A DESIGN OF A SMALL POWER GENERATING PLANT FOR A RURAL COMMUNITY

By

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CONTENTS

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I Purpose:

Within the last decade there has grown up in the rural sections of the country an almost universal desire for the conveniences of the home such as are enjoyed by people living in the cities.

The motor car and good roads have greatly simplified the problem of transportation in most rural communities, and in some sections the large power companies are attempting to solve the problem of supplying power and light for the rural population.

There are, however, many rural communities in the country, which because of the distance to a large power line, and also because of the comparatively thin population, and lack of organization in this kind of work, can hardly hope to be served by any large power company; at least not for many years. It is in view of offering suggestions toward solving the problem of supplying power and light to such communities that this thesis is written.

In summarizing, the purpose is to outline a power system, and estimate the costs of construction and operation, and determine the rate at which power can be produced and sold to the customers in a certain rural community under such conditions as are outlined in this work.

If a system can be devised by which power may be profitably supplied to this community, and thereby raise the standard of living for the community as a whole, and encourage industry and investment, the purpose of this thesis will have been accomplished.

II Location and Conditions Studied:

The community for which this study is made is that surrounding the small village of Only Tennessee.

It is situated on the banks of Duck River, in Hickman County, in the middle division of the state. This village is remote from any power line or any town of considerable size.

The village proper consists of about twenty-five homes, and in the surrounding country which is chiefly agricultural, there is a maximum of about one hundred homes which can be reached by fourteen miles of transmission lines.

This community supports three general stores, one high school, two churches, two grist mills, a planing mill, a repair shop, a garage, and two or three saw mills. The community is well supplied with fertile agricultural land and bountiful forests. The commercial products are: livestock, corn, hay, peanuts, and timber products. The country is well supplied with good water by springs and shallow wells, and it offers unlimited opportunities for dairying and stock-raising.

The marketing is done at Nunnelly, Tennessee, the nearest railway station about eighteen miles distant, the hauling is done by wagons and motor cars. The highway to market is a graded gravel road in fairly good condition, but the roads which lead out through the community are in a poor condition.

The population of the community is very stable, most of the people with the exception of the timber workers are owners of their own homes or else long term renters. There is a good local telephone system in the community, but the Cumberland System is not in use there at the present time. It could be repaired for operation at small cost, however. A supply of power as proposed would open up a new field for labor saving devices on the farms and in the homes of this community.

III The System Proposed:

The plan suggested in this paper is to consolidate several of the industries which are already existant in this community, namely, the sawmill, planing mill, grist mill and shop into one plant and operate the combined interprise for the benefit of the community. These enterprises have been very profitable in the past, hence we will assume that they will remain so in the future, if operated as a unit.

Now as this investment has already been made and is necessary for the operation of the mills alone, it is further proposed to buy and install a power generating unit in the same plant with the mills, using the same boiler and engine as the prime mover for the generator.

Thus we will calculate the cost of the power unit only from and including the generator to the end of the power system; and of course to consider its proportional share of the operating expenses of the plant.

The prime mover is a 50 H. P. boiler and engine unit, using as fuel the wood refuse from the mills which has no market value. This power is ample to drive the proposed system.

It is suggested that the mills be operated whenever practable on a basis of eight hours per day, beginning at 7:30 A.M. and closing at 4:30 P.M. to change the power of the prime mover from the mill to the generator and operate it continuously until

12:00 o'clock or about seven and a half hours power service per day. No reserve generator will be kept for a breakdown emergency and all contracts between the company and the customers should contain a clause covering interruptions of service due to breakdowns.

Now as the mill unit is assumed from past experience to be a profitable investment we will disregard it in our calculations and devote our further study, specifically, to the power generating system.

IV Methods of Studying the Problem.

There are two general phases of this problem in which the study may be conveniently divided; first, the income which might be expected from the operation of such a power system, and second, the cost of installing snd operating such a system.

The first phase is more or less a problem of assuming reasonable conditions as compared with other systems already in existance in other communities and subject to about the same limitations. This in itself requires several different types of study by the writer as follows.

(A) A general knowledge of the community and the people living therein and their attitude toward a proposition of this nature.

(B) A reliable idea as to the amount of power which the community might reasonably be expected to consume and how it might be applied with most profit to both company and consumers.

(C) A thorough study of the rates at which such power could be sold.

The first type of knowledge as acquired by the writer is due to having been for several years a resident of this community. The second and third types were acquired by an extensive study of many similar prospects of rural electrification, conducted in different parts of the country, some by small concerns, others by large central stations or power companies and some by the state universities or under their supervision. Of course the resulting figures vary somewhat with different sections of the country and under different conditions, but by taking a wide range of study in this work, and making a very careful analysis of the various causes and conditions influencing the results of these various prospects, it is believed that a fairly accurate working knowledge of this subject has been obtained.

The second phase of this subject: that the cost of installation and operation of such a unit demands of the writer the following types of information.

(A) The power demands of the customers as determined by a study of the first phase and the possibility of increase in the demand so that the proper equipment will be selected to supply that demand.

(B) The cost of such equipment from the manufacturer and transportation costs to plant.

(C) The labor supply and wage rates in the community.

The first and second types of information were acquired by a study of conditions as mentioned before, and the cooperation of a representative engineer of the Westing-house Electric and Mfg. Co. All estimates of costs of equipment are based on current prices as given by the above company for such equipment.

The third type of knowledge was acquired by the writer as a resident of that community and is only general and to be regarded as a fair average.

The following equipment and data has been selected for application to this particular installation.

Size of generator $37\frac{1}{2}$Kv-a, 3 phase, 2300 volts.

Size of steam boiler,- 40 H.P.

Size of steam engine (non-condensing),- 50 H.P.

Voltage on line,- 2300

Transformer size,- $1\frac{1}{2}$ Kv-a at each home. ""(See note)

R. P. M. of generator = 1800

Size of switchboard,- 4' X 4' standard.

Size of wire # 6 for line, for branch lines to homes # 8.

Number of poles per mile,- 30; 30X 14 = 420.

Size of poles, 30 ft. long, 4 inches smallest diameter.(Chestnut)

Length of line,- 14 miles.

Length of wire = (5280 $\neq$ 50) X 3 X 14 = 224,000 ft.

Cost of wire calculated as follows:

Allow 50 feet per mile for sag, and three phase requires three wires per mile and fourteen miles = 224,000 linear ft. of wire. No. 6 copper wire weighs 79.55 pounds per 1,000 ft., (bare). 224 X 79.55 = 1275 pounds of wire. Current price is 18¢ per pound. 1275 X 18 = $229.50 cost of wire for line.

"" NOTE. Instead of using the $1\frac{1}{2}$ Kv-a transformers in the village these 25 homes are served from 1-$7\frac{1}{2}$ Kv-a transformer on a 220 volt circuit. Each customer will do his own work and pay all expenses including wiring, fixtures, and individual meters, from the point where he connects the transformer installed by the company for his use.

Costs of Installation and Operation

1 - $37\frac{1}{2}$ Kv-a generator three phase, 2300 volts - - -	$	720.00
1 - $7\frac{1}{2}$ Kv-a transformer - - - - - - - - - - - - - - - - -		83.00
50- $1\frac{1}{2}$ Kv-a transformers @ $32.80 - - - - - - - - - - -		1640.00
1-- Lightening arrester, standard choke coil - - - -		350.00
1 - Switchboard Complete - - - - - - - - - - - - - - - - -		300.00
		3093.00
Freight on above, labor of installation, minor fixtures		707.00
		3800.00
14 miles of transmission line @ $800.00		11200.00
Total Investment		15000.00
Interest on $15,000.00 @ 6% per annum - - - - - - - - -		900.00
Taxes on $15,000.00 @ $2.50 per $100.00 - - - - - -		375.00
Annual depreciation, (3%) - - - - - - - - - - - - - - - - -		503.00
Cost of oil per annum (Lubrication) - - - - - - - - - -		100.00
Salary of one man to operate per annum - - - - - - - - -		1500.00
Total annual expense		3378.00
Repairs, minor accidents and expenses - - - - - - - - -		122.00
Total annual output		3500.00

Switchboard is 4' X 4' equiped complete with standard voltmeter, watt-hour meter, integrating type; fuses, rheostat and switches, also standard circuit breaker. Switchboard is mounted on pipe framework.

Cost of Transmission Line per Mile

30 poles per mile @ $3.00 - - - - - - - - - - - - - - - - -	$	90.00
30 through bolts @ 0.50 - - - - - - - - - - - - - - - - -		15.00
30 pole top steel pins @ 0.50 - - - - - - - - - - - - -		15.00
60 locust wood pins @ 0.02 - - - - - - - - - - - - - -		1.20
30 cross arms @ 1.00 - - - - - - - - - - - - - - - - -		30.00

(5280 ≠ 50) 3 phase = 16,000 ft. transmission line

16 X 79.55 = 1275 Lbs. @ $0.18 per lb. - - - - - - - - - - -	$ 229.30
30 X 3 insulators @ $1.50 - - - - - - - - - - - - - - - - - -	135.00
10 auto valve type lightening arresters @ $8.00 - - - -	80.00
Miscellaneous tie wires, guy wires, dead endings, etc. -	25.00
Labor, Clearing right of way - - - - - - - - - - - - - - -	10.00
" Digging pole holes - - - - - - - - - - - - - - - - - -	15.00
" Erecting poles -	15.00
" Attaching cross arms, guy wires, etc. - - - - - - -	10.00
" Stringing of line wire - - - - - - - - - - - - - - -	50.00
" Tools, hauling, and all other expenses - - - - - -	79.30
Total	800.00

To determine the annual amount or annuity which must be set aside each year for depreciation losses:

A = Annuity to be set aside

C = First cost of plant = $15,000.00

S = Salvage value at end of period = 0,000.00

r = Rate of interest received on deposit = 4%.

n = Number of years of service = 20 years.

$$A = \frac{(C - S)r}{((1 + r)^n - 1)} = \frac{(15000 - 0)0.04}{((1 + 0.04)^{20} - 1)} = \frac{600^{00}}{((1.04)^{20} - 1)}$$

$$A = \frac{600^{00}}{1.1915} = \$503.00$$

Log. 1.04 = 0.017033
0.017033 X 20 = 0.340660

Antilog = 2.1915
2.1915 - 1 = 1.1915

An estimation of the amount of power which will be used by the community under the given conditions, .

Lighting load:

Assume 75 customers in a possible 100 average 4 active lamps per home. Length of service from 5:30 - 11:00 = $5\frac{1}{2}$ hours. Assume load factor of 40%. Each lamp uses 60 watts.

$4 \times 5\frac{1}{2} \times 60 \times 30 \times 0.40 = 15.75$ Kwh per month lighting.

$75 \times 12 \times 15.75 = 14.200$ Kwh per year total lighting.

Water supply systems:

30 water systems using a $\frac{1}{2}$ H.P. motor with a capacity of 200 gallons per hour operating one hour per day.

$30 \times \frac{746}{2} \times 365 =$ 4.100 Kwh per year

Washing machines:

25 washing machines using a $\frac{1}{2}$ H.P. motor 3 hours per week $= 25 \times \frac{746}{2} \times 3 \times 52 = 1450$ Kwh per year.

Electric irons:

40 irons using 550 watts operating 3 hours each week $=$ $40 \times 550 \times 45 = 3430$ Kwh.

Toasters:

10 toasters using 550 watts $\frac{1}{2}$ hour per day, 90 days per year $= 10 \times 550 \times 45 =$ 248 Kwh.

Rotary fans:

20 fans using 60 watts per hour, 2 hours per day, 90 days per year $= 20 \times 60 \times 2 \times 90 = 216$ Kwh.

Income derived from the sale of power under the following conditions.

There will be a service charge of $3.00 per month by each customer. The first 15 Kwh used per month by each customer will cost eight cents per Kwh. All power above this amount used per month by each customer will cost five cents per Kwh. Total amount of power sold per annum as calculated is 23,644 Kwh.

Total amount used for lighting as calculated is 13,500 Kwh. Thus 23,644 less 13,500 Kwh. leaves 10.144 Kwh used per year for other purposes.

13.500 X 0.08 =$1080.00
10.144 X 0.05 = 507.20
12 X 3 X 75 = 2700.00
Total annual income $4287.20
" " expense 3680.70
Net profit - - - 606.30

$\frac{606.30}{15000.00}$ = 4% dividend above interest return or 10% on investment.

Liability of the Employer

If the employer is using more than five regular workmen in his employ he is automatically liable for damages. When an employee is injured in such employment under the Workmen's Compensation Act, unless both employer and employee officially elect to ignore the provisions of this act.

If he employes less than five regular workmen he is released from the provisions of this act, but in any case unless the employee is protected under this act he may have recourse to common law.

In this work it is believed that the better policy is to protect the workmen by accepting the provisions of this act. By this act the employer carries the premiums for the insurance of his employees. The amount of the policy for each employee is based on his wage remuneration as reported by a state auditor every six months. The rate is fixed by the state law and varies with the n nature of the work the employee performs. For example; if the engineer in charge receives $1500.00 per year, and his rate is $7.56 per $100.00, his policy will cost the employer $113.40 per year. In case of accident the employer is no longer subject to damages, but the injured employee collects damages from the insurance company, to the extent of the serious nature of his injury. These damages are laid down specifically in the state laws and are too numerous to be given here, in that the responsibility of the employer has ceased. The rates for the other workmen operating the other parts of the mill vary from $2.12 to $5.46 per $100.00 wage per year, varying with the nature of their work.

Fire Insurance.

If the building is of wood with a metal roof and provided the nearest part of the roof is eighteen inches or more from the smoke stack, the plant, that is the building and contents may be insured at the rate of about $4.50 per $100.00 against loss by fire of any origin. The electrical equipment in the building should be insured for $1500.00 at an annual premium of $67.50. Thus the electrical unit is insured against fire and accident for an annual premium of,-

Liability insurance - - - - - - - - - - - -	$ 113.40
Fire insurance- - - - - - - - - - - - - - -	67.50
Total -	180.90

For the study of those who might be interested in making a smaller investment than that necessary in the previous work, another plan is here outlined which embraces only the village with its twenty-five customers in the power system.

Cost of Installation and Operation of Plant.

1 - 37½	Kv-a generator 3 phase 2300 volts - - - - - -	$ 720.00
1 - 7½	Kv-A transformer - - - - - - - - - - - - - - - - - -	83.00
1 -	Lightening arrester, standard choke coil type-	350.00
1 -	Switchboard complete - - - - - - - - - - - - - - -	300.00
1 -	Mile of transmission line - - - - - - - - - - -	800.00
Freight, labor, installation, and minor fixtures - - -		547.00
Total Investment -		2800.00
Interest on $2800.00 @ 6% annually - - - - - - - - - - -		168.00
Taxes on $2800.00 @ $2.50 per $100.00 - - - - - - - - -		70.00
Annual depreciation (3%) - - - - - - - - - - - - - - - -		94.00
Cost of oil per year, lubrication - - - - - - - - - - - - -		100.00
Salary of one man to operate per annum - - - - - - - - -		1500.00
Repairs, minor accidents, and expenses per annum - - -		68.00
Total annual expense -		2000.00

The above equipment is the same as used in the previous calculations in order to care for the expansion of the business.

An estimation of the amount of power which might be sold in the village of twenty-five homes. For this work we use the same data as determined in the previous calculations, except the number of customers. For details the reader is refered to the more extensive previous calculations.

For Lighting Load: Assuming twenty-five customers.

25 X 12 X 15.75 = 4730 Kwh per year.

For Water Systems: Assuming twenty customers.

$$20 \times 365 \times \frac{746}{2} = 2730 \text{ Kwh per year.}$$

For Electric Irons: Assuming twenty-five customers.

25 X 3 X 52 X 550 = 2150 Kwh per year.

For Washing Machines: Assuming twenty customers.

$$20 \times 3 \times 52 \times \frac{746}{2} = 1160 \text{ Kwh per year.}$$

For Toasters: Assuming five customers.

5 X 550 X 45 = 124 Kwh per year.

For Rotary Fans: Assuming ten customers.

10 X 60 X 2 X 90 = 108 Kwh per year.

Total amount of power sold per annum as calculated is 11000 Kwh. Total power used for lighting is 25 X 12 X 15 = 4500 Kwh. This leaves 6500 K wh used per year other power.

4,500 X 0.08 =	$ 360.00
6,500 X 0.05 =	325.00
25 X $3.00 X 12 =	900.00
Total income - - - - - - - -	1585.00
Total expenses - - - - - --	2000.00
Net Loss - - - - - - - - - - -	415.00

CONCLUSIONS:

As a result of the foregoing study and calculations upon this subject as outlined in the beginning, I have come to the conclusion that this power plant as proposed might well be built and operated provided as many as sixty actual customers should be subscribed at the beginning.

It seems to the writer that this investment should be more attractive to a company of local business men and subscribers than to some outside investor, merely seeking profit on his investment.

However, it seems to the writer that the average business man should hesitate to invest in this enterprise unless as many as fifty actual subscribers should subscribe at the beginning.

The assumptions made in this thesis are based on the knowledge secured by studying a number of similar prospects in different parts of the country, and upon the writer's own knowledge of this particular community. The data from some of the more prominent of these projects is given below.

At Redwing, Minn., average monthly power consumption per customer,- 30 Kwh @ $0.22 per Kwh.

At Sioux Falls, South Dakota, the average consumer pays a fixed charge of $8.00 per month plus five cents per Kwh for the first 30 Kwh per month, and three cents per Kwh per additional power used per month.

Near Lincoln, Nebraska where patrons used about 200 Kwh per year, the charges were $8.00 per month.

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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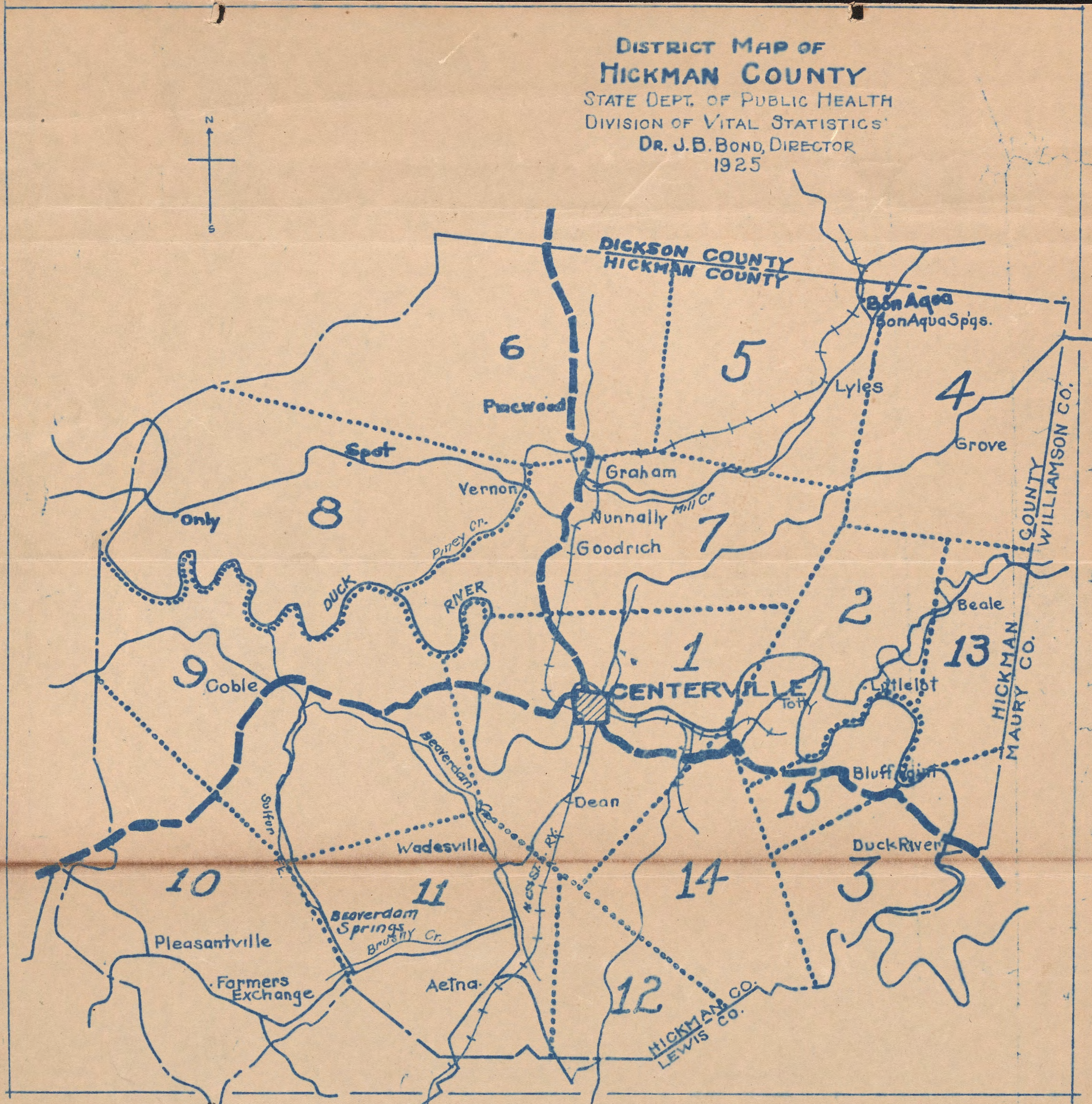
DISTRICT MAP OF
HICKMAN COUNTY
STATE DEPT. OF PUBLIC HEALTH
DIVISION OF VITAL STATISTICS
DR. J.B. BOND, DIRECTOR
1925
N
S
DICKSON COUNTY
HICKMAN COUNTY
Bon Aqua
Bon Aqua Sp'gs.
Lyles
6
5
4
Pinewood
Spot
Graham
Grove
Vernon
Mill Cr.
Nunnally
8
7
Only
Goodrich
Piney Cr.
COUNTY
WILLIAMSON CO.
DUCK
RIVER
2
Beale
13
1
9
Coble
CENTERVILLE
Littlelot
Totty
HICKMAN
MAURY CO.
Beaverdam
Bluff Point
Dean
15
Wadesville
Duck River
10
11
14
3
Beaverdam
Springs
Pleasantville
Brushy Cr.
Farmers
Exchange
Aetna
12
HICKMAN CO.
LEWIS CO.