	.426	.585	10.7
Nelson Bros.	10.5	Oats	Field, very dry	755	241.5	71.9	23.0	84	.111	.349	.333	1.047	8.0
Arthur Nelson	7	Oats	Field, very dry	662	212	94.6	30.2	52	.079	.245	.237	.735	7.4
Arthur Nelson	1.25	Barley	Field, very dry	137	65.7	109.5	52.5	20	.146	.304	.438	.912	16.0
Cady	12	Marquis spring wheat	Field, dry	614	368.4	51.2	30.7	156	.254	.424	.762	1.272	13.0
Cady	2	Oats	Field, dry	183	58.6	91.5	29.3	20	.110	.341	.330	1.023	10.0
Cady	3.5	Succotash*	Field, dry	306	137.8	87.5	39.4	64	.209	.464	.654	1.392	18.25
C. Sargent	10	Oats	Field, wet	756	242.0	75.6	24.2	136	.180	.562	.540	1.686	13.6
L. Sargent	9	Oats	Field, wet	460	147.4	51.1	16.4	112	.244	.710	.732	2.130	12.45
E. Benson	.75	Hulled oats	Stack, dry	22.5	7.2	30.0	9.6	4	.180	.556	.540	1.668	5.33
E. Benson	5	Succotash*	Stack, dry	365	164.2	73.0	32.8	56	.155	.341	.465	1.023	11.2
E. Benson	2	Oats	Stack, dry	220†	70.4	110.0	35.2	24	.109	.341	.327	1.023	12.0
Charlson	5	Oats	Stack, dry	365	116.8	73.0	23.4	60	.165	.514	.495	1.542	12
Southwick	2	Oats	Stack, dry	188	60.2	94.0	30.1	28	.149	.465	.447	1.385	14
Hedberg	2.25	Winter wheat	Stack, dry	140	84.0	62.2	37.3	36	.257	.429	.771	1.287	16

* 45 lbs. per bushel. † At 32 lbs. per bushel.

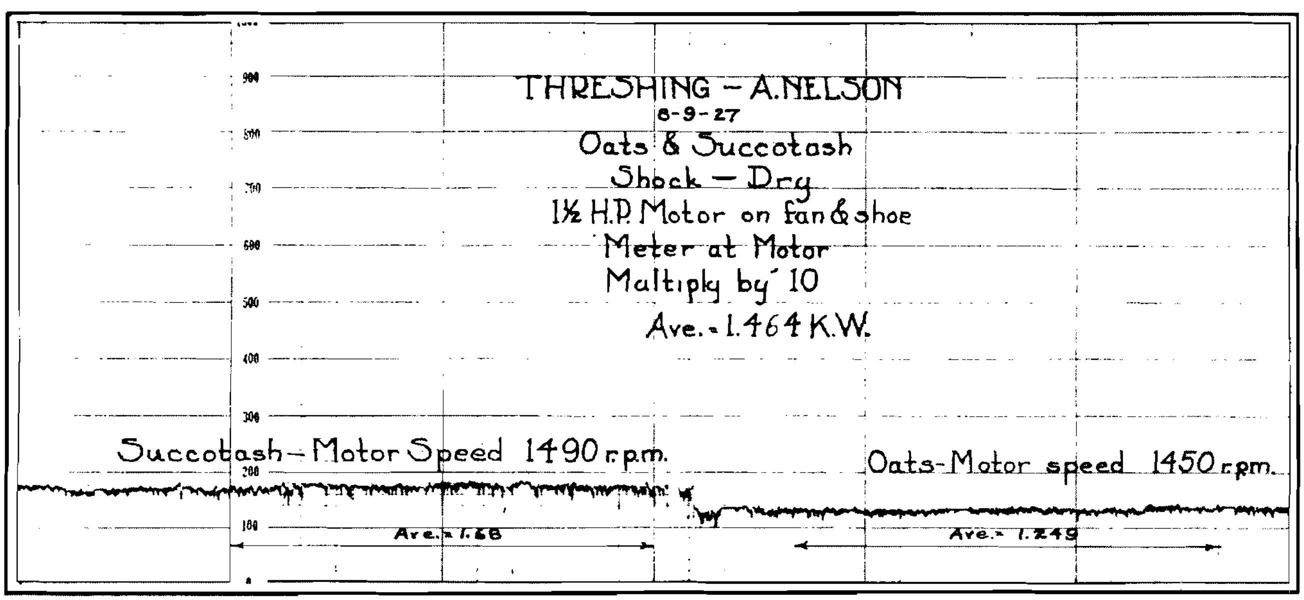

Fig. 128. Wattmeter record of 1½ h-p. motor, new rig, threshing succotash and oats.

TABLE XCVI

CADY—THRESHING, 1925, WITH ELECTRIC MOTOR

Grain	Amount Bu.	Amount Cwt.	Kw. hrs.	Kw. hrs.	Cost per cwt. at 3 cents per kw. hr., cents
Wheat	310	186		Per cwt.	
Oats	375	118		.253	
Barley	300	144	157	Per bu.	.759
Oats and wheat	525	168		.103	
Timothy	8	4			
	1,518	620			

A. C. BRYAN—THRESHING, 1925, WITH TRACTOR POWER

Grain	Amount Bu.	Amount Cwt.	Fuel	Total cost	Cost per cwt., cents
Wheat	1,140	594	Kerosene—		
Peas & oats	480	154	95 gal. at		
Oats	1,200	384	13.5 cents	$12.83	1.32
Barley	200	96	Oil—7 gal.		
Timothy	16	7	at 50 cents	3.50	
	3,036	1,235		$16.33	

B. I. MELIN—THRESHING, 1926, WITH ELECTRIC POWER

Grain	Amount Bu.	Amount Cwt.	Kw. hrs.	Kw. hrs.	Cost per cwt. at 3 cents per kw. hr., cents
Wheat	2,260	1,356		Per cwt.	
Oats	650	208	864	.50	1.50
Oats & wheat	350	157		Per bu.	
				.265	
	3,260	1,721			

TABLE XCVII

ENERGY CONSUMPTION ON TRANSFORMER TRUCK, AUGUST, 1924 TO JULY, 1925
(Meter Readings. 15 h-p. Century Motor. Readings Taken at Finish of Each Job)

Month	Consumer	Job	Kw. hrs.	Total
August	University of Minnesota	Test at A. Nelson	15	
September	Goodhue Co. Farm	Threshing	65	
	B. I. Melin	Threshing	53	
	A. C. Bryan	Ensilage cutting	133	
	B. I. Melin	Threshing	120	Sept. 386
October	F. A. Miller	Ensilage cutting	30	
	A. C. Bryan	Ensilage cutting	208	
	F. A. Miller	Grinding feed	68	Oct. 306
November	W. J. Bryan	Grinding feed	32	
	A. C. Bryan	Husking and shredding	184	Nov. 216
December	A. C. Bryan	Husking and shredding	100	
	W. J. Bryan	Husking	124	Dec. 224
January	F. A. Miller	Feed grinding	80	Jan. 80
March	W. J. Bryan	Feed grinding	83	Mar. 83
April	W. J. Bryan	Feed grinding	25	Apr. 25
				Total 1,320

Belt speeds for the main drive should be high to reduce belt tension and save bearing trouble.

A 22 x 36-inch threshing machine can be driven by 13 or 14 h-p.

Electric installations on the threshing machine should be made fool proof.

Transformer trucks should be made available on the market.

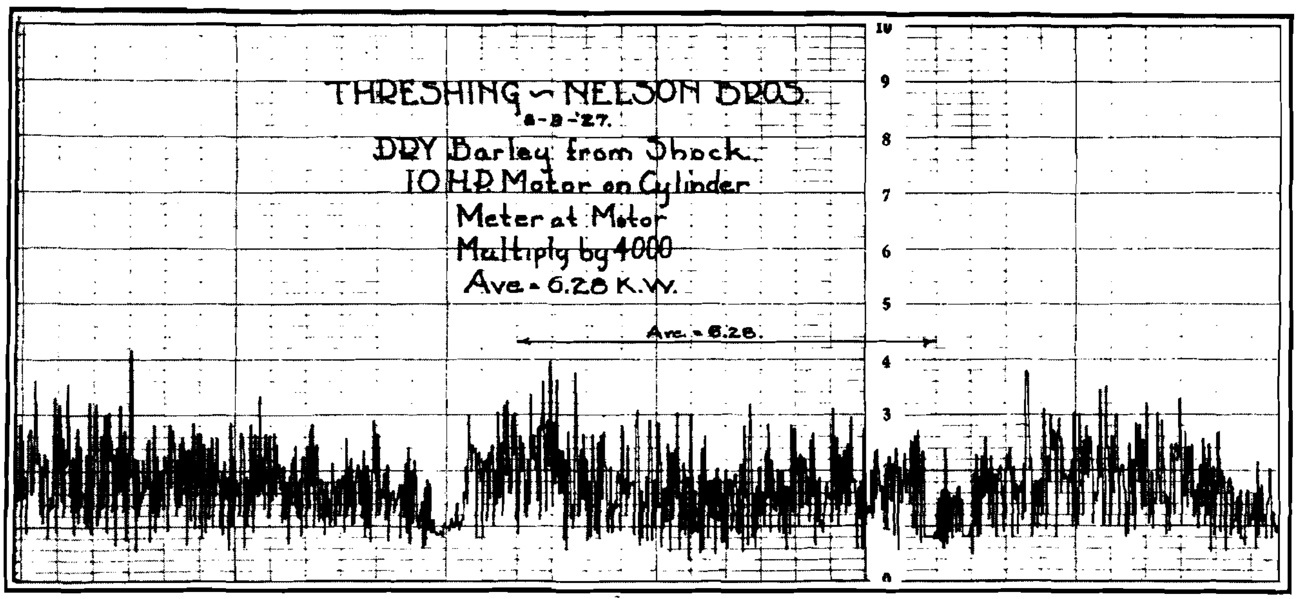

Fig. 129. Wattmeter record of 10 h-p. motor, new rig, threshing barley.

TABLE XCVIII

ENERGY CONSUMPTION ON TRANSFORMER TRUCK, JULY 1, 1925 TO JANUARY 1, 1926

Month	For whom	Charge to	Job	Large motor	Small motor		Total
August	Cady	Cady	Threshing	72	16		
August	Albert Nelson	Cady	Threshing	164	38		
August	Arthur Nelson	Cady	Threshing	84	20		
August	Cady	Cady	Threshing	152	41		
August	County Farm	Cady	Threshing	40	10		
August	Cady	Cady	Threshing	60	9		
August	L. Sargent	Cady	Threshing	76	22		
August	C. A. Sargent	Cady	Threshing	72	16		
August	Tyler	Cady	Threshing	40	10		
August	Lokkesmoe	Cady	Threshing	40	11	August	993
September	A. C. Bryan	A. C. Bryan	Ensilage	210	...		
September	B. I. Melin	B. I. Melin	Ensilage	300	...	September	510
October	Nelson Brothers	Cady	Threshing	204	108		
October	F. Miller	Cady	Threshing	188	98		
October	Charlson	Cady	Threshing	36	15		
October	Southwick	Cady	Threshing	44	21		
October	Hedberg	Cady	Threshing	80	39		
October	Melin	Cady	Threshing	100	51	October	984
November	Cady	Cady	Husking	72	...		
November	Gove	Cady	Husking	40	...		
November	Albert Nelson	Cady	Husking	48	...	November	160
December	B. I. Melin	B. I. Melin	Husking	104	...	December	104
						Total	2,751
			Charge to W. A. Cady			2,137	
			A. C. Bryan			210	
			B. I. Melin			404	
							2,751

TABLE XCIX

ENERGY CONSUMPTION ON TRANSFORMER TRUCKS, JANUARY 1, 1926 TO JANUARY 1, 1927

Month	For whom	Charge to	Job	Large motor	Small motor		Total
		Old Truck					
August	Albert Nelson	Cady	Threshing	48	15		
August	Cady	Cady	Threshing	120	37	August	220
September	B. I. Melin	B. I. Melin	Threshing	864	...		
September	A. C. Bryan	Bryan	Ensilage	264	...		
September	B. I. Melin	B. I. Melin	Ensilage	304	...	September	1,432
December	B. I. Melin	B. I. Melin	Husking	48	...	December	48
		New Truck—93 per cent of reading					
August	C. Sargent	Cady	Threshing	40	...		
August	L. Sargent	Cady	Threshing	60	...	August	100
September	Nelson Brothers	Cady	Threshing	212	...		
September	Hedberg	Cady	Threshing	73	...		
September	Southwick	Cady	Threshing	38	...		
September	Nelson Brothers	Nelson Brothers	Ensilage	111	...		
September	F. Miller	F. Miller	Ensilage	111	...		
September	Cady	Cady	Ensilage	56	...	September	601
						Total	2,401
			Charge to W. A. Cady			699	
			B. I. Melin			1,216	
			A. C. Bryan			264	
			Nelson Brothers			111	
			F. Miller			111	
							2,401

TABLE C

ENERGY CONSUMPTION ON TRANSFORMER TRUCKS, JANUARY 1, 1927 TO JANUARY 1, 1928

Month	For whom	Charge to	Job	Kw. hrs.		Totals
			Old Truck			
June	A. C. Bryan	A. C. Bryan	Sawing Lumber	204	June	204
August	A. C. Bryan	A. C. Bryan	Threshing	472		
	Harry Bryan	Harry Bryan	Threshing	532		
	B. I. Melin	Melin Estate	Threshing	1,250	August	2,254
September	B. I. Melin	Melin Estate	Threshing	262	September	262
October	B. I. Melin	Melin Estate	Ensilage	280	October	280
December	A. C. Bryan	A. C. Bryan	Husking	144	December	144
			New Truck			
August	Nelson Brothers	W. A. Cady	Threshing	320		
	A. H. Nelson	W. A. Cady	Threshing	72		
	County Farm	W. A. Cady	Threshing	80		
	Sargent	W. A. Cady	Threshing	248		
	Benson	W. A. Cady	Threshing	84		
	Charlson	W. A. Cady	Threshing	60		
	Southwick	W. A. Cady	Threshing	28		
	Hedberg	W. A. Cady	Threshing	36		
	W. A. Cady	W. A. Cady	Threshing	372	August	1,300
September	W. A. Cady	W. A. Cady	Ensilage	40		
	A. C. Bryan	A. C. Bryan	Ensilage	344	September	384
October	Sargent	W. A. Cady	Ensilage	120	October	120
					Total	4,948

SUMMARY—Charge to			
W. A. Cady	1,460	June	204
A. C. Bryan	1,164	August	3,554
Harry Bryan	532	September	926
Melin Estate	1,792	October	120
		December	144
	4,948		4,948

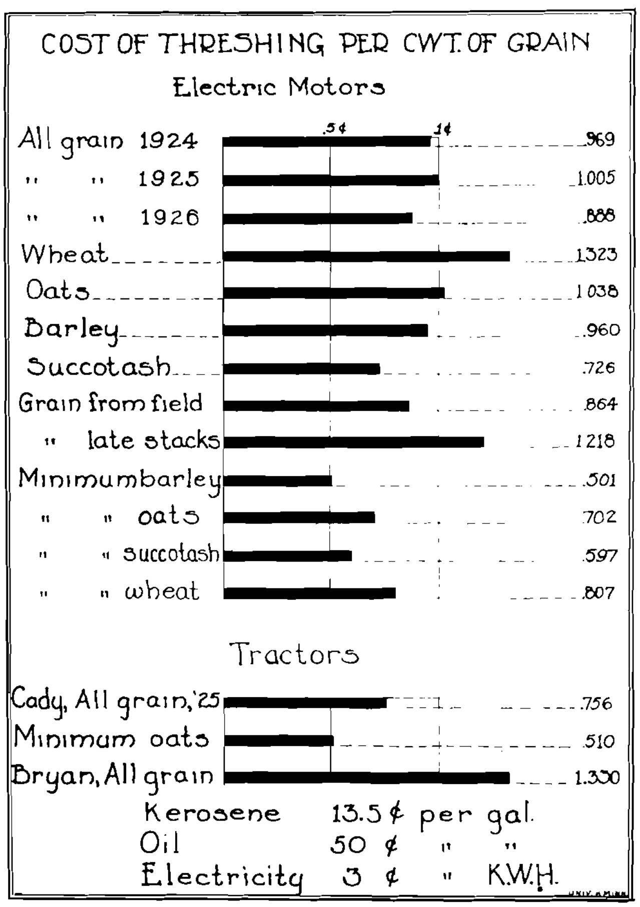

Fig. 130. Graphical results showing cost of threshing different grains

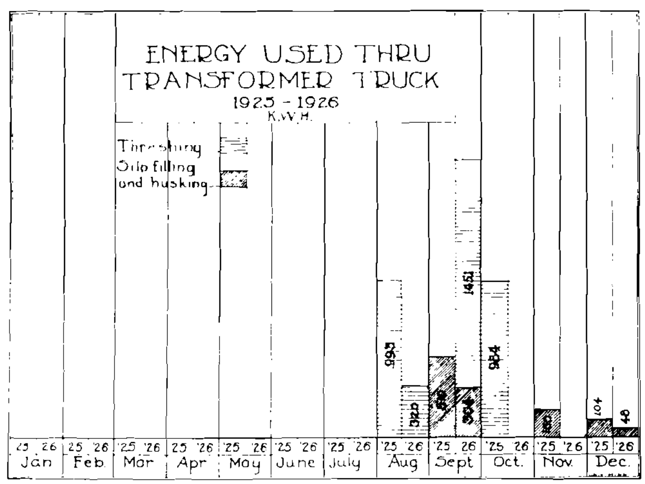

Fig. 131. Energy used through the portable transformer trucks for two years.

ELECTRIC FAN VENTILATION

The first electric fans for the experimental work were installed in the barns at the West Central Experiment Station, Morris, Minnesota, in October, 1921. Two 12-inch fans and one 18-inch fan were installed to ventilate a dairy barn 34 x 96 feet with capacity of 36 head of cattle. A home-made gravity ventilating system which had not worked well in this barn was discarded. There were ten intakes of the "King" type arranged to permit entrance of air at the ceiling center.

The fans were installed in the side walls and covered with a hood as shown in Figure 132. These in-

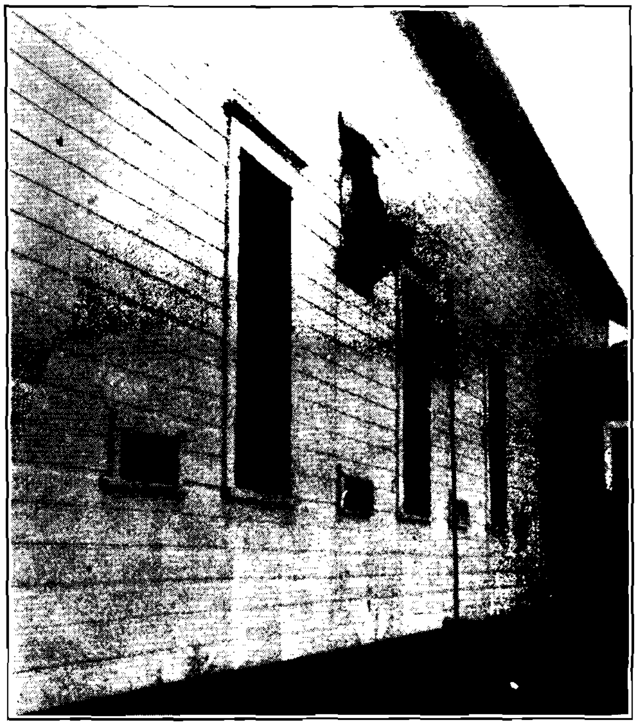

Fig. 132. Original electric fan installation at the Morris barn. Hood inadequate. Note old screened intakes.

takes were covered with screens. The cost of the installation was $135 for fans and $25.50 for installing, a total of $160.50.

Estimates had been secured for the installation of a gravity ventilating system for both the dairy barn and the beef barns. Bids for such a system were: Company 1, $865; Company 2, $869; Company 3, $750. The bids did not include the labor of installation, which was estimated at $200. Thus a gravity system for one half of the dairy barn would have cost about $500.

The fans were installed in the ends of chutes at the ceiling, one 18-inch fan on the west side and two 12-inch fans on the east side of the barn. The chutes in each case were built across the ceiling to the opposite wall, with vertical chutes down to 18 inches above floor level at each side, and with heat doors in the bottom of the ceiling chutes near the fans. Thus any one fan could draw air out of each side of the stock room near the floor level or at the ceiling. Dampers were installed in the vertical chutes so as to stop air from going out through the fans when they were not running. Hoods, as shown in Figure 132, were installed so as to keep out rain and snow and to prevent head winds from bucking the fan.

The 12-inch fans normally used 65 watts, and the 18-inch fan 120 watts. Tests were made to determine the capacity of the fans under different conditions, to determine the effect of the hoods, the heat doors, closed intakes, etc.

During the first five tests, the intakes were covered with burlap. This burlap was so dusty that no air came through. In the last test when all of the burlap screens were removed, one was plugged, six had intake velocities varying from 10 cubic feet per minute to 75 cubic feet per minute, while three of the intakes on the east side acted as out-takes.

A test of 16-inch fans installed in the beef barn, which were rated at 1,600 cubic feet per minute, showed a capacity of 700 cubic feet per minute.

The conclusions drawn from these tests are:

> These fans, as well as others tested, show an actual capacity when installed of 40 per cent to 50 per cent of the rated capacity.
>
> The hoods did not interfere with the fans, nor decrease their capacity.
>
> The ducts did not decrease the capacity of the fans.
>
> The air intakes were not necessary, as the slight increase in air out-take under the last test was caused by winds producing a slight vacuum on the east side of barn.

Other tests were made during the next three years to determine several characteristics about fan ventilation. Dry bulb temperatures were taken at two points behind each row of cows at head level, at floor, and at ceiling. Wet and dry bulb temperatures were taken at the feed alley and cross alley intersections.

These records show that an even temperature distribution can be secured by electric fans and that it is not necessary to distribute the out-takes on each side of the barn as was done. The last test reported in Table CII shows that the difference in air temperatures between floor and ceiling was slightly less when air was taken off at the ceiling than when the air was taken from 18 inches above floor level. The humidity at the floor and ceiling was nearly the same.

The fans, however, burned out. A test on one 18-inch fan was made to determine the possible cause. The damper was adjusted at different settings so as to cut down the air supply and the power input to the fan determined. The results were as follows:

Watts Input	Air capacity—cu. ft. per min., full capacity
120	1,117
144	1,028
157	727
187	611
260	No air

Within a few minutes, with no air, the motor began to heat and became noisy.

TABLE CI

CAPACITY OF 12-INCH FANS

Time	Condition	South fan	North fan
		Cubic feet per minute	
	Rated capacity	1,150	1,150
2:00 p.m.	As installed	460	453
2:30 p.m.	Hoods removed	479	443
3:00 p.m.	Hoods removed	477	453
3:30 p.m.	Heat doors open—free air	473	420
3:50 p.m.	Heat doors closed	481	465
8:20 p.m.	As installed ½ intakes opened	485	477
8:50 p.m.	All intakes opened	486	499

As a result of the study of this installation, the following conclusions were reached:

> Air may be taken out at the ceiling of a stable as well as near the floor, resulting in just as good temperature and moisture conditions and in a smaller amount of air.

TABLE CII

Barn Temperatures, Fan Ventilation

Location	Out Doors	N.E.	N.W.	S.W.	S.E.	N.	N.	N.	N.	S.	S.	S.	S.
Level Bulb	Head Dry	Head Dry	Head Dry	Head Dry	Head Dry	Floor Dry	Floor Wet	Ceiling Dry	Ceiling Wet	Floor Dry	Floor Wet	Ceiling Dry	Ceiling Wet
Test February 2, 1924													
5:30 p.m.	39	56.5	56	57	58	53	52	56	54.8	55.6	54.4	57	55.6
7:00 p.m.	38	53.5	53	54.5	54	50	48.8	53	51.6	52	51	54	53
10:30 p.m.	36	53.5	53	54.5	54	50	48.8	53.3	52	50	49	53.2	52.4
10:00 a.m.	32	51.5	51.5	52.2	52	47.3	46.5	51.6	50.3	48.5	47.6	51.8	50.8
Test December 20, 1922													
8:00 p.m.	12	40	42	42	43.5	36	34	43.5	41	42	39	44	42
11:00 p.m.	13	41.5	42	42	42	36	34	44.5	42	42	39	44	42
5:00 a.m.	22	44	44	44	44	42	40	48	45	44	41.5	48	46
11:00 a.m.	32	48	47	48	49	44	43	48.5	45.5	46	44	48.5	46
Air taken out at ceiling December 21, 1922													
6:00 a.m.	..	..	..	..	..	46	..	50	..	43	..	47	..
7:45 a.m.	..	..	..	..	..	46	..	50.5	..	48	..	49.5	..

Electric fan ventilation can be successfully used if it can be so installed as to prevent burning out the fans.

Dampers in ducts are dangerous as they may be closed when fans are running and cause fans to burn out.

Head winds must be prevented from blowing against fans, as static head produced by strong winds is sufficient to burn out small fans.

Covers may freeze shut and fans may freeze to frames and cause the fans to burn out.

Electric ventilation using from 250 to 350 kw. hrs. per year for 36 head of cattle will cost less than gravity ventilation.

When the two barns at Red Wing were built, electric fan ventilation was installed. In Mr. Cady's barn the fans were so placed as to take air out at the ceiling only. The walls of this barn were concrete and the fans were installed just above the ceiling. Metal doors were placed on the outside of fans, and wood doors in the ceiling opening to the fans. No vertical ducts were used but a cross duct was used on the 18-inch fan, so as to take air from both sides of stock room. No inlets were provided. Two 12-inch fans were used on the east side of the cattle barn, one 18-inch fan on west side and one 12-inch in the horse stable. The cost was as follows:

Price of fans: one 16-inch fan @ \$42.00; three 12-inch fans @ \$32.50; \$97.50; total, \$139.50.
Ducts: material, \$19.85; labor, \$5.00; total, \$24.85.
Metal covers and shields, \$6.99.
Miscellaneous hardware, \$0.77.
Labor installing fans, \$5.00.
Grand total, \$177.11.

A number of tests were made of the capacity of these fans and of the results secured in the barn. Many temperature and humidity records were made. The following conclusions were reached:

The 12-inch fan has such a small motor that it is likely to become overloaded with heavy static wind pressure, and to burn out. These small fans should not be used.

Two or three small fans are to be preferred to one large fan.

Fans, installed as these were, are hard to take care of and will be neglected.

Ducts of any kind are unnecessary.

A good hood with screen protection is necessary to prevent head winds from burning out fans.

Fans when not running must be protected from air leakage from the stable by tight fitting doors or else fans will freeze to frames.

Doors for fans must be on inside of fans to prevent doors from freezing shut.

Nelson Brothers' Barn

The next installation was made in the new barn of Nelson brothers. These fans were installed in the side wall, below the ceiling, without ducts as shown in Figure 133. Three fans were installed, two on the south side of the barn and one on the north side. The

Fig. 133. Fan installed at Nelson brothers' farm. Note the inside cover.

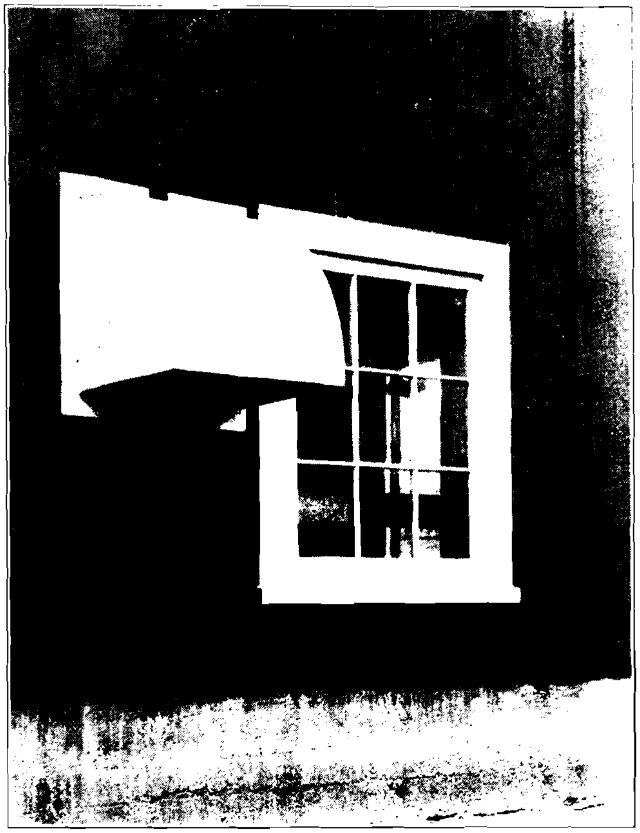

Fig. 134. Hood to protect electric ventilating fan. Lower face protected by ½-inch mesh wire screen.

fans were protected by a metal door on the inside. This door was opened by a rope located at the electric switch which controlled the fan. A hood as shown in Figure 134 was used on the outside of the barn. The bottom of this hood was covered with a ½-inch mesh screen to keep birds and rodents from entering the fan. The cost of this system is given below:

3 Ventura disc fans, 2 No. 3, and 1 No. 3½	$206.50
Installation	
Materials:	
Hinges for covers	.45
Screws	.10
Pulleys	.32
Sash cord	.35
Metal covers (made in tin shop) 24-gauge metal	1.92
Labor	3.15
3 doz. knobs	1.08
150 ft. No. 14 R. C. Wire	1.50
Hoods (made in tin shop)	12.00
3 snap switches	2.40
Labor	
12 hours @ $0.50	6.00
15 hours @ $0.60	9.00
Total	$244.77

Temperature records and humidity records were taken in this barn. The humidity can be kept at a proper amount, except in extremely cold weather. The stable is not warm enough to hold temperatures above freezing when fans are operated to keep down humidity in below-zero weather. On the other hand, Mr. Cady does not have such trouble, because his barn wall has lower heat conductivity and because he uses storm windows. This system of ventilation will use from 100 kw. hrs. to 300 kw. hrs. per year. Mr. Nelson used about 125 kw. hrs. last season.

The system has worked very well. The troubles had with former systems have been eliminated. The fans are easily cared for, and none has been burned out. A door fan may drop shut while the fan is running, shutting off the air, or a fan door may warp or become loose, causing the fans to frost over and give trouble in starting, but these are not major difficulties. Barn walls with a heat conductivity of less than .2 should be used and all windows provided with storm sash, if good ventilation and a warm barn are to be secured. To properly ventilate you must insulate.

After tests had been made with these systems and after the causes of unsatisfactory operation had been determined, a system was designed which would replace fans such as had given trouble at the Morris station.

In Figure 135 is shown one of the frames in which the fan is installed. It is similar to a window frame and is inserted in the wall in the same manner.

Figure 136 is a diagram of one of the fans and frames inserted in the wall. The fan is fitted into the frame and the frame is placed flush with the outside of the barn wall.

Since one of the difficulties was that air leaked past dampers or poorly-fitting doors and caused the fans to become frosted-over, a door was made to fit very closely so as to prevent warm air from going out and to prevent its acting as an intake when other fans were running. Since the door was to be exposed to extremely cold air on the outside and warm air on the inside, it was insulated with ½-inch material. The edges of the door were covered with 20-gauge galvanized iron to prevent splitting at the edges when opening and closing it.

One of the difficulties with earlier systems was that sometimes an operator would turn on a fan and neglect

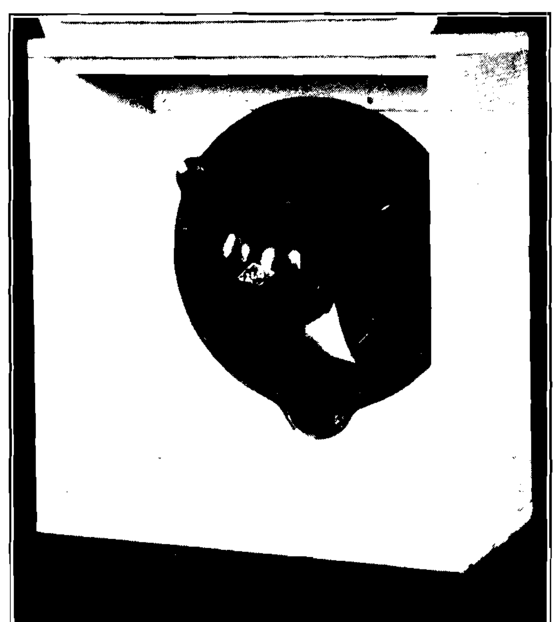

Fig. 135. Electric fans mounted in a frame ready to install at the barn at Morris, Minnesota.

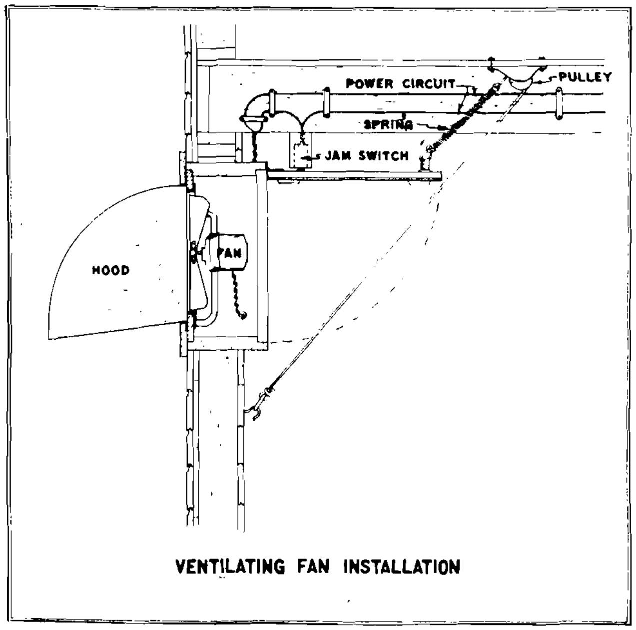

Fig. 136. Diagram for fan installation showing hood, fan and door operated switch.

to open the damper or the door inside, and the fan motor would burn out as a result of excessive resistance caused by "bucking" a partial vacuum. To avoid this, a jam switch was designed, which would close when pressure was against it and automatically open when the pressure was released. This switch was placed on the ceiling where the door, which is hinged at the top edge, would be brought to bear against the switch and close it, thus starting the motor. This made it impossible to start the motor unless the door was wide open, and if for any reason the door should drop, the motor would stop and no harm would be done. With this arrangement there were no ducts to draw the air through and to be in the way, as was so often the case where ducts are run to the center of the barn and to the floor. Where ducts are used there must be dampers to close them off, and dampers are very objectionable because they usually do not close tightly and are often neglected entirely.

A hood was placed over the outside of the fan to prevent wind and weather from ruining it. The hood also avoided undesirable louvers, or slatted panels. The hood was covered with a screen of ¾-inch mesh to prevent birds from nesting in the fan housing. This screen was coarse enough to prevent frost from accumulating on it and obstructing the opening.

Fans installed in this manner are very easy to take care of, and are simple to operate. The operator can see them each time he turns them on and if there is any part that needs care it can be attended to without removing ducts. Fans less than 16 inches in diameter should not be used.

Tests Made on Systems

A close observation was made of the system at the West Central Experiment Station, with two fans installed as shown in Figures 136, 137, and 138.

This barn is entirely of wood construction. The walls are made of 2 x 6-inch studs, diagonally sheathed on the outside, covered with tarred felt and then covered with 6-inch drop-siding. The inside is sealed with 6-inch matched lumber. The ceiling, which is 10 feet to the joists, was unsealed and hay in the mow had to be depended upon for insulation. The windows on the west side had storm sash but on the south end and east side had none. All outside doors were double.

Two double-bulb recording thermometers were used to get a record of the temperature and the relative humidity. One instrument was placed with one bulb at the ceiling and the other bulb near the floor in order to get an idea of the temperature differences between the two levels. The other instrument was used to obtain a psychrometric record.

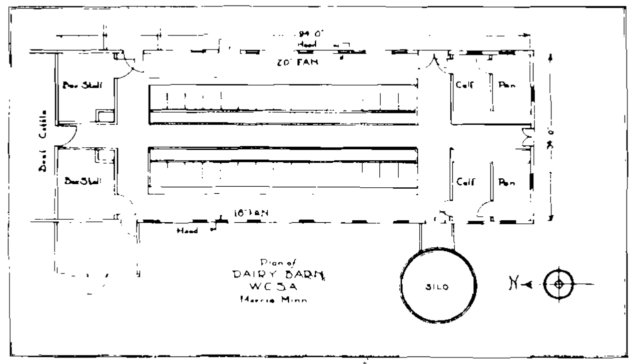

Fig. 137. Plan of barn at Morris showing location of two fans.

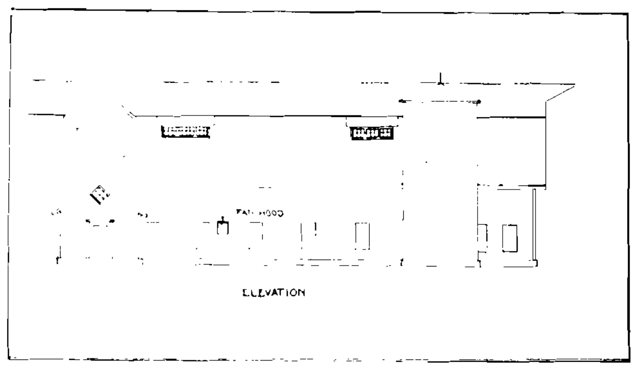

Fig. 138. Barn elevation at Morris showing location of fan.

Temperature Differences

The recording thermometer showed no great variation in the temperature between the floor and the ceiling. The difference varied from 4 to 8 degrees and the average was 6.2 degrees. In cold and windy weather, if a door was left open, the temperature difference was sometimes as high as 12 degrees. This is a very small temperature difference for a barn with a 10-foot, 10-inch ceiling.

Relative Humidity

A continuous graphic record of the moisture content of the air was kept for two months—from January 20 to March 24—during which there was a good deal of very cold weather and also some weather slightly above freezing.

Records for two weeks are shown. Figure 139 gives a record secured during the week commencing at midnight, February 13 and ending February 20.

In this period, the weather stayed below freezing outside at all times, as can be seen by the curves near the bottom of the graph. The maximum temperature was 28° F. The lowest maximum temperature was —7° F. On the following day, Monday, the temperature dropped to −36° F. as a minimum and on Tuesday rose again to 22° F. Those are extreme weather changes.

The temperature curve inside of the barn indicates how easy it was to maintain a fairly high and uniform temperature even with the sudden and big temperature variations outside.

The temperature in this barn was higher than is ordinarily maintained in most barns, but it was the desire to keep it high if possible, and still maintain proper ventilation. As seen from the graph, the temperature rose considerably each night. The fans were turned off at about 9 p.m., and turned on at 5 a.m. the next day.

In a similar manner the relative humidity would rise toward morning of each night, but after the fans had been turned on for an hour or two, the barn would dry out and the temperature would come back to its normal level of about 52°.

Figure 140 shows a similar record, taken at a later date when the temperature was more moderate. From the lower curve on the graph, it will be noted that the temperature went below freezing four nights and every day it reached a maximum that was considerably above freezing. The mean was slightly above freezing, or

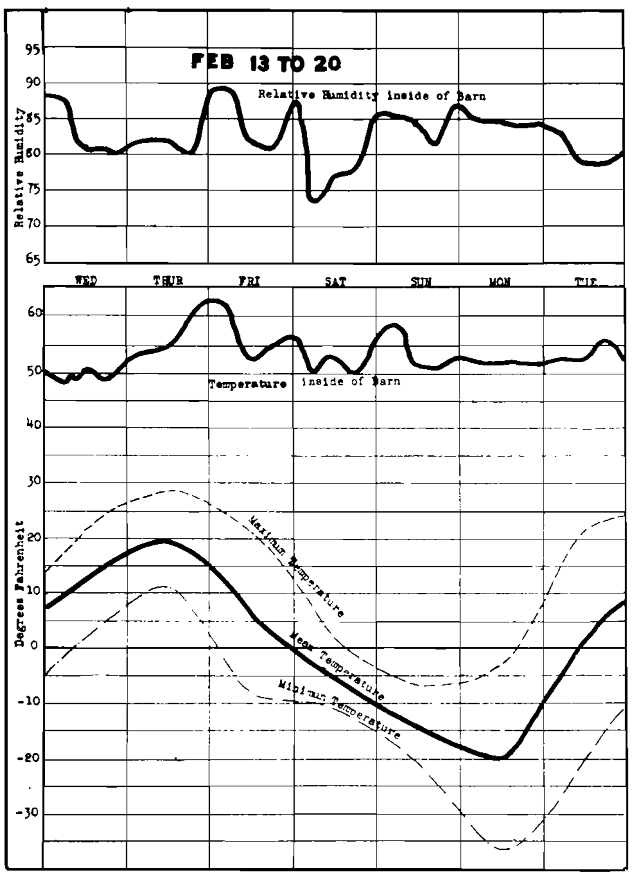

Fig. 139. Temperature and humidity records, week of February 13 to 20, in the barn at Morris with electric fan ventilation.

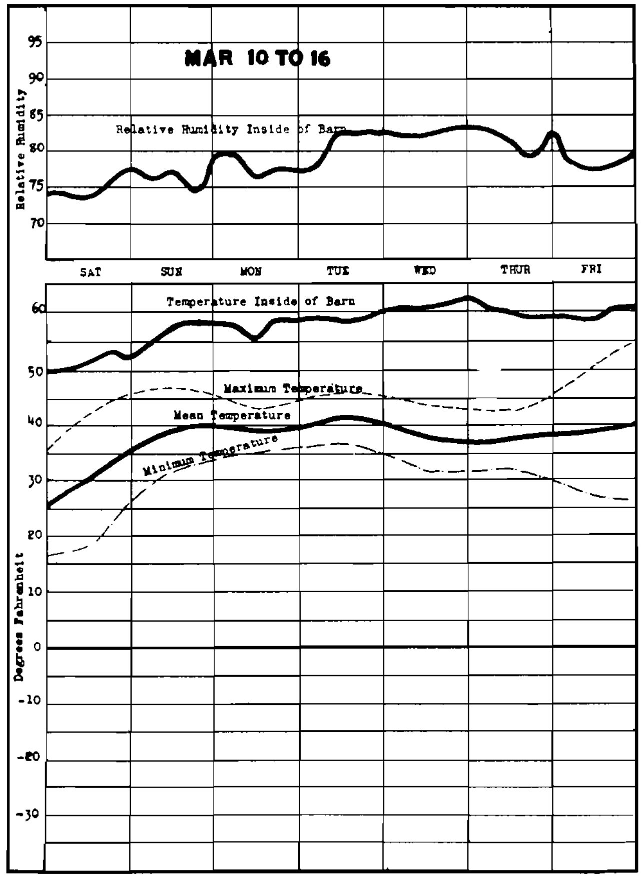

Fig. 140. Temperature and humidity records, week of March 10 to 16, in the barn at Morris with electric fan ventilation.

37.7° F. for the week. During this period both fans were run continuously day and night. Since the temperature outside varied less than it did during the period shown in Figure 139, it is only natural that the temperature inside should be more uniform. The relative humidity also remained more nearly constant, rising only gradually as the temperature increased both outside and inside of the barn toward the end of the period.

It has been found that whenever a barn is so constructed that a temperature above 38° F. can be maintained, when several changes of air are being made per hour, fans can be used to a very great advantage if properly installed.

A test was made to see what effect wind-pressure would have on the fans while in operation. With the hood on, the velocity head or pressure does not affect the fan so it was only the static head set up by the wind that the fan had to resist.

One day when the wind had an average velocity of 24 miles an hour, a graphic record was made of the input to the motor. In quiet weather this fan required an input to the motor of 150 watts. Figure 141 shows what happened while the wind was blowing at 24 miles an hour. Each gust of wind caused an increase in the input, as may be seen from the graph. At one time the wind blew so hard that it actually broke down the torque of the motor to such an extent that the speed of the fan dropped from its normal rating of 1,155 r.p.m. to 650 r.p.m. Some time elapsed before the

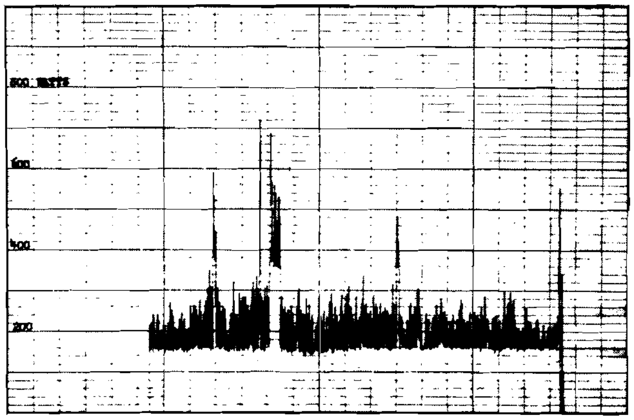

Fig. 141. Wattmeter record of fan at Morris. Variations in power due to changing wind. Note high peaks caused by gusts of wind.

wind subsided enough to permit the fan to come up to speed again and the input to get back to normal. On the graph will be seen one of these points where the motor speed broke down causing an input to the motor of nearly three times its normal rating. The fine vertical lines on the graph represent a lapse of ten minutes so it can be seen that this extremely high input continued for about four minutes. How much longer the fan would have operated under this condition is not known. The input for a short interval went to 720 watts or nearly five times normal rating. The fan delivered, during the high wind at any time, only about one-third of the air that it normally did.

In the barn at Morris no definite intakes at all were used. Infiltration was depended on for fresh air. This worked very satisfactorily and gave very uniform distribution.

The cost of these fans installed was $172, and the operating cost is so little that it is almost negligible as compared with the interest on a gravity system for the same barn. From November 9, 1928, until March 23, 1929, these two fans used 315 kw. hrs. At 3 cents per kw. hr. this would cost $9.45, which is about all that it cost to ventilate the barn for the entire winter.

The outstanding feature of this type of installation is its simplicity and ease of operation and care.

USES OF ELECTRICITY IN THE DAIRY

In the dairy industry electricity may be used for pumping water, grinding feed, cutting ensilage, cutting roots, threshing grain, husking and shredding corn, illuminating stables, ventilating, heating water, sterilizing milking utensils, refrigeration, operating milking machines and cream separators. Some of these uses have already been discussed. Others may be treated here in brief.

Refrigeration

Very little work has been done on refrigeration at Red Wing. There were no farm electric refrigerators on the market when the project was started. A special refrigerator shown in Figure 42 was built. Records of milk and butterfat production and sales were kept for one year. The farmer received a bonus for sweet cream and the refrigerator was used to keep the cream sweet until it could be hauled to town.

In six months the farmer sold 1,398 pounds of butterfat. He did not receive a bonus on five days for cream deliveries amounting to 43 pounds. His bonus amounted to $67.75. The depreciation and interest charge on his refrigerator would be about $32. He used 228 kw. hrs. of energy at a cost of $6.84. His extra earnings were, therefore, $28.91. In addition to these earnings, the family had household refrigeration. Ice for such purposes as put up by one of the farmers cost in labor about $12. In addition to the labor cost is the cost of an ice-house, sawdust, and the labor of taking out the ice. Without placing any value on the labor of taking out the ice, the icing of the household refrigeration would cost about $21. Thus the refrigerator earned and saved about $50 for this farmer.

This refrigerator was the water-cooled ammonia type. The box was experimental and consisted of three chambers, one for wet cooling, one for dry storage, and one for household refrigeration. The machine was economical and the storage arrangement was good. The machine did not regulate well and did not give satisfactory temperatures in the different chambers. The water-cooled feature was bad, but no other type was available at the time.

Milking Machines

Three makes and types of milking machines were placed in use on the experimental farms. Two of these machines were considered very successful by the users. The third machine did not prove as satisfactory because of a small herd (about 13) of cattle and because of some difficulty with the machine. The machine was finally put into first class shape by the use

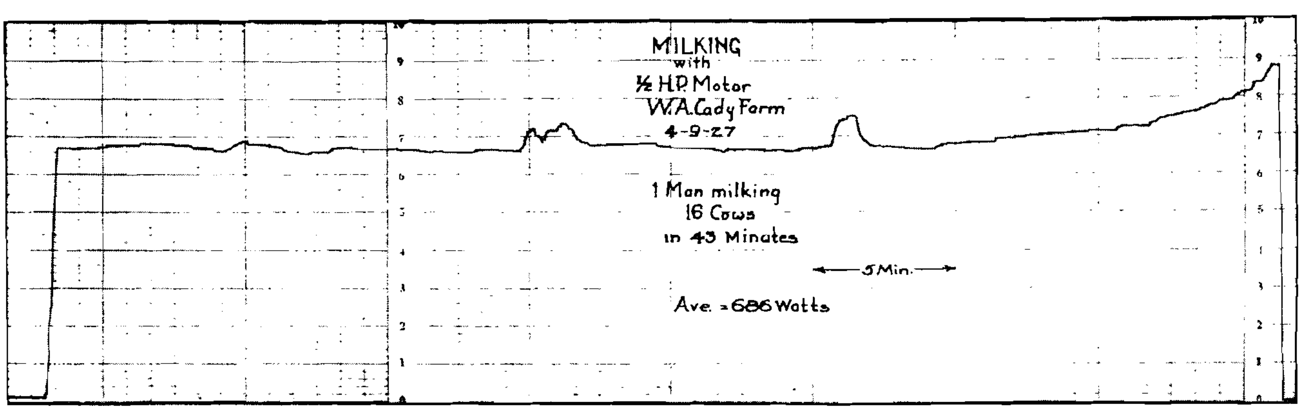

Fig. 142. Wattmeter record of power required to operate one double unit pipe line milking machine.

of newly designed parts and the farmer was well enough pleased so that he bought the machine.

Records of hand milking at Mr. Cady's farm showed that 10.2 man-minutes per cow for cows recently fresh and 7.2 man-minutes per cow for cows in the latter half of the lacation period were required for each milking period (cows milked twice daily). For his herd of 10 cows recently fresh and 8 strippers, the total milking period gave an average of 160 minutes or 8.9 man-minutes per cow per milking. After installing a pipeline machine, the milking period was shortened to 100 minutes or an average of 5.5 man-minutes per cow per milking, which was 6.0 man-minutes per cow for the cows recently fresh, and 5.0 man-minutes per cow for the strippers. This includes all the time used to take care of the equipment and utensils. The saving in labor on this farm is practically two hours per day by the use of the milking machine.

The eighteen cows gave about 390 pounds of milk per day. The rate of milking by hand was 146.2 pounds per hour and by machine milking it was 234 pounds per hour. Energy consumption records showed the use of .56 kw. hr. for milking 193 pounds of milk from 16 cows or .07 kw. hr. per cow per day and .29 kw. hr. per hundred pounds of milk.

On another farm, hand milking of heavy Holsteins required 10.2 man-hours per day for a herd of 22 cows. Within one week after installing a milking machine, the time was reduced to 6.6 man-hours, and two cows were still being milked by hand. This saving in time represented a real saving to this farmer as he was paying $50 per month and board for hired help. In terms of this man's wages only, the milking machine saved $20.40 of time per month. If the interest and depreciation, figured at $4 per month, and cost of electricity at $1.80 per month are subtracted from the above saving, the net saving is $14.60 per month.

Several tests were made to determine power requirements, energy used, etc., for milking machines. Records of two tests are given below for a one-man and a double unit milker.

Test No.	No. of cows	Weight of milk, pounds	Time milking, minutes	Watts power	Kw. hrs. used	Kw. hrs. per 100 lbs. of milk	Pounds per hour milked
1	16	191	45	695	.53	.27	254
2	16	193	49	695	.56	.29	236

A graphical record of the power required for the ½-h-p. single phase motor is shown in Figure 142. The record was taken from right to left. The power decreased as the machine warmed up. The sudden rise in power for a minute or so was probably caused by the machine's not being in use on the cows at the time. The ½-h-p. motor is slightly overloaded on this job and gives a little trouble in cold weather. By connecting the motor to a 220-volt circuit instead of to a 110-volt circuit most of the trouble was eliminated.

The energy used per year is quite large and makes a desirable load. The amount of energy used for milking is given in Table CIII. The amount varies from 211 to 541 kw. hrs. per year. The amount of energy per cow varies from 13 to 26 kw. hrs. per year.

TABLE CIII
ENERGY USED FOR MILKING MACHINES

Month	Cady		E. Johnson			Miller
	1926	1927	1925	1926	1927	1927
January	0	0	38	54	41	18
February	34	34	41	55	43	20
March	23	37	32	56	36	16
April	23	37	31	63	48	17
May	26	19	39	57	46	17
June	25	28	46	57	47	19
July	17	44	58	37	41	21
August	0	17	44	29	38	17
September	0	0	20	31	37	15
October	0	0	29	30	36	18
November	4	0	35	35	34	17
December	6	0	20	37	32	16
Total	158	216	433	541	479	211
Average	..	..	36	45	40	..

Cream Separators

Cream separators can be run by an electric motor most profitably. The time saved varies from one-half an hour to an hour each day per farm. The cream separator on the average farm uses from 1 to 3 kw. hrs. per month. One farmer stated his satisfaction with the electrically driven cream separator by saying, "No man can afford to be a crank for 11 cents a month."

A 1/6-h-p. motor is large enough to drive most of the cream separators, but a ¼-h-p. motor may be used on some of the large machines and is advisable if a separator is to be driven through any counter shaft or other speed reduction device. The amount of energy used is so small that the rate per 100 pounds of milk is not of any interest.

CORN HUSKING AND SHREDDING

Several different rigs for husking and shredding corn have been electrically driven. A 10-roll husker was driven by a 15 h-p. motor (see Fig. 143). Another 8-roll husker was driven by a 15 h-p. motor one year and by a 10 h-p. motor another year. One 6-roll machine was driven by a 10 h-p. motor, and when the speed was reduced, it was driven by a 7½ h-p. motor. A 4-roll husker was driven by a 10 h-p. motor and a 7½ h-p. motor. A 2-roll husker was driven by a 5 h-p. motor. The husking and shredding came at a time of the year when it was difficult to carry on any extensive experimental work. The subject requires much further study. It should be possible to drive a 4-roll machine with a 5-h-p. motor and a 6-roll machine with a 7½-h-p. motor, but this is not very satisfactory with the present machines.

Corn husking is frequently done in early winter. Farmers find that the use of tractors for power during freezing weather causes considerable delay. One farmer was husking in December. He used just the four men working on the place from about 10:00 a.m. until 3:00 p.m. He used a tractor five days and husked 470 bushels. He used 15 gallons of kerosene per day as the tractor had to run continuously to keep it from freezing. The kerosene cost $1.87 per day. The 15-h-p. motor was used for 12 days and he husked 1,130 bushels. The motor used approximately 26 kw. hrs. per day at a cost of 78 cents. The amount of energy

Fig. 143. Ten-roll husker and shredder driven by a 15 h-p. motor mounted on skids. Smaller outfits will generally be used.

used per year for husking and shredding varies from 50 kw. hrs. to about 150 kw. hrs. per farm.

On one farm a two-roll husker was operated by a 6-h-p. gasoline engine. At the time of the test the capacity was 12 bushels per hour. With very dry corn, well eared, the husker was capable of husking 15 bushels per hour. The cost of gasoline and oil was 92 cents per 100 bushels. A 5-h-p. motor was substituted for the engine and the capacity was increased to 20 bushels per hour. The increase in capacity was due to the fact that the motor was capable of carrying the instantaneous overloads without slowing down enough to interfere with feeding or with the blower. The cost of electricity was 60 cents per 100 bushels. The increase in capacity was sufficient to change the time of husking one load from an hour and 15 minutes to 45 minutes. On 27 loads this represented a saving for two men of 27 hours. This farmer had about 400 bushels of corn. The saving in the cost of fuel was $1.28 and in labor was $10.80 or a total saving of $12.08. The actual saving was, of course, greater than this, as the gasoline engine cost $170 and the electric motor $140.

ROOT CUTTING

An electric root chopper can be used to save much labor. One such machine was used to cut about 400 bushels of roots. The machine was equipped with a ¼-h-p. motor. The motor required 400 watts and used .243 kw. hrs. to cut 740 pounds of mangles in 37 minutes. This cutting was at the rate of 1,200 pounds per hour, and used .0328 kw. hrs. per hundredweight of roots. The cost of electricity was about 2 cents a ton.

GLOW HEATER FOR BABY PIGS

An adjunct of the dairy business is swine raising, and one of the serious causes of losses to swine raisers is the mortality of baby pigs. One of the farmers on the Red Wing line reported that in February and March, 1926, he lost 40 per cent of his pigs at farrowing time. His sows began farrowing in February, 1927. He lost all of the pigs of his first litter. A 550-watt glow heater was obtained. When the second sow farrowed, the heater was used for a short time to warm and dry the pigs. In spite of the fact that the temperature was 5 degrees below zero at the time, he did not lose a pig from this litter. In the season of 1927 he lost but 3 per cent of his baby pigs, and none was lost by chilling. The cost of the electricity for warming and drying ten or twelve litters was from 25 to 50 cents.

USE OF ELECTRICITY IN POULTRY INDUSTRY

The poultry industry offers more varied uses of electricity than any other phase of farming, and considerable advance has been made in developing commercial equipment for the work. Electricity may be used to light the poultry houses, to provide ultra-violet light, for incubating and brooding, for heating water fountains, for ventilation, for candling eggs, for cleaning the dropping boards, and for other general uses such as feed grinding and pumping water.

Lighting the Poultry House

The investigations at Red Wing showed that farmers could install electric lights in poultry houses at a cost varying from $2.50 to $4 per hundred hens. Lights placed so as to cover a space varying from 16 x 16 feet to 20 x 20 feet are satisfactory. A 40-watt light with a good reflector placed about five feet from the floor (see Fig. 144) gives satisfactory lighting for a space 16 x 16 feet. Without a reflector a 50-watt lamp should be used. While the 40-watt lamp is satisfactory under normal conditions, if the pen is crowded or if

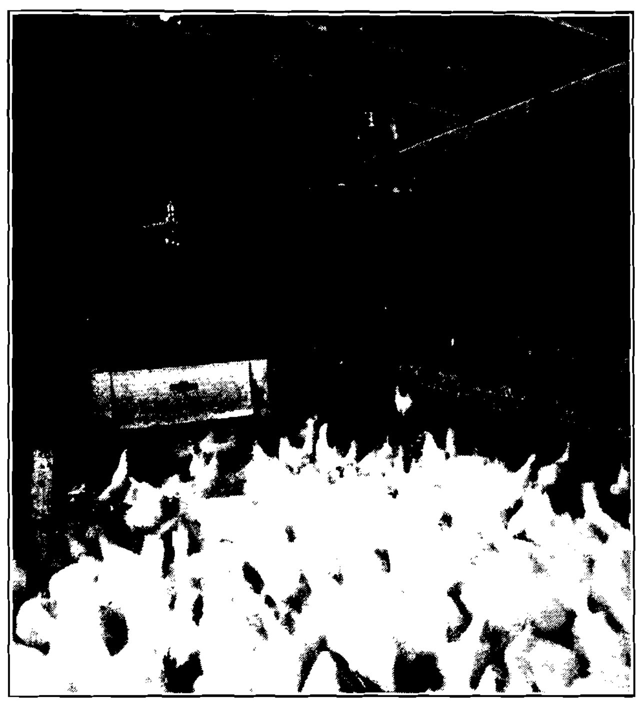

Fig. 144. Poultry house showing good type of lighting unit and good distribution. Note ultra-violet lamp in foreground near ceiling.

the walls are dark, a 60-watt lamp should be used to give satisfactory illumination near the walls.

The value of a good reflector was shown by tests at one farm. An 8-inch can-cover was tried above a light. Tests showed that the unpolished, dark cover absorbed so much light that it did not increase the illumination on the floor. A good reflector placed on the same lamp increased the illumination from 1.1 foot candles to 2.0 foot candles.

The cost of electricity for poultry house lighting is nominal. Table CIV shows the number of kw. hrs. used for the purpose.

Preliminary work showed that the farmers could use the lights better in the evening than in the morning or than in a combination of morning and evening. An automatic switch is usually necessary for morning use. Lights were turned on at dusk and then the grain feed was given usually at 8 or 8:30, and the lights were turned off about half an hour later. Previous experience had shown that dimmers were not necessary. After a week or two of experience the hens learned to be on the roosts about a half-hour after they were fed.

TABLE CIV
ENERGY USED PER YEAR

No. of hens	140	850	130	80	110	700	150
January	6.5	....	14	12	4	80	9
February	4.5	104.0	11	13	7	37	2
March	...	82.0	..	10	..	9	1
April	...	28.7	..	1	..	4	..
September	...	9.0	..	..	..	..	..
October	...	73.0	..	..	..	16	10
November	6.0	107.5	..	..	5	60	14
December	18.0	114.0	23	10	6	67	11
Total	35.0	518.0	48	46	22	273	47
Kw. hrs. per 100 hens	25.0	61.0	37	57	20	39	31

Effect of Lighting

Most of the farmers in the project did not secure enough eggs from their flocks of 80 to 150 hens during November and December to supply their own household needs the first year of the experimental work, before lights were used. Two farmers decided to use lights the following winter. Lights were installed in the poultry houses of Mr. Miller and Mr. Eckblad at a cost of about $7 and $11, respectively. Egg records were kept for the flocks on these two farms as well as on some of the other farms. The flocks were not large producers but were probably better than the average. Mr. Eckblad had Leghorns and Rhode Island Reds, and Mr. Miller and Mr. Melin had White Leghorns. Mr. Miller and Mr. Eckblad housed their flocks in old made-over buildings and Mr. Melin used a nearly new, well made poultry house. Mr. Miller's poultry house was very cold. Records for production are given in Table CV.

Mr. Eckblad sold part of his hens on February 1 and the remainder a month later. In order to bring out the production of these different flocks more clearly, the production is shown graphically in Figure 45. The horizontal spaces represent weeks. A very large production was obtained in the lighted houses during November and December when egg prices are usually high. The value of lights cannot be determined merely by the increase in egg production, but, rather, by knowing the value of the eggs received. In the previous winter Mr. Eckblad had bought three dozen eggs for home use during November, December, and January, owing to slack production from a similar type of flock of approximately the same size as he had in 1925-26. During the three months, November, December, and January, 1925-26, the egg yield, and value of eggs at prices received for each of the three flocks were as follows:

Name	No. of hens	No. of eggs	Value
B. I. Melin (no lights)	150	807	$ 33.30
F. A. Miller (lights)	130	3,168	105.00
C. H. Eckblad (lights)	140	4,530	175.87

Records of sales could not be kept longer than three months as Mr. Eckblad sold his hens. Electricity for lighting on each of the two farms did not cost $1 for the three months' period.

The egg yields for flocks in lighted houses differ considerably from the yields for other flocks. Records for such flocks are shown in Tables CVI and CVII. The egg yield is very low for November, December, January, and February, with a high maximum yield in April and comparatively high yield in the last part of March and in May for flocks without lights. On the other hand, the flocks in lighted houses in the winter time give a comparatively low maximum in December and another maximum in February or March, while the production in April and May is about the same as in January.

One farmer, Mr. Lokkesmoe, turned to poultry farming after the experimental work was begun. The poultry houses are shown in Figure 145. Each house would hold about 300 Leghorns. Records of egg production for this flock were begun in November with nearly 850 pullets. Electricity was not installed until February 4, 1926. Before installing lights, the east house was divided into two pens and the hens apportioned according to floor space. The west pen with 106 hens was unlighted, while the remaining 714 hens were in lighted pens (see Fig. 144). The egg production record for this flock for a year is given in Table CVIII. During August, September, and October about 375 were sold and pullets were put into the pens.

A much higher production was obtained at the end of October, 1926, when lights were used, than during the first part of November, 1925. The production record for the check pen without lights and for the other

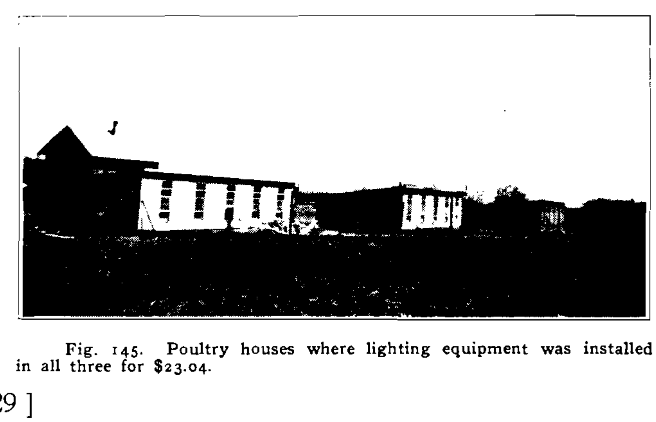

Fig. 145. Poultry houses where lighting equipment was installed in all three for $23.04.

lighted pens is given graphically in Figure 46. Lights were first used on February 4. The graphical record starts on that day, and is continued until March 6. In the pen without lights the average was 11.9 eggs per hen. In the lighted pens the average was 15.9 eggs per hen for the month. The increase in egg production for the lighted pens over the unlighted was 225 dozen eggs. Eggs were sold at an average price of 32 cents per dozen. The increased egg production, therefore, was worth $87.04 for one month, while the electricity for lighting the poultry houses cost $3.12.

TABLE CV

EFFECTS OF LIGHTING ON EGG PRODUCTION, 1925-26

	Miller		Melin		Eckblad	
Number hens per pen	130		150		140	
Egg production, Nov. 1	4		2		4	
	Per pen	Per 100 hens	Per pen	Per 100 hens	Per pen	Per 100 hens
November						
1st week	67	51	12	8	56	40
2nd week	167	128	11	7	124	88
3rd week	237	182	6	4	245	175
4th week	297	228	10	7	348	248
December						
1st week	312	240	17	11	427	305
2nd week	335	257	39	6	484	345
3rd week	364	280	44	29	511	365
4th week	278	213	74	49	469	335
5th week	271	208	84	56	368	262
January						
1st week	229	176	61	41	357	255
2nd week	238	183	110	72	351	251
3rd week	203	156	200	133	418	298
4th week	160	123	191	127	365	261
February						
1st week	162	124	151	101	224*	160
2nd week	266	204	207	138	287	205
3rd week	295	226	192	128	317	226
4th week	325	250	239	158	245	175
March						
1st week	336	258	190	127	...	...
2nd week	304	233	170	113	...	...
3rd week	244	187	226	151	...	...
4th week	233	179	250	166	...	...
5th week	247	190	390	260	...	...
Totals	5,570	...	2,874	...	5,596	...

* One group sold but production increased pro rata for remainder.

Ultra-Violet Light

Very little data on the use of these lights were secured. The machine was one of the earliest types and gave much trouble. The light was installed in the middle house at Mr. Lokkesmoe's farm (Figure 144). The photograph was taken while the ultra-violet light was on. The hens would gather underneath the light. They seemed to think it was sunlight. One hundred seventy-two hens were given electric lights and the ultra-violet light, while 114 hens were given electric lights only. The pens were kept separate for a little more than a month. Egg records showed an increase in egg production from 30.8 per cent to 40.3 per cent for the pen with lights only, and an increase from 32.6 per cent to 50.2 per cent for the pen with the ultra-violet light, from the first week in February to the first week in March.

Other tests with the ultra-violet light indicated that deaths from disease in the winter time were fewer in pens where the ultra-violet light was used. Two settings, of 30 eggs each, were made in the same type of incubator. One half of each machine was filled with eggs from hens on which the ultra-violet light had been used. A 68 per cent hatch (of all eggs set) was secured from the setting treated with ultra-violet light and a 57 per cent hatch from the others. During the first week after hatching, 8 chickens were lost from the first group and 22 from the untreated hens. An accident prevented further records.

The ultra-violet light required about 400 watts power. It was placed about six feet from the floor and was used from 30 minutes to two hours during the feeding period. The energy consumption varied from 3 to 20 kw. hrs. per month.

Results indicated that a reliable machine could be used profitably for helping to increase egg production with late hatched pullets, and that it could be used for treating hens whose eggs were being used for hatching.

Electric Incubation

Two farmers of the group had been using oil-heated incubators. On these two farmsteads, both oil-heated and electric incubators were tried, in order to get comparative data.

On one farm the two incubators were placed in the same room and filled with eggs from the same group of hens. The operator was familiar with the oil-heated incubator but was unfamiliar with the electric machine. A 77 per cent hatch was secured with the electric machine and a 55 per cent hatch with the oil-heated machine. On the other farm two machines were operated in succession instead of simultaneously. A 72 per cent hatch with the oil machine and a 54 per cent hatch with the electric machine were secured. The electric machine did not have good temperature control and the temperature ran too high. This machine was later returned to the manufacturer as defective. In general the electric incubators gave very little trouble with heat regulation. The cost of fuel for the four incubators referred to above was as follows: In the first case, for the oil-heated, $.84 per 100 eggs; for the electric-heated, $.42 per 100 eggs. In the latter case, for the oil heated, $.50 per 100 eggs; for the electric heated, $1.00 per 100 eggs.

In the second test with the first two incubators mentioned above, the results were an 82 per cent hatch for the electric and 55 per cent hatch for the oil-heated. Two other hatches with the oil-heated machine gave hatches of 35 per cent and 45 per cent. The oil-heated machine was discontinued.

Electric incubators were placed on six of the experimental farms. It is not necessary to give records from many of these machines. An incubator of 1,400-egg capacity was placed in one farm, and a group of nine incubators with a total capacity of 2,700 eggs (Figure 146) was placed on a poultry farm. Records were kept for two seasons on the 1,400-egg incubator and are given in Tables CIX and CX. The early hatches are invariably poor although the fertility is nearly the same in the early spring as later in the season. Hatches from eggs set after the first week in April are usually very good. Information is given in these tables showing the amount of energy used for hatching.

TABLE CVI

Egg Record, No Lights—130-150 Hens

Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3	7	14	62	55	42	42	53	16	6	2	1
2	2	5	6	58	80	45	28	20	18	4	3	1
3	5	8	10	50	51	37	29	20	20	3	1	1
4	4	1	3	69	80	37	32	21	30	5	2	3
5	2	4	6	57	53	35	46	25	18	3	1	8
6	1	2	6	56	63	44	52	21	20	4	2	2
7	2	1	10	70	60	33	27	25	16	2	1	10
8	3	0	14	42	50	47	47	35	20	3	3	7
9	2	6	7	50	47	41	22	31	25	2	1	2
10	1	1	14	50	37	25	32	25	18	2	2	8
11	3	2	18	79	61	57	25	34	22	1	3	5
12	2	3	17	35	48	35	27	43	16	2	2	5
13	2	4	24	87	56	35	28	31	19	1	3	4
14	2	2	35	85	47	20	15	23	28	1	2	7
15	3	2	15	73	62	35	25	22	20	2	1	5
16	0	3	32	50	61	34	18	20	20	1	1	5
17	1	8	35	76	49	35	12	25	20	1	1	5
18	3	8	40	55	46	34	15	32	20	2	2	8
19	3	10	42	60	46	28	11	28	13	1	1	10
20	5	2	20	50	57	35	23	23	16	2	2	11
21	3	9	35	50	41	35	16	22	15	3	1	10
22	2	9	42	65	39	34	19	27	14	1	2	12
23	3	7	37	74	58	33	20	25	14	2	1	12
24	3	12	40	64	37	47	17	32	19	1	1	16
25	8	6	57	70	49	45	18	28	12	2	2	13
26	3	11	58	52	33	42	12	36	13	3	1	11
27	9	9	54	71	56	32	32	26	9	4	1	22
28	4	7	63	60	42	35	15	26	8	2	2	12
29	4	8	36	80	45	32	17	41	9	2	2	13
30	9	6	58	52	40	54	12	28	8	1	1	10
31	3	10	60	54	25	46	12	29	7	1	1	12
Total	100	173	908	1,915	1,574	1,169	746	877	523	70	51	251

TABLE CVII

Egg Record, Lights—November, December, January, February—110-130 Hens

Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	36	19	46	33	28	26	31	13	14	4	4	41
2	31	20	44	35	32	24	23	18	11	6	7	42
3	34	31	50	30	31	29	28	16	17	3	10	48
4	29	25	50	38	35	31	26	21	10	5	12	53
5	36	28	47	31	31	28	21	23	15	8	8	48
6	33	29	52	35	38	32	27	19	13	2	11	51
7	33	39	48	29	32	27	18	21	10	3	15	40
8	35	38	41	36	33	29	25	17	14	1	18	47
9	34	29	40	33	28	33	20	14	9	0	16	48
10	33	38	45	39	31	37	29	19	13	4	19	48
11	38	39	47	35	37	31	19	18	12	1	24	50
12	34	40	41	33	30	34	21	21	11	2	28	51
13	36	43	46	31	31	29	26	17	16	3	29	55
14	32	43	44	38	35	31	17	14	12	2	33	60
15	31	40	38	42	36	28	19	22	18	4	25	60
16	30	34	32	35	31	24	18	27	14	1	32	55
17	29	38	30	30	28	22	23	21	10	2	32	40
18	33	44	37	33	29	23	16	17	8	1	26	41
19	25	48	35	28	33	28	12	22	12	2	41	43
20	28	48	38	32	30	31	21	18	14	2	40	42
21	27	42	35	35	35	34	17	25	11	3	41	40
22	30	47	40	29	31	30	23	18	10	1	38	41
23	25	43	33	30	28	38	16	21	9	1	42	40
24	26	48	28	35	33	30	11	23	11	2	46	42
25	23	48	33	31	31	26	19	17	7	3	44	49
26	22	47	32	37	27	32	22	15	10	4	37	40
27	21	50	34	32	24	25	14	14	12	1	57	34
28	23	47	31	36	29	31	17	19	8	2	33	41
29	20	..	33	30	31	28	21	21	10	3	40	41
30	20	..	32	31	30	30	16	16	8	1	40	37
31	..	..	25	29	28	24	13	18	6	2	..	38
Totals	887	1,085	1,207	1,031	966	905	629	585	355	79	848	1,406

TABLE CVIII

EGG RECORD AT LOKKESMOE'S

Days	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
1	14	144	172	197	482	469	480	452	368	160	144	94*
2	10	151	192	241	448	494	465	432	375	178	157	97
3	17	160	196	247	464	442	480	423	403	185	162	80
4	15	158	182	221	425	431	462	416	368	178	144	103
5	18	145	180	246†	457	426	487	402	366	168	143	103
6	15	172	193	271	455	386	444	400	373	194	158	103
7	18	173	192	256	503	436	485	368	357	166	123	90
8	26	155	194	292	452	401‡	472	378	368	182	120	100
9	25	180	190	316	468	396	504	378	345	164	115	126
10	30	180	200	299	456	413	478	375	364	160	120	114
11	42	168	206	304	447	432	451	376	372	170	115	120
12	45	185	186	345	448	466	464	342	337	117	126	139
13	47	178	223	342	470	435	479	387	300	160	120	129
14	58	187	199	377	486	471	461	378	322	125	108	141
15	71	171	215	401	511	464	427	340	274	152	116	135
16	67	193	224	436	478	464	460	352	289	174	108	139
17	66	172	228	435	510	453	445	374	270	152	104	137
18	73	185	210	448	534	534	440	342	286	157	107	159
19	77	185	235	450	507	477	467	359	253	161	113	153
20	68	179	234	456	566	443	422	340	260	155	107	145
21	92	201	214	465	540	489	434	332	264	162	114	162
22	98	183	237	497	568	467	449	303	244	152	108	141
23	87	198	233	448	562	513	430	362	222	161	102	150
24	106	180	214	451	540	502	445	330	248	181	100	156
25	112	188	229	450	528	513	451	311	212	172	95	140
26	118	191	228	455	540	482	459	312	214	153	108	146
27	125	190	239	464	500	486	464	342	191	172	90	167
28	128	158	215	430	486	477	399	330	195	173	87	140
29	129	190	222	...	497	453	443	326	198	134	85	161
30	126	168	209	...	515	482	460	372	207	172	90	170
31	...	182	255	...	553	...	440	...	187	179	...	187

* Lights used on all pens.
† Lights used on all but 106 hens in check pen.
‡ Lights discontinued on all pens.

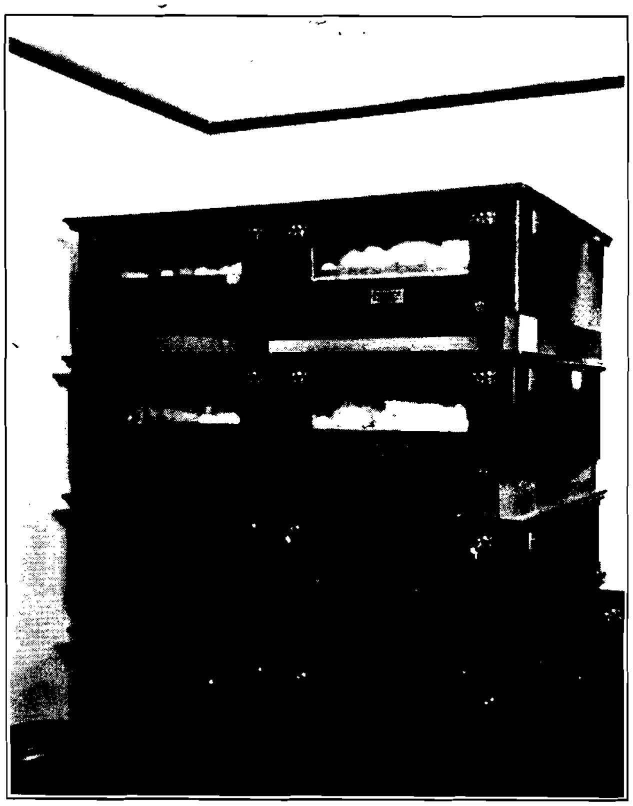

Fig. 146. Group of electric incubators of 300-egg capacity each.

TABLE CIX

HATCHING RECORD AT ECKBLAD'S

Date of hatch	Number of eggs set	Chicks hatched	Per cent hatch of all eggs	Per cent hatch of fertile eggs
First setting made March 9.				
March 30	312	85	27	46
April 3	191	89	46	79
April 6	90	13	14	37
April 10	336	198	59	80
April 17	336	174	51	65
April 24	336	168	59	54*
May 1	336	235	70	77*
May 8	392	316	81	90*
May 22	672	495	73	81*
May 29	336	269	80	89*
June 7	336	229	68	75*
Total	3,673	2,271	62	

* The eggs were not tested for these settings. The per cent hatch of fertile eggs is based on an assumed fertility of 90 per cent.
Energy consumption, 991 kw. hrs.
.27 kw. hr. per egg set.
.43 kw. hr. per chick hatched.

Records for three different incubators are given in Table CXI. These records indicate that 70 per cent to 80 per cent hatches could be secured by the farm operators without much difficulty.

The energy consumption for hatching depends on the make of incubator and on the room temperature.

The records indicate a consumption varying from .14 kw. hr. to as high as .33 kw. hr. per egg-set. Under good operating conditions it appears that an average of .2 kw. hr. per egg-set could be used for estimating energy consumption.

The power requirements of these incubators vary from 150 watts for an incubator of 150-egg capacity to 630 watts for the 1,400-egg machine. The power varies from .5 watt to 1 watt per egg. The power requirements of the 1,400-egg incubator are given below. This incubator is of the rotary type, having two heating elements and a motor for operating the fan.

	Amps.	Volts	Watts	P.F., per cent
Motor and both units	7.11	113.1	629	78.1
Motor and one unit	5.74	115.0	402	60.3
One unit	2.50	116.6	270	92.5
Motor only	4.68	113.8	138	25.9

TABLE CX

Eckblad Hatching Record

Date of hatch	Number of eggs set	Chicks hatched	Per cent hatch of all eggs	Per cent hatch of fertile eggs
March 17	364	131	36	40
March 22	336	134	40	43
March 27	364	144	39	42
April 4	364	193	53	58
April 10	336	270	80	83
April 16	364	309	84	88
April 22	364	229	63	79
April 28	336	268	80	84
May 4	364	333	91	94
May 10	364	312	85	91
May 16	336	280	83	90
May 22	360	247	69	80
May 28	360	273	73	84
Total	4,612	3,123	67	74

Energy consumption 901 kw. hrs.
.19 kw. hr. per egg set.
.28 kw. hr. per chick hatched.

TABLE CXI

Hatching Records

Date of setting	Number of eggs set	Number of fertile eggs	Chicks hatched	Per cent hatch of fertile eggs
Incubator No. 1				
March 17	146	128	78	61
April 12	160	149	118	80
May 7	150	134	108	80
June 2	150	123	109	88
Energy consumption 87 kw. hrs. or .14 kw. hr. per egg set.				
Incubator No. 2				
April 1	180	130	95	73
April 27	200	168	115	67
May 21	176	158	115	73
June 16	180	157	117	74
Energy consumption 178 kw. hrs. or .24 kw. hr. per egg set.				
Incubator No. 3				
March 24	[illegible]	146	51	35
April 15	178	150	120	80
May 9	[illegible]	[illegible]	96	70
June 3	[illegible]	133	107	80
Energy consumption [illegible] kw. hrs. or .33 kw. hr. per egg set.				

Incubator Tests

These tests were conducted to determine the temperature ranges inside of the incubator as compared with room temperatures, and to determine the number of times the control switch went on and off and the effect of shielding the thermostatic switch from the direct rays of light from the 10 60-watt carbon filament lamps used in heating the incubator.

The first incubator tested was of 250-egg capacity, manufactured in New York. The incubator had ten 60-watt carbon filament lamps hooked in 5 pairs and each pair of lamps was in series, thus making 5 separate circuits. When all of the bulbs were on, they drew a current of about 2 amperes on a 110-volt circuit making a load of 220 watts. The incubator was set in a room where the incubator temperature could be controlled from 45° to 85° F. without causing any drafts or great variations in temperatures within the room. The room thermometer was placed just beside the incubator on the same table. The current was turned on several days before the test to insure proper temperature regulation.

The first test was run under a room temperature of about 70° F. during which the bulbs of the thermographs were placed as near the same point as physically possible and run for one week to check them. The second week the bulbs were placed as shown in Figure 147 and run at ordinary room temperatures. Each day at noon the sun would shine through the window on the incubator and the room temperature at the incu-

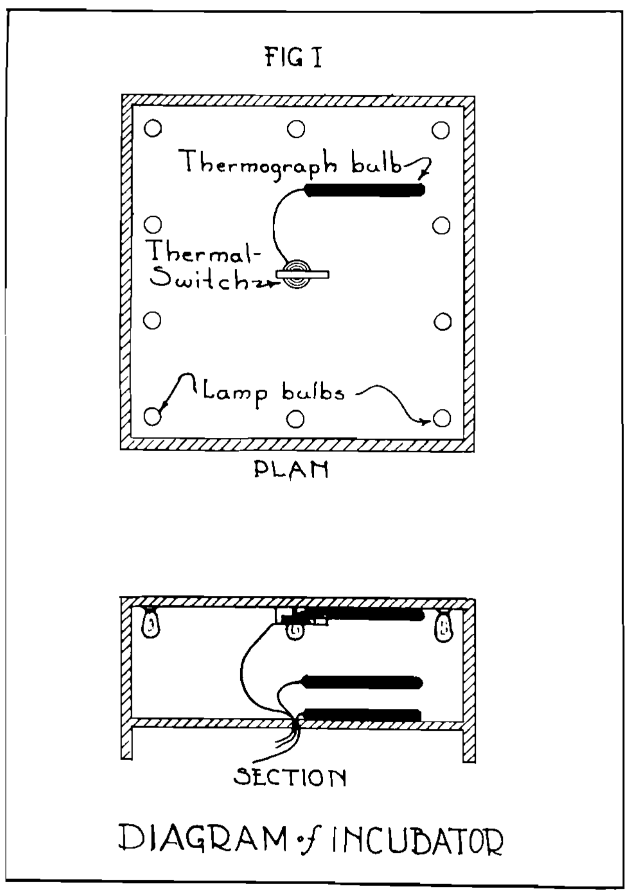

Fig. 147. Diagram showing both horizontal and vertical location of thermometers in incubators during test.

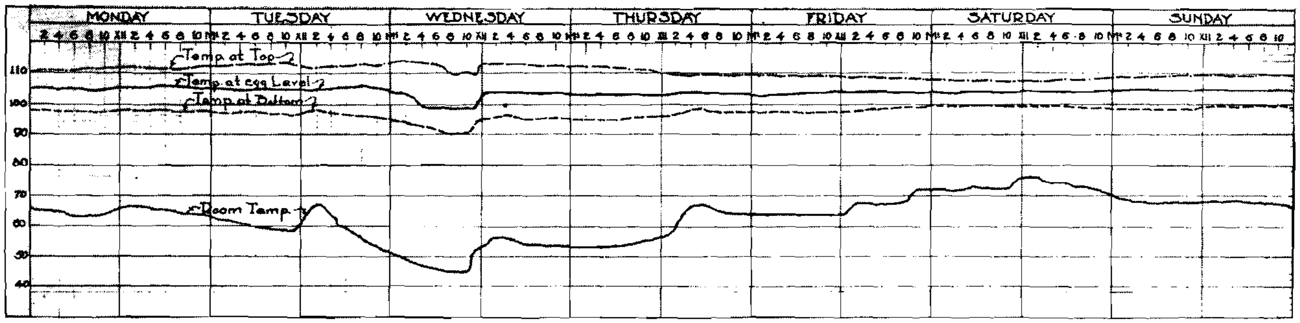

Fig. 148. Temperatures taken in incubator and in room. Note that incubator does not keep proper temperature when room is colder than 50° F.

bator rose to about 80° F. from an average of 60° F. Graphical records showed that the temperature at the bottom of the incubator rose slightly—1 to 3 degrees. There was no appreciable change in temperature at the egg level, while, at the top of the incubator there was a slight drop of 1 or 2 degrees. This shows that a sudden change for an hour or two does not affect the operation of the incubator materially.

The temperature records shown in Figure 148 are the outside temperatures and the temperatures at three levels in the incubator. When the outside temperature fell below 50° F. the heating elements remained on continuously and raised the temperature at the top of the incubator to about 116° F., yet the temperature at the egg level dropped to 99° F. and at the bottom of the incubator the temperature dropped to 90° F. This incubator gave poor hatches when kept in a cold room and the reason became clear.

A series of temperature values were plotted from these results as shown in Figure 149. Outside temperatures from 46° F. to 76° F. were used as abscissas and inside temperatures from 90° F. to 120° F. were used as ordinates. The upper curve A shows how the temperature at the top of the incubator varies with the room temperature. Curve B shows the variations in temperature at the egg level. Curve C shows the variations at the bottom of the incubator. The dotted curve D shows the number of times per minute the circuit was cut out by the thermostatic switch and how this varied with the change in outside temperature.

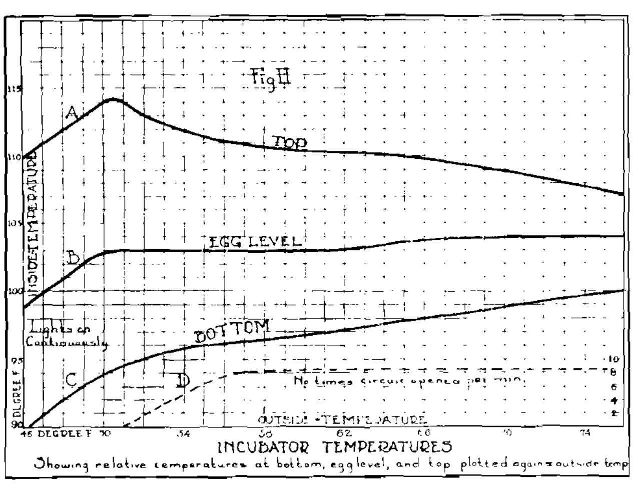

Fig. 149. Graph showing effect of room temperature upon the temperature in the incubator and upon the operation of circuit breaker.

As would be expected, the lower the room temperature the fewer times the circuit was cut out. This was measured by a graphic wattmeter. At room temperatures above 60° F. there was very small change in the number of times the circuit was cut out. Below 60° F. the number of times drops off very rapidly until the room is about 51° F. at which temperature the lights are on continuously.

While the lights were on continuously it was possible to maintain the temperature for a short time, but it soon dropped off very rapidly. The top of the incubator was affected the most, as seen by the curves in Figure 149. Being near the source of the heat and at top the temperature naturally rose as the lights were burning more of the time. It reached a maximum just

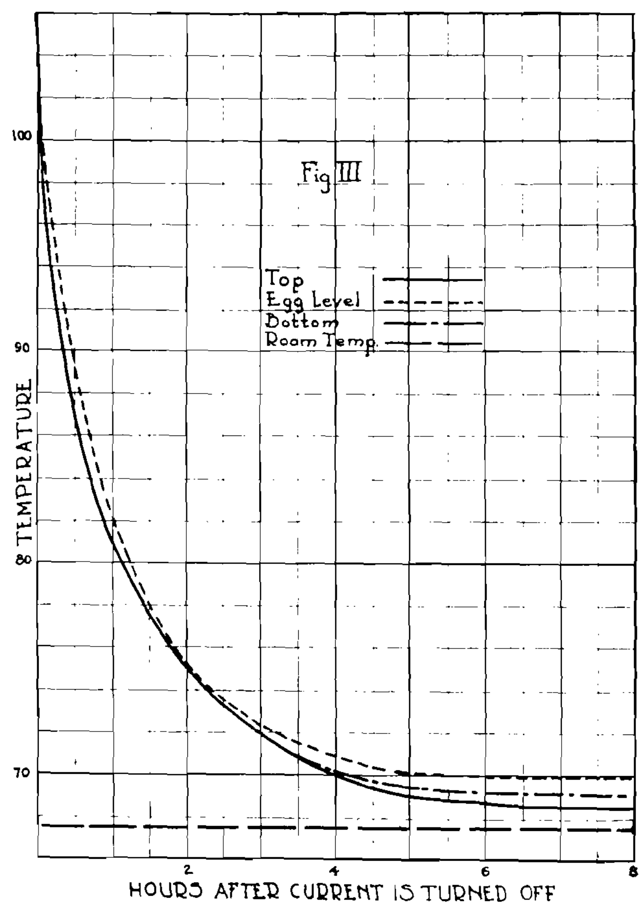

Fig. 150. Graph showing rate at which temperatures drop in the incubator when electricity is cut off.

after the switch ceased cutting out. Only so much heat was given off by the lamps and after the temperature of the room went below 51° F. it was not enough to keep up the temperature in the incubator and it dropped off very abruptly from there on.

From the temperature curves can be learned some of the precautions that should be taken in operating this type of incubator. First of all it is easily seen that the temperature of the room should not be allowed to go below 51° F. at the lowest; or perhaps, better, not below 55° F., as here the temperature difference from top to bottom is so great that it is hard to say just what the egg temperature would be. The room temperature could, of course, go to 103° F. but the thermostat would have to be changed and the operator might not be at hand to make the change when it was needed, so the safest thing would be to keep the incubator in a room where the temperature remained about 60° F. to 70° F.

The thermometer should be kept as near the eggs as possible. The bulb of the thermometer should, if possible, rest on one of the eggs and not be hung two or three inches above the eggs. The reason is that there is such a great difference in temperature at different levels inside of the incubator that, unless the temperature is taken at the egg instead of above it, the eggs are apt to be too cold. There is a temperature difference of from 3° to 11° F. at the egg level and at the top of the incubator with only a 20° change in room temperature.

In any form of electric service the power is likely to be cut off for any one of many causes for a period of 3 or 4 hours. This is too long for the welfare of a hatch, and if incubators could be insulated so as to hold the heat better, better hatches could often be obtained. Figure 150 shows that the temperature at the egg level dropped off 16° F. the first 30 minutes and in 2 hours it dropped 28° F.

Another difficulty in the type of incubator described was that the lights were forced to go off and on so often that the contacts in the switch soon burned and failed to work as they should. It was surmised that the energy from the light rays was what caused the wafer to expand and make the lights go off and on continuously. A shield was put around the thermostat which protected it from the light rays and this reduced the number of times the switch opened per minute to about 3½, or less than half as many times as without the shield.

Again the bulbs were enameled black so that no light whatever was emitted. This reduced the number

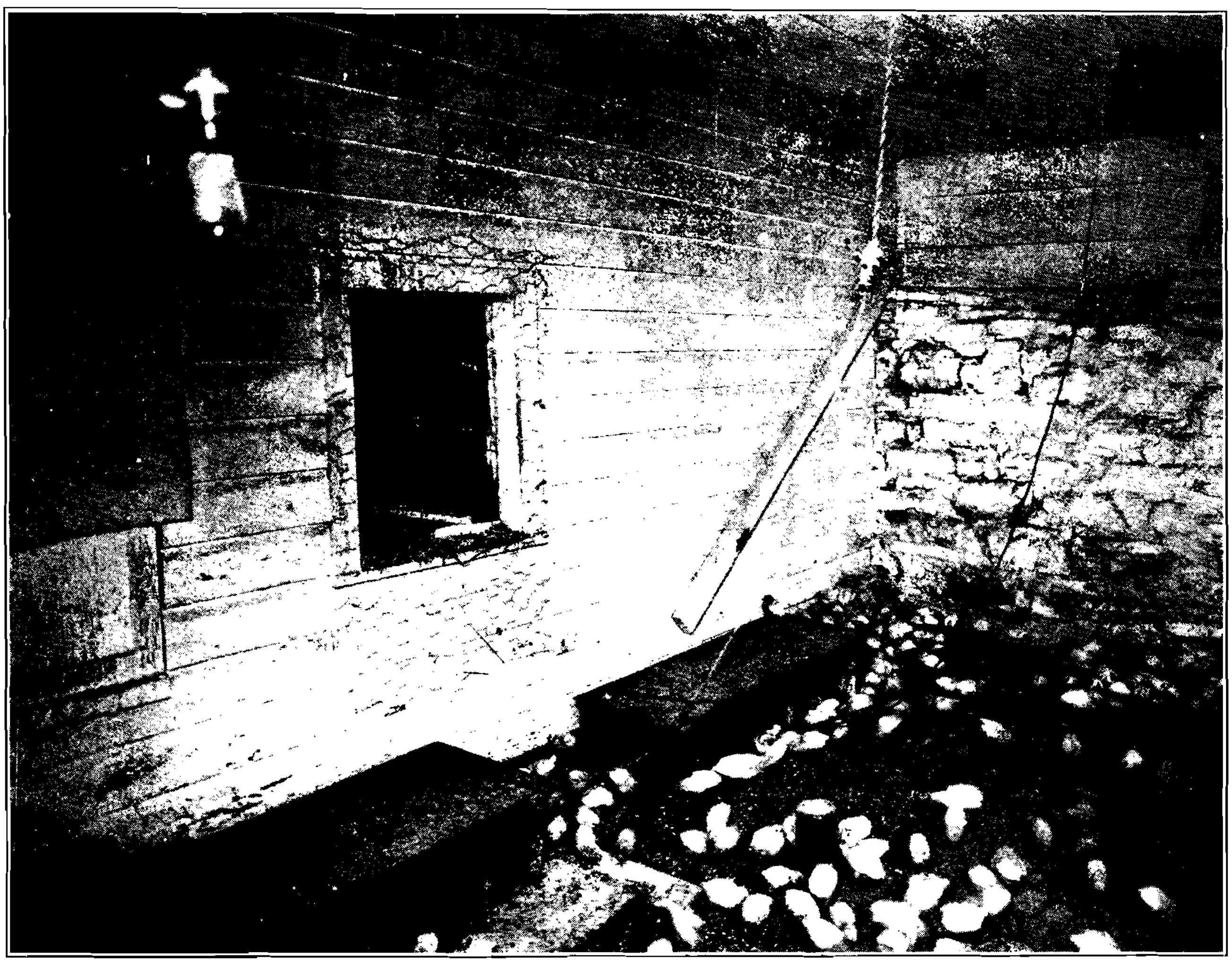

Fig. 151. Electric chick brooders. One at right is commercial and one at left is home made.

of times the switch operated to about once in 2½ minutes, about 1/4 as often as it did with the clear bulbs and no shield. The drop in temperature while switch was open was so slight that the recording thermometers showed no change.

A similar test was made on an incubator which was heated by means of a hot wire in the top. This showed about the same temperature range and the length of time that the heat unit was on compared favorably with that of the other when black bulbs were used. The number of times the switch opened and closed had very little to do with the amount of energy used. There was only about 2½ per cent difference between the two extremes.

All of these tests were made without any eggs in the incubators. Different temperature conditions prevail when there are eggs in an incubator, especially after about the fourteenth day of the hatching period.

Electric Brooding

Electrically heated brooders were used on seven of the experimental farms. Some of these gave excellent satisfaction while others did not. Most of these brooders were of the commercial circular type. The one at the right in Figure 151 is a commercial rectangular type and the one at the left is home-made. These two were heated with electric light globes. Most of the others use resistance heaters. The heating of the brooders with electricity was very satisfactory and where they were used along with oil-heated or coal-heated brooders, they maintained better temperature conditions.

The power requirements varied from 100 watts for a 50-chick size to 220 watts for a 250-chick size. Some of the brooders did not have heating capacity sufficient for use in the cold weather of late winter or early spring, in unheated buildings. The energy used varied from 48 kw. hrs. per year for one batch of chickens in a small brooder to 239 kw. hrs. per year for three batches of chicks in a 150-chick size brooder. The consumption varied from .5 kw. hr. per chick per brooding season to 2 kw. hrs. per chick.

UNLOADING HAY WITH A POWER HOIST

There were no hay hoists designed for use with an electric motor, available in America. A hay hoist that was designed for operation with a gas engine was, therefore, obtained in 1925 and placed in use on the A. C. Bryan farm. This hoist would not operate satisfactorily with a motor because of the high speed of the motor even when a 4-inch pulley was used on the motor. Investigation showed that a 5 h-p. motor needed an advantage of about 50 to 1 in order to operate the hoist. A 30-inch pulley was put on the hay hoist in place of the 20-inch pulley and the original gear ratio of 16 to 68 was changed to 10 to 64. These changes made it possible to lift the largest forkfuls of hay without requiring more than 4,400 watts at the motor.

This hoist consumed about .65 kw. hr. per ton of hay. The time required to haul up one forkful and return the fork was 50 seconds. The speed of the 6-inch drum on which the rope was wound was 44 r.p.m. The average day's run was about 18 loads of hay with two teams hauling. Mr. Bryan unloaded 116 loads of hay, and the cost of electricity for this was $2.25. A fair charge for interest and depreciation on the hay hoist was $8.80. Hay hoists can be built at a lower cost. Similar charges for a motor for such work would be about 50 cents. The total cost of power for unloading the hay on this basis was $11.55. If a boy were hired to do this work, he would be needed for about 7½ days. His wages and board would cost $15. The cost of horse hire using the figure of $2.50 per day, as given by G. F. Warren in Cornell University Bulletin No. 414, would be $18.75. The total power cost for unloading with a boy and a horse would be $33.75. Such savings as this help to eliminate the electric bill as an expense item.

The clutch in this hoist was between the power pulley and the gears. Thus the heavy gears were still attached to the rope drum when the clutch was released. When the fork was pulled back, the rope unwound from the drum and the inertia of the heavy gears kept the drum turning after the rope stopped unwinding. This caused the rope to tangle. Another hoist was obtained. This hoist had the clutch between the gears and the rope drum. When the rope was being unwound the gears were not connected to the drum. The drum had but little inertia and no trouble with the rope's unwinding was encountered.

One of these hoists (Figure 66) was installed on the farm of W. A. Cady and has done the job very satisfactorily, and is simple to operate. The hoist is located in the feedery and small ropes are strung out to the end of the barn where the man on the load can easily reach them. Figure 152 shows how the man on the load can handle the entire operation by pulling one rope to raise the load and then the other to return the empty carrier to the outer end of the track.

The objects in view in this test were to determine the amount of power required to do the job and some of the problems involved in the arrangement and operation of equipment.

The equipment used in this experiment consisted of a Louden Single Drum Power Hoist, a 5 h-p. Westinghouse motor driving a line shaft from which the hoist was driven. The motor had a 6-inch pulley running 1,750 r.p.m. The line shaft was belted to the motor by a 14-inch pulley which gave the line shaft a speed of 700 r.p.m. The hoist had a 20-inch pulley

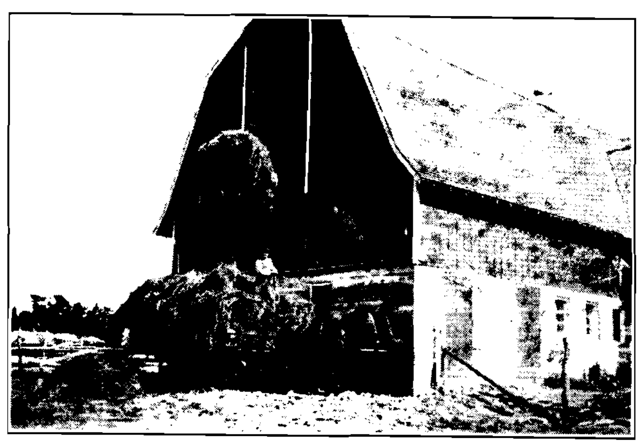

Fig. 152. Hay hoist in operation, showing control ropes going to hoist in feedery.

driven by an 8-inch lagged pulley on the line shaft. This gave the intermediate shaft a speed of 290 r.p.m. On this shaft was the return rope drum which made the return rope travel at a speed of approximately 300 feet per minute. The intermediate shaft drove the main lifting drum by means of gears at a ratio of 9 to 44, which made the drum turn at 60 r.p.m. and with a couple of layers of rope on the drum gave the rope a speed of 120 feet per minute while lifting the load or it lifted the load at a speed of 60 feet per minute when a two-rope carrier was used.

A Hudson combination fork and sling carrier was used and was operated with a 24-inch double harpoon Hudson fork.

When unloading with a 24-inch fork at the above rate, the required power is within the capacity of a 3 h-p. motor. The maximum input to the motor for any of these readings was 3.75 kw. with an average of 2.93 kw. One maximum input was found to be 4.5 kw., when there was an exceptionally large amount of hay lifted from the load, part of which fell off. Even this is within the range of a 3 h-p. motor as it is not a continuous load. The following figures give maximum readings obtained for each forkful of hay.

Load No.	Amps.	Volts	Watts	Energy	P.F.
				kw. hr.	per cent
1	18.75	216	3,750	.249	92.7
2	13.75	216	2,650	.324	89.2
3	12.5	219	2,680	.225	97.8
4	16.0	215	2,300	.217	67.0
5	17.3	214	2,880	.290	77.8
6	22.5	212	3,330	.354	70.0
Averages	16.75	215	2,930	.276	82.4
Hoist idling	10	222	1,100	...	50.0

Among the instruments used was a graphic wattmeter which gave the results shown in Figure 153. This shows the entire load on the motor at all times while two loads of hay were taken off. The maximum power required for raising any one of the forkfuls was 3,600 watts and that was considerably above the average. The motor, lineshaft, and hoist idling required only a little more than 1,000 watts on the average. About 14 minutes was required to unload a wagonload. After the farmer used this outfit, he decided to buy a set of slings to replace the fork as then he could unload in much less time. He now takes off a load from an 8 x 16 foot rack with two slings in little more than half the time, and the 5 h-p. motor does the job very well.

Several of the graphic wattmeter records were integrated and the following results obtained:

Average of total kw. input	Kw. input for motor only	Time, min.	Energy required, kw. hrs.		
			Total	Motor and hoist only	Net for lifting
1.59	1.17	9.25	.246	.180	.066
1.26	.96	17.75	.372	.284	.088
1.18	.955	16.25	.321	.258	.063
1.36	1.075	13.25	.301	.239	.062
1.65	1.135	12.00	.330	.223	.107
. 1.25	.94	13.75	.286	.216	.070
1.29	.955	10.25	.220	.167	.053
Averages					
1.37	1.02	13.20	.296	.223	.073

From these figures can be seen that the largest part of the energy used was consumed in the overhead load, with the motor and hoist running idle between lifts. The total cost of energy used is so low that the amount that could be saved by the use of a remote control switch would be so small that it is hardly worth considering.

SAWING WOOD AND LUMBER

The sawing of wood by small power-driven, crosscut saws has become quite a general practice on Minnesota farms. A few farmers have used small (5 to 8 h-p.) gas engines, but generally tractors or larger engines have been used for such work.

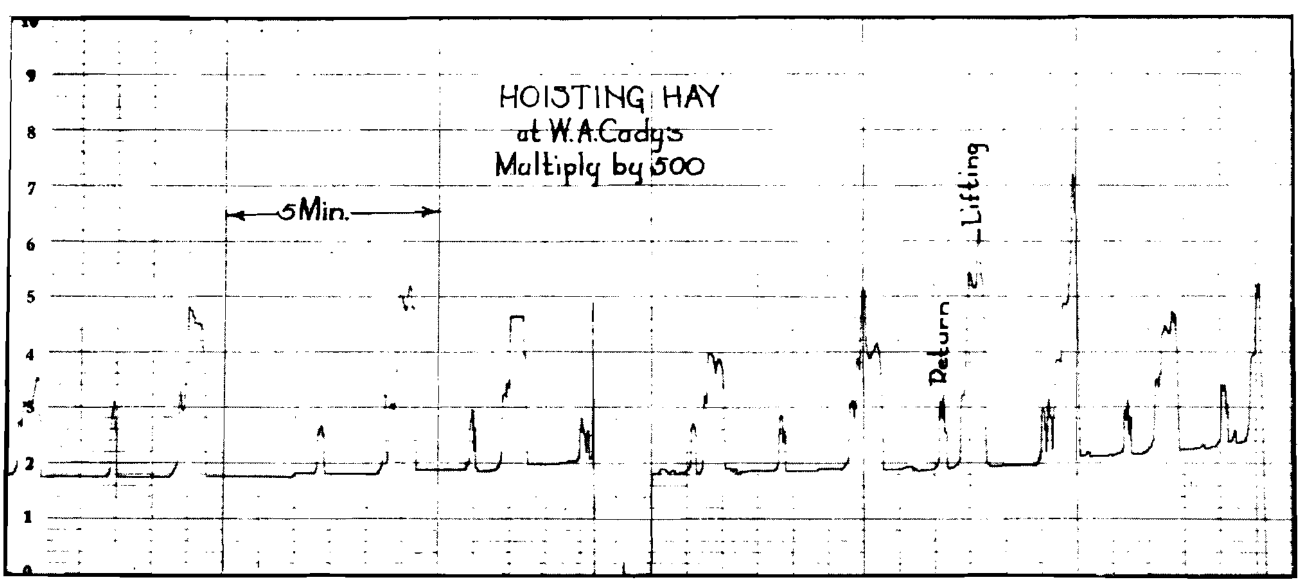

Fig. 153. Wattmeter record of hay hoisting. Note that idling current is quite large and that the energy used for lifting is a small part of total energy used.

The 5 h-p. portable motors have been used at Red Wing for the work. (See Figure 154.) The motors at first did not appear to be as satisfactory as was expected. The load on a motor when operating a saw varies largely. The overloads are very large but last usually for a short interval. Overloads up to 9 and 10 h-p. were very frequent when sawing hardwood, but they would last only from 2 to 10 seconds. Under such conditions, the flywheel on a gasoline engine would carry the overload readily, but the motor did not have enough stored-up energy. The motor speed would usually drop enough to cause the motor to run on the brushes.

In order to remedy the trouble, some of the saw mandrels were equipped with an extra flywheel. In one case two heavy flywheels were used. This gave very satisfactory results. A Horton variable speed pulley, to operate backwards, was placed between the motor and saw. This gave the desired results, but it was not convenient and was difficult to adjust for the large variation in load.

Figures of tests conducted to show the effect of a large flywheel and of the Horton pulley are given in Table CXII.

The reading are only a few to show the trend of the power under different conditions. The average values are taken from a large number of readings. The voltage would drop so low as seriously to interfere with the operation of the motor when the saw was operated with the regular flywheel equipment. (See Figure 154.) The motor was overloaded about 90 per cent. If the motor had been located close enough to the transformer so that the voltage would not have fallen below 200 volts, it would have carried the overload without slowing down enough to interfere with the sawing. The saw under this condition is satisfactory for small (6-inch) logs or for most soft woods, when the motor is not more than 150 feet from the transformer.

TABLE CXII

LOAD CONDITIONS WHEN SAWING

Meter readings at intervals

	Minimum volts	Maximum amp.	Maximum watts	Minimum watts
	Test I Sawing Mandrel and Flywheel			
	92 x 2	11.0 x 5	1,500 x 5	360 x 5
	89	12.4	1,520	500
	93	10.4	1,440	600
	95	9.1	1,200	620
	100	7.2	1,000	620
	104	6.4	960	700
Average	95.5	9.4	1,270	567
	Test II—With Extra Flywheel			
	102 x 2	7.0	1,240 x 5	380
	103	6.4	1,200	800
	104	6.2	1,120	780
	102	5.5	1,140	600
	103	6.4	1,080	620
Average	103	6.3	1,156	636
	Test III—With Flywheel and Horton Pulley			
	106 x 2	5.4 x 5	980 x 5	800 x 5
	104	5.8	1,020	920
	107	4.8	960	820
	105	5.5	1,000	800
	107	4.6	940	740
Average	106	5.2	980	816

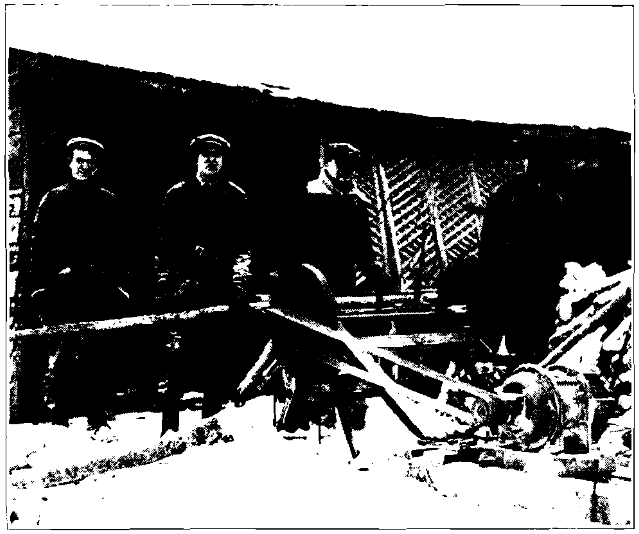

Fig. 154. A 5 h-p. motor driving a 24-inch saw. Another flywheel mounted on a saw mandrel will assist a great deal in smoothing out the load.

When the extra flywheel was added, the voltage improved, and the maximum amperes and maximum watts decreased considerably. At the same time, the minimum watts, taken when the saw was not in a log, increased. The addition of the extra flywheel improved the operation so much that it was used with other outfits. The minimum watts increased less than the maximum watts decreased, and less energy was used for sawing.

The Horton pulley gave results very similar to that of the flywheel. The motor was not overloaded seriously at any time with the pulley.

Tests were made to determine the energy used in sawing wood. A tractor was used to cut about 60 cords of wood. Twenty-one gallons of gasoline at 19 cents per gallon and 2 gallons of oil at 60 cents per gallon were used. The total cost of fuel was $5.19 or about 8 cents per cord. Five men were used on this work for 30 hours or 2½ man-hours per cord.

Mr. Bryan with three boys cut 6 cords of oak in 1¾ hours, and used 5 1/3 kw. hrs. with a 5 h-p. motor. With electricity at 3 cents per kw. hr. the energy used was .9 kw. hr. per cord, or 2 2/3 cents per cord. The cutting was done at the rate of 1 1/6 man-hours per cord. The motor cut the wood at more than three cords per hour. The logs were mostly less than 6 inches in diameter.

At another farm a 5 h-p. motor was used to saw 25 cords of wood and used 40 kw. hrs., or at the rate of 1.6 kw. hrs. per year per cord. The wood was quite large logs, some 18 inches in diameter.

The amount of energy used for sawing does not exceed 100 kw. hrs. for an average farm. The average load while sawing appears to be about 5 h-p. so that small 5 h-p. portable motors can handle the sawing. The addition of one or two extra flywheels on the saw mandrel costs very little and assists greatly in reducing the maximum power required. It saves stoppages to allow the motor to pick up speed when sawing heavy logs.

Sawing Lumber

A test in sawing lumber was made with a 15 h-p. Century motor and a portable saw mill. The mill had a 46-inch circular saw which ran at 630 r.p.m. when idling. The carriage was moved by a flat friction clutch, pulling a pinion with a rack on the carriage. The material sawed was oak averaging about 18 inches in diameter and 8 to 10 feet in length. The logs were nearly all dried out as they had been cut for more than a year and a half and had been lying on the ground. They were free from any free water to aid in softening the wood or cooling the saw. The power was transmitted from motor to saw by means of an 8-inch, 75-foot belt, tightened so there was only slight slippage.

Electrical instruments were put in at the transformer ahead of the 750-foot extension cable.

Voltage at transformer, no load, 484 volts.

Voltage at transformer, mill idling, 476 volts.

Amperes of load, mill idling, 8 amperes.

Watts of load, mill idling, 3,200 watts.

Power factor, mill idling, 84 per cent.

As each cut was made the watts input increased and the current increased, and the voltage showed a considerable drop, as seen by the following readings:

No.	Volts	Amps.	Watts input	P.F.
				per cent
1	476	8	3,200	84.0
2	460	60	24,000	87.0
3	440	90	36,000	91.0
4	440	110	38,400	79.5
5	420	125	36,800	70.1
6	408	130	37,000	72.3

This gives a comparison of the readings for various loads.

The graphic watt-meter record gives the varying demands. The long low-reading interval was made while the sawyer was placing and turning the logs and cants on the carriage. This had to be done by hand.

The amount of material sawed was 32 6x8x8 ties, 1,024 board feet; 465 feet of ½-inch basswood lumber; approximately 5,000 feet of miscellaneous lumber in various dimensions and kinds of wood; total 6,489 feet. The energy consumed was 204 kw. hrs. The rate per 1,000 feet was 31.5 kw. hrs.

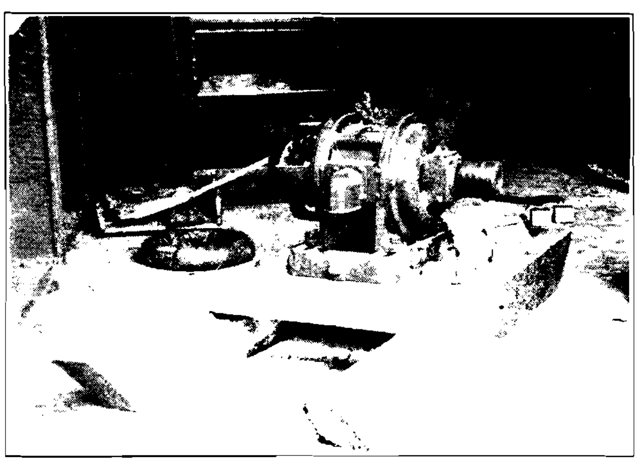

Fig. 155. First portable motor outfit built at Red Wing. Skids not very practical.

The material was hard to saw, as can be seen from the watt-meter readings. Every cut made by the saw required an input into the motor of 24 kw. or more, some of them reaching 36 and 38 kw. and then it was necessary to release the load for a bit to allow the saw to come back up to speed. This was done as much as three or four times during a cut.

THE PORTABLE MOTOR

Some type of power is required for many minor jobs on the farm. Such jobs as sawing wood, mixing concrete, planing lumber, cleaning grain, hoisting hay, cutting ensilage, husking corn, grinding meat, shelling corn, and elevating grain into granaries might all be handled by one motor operating a line shaft. A portable motor, however, would be desirable for the other jobs.

The first portable motors used at Red Wing were mounted on skids. There were no portable motors on the market and trucks were quite costly. Three motors were mounted similarly to that shown in Figure 155. They gave trouble in anchoring, however, when small pulleys and tight belts had to be used, and were unhandy in moving. All three of these motors are still being used on the skids.

A truck seemed so much more desirable, that some of the motors were mounted on frames and then trucks were attached to the frames. One of the first outfits of this type is shown in Figure 156. This is a 3 h-p. motor. The thermal cutouts and switch were mounted on the frame. The cable leading to the motor, in this case, was brought in through a collapsible pipe mast as shown. This made it possible to keep the wires off the ground, and they could be placed high enough so that traffic could go underneath. These masts were very cumbersome and have been discarded. The cable

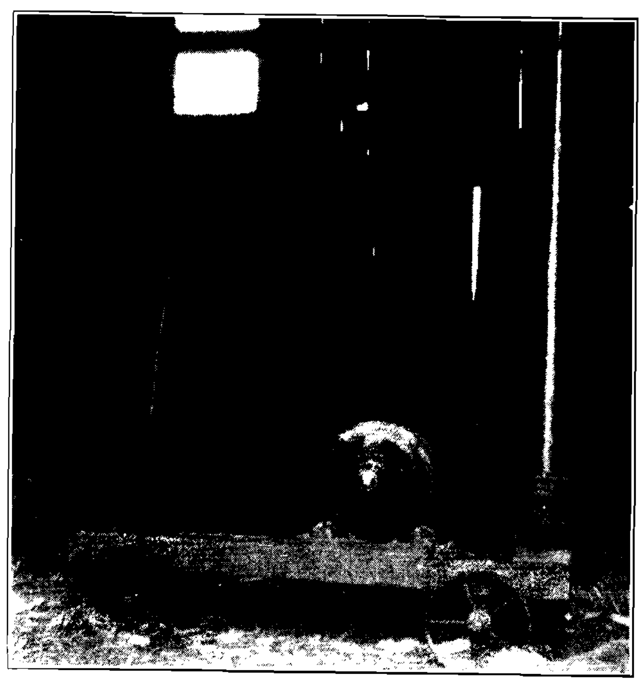

Fig. 156. First portable motor truck built at Red Wing. Collapsible mast not recommended.

Fig. 157. Portable motor truck with speed reduction gear jack. This outfit has been quite satisfactory.

can be protected amply, while lying on the ground, with a board or plank covering.

Most of the farm machines for jobs of the kind run at low speeds. Some device was necessary to cut down the speed, and to supply different speeds. One portable outfit shown in Figure 157 was equipped with a geared-speed jack of a commercial type, with a cone clutch. Three reduced speeds could be secured with this outfit. This has given very satisfactory service but it requires two belts and the loss in power is considerable. For such jobs as elevating grain, mixing concrete, etc. it works very well.

Another truck, shown in Figure 158, was equipped with a jack shaft and pulleys of three different sizes. This gave a higher efficiency than the one shown in Figure 157, and it was less expensive. As shown in Figure 158 it is being used for two jobs at once. The 5 h-p. motor is driving a rotary grain cleaner and a 6-inch burr feed mill at the same time. One man could handle both operations, and thus save time when the feed-grinding equipment was not arranged with hopper bins for automatic feeding. This was the most satisfactory type of portable motor with speed reduction device attached. Following the development of this motor truck, a motor manufacturer developed and placed on the market the first commercial portable farm motor. This is shown in Figure 159 operating a pump jack. Pulleys of different sizes were placed on the jack shaft, so that different speeds were available. But the truck wheels were too small and other features were found undesirable, so that it was soon superseded.

A portable motor truck involving many desirable features (Figure 160) was built by a manufacturer. Pulleys of two sizes, one on each end of the shaft, were provided. Large-sized wheels were used, and the truck was made in the form of a wheelbarrow. The two legs were sharpened so as to assist in anchoring and the cable was coiled up on the handle. This outfit was very satisfactory, but the design has been changed in many respects.

For some of the larger power jobs such as threshing or husking with the larger machines, a 10 h-p. or a 15 h-p. motor was mounted on a portable truck. The 15 h-p. portable outfit is shown in Figure 80. Such an outfit as this can be used to operate a portable saw rig or any other heavy power job.

Portable motors ranging in size from 3 to 15 h-p. have been used in the experimental work. At the present time it appears that a 5 h-p. motor is the most suitable size for various farm jobs. If a farmer wishes to grind feed at a relatively high rate or wishes to cut a large amount of ensilage in a season, then a 7½ h-p. motor should be used. Larger motors than 7½ h-p. are not necessary unless threshing is done by electricity.

From the standpoint of the power company, the portable motor makes a desirable load. It is used mostly during the daytime on off peak load, and it can generally be used at times when very little other electrical equipment is in use on the farm.

Very little of the equipment used on the farm with the 5 h-p. motor has to be driven at very low speed. When low speed is necessary it can be given by the use of countershafts or other devices. Most of the portable motors now being placed on the market have no speed reduction device.

Fig. 158. Portable motor being used for two jobs at the same time. Truck with counter shaft and pulleys for various speeds.

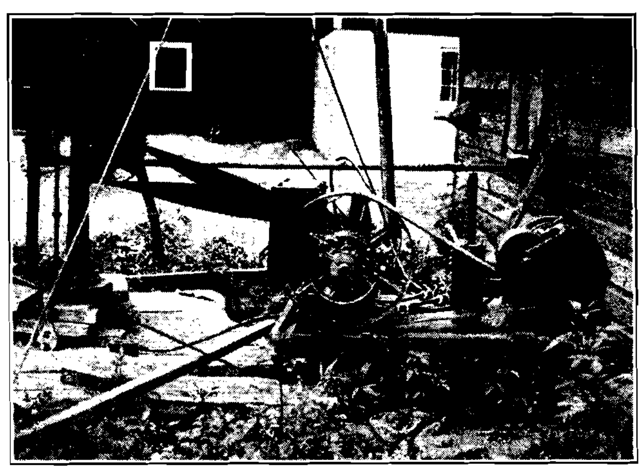

Fig. 159. The first type of portable motor truck built by a commercial firm.

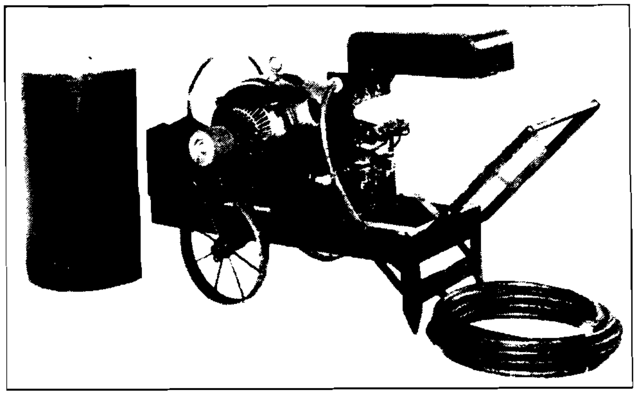

Fig. 160. Second type of portable motor truck. Many principles of European trucks embodied in this type.

WATER HEATING

The use of the hot-water front on a kitchen range or in a furnace will supply hot water during the winter season on the farm, but during the summer, when an electric range is used, some other type of water heater is necessary.

In two of the farm homes of the Red Wing project two-burner kerosene heaters were installed. In one, with a family of three, 88 gallons of kerosene were used from May 17 to November 2. During the rest of the year the hot-water tank was connected to the water front in the furnace. The kerosene cost $11.88. This is quite a satisfactory method, although somewhat slow.

Electric water heaters were just being placed on the market when the experimental work started. Two such heaters were installed on the Red Wing Line, and they have disclosed some interesting facts. One of these, a Sepco, of 15 gallons capacity, manufactured by the Automatic Electric Heater Company, has been in use a little over three years in a home where there are only two persons. It is fully automatic to give hot water at all times and the water has been used for all kinds of domestic purposes, including those of a small dairy which requires hot water for cleaning and sterilizing milk utensils.

The second, a 15-gallon Clark Electric Water Heater made by the Stoughton Manufacturing Company, has been used for one year in a home where there are about six persons the year round. This farm has a large dairy herd, which means a large amount of hot water for cleaning and sterilizing. This heater was also connected so as to give hot water at all times. Table CXIII shows the amounts of energy used for each month of the year by the two heaters.

The temperature of the water at the sink was 200° F. in the case of the Clark heater and 184° F. at the sink from the Sepco heater.

These heaters gave satisfactory hot-water service. But at a cost of 3 cents per kw. hr. the farmers cannot afford to heat water in this manner, or else they must use less hot water. The cost of water-heating varied from $4.60 to $6 per month for the family of two persons, and from $11.40 to $18.60 per month for the family of six persons and a large dairy. With electricity for water heating at 1½ cents per kw. hr. these farmers could afford to use electric heaters.

Figure 161 shows the watt-meter record taken of the Clark heater mentioned. The graph shows the demand of this heater, which was about 2,500 watts, also the distribution over a typical 24-hour period. The heater came on once from 11 p.m. until 6 a.m. which shows that there must be very little radiation from the tank. More water was used in the earlier part of the day and in the evening, which this graph clearly shows.

TABLE CXIII

Water Heating

Month	Sepco Heater			Clark Heater		
	Kw. hrs.	Gallons heated	Kw. hrs. per gallon	Kw. hrs.	Gallons heated	Kw. hrs. per gallon
January	167	323	.517	537	894	.602
February	140	248	.564	333	600	.555
March	188	248	.758	369	786	.470
April	*	*	*	380	860	.442
May	177	278	.636	515	1,200	.429
June	156	255	.612	336	780	.432
July	104	368	.528	543	1,100	.494
August	144	293	.492	615	1,211	.507
September	151	210	.719	535	1,020	.525
October	165	225	.733	582	1,110	.524
November	188	285	.660	620	1,040	.595
December	201	263	.764	415	880	.472

* No readings.

TABLE CXIV

Energy Used for Water Heater

Month	A. Nelson			E. Johnson		
	1925	1926	1927	1925	1926	1927
January	17	167	185	...	425	438
February	22	252	205	...	369	333
March	19	188	188	...	675	369
April	26	167	167	...	424	380
May	24	178	178	...	658	542
June	20	160	156	...	681	524
July	7	185	194	...	564	626
August	7	129	145	...	628	615
September	7	92	151	...	720	555
October	184	173	165	...	703	583
November	248	244	188	...	644	620
December	342	...	180	...	525	415
Total	923	1,935	2,102	...	7,016	6,000

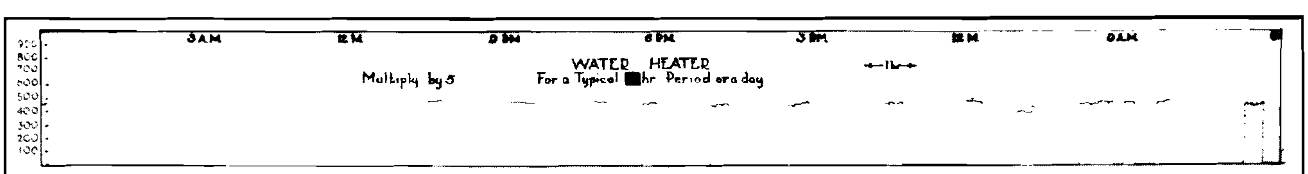

Fig. 161. Wattmeter record of water heater. Read right to left. Note heater was on only twice between 9:00 p.m. and 6:00 a.m.

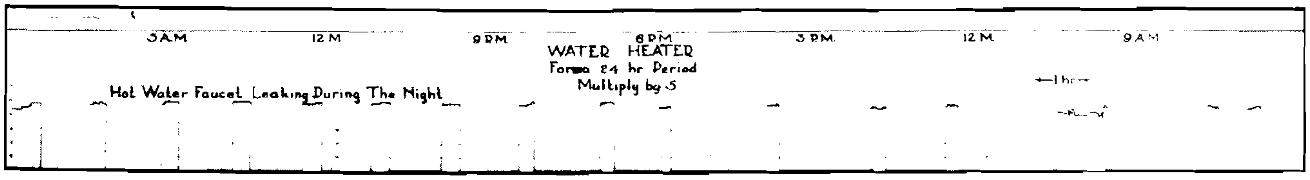

Fig. 162. Wattmeter record of water heater. Note wasting of energy at night due to faucet leak.

Figure 162 is another typical day's record. The faucet was not closed completely, and a small stream of water ran all night. This caused the heater to come on 6 times more than in the case mentioned just above. At three cents per kw. hr. it meant a waste of about 15 cents in this one period of nine hours.

Meter records for the two water-heaters are given in Table CXIV. Until October, 1925, the heater at Nelson's was turned on by a hand switch whenever they wanted hot water. They were so saving of the water that they did not have satisfactory service. In October the heater was made automatic. The heater for a small family will use, as shown, about 2,000 kw. hrs. per year or 1,000 kw. hrs. per person. This ratio holds about the same for the other heater where they used from 6,000 to 7,000 kw. hrs. per year for six persons.

HOUSEHOLD USES OF ELECTRICITY

Electric Ranges

Electric ranges were placed in seven of the experimental farm homes, a two-burner hot plate was placed on one farm, and separate cooking devices and an electric oven was placed on the ninth farm. Two ranges were combination electric and wood.

In one home the wood range was dispensed with for about two years, and the electric range was used summer and winter for all purposes. Then it was replaced by a new wood range. This home had a furnace, a hot-water system connected with the furnace and with a kerosene water heater. The family consisted of three adult persons and conditions were very good for the use of an electric range. But the family felt that the range was costing too much. They used from 125 kw. hrs. to 200 kw. hrs. per month for cooking. The larger amounts were used at times when extra farm help was there for threshing, etc.

The combination ranges (Figure 163) have been quite satisfactory. One of these has been used for all of the period since the work was started. This type of range appears to offer a solution for farm homes in which it is necessary to heat the kitchen. This range can be used to heat water by use of coils in the fire box, but some other heater should be used for summer hot-water supply. Many of the ovens on electric and combination ranges are not so large as the ovens on the old wood ranges. The housekeepers complain that the ovens are not large enough to handle readily the large farm baking jobs. One farm woman handled one week's baking with the combination range and then practically a duplicate baking the following week with the old wood range. The baking consisted of: 17 loaves of bread (1¾ lbs.), 2 pans (large) biscuits, 2 layer cakes, 4 pies, and 80 cookies.

The total baking time with the combination range was 9 hours and 15 minutes and with the wood range, 6 hours and 10 minutes. In one case it required all day and in the other case the housekeeper was through soon after noon and free to go to town.

The electric ranges such as shown in Figure 164 have been used largely to supplement the wood ranges. The energy used in electric ranges is given in a discussion on energy uses.

Range Tests

Tests of ranges in use on farms have shown a wide difference in the speed with which the units heat up. Part of this is due to the type of element in use and part to the variation in voltage. Tests on the surface units of seven ranges showed a variation from 5.1 minutes to 13.5 minutes for the time required to bring one pint of water from room temperature to the boiling point. The range unit which took the least time was the one with the lowest wattage (1,200 watts). One range using 50 per cent more, however, required 6 minutes to bring the water to boil.

The voltage at the range controls the rate at which heat is produced. A variation from 99 to 117 volts was found for the surface units on ranges in different

Fig. 163. Combination electric range makes a satisfactory stove for many farm kitchens.

Fig. 164. Good tyne of electric range where a wood range may be retained to heat the kitchen.

homes. In one home the voltage at the range varied from 94 to 118 volts, depending upon what other equipment was in use at the same time. Such a wide variation in voltage makes it difficult to do good oven-cooking. In either of the two cases given above, it requires 40 per cent more time with the low voltage to produce the same amount of heat as with the higher voltage. This is a very important thing in cooking pies, buns, etc. In extreme cases, with low voltage, much difficulty is experienced in getting the oven to a proper temperature.

Refrigerators

The electric refrigerator (Fig. 165) has been one of the most popular pieces of equipment. One special combination dairy and household refrigerator and four household refrigerators were placed in use when experimental work began. Three additional household refrigerators have been purchased. But no experimental work has been carried on.

Fig. 165. The electric refrigerator is one of the most popular electric household appliances.

Fig. 166. Washing machine should be a part of every home equipment. Note laundry trays.

The energy used for refrigerators is given in Table CXV. Some of these machines are used for four or five months and one machine has been used the year around for two years. When refrigerators were used for summer use only, they required from 212 to 451 kw. hrs. per year, or from 35 to 64 kw. hrs. per month. The size of the refrigerator influences the amount of energy used, but the amount of material refrigerated and the amount of water placed in the refrigerator are important factors. The large refrigerator (8.76 cu. ft. capacity) required from 46 to 64 kw. hrs. per month. The actual monthly variation was from 28 to 108 kw. hrs.

TABLE CXV

ENERGY USED IN REFRIGERATORS

	Lokkesmoe		Nelson Brothers			Eckblad	Melin		
Size of refrigerator, cu. ft.	5.14		5.88			6.39	8.76		
	1926	1927	1925	1926	1927	1927	1925	1926	1927
January	0	0	0	0	0	0	60	26	48
February	0	0	0	0	0	0	73	0	0
March	0	0	0	0	0	0	47	10	0
April	0	0	37	25	5	0	61	58	0
May	38	21	70	63	54	23	74	89	0
June	45	39	62	68	67	65	81	108	15
July	42	47	56	71	75	73	84	92	63
August	43	41	62	71	66	86	87	68	53
September	37	40	63	60	98	0	80	77	59
October	30	24	31	40	69	1	79	66	56
November	22	0	0	0	17	1	77	62	46
December	0	0	0	0	0	0	8	59	28
Total	257	212	381	398	451	249	811	715	368

Washing Machines

Every one of the farmers secured an electric washing machine when the work was begun. Wherever it was possible the laundry was equipped with laundry tubs (Fig. 166). When laundry tubs could not be installed, hot and cold water faucets were installed in the room where the washing was done.

The washing machines use only from 2 to 5 kw. hrs. per month. This amount is so small as to be of no consequence either to the user or the power company.

Ironing

All of the farmers also bought electric irons for laundry use. Three ironing machines were placed in the homes. The machines, like the one shown in Figure 167 have been very successful and have saved the farm women much time. Records indicate that the use of an ironing machine saves from one-third to one-half of the time required to do an ironing by use of the electric iron.

The connected load in these machines varies from 700 watts to 1,500 watts. The machines are heated and ready for use in about 15 minutes. The larger machine used in a family of six persons used from 140 to 272 kw. hrs. per year, or from 12 to 22 kw. hrs. per month. The smaller machines used from 80 to 110 kw. hrs per year for families of three and six persons. This is about the same as the amount of energy used by the electric iron in the same type of home.

The ironing machine is not large enough to overload the 3 kva. transformers when a 5 h-p. motor is being used, and does bring in quite an additional amount of revenue.

Individual Cooking Devices

One farm home was equipped with an electric frying pan, a toaster, an electric griddle (Figure 168), an electric oven, a fireless cooker, and other individual pieces. The energy used by these individual pieces of equipment is less than is used by a range for similar service in many cases. More research work along this line is necessary before any general conclusions can be drawn. The convenience of using this type of equipment at the table is a feature worthy of consideration. A home can be equipped with such equipment at less cost than for a large electric range and other cooking equipment.

Fig. 167. An ironing machine uses about the same amount of electricity as an electric iron.

Fig. 168. Separate electric cooking appliances.

Dishwashing

A dishwashing machine (Fig. 48) used in a farm home with six in the family was considered very successful. The wife stated that the machine saved about one-half of the time required for her to do the dishes. The men folks used the dishwasher while the wife was sick, and they were very enthusiastic about it. The machine used an average of 2 kw. hrs. per month. One machine has been used in a family of seven for over two years, and the wife reports that she would not get along without it. This washer uses an average of 1.4 kw. hrs. per month. It has a connected load of 180 watts. This would indicate that the washer is used an average of 15 minutes a day, which checks with other observations. An average of four lots of dishes are washed a day. The machine requires about six gallons of hot water a day and about two ounces of washing powder. The washing powder costs about 50 cents a month. The use of the machine saves practically the entire time used actually to wash dishes by hand. In the case of the family referred to this amounts to approximately 28 minutes per day for the housewife.

Many other pieces of electrical equipment such as sewing machine motors, vacuum cleaners, egg beaters, food choppers, fans, etc., have been used on these farms. This class of equipment uses but very little energy, only one or two kw. hrs. per month, but the equipment takes the drudgery out of housekeeping, and makes homes cleaner and healthier.

APPENDIX

ENERGY USED AT A. C. BRYAN'S FARM, 1925

Month	Stove	Cistern pump	Electric iron	Utility motor	Washing machine	Incubator	Lights	Transformer truck
January	0	1.5	8	122	4	0	36	...
February	0	1.5	6	116	3	0	27	...
March	0	1.5	5	74	3	0	36	...
April	10	0.0*	6	111	2	14	45	...
May	1	0.0	7	81	3	23	67‡	...
June	150	4.0	8	34	4	4	80‡	...
July	265	2.0	8	48	2	0	47‡	...
August	233	2.0	12	132	2	0	42	...
September	180	3.0	12	80	3	0	49	210
October	17	4.0	1†	68	3	0	45	...
November	2	3.0	12	42	4	0	60	...
December	0	3.0	13	50	3	0	56	...
Totals	864	25.5	98	958	36	41	590	210

* Cistern went dry.
† No women at home.
‡ Includes use of small brooder.

ENERGY USED AT W. J. BRYAN'S FARM, 1925

Month	Stove	Well pump	Cistern pump	Milking machine	Water heater	Electric iron	Lights	Transformer truck
January	227	42	3	38	44	...	123	...
February	301	45	5	41	48	0	137	...
March	220	78	3	32	59	2	105	83
April	327	91	2	31	100	9	137	25
May	366	54	1	39	162	18	102	...
June	267	40	2	46	230	1	105	...
July	272	35	1	58	75	4	79	...
August	355	35	1	44	3	4	117	...
September	190	19	1	20	0	4	120	...
			Emory Johnson*					
October	...	43	...	...	...	...	...	...
November	1	48	1	...	1	0	53	...
December	11	77	0	...	20	4	41	...
Totals	2,537	607	20	349	742	46	1,119	108

* New owner took over place in October but did not move in until November.

ENERGY USED AT W. A. CADY'S FARM, 1925

Month	Washing machine	Utility motor	Cream separator	Stove	Ventilating fans	Lights	Transformer truck
January	1.0	15	2	12	..	54	...
February	1.0	20	2	19	..	42	...
March	1.0	16	2	10	..	31	...
April	1.0	26	2	29	..	28	...
May	1.0	16	3	38	..	20	...
June	1.0	22	2	132	..	20	...
July	1.0	12	2	134	..	20	...
August	0.5	24	1	90	..	20	889
September	0.5	34	1	80	..	25	...
October	0.5	20	1	55	..	24	235
November	0.5	29	2	7	..	31	160
December	0.5	62	2	16	6	27	...
Totals	9.5	296	22	631	6	342	1,284

ENERGY USED AT C. H. ECKBLAD'S FARM, 1925

Month	Iron	Dish washer	Cream separator	Pump	Washing machine	Incubator	Poultry lights	Brooder	Lights
January	8	2	1	4	2	0	0	0	17
February	13	3	2	5	2	0	0	0	28
March	9	3	1	8	0	361	0	0	32
April	4	1	0	5	2	298	0	42	34
May	10	3	1	8	2	332	0	60	28
June	9	2	2	6	2	138	0	36	26
July	7	1	1	4	2	0	0	0	31
August	8.5	2	1	6	2	0	0	0	46
September	8	1	0.5	7	2.5	0	0	0	28
October	7.5	*	1.5	10	2	0	0	0	60
November	10	..	1	13	2	0	0	0	46
December	6	..	1	6	1	0	7	0	53
Totals	100	18	13	82	21.5	1,129	7	138	429

* Dish washer returned to manufacturers.

ENERGY USED AT B. I. MELIN'S FARM, 1925

Month	Range	Cream separator	Mangle heater	Mangle power	Utility motor	Refrig-erator	Well pump	Washing machine	Cistern pump	Incu-bator	Lights	Transformer truck
January	80	1	28	1	30	60	25	2	..	0	70	...
February	56	1	22	1	27	73	38	2	..	0	55	...
March	48	0	23	1	65	47	22	2	..	0	63	...
April	31	0	18	1	29	61	18	3	*	18	158†	...
May	16	2	21	1	35	74	12	3	3	24	78†	...
June	55	2	22	1	0	81	22	4	1	31	52	...
July	50	1	22	1	5	84	26	2	1	14	86	...
August	43	0	25	1	20	87	26	3	10	0	54	...
September	50	2.5	30	1	23	80	20	3	1.5	0	21	300
October	72	1.5	28	0.5	‡	79	17	2	1.5	0	43	151
November	65	0§	15	0.5	..	77	20	1¶	1	0	77	...
December	73	0	8	0.5	..	8	21	1.5	1	0	56	104
Totals	639	11	262	10.5	234	811	267	28.5	20	87	813	555

* Cistern pump installed in April.
† Includes use of smaller brooder.
‡ Stock moved to E. Johnson farm.
§ Whole milk was sold.
¶ Part of family moved to another home.

ENERGY USED AT F. A. MILLER'S FARM, 1925

Month	Stove	Cream separator	Well pump	Washing machine	Electric iron	Milking machine	Incubator	Poultry lights	Refrigera-tor	Lights	Transformer truck
January	5	2	30	1	4	18	..	..	..	60	80
February	2	3	40	1	5	20	..	..	..	72	..
March	5	2	30	1	5	16	39	..	..	50	..
April	11	2	27	1	1	17	35	..	..	70*	..
May	16	3	24	2	5	17	37	..	2	74*	..
June	83	3	28	2	8	16	0	..	39	51	..
July	60	3	31	2	5	21	0	..	44	57	..
August	30	3	18	2	4	20	0	..	40	21	..
September	0	3	15	2	3	4†	0	..	24	56	..
October	0	3	15	2	3	..	0	..	2	65	286
November	0	4	20	2	5	..	0	8‡	..	59	..
December	0	4	16	2	2	..	0	10	..	77	..
Totals	212	35	294	20	50	149	111	18	151	712	366

* Includes use of small brooder.
† Discontinued milking machine on September 6.
‡ Lights installed on November 4.

ENERGY USED AT A. NELSON'S FARM, 1925

Month	Cream separator	Washing machine	Utility motor	Water heater	Pump	Stove	Lights	Transformer truck
January	2	1	18	17*	8	..	56	...
February	3	1	6	22	9	..	45	...
March	2	1	13	19	6	..	36	...
April	1	1	10	26	9	23	30	...
May	3	2	9	24	8	29	19	...
June	2	2	11	20	7	92	20	...
August	2	0	5	7	5	139	17	...
September	2	1	8	7	8	135	14	104
October	1	1	20	7*	8	120	15	...
November	1	2	11	184†	7	33	15	...
December	1	1	98‡	248	8	0	21	...
	1	1	5	342	7	0	32	...
Totals	21	14	214	923	90	571	320	104

* Water heater turned on by hand.
† Water heater working automatically.
‡ Only 22 kw-hrs. were used for grinding feed; 76 kw-hrs. were used for husking corn.

ENERGY USED AT NELSON BROTHERS' FARM, 1925

Month	Well pump	Cream separator	Washing machine	Stove	Refrig-erator	Cistern pump	Utility motor	Iron	Lights	Transformer truck
January	9	4	2	186	0	1	...	6	80	...
February	8	4	3	149	0	1	...	8	94	...
March	7	4	2	176	0	1	...	4	102	...
April	9	3	1	166	37	1	...	5	69	...
May	10	4	2	195	70	1	...	8	46	...
June	9	3	1	163	62	1	...	8	48	...
July	9	3	2	177	56	1	...	7	49	...
August	7	1	1.5	180	62	1	10.0	7	41	...
September	6	1.5	1.5	184	63	1.5	19.0	7	46	...
October	9	3.5	2	236	31*	1.5	20.5	7	36	312
November	10	5	1	204	0	1	20.0	8	57	...
December	16.5†	4	1	141	0	1	10.0	5	30	...
Totals	109.5	40	20	2,157	381	13	79.5	80	698	...

* Disconnected refrigerator on October 15.
† Started using drinking cups in barn.

ENERGY USED AT A. C. BRYAN'S FARM, 1926

Month	Stove	Cistern pump	Electric iron	Feed grinder	Washing machine	Brooder	Churn	Lights	Transformer truck
January	0.0	3.4	10.0	81.5	2.0	...	...	95	...
February	0.0	3.0	15.5	98.0	1.5	...	...	71	...
March	1.0	3.0	10.0	87.0	1.0	...	0.5	49	...
April	9.2	3.2	8.8	97.5	2.0	...	0.8	86	...
May	29.8	3.8	0.2	45.5	3.0	39.4	0.7	50	...
June	71.0	3.8	7.5	86.2	1.5	20.0	1.5	25	...
July	70.0	5.2	1.5	70.8	2.5	...	0.8	79	...
August	68.8	5.0	3.7	104.0	4.5	...	1.0	66	...
September	27.2	3.5	9.3	104.3	3.0	...	1.7	62	264
October	0.8	3.5	0.0	43.0	4.5	...	3.5	65	...
November	0.2	5.4	3.5	55.0	3.5	...	2.0	115	48
December	0.0	4.0	5.0	146.0	0.5	...	...	95	...
Totals	278.0	46.8	75.0	1,018.8	29.5	59.4	12.5	858	312

Energy Used at W. A. Cady's Farm, 1926

Month	Washing machine	Feed grinder	Cream separator	Stove	Ventilating fans	Corn ventilator	Milking machine	Lights	Transformer truck
January	0.0	51.0	3.0	10.0	9.0	3.0	0.0	19	...
February	1.0	61.0	4.0	82.0	11.0	5.0	34.0	22	...
March	0.0	44.0	2.0	69.0	1.0	1.0	23.0	22	...
April	0.8	50.3	2.5	108.4	0.0	0.0	22.7	25	...
May	0.7	36.7	2.5	130.0	0.0	0.0	26.3	28	...
June	0.9	24.0	2.5	103.0	0.8	0.0	25.0	29	...
July	0.1	17.0	1.5	137.0	0.2	0.0	17.0	26	...
August	1.5	35.0	1.0	147.0	0.0	0.0	0.0	30	320
September	0.5	6.0	0.5	170.0	0.0	0.0	0.0	32	167
October	1.0	23.0	2.3	72.0	0.0	2.8	0.0	42	...
November	0.5	42.0	27.2*	77.0	0.0	0.5	3.6	55	...
December	1.0	70.3	31.6*	44.0	3.5	0.5	6.4	97	...
Totals	8.0	460.3	80.6	1,149.4	25.5	12.8	158.0	427	487

* Charging battery.

Energy Used at C. H. Eckblad's Farm, 1926

Month	Poultry lights	Water pump	Electric iron	Cream separator	Incubator	Refrigerator	Stove	Washing machine	Brooder	Lights
January	6.5	6.5	5.0	0.5	0	...	1.0	2.0	...	67
February	4.5	7.5	6.0	0.5	1	...	0.0	1.0	...	65
March	0.0	5.0	3.0	1.0	192	...	0.0	2.0	...	40
April	0.0	6.6	9.0	0.8	203	...	0.0	1.0	61.2	82
May	0.0	7.4	9.0	1.2	267	...	10.0	2.0	28.8	78
June	0.0	6.0	12.8	1.5	139	*	23.0	2.0	...	80
July	2.0	3.8	9.2	12.5†	11	25.5	35.5	2.0	...	75
August	1.0	2.2	14.0	3.0	0	72.5	31.5	2.0	...	87
September	0.0	3.0	8.0	1.0	0	64.0	33.0	2.0	...	82
October	0.0	7.0	12.0	0.5	0	22.0	23.0	3.0	...	76
November	6.0	6.0	8.0	0.5	0	0.0	10.0	1.5	...	106
December	18.0	2.9	6.0	1.0	0	0.0	12.0	2.0	...	84
Totals	38.0	63.9	102.0	24.0	813	184.0	179.0	22.5	90.0	922

* Refrigerator installed in June.

Energy Used at E. Johnson's Farm, 1926

Month	Stove	Well pump	Milking machine	Water heater	Mangle	Washing machine	Lights
January	19.5	68.2	0.0	25.0	2.4	0.0	6.2
February	6.0	70.0	0.0	368.5	2.0	1.5	86
March	5.0	42.0	56.2*	675.0	11.0	1.5	78
April	17.2	60.7	63.2	424.0	1.7	0.0	88
May	66.8	50.3	56.8	658.0	7.3	0.0	117
June	101.0	58.0	56.6	681.0	19.2	0.0	147
July	97.0	51.0	37.4	564.0	8.8	0.0	150
August	96.0	52.0	29.0	628.0	4.0	0.0	170
September	7.0	65.0	31.2	720.0	5.8	0.0	184
October	38.0	91.0	29.8	703.0	10.2	0.8	154
November	110.0	75.0	35.0	644.0	9.0	1.4	164
December	14.0	69.8	37.0	296.0	9.5	1.4	185
Totals	577.5	762.0	432.2	6,386.5	90.9	6.6	1,585

* Milking machine installed March 4.

Energy Used at J. B. Lokkesmoe's Farm, 1926

Month	Poultry lights	Water pump	Uviarc	Incubator E. E.	Incubator	Refrigerator	Lights
January	...	...	...	...	...	...	..
February	104.0	34.0	...	...	...	...	38
March	82.0	19.0	2.0	...	...	...	36
April	28.7	0.6	3.3	240.0	95	...	42
May	0.3	6.4	18.7	237.7	166	38.0	30
June	0.0	3.3	15.0	28.0	83	44.8	25
July	0.0	5.8	0.0	10.0	0	42.2	28
August	0.0	6.0	0.0	91.0	0	43.0	22
September	9.0	5.0	0.0	0.0	0	37.0	30
October	73.0	6.8	0.0	0.0	0	30.0	35
November	107.5	11.0	11.0	0.0	0	21.6	45
December	114.0	7.2	17.0	0.0	0	0.6	37
Totals	518.5	105.1	67.0	606.7	344	257.2	308

Energy Used at B. J. Melin's Farm, 1926

Month	Stove	Cream separator	Mangle heater	Mangle power	Feed grinder	Kelvinator	Well pump	Cistern pump	Incubator	Lights	Transformer truck
January	47.4	1.5	11.7	0.5	26.0	25.6	29.0	0.8	...	64	...
February	33.0	2.0	4.0	0.0	59.0	0.0	22.0	0.0	...	54	...
March	46.0	1.0	5.0	2.0	65.0	10.0	20.0	0.0	...	65	...
April	23.0	2.8	9.0	1.0	0.0	58.2	15.0	0.0	...	50	...
May	29.0	3.2	14.0	0.0	0.0	88.8	7.0	4.0	29.0	32	...
June	55.5	2.0	10.0	1.0	0.0	107.8	14.0	0.5	22.8	22	...
July	61.5	3.5	13.0	0.8	0.0	92.2	6.6	1.5	...	18	...
August	36.0	4.5	27.0	2.0	0.0	68.0	9.4	1.0	...	33	...
September	26.0	0.5	5.0	1.0	6.0	77.0	9.8	2.5	...	34	1,104
October	43.0	1.5	9.0	0.8	0.0	65.8	33.2	0.0	...	38	...
November	33.5	2.0	8.0	0.2	0.5	62.2	27.0	0.0	...	80	...
December	80.5	3.0	14.0	2.5	0.3	58.5	37.0	0.7	...	96	...
Totals	514.4	27.5	129.7	11.8	156.8	714.1	230.0	11.0	51.8	586	1,104

Energy Used at F. A. Miller's Farm, 1926

Month	Refrigerator	Stove	Cream separator	Pump	Washing machine	Incubator	Brooder	Feed grinder	Poultry lights	Electric iron	Lights	Transformer truck
January	...	...	2.0	22.0	1.0	...	...	40	69*	1.0	45	...
February	...	...	3.0	26.0	1.0	...	...	40	11	0.0	46	...
March	...	...	3.0	20.0	2.0	...	...	24	...	3.0	52	...
April	...	0.2	2.0	23.8	1.4	47.5	12.0	15	...	5.8	30	...
May	...	1.8	3.0	19.2	2.6	40.0	186.0	13	...	5.2	21	...
June	17.0	...	4.0	17.0	1.5	90.5	41.5	30	...	4.2	22	...
July	16.5	2.0	2.0	20.0	3.5	...	...	87	...	5.8	27	...
August	34.5	2.0	2.0	22.0	1.0	...	...	19	...	5.0	30	...
September	22.0	...	1.6	17.0	2.0	...	...	36	...	7.0	35	111
October	6.8	...	1.9	16.0	2.0	...	...	11	...	4.0	30	...
November	...	...	1.5	22.0	2.0	...	...	84	...	5.0	50	...
December	...	...	3.0	30.0	2.0	...	...	88	23	1.5	40	...
Totals	96.8	6.0	29.0	255.0	22.0	178.0	239.5	487	103	47.5	428	111

* Fourteen kw-hrs. were used for light; 55 kw-hrs. were used for heating water.

ENERGY USED AT A. NELSON'S FARM, 1926

Month	Feed grinder	Cream separator	Stove	Washing machine	Water heater	Pump	Electric iron	Lights
January	15.4	1.2	...	0.5	166.6	7.3	0.0	47
February	29.0	1.0	...	0.5	252.0	7.0	0.5	34
March	20.0	1.0	...	1.0	188.0	7.0	1.0	35
April	14.8	1.8	...	2.1	107.0	10.6	0.3	38
May	4.2	2.2	...	0.9	0.0	10.4	1.2	29
June	5.0	1.8	152.2	1.0	26.0	7.5	4.0	16
July	7.0	1.2	168.3	0.0	0.0	7.5	1.0	15
August	7.8	1.5	159.0	1.5	128.5	8.5	1.0	14
September	9.2	1.5	111.5	1.5	91.5	6.5	1.0	15
October	9.5	1.8	59.3	1.5	173.0	7.0	1.2	28
November	10.5	1.4	2.5	1.5	244.0	5.0	0.8	30
December	24.0	1.4	0.1	1.0	0.0	8.5	0.0	32
Totals	156.4	17.8	652.9	13.0	1,376.6	92.8	12.0	333

ENERGY USED AT NELSON BROTHERS' FARM, 1926

Month	Well pump	Kelvinator	Cream separator	Washing machine	Cistern pump	Electric iron	Feed grinder	Stove	Lights	Transformer truck
January	28.5	0.0	4.0	1.0	0.0	7.0	0.0	191.0	49	...
February	26.0	0.0	4.0	1.0	0.0	7.0	0.0	211.0	47	...
March	18.0	0.0	3.0	1.0	1.0	4.0	51.0	200.0	40	...
April	25.5	24.5	3.7	1.3	1.2	5.8	11.2	176.0	45	...
May	25.5	63.2	3.3	0.7	0.8	9.2	18.8	177.3	54	...
June	16.5	68.0	3.2	1.25	1.0	8.8	24.0	185.0	35	...
July	22.5	71.0	1.8	1.25	1.0	6.0	37.0	169.0	40	...
August	20.7	71.0	1.0	0.5	1.0	5.2	8.0	246.0	48	...
September	13.3	60.0	4.0	2.0	1.5	8.0	35.0	247.0	68	323
October	13.0	40.0	3.0	1.0	0.5	9.0	21.0	*	102	...
November	20.0	0.0	4.0	1.0	1.0	6.0	35.0	....	108	...
December	33.5	0.0	5.0	1.5	0.8	5.0	76.8	....	91	...
Totals	263.0	397.7	40.0	13.5	9.8	81.0	317.8	1,802.3	727	323

* Stove was removed in October.

ENERGY USED AT A. C. BRYAN'S FARM, 1927

Month	Stove	Cistern pump	Electric iron	Feed grinder	Washing machine	Poultry lights	Pump	Root cutter	Churn	Incubator	Lights	Transformer truck
January	...	3.0	2.5	80.0	3.0	12	...	1.8	0.8	...	135	...
February	...	2.0	3.0	97.0	2.0	13	...	1.0	1.5	...	90	...
March	...	2.5	1.8	80.0	1.7	10	...	0.8	1.2	...	82	...
April	...	2.5	2.2	31.0	2.3	1	...	0.2	1.3	...	103	...
May	0.2	3.6	1.5	29.3	2.5	...	0.4	...	1.0	18	96	...
June	25.3	2.2	7.0	35.5	2.5	...	0.1	...	1.0	...	77	204
July	50.5	4.1	9.3	19.2	3.2	...	5.0	...	0.5	...	60	...
August	7.0	0.6	13.2	71.0	3.1	...	3.2	...	1.3	...	53	1,004
September	...	4.0	6.8	106.0	2.9	...	2.0	...	2.1	...	45	344
October	...	2.5	10.2	52.8	3.8	...	1.0	...	1.5	...	88	...
November	...	4.0	9.0	65.2	3.0	10	7.0	...	0.5	...	76	...
December	...	3.3	1.0	46.8	2.0	...	9.0	...	1.0	...	154	144
Totals	83.0	34.3	67.5	713.8	32.0	46	27.7	3.8	13.7	18	1,059	1,696

Energy Used at W. A. Cady's Farm, 1927

Month	Washing machine	Feed grinder	Cream separator	Stove	Ventilator fans	Corn ventilator	Milking machine	Lights	Transformer truck
January	0.5	57.8	33.4*	53.0	0.5	0.2	0.0	86	...
February	1.0	57.8	12.0*	72.0	23.0	3.0	34.0	80	...
March	0.7	55.2	11.8*	55.2	12.1	9.3	37.0	71	...
April	0.8	55.8	0.2	39.8	1.0	0.7	37.0	92	...
May	0.5	14.0	1.0	37.0	...	0.0	19.0	70	...
June	0.7	8.0	0.2	75.5	...	0.0	28.0	35	...
July	0.8	26.0†	0.6	159.0	...	0.0	44.0	46	...
August	1.5	32.0†	0.2	163.5	...	0.0	17.2	44	908
September	0.8	15.3	1.0	113.0	...	0.0	0.0	87	40
October	0.7	33.7	1.0	133.0	...	7.0	0.0	81	120
November	0.5	17.0	0.0	48.0	...	0.0	0.0	90	...
December	0.8	35.5	0.5	86.5	...	1.0	0.5	125	...
Totals	9.3	408.1	61.9	1,035.5	36.6	21.2	216.7	907	1,068

* Charging battery.
† Twenty kw-hrs. were used for hoisting hay.

Energy Used at C. H. Eckblad's Farm, 1927

Month	Poultry lights	Water pump	Electric iron	Cream separator	Incubator	Refrig-erator	Stove	Washing machine	Brooder	Lights
January	9.0	2.1	4.0	1.0	0	...	7.0	0.5	...	76
February	2.0	3.0	5.0	1.0	0	...	9.0	1.0	...	50
March	0.7	2.6	8.0	1.0	147	...	5.0	1.7	...	45
April	97.3*	3.4	7.0	1.0	322	...	7.0	3.3	28†	60
May	101.0*	5.0	11.8	1.5	272	22.5	16.8	2.0	41	70
June	13.0*	3.0	9.6	5.1	78	64.5	16.2	1.5	1	76
July	15.8*	6.0	7.3	1.4	...	73.2	50.5	2.5	...	67
August	9.6*	9.0	5.5	4.0	...	85.6	27.3	1.5	...	73
September	0.6	5.0	5.0	1.0	...	0.2	6.0	2.0	...	81
October	10.0	5.0	6.0	0.5	...	1.0	37.2	1.4	...	58
November	4.0	5.0	6.5	0.5	...	1.0	23.0	1.6	...	72
December	11.0	5.0	14.5	1.0	...	0.0	38.0	2.0	...	87
Totals	274.0	54.1	90.2	19.0	819	248.0	243.0	21.0	70	824

* Brooder.
† Used for six days in April.

Energy Used at E. Johnson's Farm, 1927

Month	Stove	Well pump	Milking machine	Water heater	Mangle	Washing machine	Refrig-erator	Lights
January	5.0	83.2	41.0	...	8.5	1.4	...	116
February	11.0	50.0	43.0	...	9.0	2.0	...	104
March	28.4	46.8	36.0	...	14.0	3.0	...	115
April	32.6	68.2	48.0	*	10.0	2.0	...	86
May	29.0	114.0	46.0	541.5	11.0	2.0	...	92
June	37.0	65.5	46.6	523.5	16.2	1.8	...	83
July	105.0	82.5	41.4	626.0	14.0	2.2	54.8	60
August	91.5	87.0	38.2	615.0	15.4	2.0	50.6	73
September	49.0	73.5	36.5	555.0	12.0	2.2	59.5	87
October	19.5	85.0	36.3	583.0	14.5	2.6	80.5	98
November	62.0	58.5	34.0	620.0	13.0	1.8	66.0	141
December	6.0	46.0	32.0	415.0	8.0	1.4	24.0	122
Totals	476.0	860.2	479.0	4,479.0	145.6	24.4	335.4	1,177

* New heater installed in April.

Energy Used at J. B. Lokkesmoe's Farm, 1927

Month	Poultry lights	Water pump	Uviarc	Incubator E. E.	Incubator	Refrigerator	Hot plate	Lights
January	80.0	8.0	7.0	...	0.0	4	...	28
February	37.0	7.0	2.0	...	0.0	0	...	30
March	9.0	6.5	2.2	...	2.0	0	...	25
April	4.0	7.5	0.8	155.0	84.0	0	50	20
May	3.5	7.2	3.9	48.0	186.0	21	120	18
June	0.0	8.3	2.9	12.0	7.0	39	165	18
July	0.2	9.5	0.0	0.2	0.0	47	155	25
August	0.1	7.0	0.0	0.8	5.0	21	183	20
September	0.0	2.8	0.5	1.0	15.5	40	91	16
October	16.2	5.2	0.0	0.0	0.0	24	32	20
November	60.0	6.0	0.0	0.0	0.0	0	0	25
December	67.2	2.0	0.0	0.0	0.0	0	0	28
Totals	277.2	77.0	19.3	217.0	299.5	196	796	273

Energy Used at B. I. Melin's Farm, 1927

Month	Stove	Cream separator	Mangle heater	Mangle power	Kelvinator	Well pump	Washing machine	Cistern pump	Lights	Transformer truck
January	107.0	2	7	0.5	49.7	59.0	0.0	0.8	74	...
February	56.0	..	0	0.0	0.0	76.0	0.2	0.0	64	...
March	105.0	..	14	1.0	0.0	8.8	1.4	2.5	98	...
April	165.0	..	17	1.0	0.0	28.2	1.6	0.5	93	...
May	87.0	..	2	0.0	0.0	12.0	0.5	0.0	53	...
June	95.0	..	29	1.5	15.3	29.0	4.5	0.0	35	...
July	154.0	..	17	0.6	62.5	6.8	2.5	2.5	35	1,250
August	73.0	..	29	0.9	53.0	90.2	2.5	2.5	27	262
September	82.5	..	10	0.5	59.0	8.0	0.3	0.0	42	280
October	25.5	..	17	1.0	56.0	23.0	2.7	0.0	51	...
November	53.5	..	14	0.5	46.0	40.0	2.0	0.0	44	...
December	108.0	..	4	0.5	28.0	26.0	0.5	0.0	63	...
Totals	1,111.5	2	160	8.0	369.5	407.0	18.7	8.8	679	1,792

Energy Used at F. A. Miller's Farm, 1927

Month	Refrigerator	Stove	Cream separator	Pump	Washing machine	Milking machine	Incubator	Brooder	Feed grinder	Poultry lights	Electric iron	Lights
January	...	...	1.5	23.0	1.5	...	...	...	76.0	4	4.5	58
February	...	5	2.5	30.0	2.5	...	...	...	143.0	7	5.0	39
March	...	0	2.0	23.0	2.0	...	3.0	...	68.5	...	4.0	47
April	...	1	3.0	23.0	2.0	...	0.0	...	54.5	...	8.0	36
May	...	2	2.8	21.0	2.8	17.0	84.7	224	33.0	...	...	30
June	31.2	11	3.2	17.0	2.0	18.5	...	...	46.5	...	...	27
July	65.8	20	3.0	22.0	2.2	21.0	...	...	57.5	...	...	22
August	64.7	6	2.4	15.5	2.2	16.5	...	...	44.0	...	...	34
September	35.5	3	2.1	12.5	2.8	15.0	...	...	108.0†	...	...	29
October	...	...	12.5*	18.0	2.0	18.0	...	...	36.0	...	...	49
November	...	...	3.0	21.0	2.0	17.0	...	...	41.0	5	...	53
December	...	...	2.0	18.0	1.0	16.0	...	...	66.0	6	...	84
Totals	197.2	48	40.0	244.0	25.0	139.0	87.7	224	774.0	22	21.5	508

* Iron used on this meter by mistake.
† Cutting ensilage.

ENERGY USED AT A. NELSON'S FARM, 1927

Month	Feed grinder	Cream separator	Stove	Washing machine	Water heater	Pump	Iron	Lights	Transformer truck
January	20.0	1.6	0.1	0.5	185.0	5.5	...	28	...
February	32.0	1.0	0.0	0.5	205.0	6.0	1.0	34	...
March	19.8	1.8	0.0	1.2	*	6.3	0.0	26	...
April	16.2	1.2	20.3	0.8	*	6.7	1.2	16	...
May	6.5	1.8	23.0	1.5	177.5	5.5	1.2	28	...
June	12.1	1.2	118.0	0.7	155.5	4.5	1.0	15	...
July	3.2	1.0	179.0	0.8	193.5	7.5	1.8	16	...
August	11.2	1.0	166.0	1.0	144.5	8.5	0.3	19	22
September	22.0	1.0	125.0	1.0	151.0	6.5	0.6	28	...
October	0.0	1.0	88.0	2.0	165.0	6.5	1.1	32	...
November	12.0	2.0	9.0	1.0	188.0	6.0	1.2	27	...
December	16.0	1.0	0.0	1.6	180.0	6.0	0.0	36	...
Totals	171.0	15.6	728.4	12.6	1,745.0	75.5	9.4	305	...

* Water heater out of order during March and April.

ENERGY USED AT NELSON BROTHER'S FARM, 1927

Month	Pump	Kelvinator	Cream separator	Washing machine	Cistern pump	Electric iron	Feed grinder	Lights	Transformer truck
January	37.5	...	5.0	0.5	0.2	7.0	100.2	82	...
February	33.0	...	5.0	1.0	0.0	6.0	23.0	76	...
March	25.0	...	4.0	1.0	1.5	5.5	60.2	71	...
April	26.0	5.0	4.0	2.0	0.5	9.5	11.8	118	...
May	13.8	54.0	4.0	1.0	1.0	9.2	9.0	67	...
June	10.2	67.3	2.5	1.2	0.8	8.6	30.5	51	...
July	12.5	74.7	1.5	1.8	0.7	8.2	12.5	60	...
August	13.9	66.0	0.0	1.0	0.8	6.0	21.0	57	320
September	9.6	98.2	2.3	1.2	1.2	3.6	106.7*	67	...
October	15.0	69.0	3.7	1.8	1.5	7.4	13.3	88	...
November	17.0	16.6	4.0	2.0	1.0	7.0	25.0	82	...
December	26.0	0.2	4.5	2.2	0.2	7.8	46.0	92	...
Totals	239.5	451.0	40.5	16.7	9.4	85.8	459.2	911	320

* Power for silo filling added.