

DELCO LIGHT INVESTIGATION

A Major Thesis Submitted to the

DEPARTMENT OF AGRICULTURAL ENGINEERING  
VIRGINIA POLYTECHNIC INSTITUTE,  
BLACKSBURG, VIRGINIA,

In Partial Fulfillment of the Requirements  
for the Degree of

Master of Science

by

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June 1, 1929.

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### Introduction.

The problem of electric service on Virginia farms has received considerable consideration and study in recent years. Rural electric service has been extended to many farms and the development has been extensive enough, in some cases, to justify the organization of a rural service department within the company organization. A graduate Agricultural Engineer is generally in charge of the department. The importance of this movement is verified by the fact that rural service departments are being organized in all the leading power companies in Virginia.

Central station service is generally recognized as the most desirable type where it can be obtained without too large an expense to the farmer and company. However, there are many farmers who are unable to secure central station service. As a result, they have to choose between individual water power plants or individual gas-engine-driven plants. Due to the large supply of water required to produce a comparatively small quantity of electrical power, few farmers can install water power plants on their farms. The individual gas-engine-driven plant must, therefore, supply the demands of the vast number of farmers who can neither obtain central station service, nor install

individual water power plants. It is, therefore, the individual gas-engine-driven plant with which this study is chiefly concerned.

#### Object.

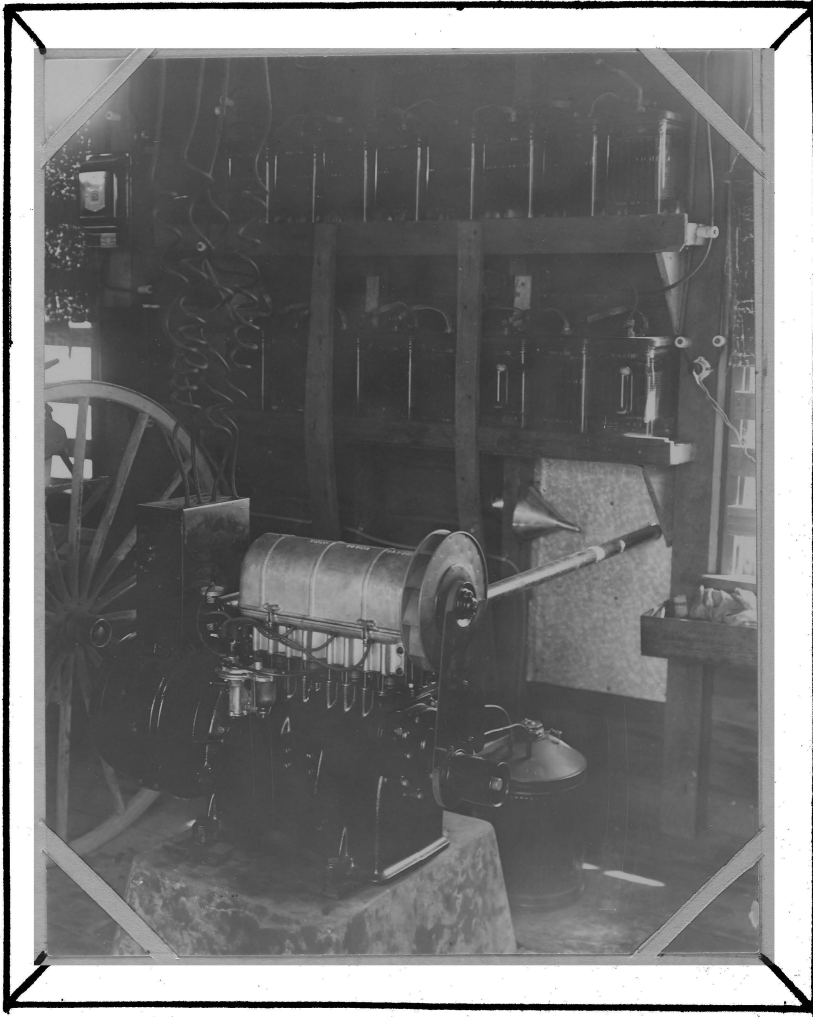
The object of this investigation is to make a comprehensive study and obtain reliable information on the possibilities and limitations of an isolated electric light plant; operating cost will be determined with practical equipment to be used in connection with same, under actual farm conditions.

#### Location of Project.

The study was made on "Sandy Mound Farm" owned and operated by Mr. W. E. Hubbard. The farm is located two and one-half miles from Blacksburg, Virginia, near Shadow Lake. It consists of about 180 acres of crop land and 60 acres of woods. Mr. Hubbard operates a 20-cow dairy and sells cream to the Southern Dairies at Christiansburg, Virginia. A complete farm management study was made of this farm as a Minor Problem.

#### Subject.

The subject of this study is the new Four Cylinder Delco Light plant, Model No. 178, generating unit, and 160 amperes an hour battery.



The new Four-Cylinder Delco Light

Installed at the Hubbard Farm.

A. Specifications.

I. Engine.

1. Bore - 2 1/4 inches.
2. Stroke - 2 3/8 inches.
3. Speed - 1100 to 1200 r. p. m.
4. Air cooled (copper finned).
5. Four cylinder - four cycle.
6. Valve-in-head engine.
7. Firing order - 1, 2, 4, 3.
8. 32 volt ignition.
9. Operates on gasoline.
10. Self cranking.
11. Fuel pump - "A. C."
12. Oil pump - oil capacity 2 1/2 gallons.
13. Pulley for belt - belt H. P., 3.
14. Weight - 565 lbs. (Generating unit only).

II. Generator.

1. 4 pole.
2. Compound cranking circuit.
3. Shunt generating circuit.
4. Directly connected to engine.
5. 32 volt - direct current.
6. Full load output - 1500 watts.
7. Cooled by vents in fly wheel.

### III. Control.

1. Voltage controlled by battery.
2. Starting and stopping controlled by automatic switch board (Mounted on generator), except when necessary to operate by hand.
3. Automatic features include:
  - (a) Electric throttle which responds to changes in load.
  - (b) Electric choke coil for starting.
  - (c) Cranking cut-out to prevent discharging battery.
  - (d) Control box containing, "Low Voltage Cut-out" and "Voltage Limiting Relay", mounted on wall.
  - (e) Plant starts when line load exceeds approximately 300 watts.
  - (f) Plant stops when line load reduces to approximately 150 watts.

### IV. Battery.

1. Delco light exide glass jar 160 ampere hour battery, (16 cell - K x G - 13).

### B. Construction.

The generating unit is composed of the following parts:

1. Engine.
2. Generator.
3. Switch board.
4. Throttle control.

5. Control box.

6. Battery.

Each of these parts must operate in harmony with one another in order to have a perfect running machine.

#### Arrangement.

Three meters were used on the test. Meter No. 3994860-, 50 amp. - 32 volt, was used as a master meter at plant. Meter No. 4228049, 50 amp. - 32 volts, was used on the frigidaire circuit. Meter No. 4262742, 25 amp. - 32 volt, was connected up with extension cord and used for short test on the various appliances such as Maytag washing machine, Hoover cleaner, Hoover wall cleaner, electric iron, churn and chore motor.

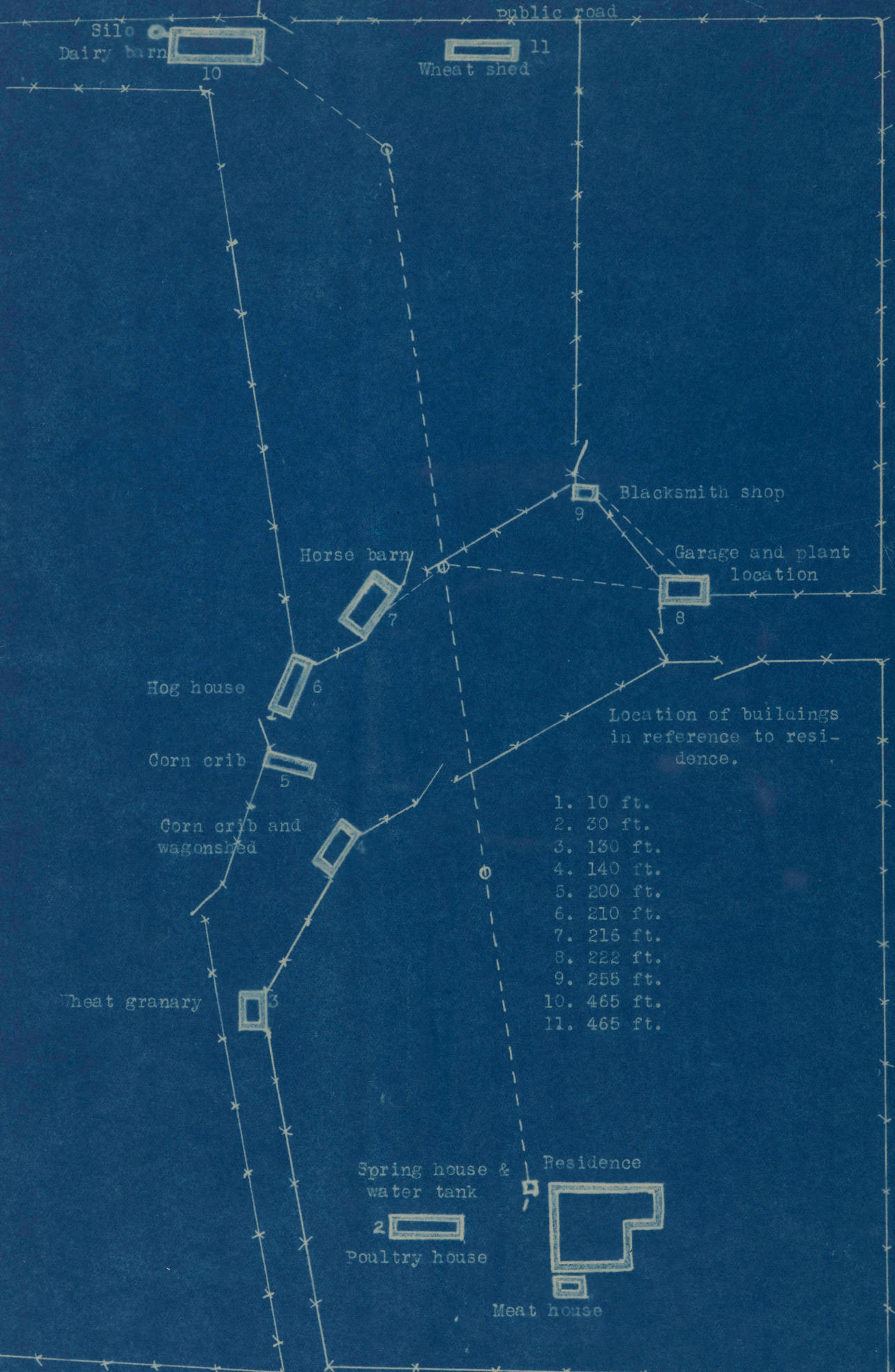
#### Conduct.

A few visits were made to the farm during the summer to make arrangements for the project. During the month of September two men spent three weeks at the farm, wiring and installing equipment. The plant was installed and started operating September 29, 1928. Some of the equipment, such as meters, etc., was late in arriving. The test, therefore, did not start until November 1. Trips were made to the farm at least once a week and in many cases twice a week to observe the operation of the equipment. Data sheets were prepared for the various operations. When a piece of equipment was



The Hubbard Farmstead.

Note:- The light on each line pole between the house and dairy barn.  
This arrangement is three-way connected and furnishes ample light for  
the lawn and stockyard.



Silo  
Dairy barn 10

Wheat shed 11

public road

Horse barn 7

Blacksmith shop 9

Garage and plant location 8

Hog house 6

Corn crib 5

Corn crib and wagonshed

Location of buildings in reference to residence.

- 1. 10 ft.
- 2. 30 ft.
- 3. 130 ft.
- 4. 140 ft.
- 5. 200 ft.
- 6. 210 ft.
- 7. 216 ft.
- 8. 222 ft.
- 9. 255 ft.
- 10. 465 ft.
- 11. 465 ft.

Wheat granary 3

Spring house & water tank 2

Residence

Poultry house

Meat house

Farmstead of Mr. W. E. Hubbard

Scale 1" = 50 ft.

used, one of these sheets was filled in and returned. The master meter was read each month. A book was placed at the plant, in which the amount of gas, oil and time used on the plant was recorded by Mr. Hubbard.

Calculations.

A. Installation. Cost of wiring.

The thick stone walls in the dwelling house necessitated the use of metal moulding. The dairy and horse barns were wired with BX cable. The other outbuildings such as poultry house, meat house, spring house, blacksmith shop and garage were wired with knob and tubing.

The following is a complete bill of material used:

Bill of Material.

No. of units	Size	Name of unit	Cost per unit	Total cost
8	5/16	Copper lugs	2	\$ .16
8		Federal Bushings		.60
3 ft.		Exhaust pipe	10	.30
9	10 in.	Shades-Holders		11.25
1	Sq. D	Safety Switch 60 amps.		1.65
2		60 amp. Fuses	15	.30
2		Cleat receptacles	15	.30
40		Pierce Insulators	13	5.20
5		P Sockets	26	1.30
25		3" Knockout Boxes	7.21 C	1.82
18		Pull chain receptacles		4.92
6		3 mag. Snap Switches		1.88
7		Type "H" Switch Bases	23	1.61
3		Single Branch Blocks	18	.54
16		Plug Fuses	4	.64
128		Bx straps		1.28
53		Bx connectors	4	2.12
3		1/2" Type T Conduits		1.23
3		2 Hall Par Covers		.41

Bill of Material (Cont'd.)

1144 ft.	#4 M P wire	5	57.20
1250 ft.	#10 wire	2	25.00
100 ft.	#6 R. C. wire		3.26
940 ft.	#12 R C wire		15.15
1100 ft.	#14 R C wire		6.66
500 ft.	Bx Cable		16.25
4 6 in.	Goose Neck Fixture	94	3.76
4 14 in.	Reflectors	3.23	12.92
1 14 ft.	Shade-Holders		.40
150 ft.	Lamp cord	2	3.00
7	#5781 Connectors	17	1.19
4	#4200 Binco Sockets	53	2.12
8	#355 Insulators		.75
50	#504 Supporting Strap		.75
38	#5732 2 1/2 outlet boxes	23	8.74
25	5711 Flat elbows	11	2.75
22	515 Flat tees	19	4.18
3	510 Cross	20	.60
24	5717 Internal elbows	13	3.12
8	5751 Adaptive plate and cover		.12
14	5721 Rosetts Moulding	20	2.80
20	Key Sockets	26	5.20
9	Cleat Rosettes	13	1.17
21	SP Snap Switches		4.41
7	3" Round Blank Covers	3	.21
8	Keyless Moulding Receptacles	55	4.40
9	3844 Brackets	98	8.82
1 Gross	6 Wood Screws		.60
25	1 1/2 Wood Screws		.10
25	1 1/2 # 9 Wood Screws		.10
3	Rolls Etric Tape	30	.90
1	Roll Compound Tape		.40
154	Knobs		2.03
68	3" Tubes	1	.68
7	6" Tubes	7 1/2	.52
35 ft.	Loom	18.55	.66
1	Switch Box		.14
1	Duplex Ironing plug plate		1.20
650 ft.	Metal Moulding		35.10
6	Hard Saw Blades		.60
Total Material .....			\$275.47
25	25 watt 32 volt lamps	30	7.50
25	50 watt 32 volt lamps	32	8.00
Total .....			\$290.97

Note: The above bill of material gives the wholesale cost of material as payed The H. C. Baker Company, Roanoke, Virginia, by Mr. Hubbard.

B. Cost of Plant Installation.

1. Cost of Plant.

# 152 generator F. O. B. Roanoke,	\$556.35
16 cells, K X 6 - 13 Batteries, F. O. B. Roanoke,	<u>196.00</u>
Combination making a complete No. 186 plant (installed).....	\$866.00

2. Cost of foundation for plant.

2 yards of sand	3.00
2 yards of rock	3.00
12 sacks of cement .90	10.80
4 base bolts	.20
Labor	<u>3.00</u>
Total cost of foundation.....	\$20.00

Note: This cost is rather high due to the rich mixture used, and large foundation built. However, this makes an excellent job absolutely free from vibration.

3. Cost of battery rack.

Lumber and nails	.50
Labor	<u>.50</u>
Total cost of battery rack.....	\$1.00

C. Operation cost of plant.



Another View of the Stockyard.

Note: The main line is mounted on bracket insulators and the  
3way circuit is mounted on knob insulators.

Date	Fuel	Oil	Labor	Remarks
Nov. 1	5 gallons	2 $\frac{1}{2}$ gallons	7 minutes	-----
Nov. 4	----	---	-----	Charge battery 6 hrs.40 min.
Nov. 7	3 gallons	---	-----	-----
Nov.11	----	---	8 minutes	Charge battery 2 1/2 hours.
Nov.13	----	---	-----	Changed oiling system to reduce pressure on oil pump
Nov.16	----	---	-----	Charged battery 4 1/2 hours.
Nov.17	5 gallons	---	2 minutes	-----
Nov.21	----	---	-----	Charged battery 3 hours.
Nov.26	----	---	-----	Charged battery 7 1/2 hours.
Nov.27	3 gallons	---	10 minutes	-----
<b>Total</b>	<b>16 gallons</b>	<b>2<math>\frac{1}{2}</math> gallons</b>	<b>27 minutes</b>	
Dec. 1	2 gallons	---	20 minutes	Charged battery 9 hours.
Dec. 3	5 gallons	---	2 minutes	-----
Dec. 8	----	---	-----	Charged battery 2 1/2 hours.
Dec. 9	----	---	-----	Charged battery 2 hours.
Dec.11	----	---	-----	Charged battery 3 hours.
Dec.12	4 gallons	---	10 minutes	-----
Dec.16	1 gallon	---	-----	-----
Dec.17	4 gallons	---	30 minutes	-----
Dec.26	1 gallon	---	2 minutes	-----
Dec.28	4 gallons	---	2 minutes	-----
Dec.30	1 gallon	---	2 minutes	-----
<b>Total</b>	<b>22 gallons</b>	<b>---</b>	<b>68 minutes</b>	

Date	Fuel	Oil	Labor	Remarks
Jan. 1	4 gallons	---	20 minutes	-----
Jan. 9	5 gallons	---	5 minutes	Charged battery 4 hours.
Jan. 16	5 gallons	---	5 minutes	-----
Jan. 22	3 gallons	---	3 minutes	Charged battery 4 hours.
Jan. 25	2 gallons	---	2 minutes	-----
Total	19 gallons	---	35 minutes	-----
Feb. 5	5 gallons	2 $\frac{1}{2}$ gallons	20 minutes	Charged battery 4 hours.
Feb. 6	3 gallons	---	2 minutes	-----
Feb. 9	2 gallons	---	2 minutes	-----
Feb. 11	-----	---	20 minutes	-----
Feb. 20	5 gallons	---	2 minutes	-----
Feb. 28	-----	---	20 minutes	Charged battery 4 hours.
Total	15 gallons	2 $\frac{1}{2}$ gallons	66 minutes	-----
March 4	3 gallons	---	2 minutes	-----
March 12	2 gallons	---	2 minutes	-----
March 17	3 gallons	---	2 minutes	-----
March 23	2 gallons	---	2 minutes	-----
March 25	-----	---	5 minutes	-----
Total	10 gallons	---	13 minutes	-----
April 1	5 gallons	---	5 minutes	Charged battery 4 hours.
April 10	5 gallons	---	3 minutes	-----
April 14	4 gallons	---	2 minutes	-----
April 18	1 gallon	---	2 minutes	-----
April 20	5 gallons	---	3 minutes	-----
April 25	5 gallons	---	5 minutes	-----
April 30	5 gallons	---	3 minutes	-----
Total	30 gallons	---	23 minutes	-----

Oil.- Maximum 2 1/2 gallons per month, minimum 0 gallons  
per month, average .83 gallons per month.  
Average cost per month, \$0.83.

Fuel.- Maximum 30 gallons per month, minimum 10 gallons  
per month, average 18.6 gallons per month.  
Average cost per month, \$3.53.

Labor.- Maximum 68 minutes per month, minimum 13 minutes  
per month, average, 38.6 minutes per month.  
Average cost of labor per month, \$0.16.

Interest.- \$866.00 at 6% for one year, \$51.96.  
Interest charge per month, \$4.33.

Depreciation.- Battery, \$196.00 - \$39.20 per year - \$3.27 per month.  
(5-year life).  
Plant, \$556.35 - \$55.64 per year - \$4.64 per month.  
(10-year life).

Note: Depreciation figured on F. O. B. prices, Roanoke, Virginia.

Kw hours per month - maximum 60 - minimum 12.

Kw hours per month - (Average for 5 months) 19.

Table No. 1.- Kwhr. cost per month for period of the test.

Kwhrs. per month	19
Fuel - 18.6 gallons at 19 cents	\$ 3.53
Oil - .83 gallon at \$1.00	.83
Labor - 38.6 minutes at 25 cents per hour	.16
Total . . . . .	\$ 4.52
Kwhr. cost (Fuel, oil and labor). . . . .	\$0.238
Interest charges	4.33
Depreciation (a) battery	3.27
(b) plant	4.64
Total . . . . .	\$12.24
Kwhr. cost (Interest and depreciation) . . . . .	\$0.644
Total Kwhr. cost . . . . .	\$0.882

Table No. 2.- Kwhr. cost for one month.

Kwhrs. for the month	60
Fuel - 30 gallons at 19 cents	\$ 5.70
Oil - .83 gallon at \$1.00	.83
Labor - 23 minutes at 25 cents per hour	.10
Total . . . . .	\$ 6.63
Kwhr. cost (Fuel, oil and labor). . . . .	\$0.110
Interest charges	\$ 4.33
Depreciation (a) battery	3.27
(b) plant	4.64
Total . . . . .	\$12.24
Kwhr. cost (Interest and depreciation). . . . .	\$0.204
Total kwhr. cost . . . . .	\$0.314

Note: Frigidaire was used this month.

Table No. 3.- Comparison of Tables 1 and 2.

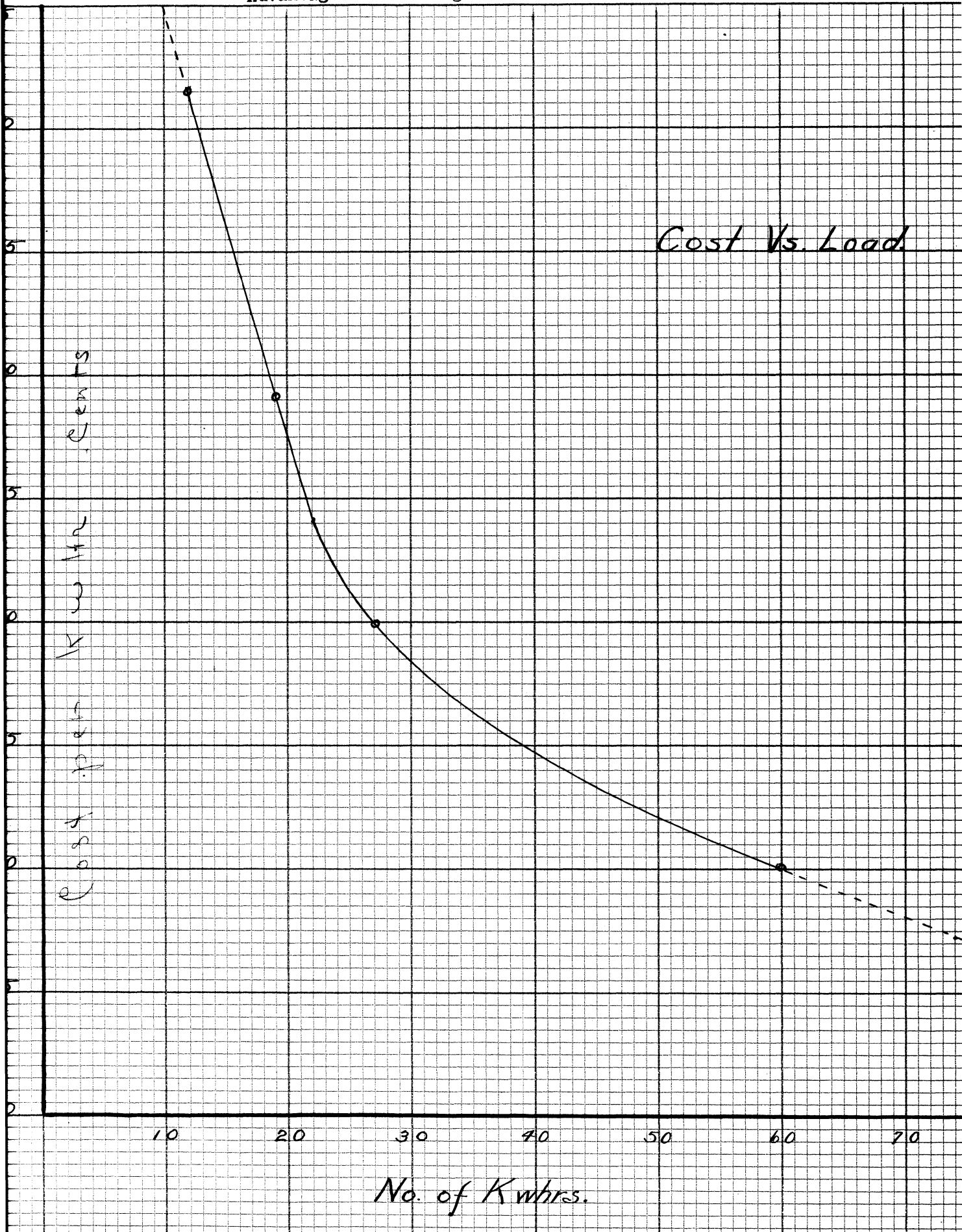
	Table 1	Table 2	Saving
Kwhr. cost - (Fuel, oil and labor)	\$0.238	\$0.110	\$0.128
Kwhr. cost - (Interest and depreciation)	0.644	0.204	0.440
Total saving per kwhr. . . . .	. . . . .	. . . . .	\$0.568

Note: Table No. 3 brings out very clearly the necessity of building up the kwhr. load. The fuel, oil and labor charge per kwhr. is reduced from \$0.238 for 19 kwhrs. to \$0.11 for 60 kwhr. load and the interest and depreciation charge per kwhr. is reduced from \$0.644 for 19 kwhrs. to \$0.204 for 60 kwhr. load, showing a total saving of \$0.568 per kwhr.

The following tables cover the cost of operation of the various equipment. In each case the kwhr. cost has been considered as 88 cents. This is rather high, due to the high cost of depreciation and interest charges and low average monthly kwhr. consumption. However, this makes the result obtained from the use of electricity more outstanding since it shows a saving in every case.

Advantage of Building the Load.

Cost Vs. Load





The washing machine saves the back and does the wash better. It is a real time  
and labor saver.

Table No. 4.- Washing Data.

Values are averages	Old Method		New Method		Differ- ence
	Per week	Per year	Per week	Per year	
Hours required	5	270	1.17	60.84	209.16
Weight of wash-lbs.	40	2080	40	2080	
Cost of labor	\$1.00	\$52.00	\$0.30	\$15.60	\$36.40
Current used - Kw.			.75	39	39
Cost of current			\$0.66	\$34.32	\$34.32

Note:-52 washings per year - average family.

-Cost of labor, \$1.00 per week refers to cost of hiring a wash woman - old method.

-Cost of labor, \$0.30 per week refers to value of housewife's time doing washing - new method.

From the above table the cost of labor saved exceeds the cost of current used by \$2.08. This makes the use of electric washing machines practical, not counting the 209.16 hours saved by its use, which, if valued at \$0.25 per hour, would mean an additional saving of \$52.29 per year, making in all, \$54.37 saved per year.

Table No. 5.- Ironing Data.

Values are averages	Flat Iron		Electric Iron		Differ- ence
	Per week	Per year	Per week	Per year	
Hours to heat irons	.5	27	.2	10.4	16.6
Hours to iron wash	6.5	338	2.75	143	195
Cost of Fuel	\$0.07	\$3.64			\$3.64
Cost of labor (25¢ hr.)	1.63	\$81.00	.69	\$35.88	\$45.12
Current used (Kw.hr.)			1.2	62.4	62.4
Cost of current			\$1.06	\$55.12	\$55.12

Note: - 52 ironings per year - average family.

From the above table, figuring time saved, and labor saved, at \$0.25 per hour, the use of the electric iron shows a saving of \$42.90 per year.

Table No. 6.- Churning Data.

Values are averages	Hand churn		Electric churn		Differ- ence
	Per time	Per year	Per time	Per year	
Hours required to clean, before and after	.33	32	.17	8.84	23.16
Hours required to churn	.75	72	.416	39.90	32.10
Quantity churned, lbs.	60	5760	43	4128	1638
Pounds of butter made	3.5	336	2.5	240	96
Pounds of butter milk	56.5	5424	40.5	3888	1536
Cost of labor	\$0.30	\$28.80	\$0.15	\$14.40	\$14.40
Current used (Kwhrs.)			.012	1.15	1.15
Cost of current			\$0.011	\$1.06	\$ 1.06

Note: - Whole milk churned 96 times per year - average family.

From the foregoing table the cost of labor saved exceeds the cost of current used by \$13.34 per year. Figuring time saved at \$0.25 per hour, we have saved \$13.82, making a total saving of \$27.16 in favor of the electric churn.

Table No. 7.- House Cleaning.

Values are averages	Broom	Electric cleaner	Difference
Time required to clean one room	55 minutes	25 minutes	30 minutes
Cost of labor (25¢ per hour)	\$0.23	\$0.10	\$0.13
Current used (Kwhrs.)		.02	.02
Cost of current		\$0.018	\$0.018

Note: Cleaning refers to sweeping and wall cleaning.

From the above table, figuring labor and time saved at \$0.25 per hour, we see a saving of \$0.24 per room per cleaning in favor of the electric cleaner. Assume that the room is cleaned three times a week. This would show a saving of \$37.44 per room per year.



The vacuum cleaner and wall cleaning attachment make house cleaning a pleasure. It is also very useful in cleaning auto upholstery.

Table No. 8.- Kerosene Lights.

Total number of lamps	10
Approximate value of lamps	\$17.00
Average number of lamps in use at one time	4
Time required to clean lamps, per year	52 hrs.
Time required to fill lamps, per year	26 hrs.
Total time required to clean and fill lamps, per year. . .	78 hrs.
Kerosene used, per year	120 gals.
Cost of oil, per year, 120 x 20¢	\$24.00
Cost of labor, per year, 78 x 25¢	\$19.50
Interest on \$17.00 at 6%, per year	1.02
Total cost . . . . .	\$44.52
Average cost per lamp operated, per year . . . . .	\$11.13

Table No. 9.- Electric Lights.

Number of outlets in house (11 rooms, 3 porches)	71
Number of outlets in horse barn (8 horse capacity)	9
Number of outlets in dairy barn (20 cow capacity)	16
Number of outlets in other buildings	<u>20</u>
Total number of outlets . . . . .	116
Average cost of material per outlet	\$2.57
Average cost of labor per outlet	<u>1.29</u>
Total cost per outlet . . . . .	\$3.86
Average number of lights in use at one time	5
Kwhrs. per month, average	8



The frigidaire is a clean, convenient and efficient storage for food supplies. It is a great time saver in preparing frozen desserts or serving iced drinks.

Frigidaire - M-9 - capacity.

The frigidaire was operated on test for one month during which time meters were put on frigidaire motor and found that it drew a peak load of approximately 25 amperes and 28 volts, or 700 watts, on starting. The running load drawn was 11 amperes and 35 volts, or 385 watts. Since the plant starts at 300 watts, it is obvious that each time the frigidaire motor started the plant started. The plant ran approximately five minutes and was off approximately 30 minutes. The result was about 30 starts and stops per day or 900 per month. This means that the plant operated 2.5 hours per day or 75 hours per month when frigidaire was operated.



Water tank and spring house

Note: Line enters the house from the tank tower. The tower makes a good location for the back yard light.

Summary.

Cost of plant installed	\$806.00
Cost of plant foundation	20.00
Cost of battery rack	1.00
Cost of material used in wiring installation	290.97
Depreciation on battery per month	3.27
Depreciation on plant per month	4.64
Interest charge per month	4.33
Cost of oil used per month	.83
Cost of fuel used per month	3.53
Cost of labor on plant per month	.16
Kwhrs. per month	19
Kwhr. cost per month (fuel, oil and labor)	.238
Kwhr. cost per month (interest and depreciation)	.644
Total kwhrs. cost	.882
Total kwhrs. cost (month frigidaire was used)	.314

### Conclusions.

1. Too much weight can not be placed on the results obtained from this study thus far due to the short period of the test.
2. The test should be continued for a number of years (life of the plant, if possible), and additional equipment, such as milk cooling, milking machines, dairy refrigeration, incubators and brooders, tested along with the present equipment.
3. The isolated gas-engine-driven electric light plant is a satisfactory piece of farm equipment. However, not as desirable as central station service where the latter can be obtained.
4. The farmer should endeavor to increase the kwhr. load, thereby reducing the kwhr. cost as shown in Table 3 and Graph 1. However, the kwhr. cost from an isolated light plant can probably never be reduced to the cost of central station service.
5. The use of such appliances as washing machine, iron, churn, vacuum cleaner, wall cleaner and chore motor is both practical and profitable.
6. When frigidaire is used, some method should be employed to reduce the number of times the light plant is required to start.
7. Where large equipment is to be used, producing a rather constant load, it would probably be more profitable to increase the capacity of the battery, thus making it possible to raise the "cut in" point on the plant above 300 watts.

8. Mr. Hubbard is very much pleased with the installation and should be helped and encouraged in the purchase of more equipment.

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