T H E S I S

ESTIMATES AND SPECIFICATIONS FOR A HYDRO-ELECTRIC PLANT ON THE CLINCH RIVER.

For the Degree of

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING.

Under

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"THE HYDRAULIC DEPARTMENT".

The location of the proposed plant is on the Clinch River, in Hancock County, East Tenn., about half way between Bristol and Knoxville. The nearest government river station and railroad point is twelve miles up the river at Speer's Ferry, Va., and the next nearest railroad station is Rogersville, Tenn., eighteen miles south.

The site of the power has an elevation of 1200 feet and is at a point where the mountain, around which the river runs (See Appendix Plates I and II) forms a very narrow neck. By tunneling through this mountain, which measures 280 feet at this point, we can obtain a head of 12¼ feet due to the fall of the river in its course, 3½ miles around the mountain. In addition to this natural head we are proposing an 8 foot dam, making a total head of 20¼ feet from the top of the dam which is on the south side of the mountain, to the water level at the mouth of the tunnel on the north side. The power house is to be situated on the north side of the mountain at the mouth of the penstock or tunnel.

From the United States Government river report we obtain curves showing (See Appendix Plates III and IV) the average and annual horse power (H.P.) for 10 years and a mimima curve for the same time. We also found that in 10 years we had a 24 foot rise only once, a 21 foot rise or more 5 times,a 17 foot rise or more 8 times,

a 15 " " " " 12 " " 10 " " " " 15 "

The tributaries of the river are all small mountain streams which are subject to very sudden rises, and almost as sudden falls. The catch-

ment area above the site of our proposed plant is about 1000 square miles. Owing to this being a swift mountain stream the evil of floating ice is eliminated entirely from our problem. Although this is in a comparatively cold climate, the stream has never been frozen over as far as the oldest inhabitants can remember.

High water will not decrease our head owing to the fact that the river, at the site of the dam is in a gorge where it can only spread to about double its original width, while on the lower side at the site of the power-house, the river bottom is sufficiently wide for the river to spread at least four times its original width, so in this case the high water will tend to increase the head instead of dimimishing it. The curves and tables referred to in the Appendix show the river conditions just as far back as a record has been kept.

The Dam.

It is strictly essential in this case to build a dam for the purpose of holding back or obstructing the flow and elevating the surface of the water in order to concentrate the fall of the stream so as to admit of the economical development of power, and also to store water so that it may be utilized in the same way. Since we want the benefit of both head and volume, the dam must extend from bank to bank and be constructed of as great a height as practical. After calculating the height and cost and considering the local conditions, an 8 foot dam is thought to be the best adapted for this plant. This will not at any point back water over river bottoms of very great value. The fall of the river is three feet per mile, so the back-water will extend 2 2/3 miles up stream, and will cover .8 of a square mile

including the present river bed which has an area of .13 square miles. At Horton's Ford, 1¾ miles above the dam, the depth of the water will be increased about 5 feet, so this will necessitate a ferry here. The county road runs parallel to the river, but will not be interfered with at any point. During high water the dam will not increase the amount of land overflowed by any appreciable amount, owing to the very high banks. A further increase of the dam would not be advisable because one foot more would more than double the amount of land submerged and would only increase the capacity about a hundred H.P. during low water. A further increase would also effect the flooding of a reservoir which is about four miles above the site of the dam.

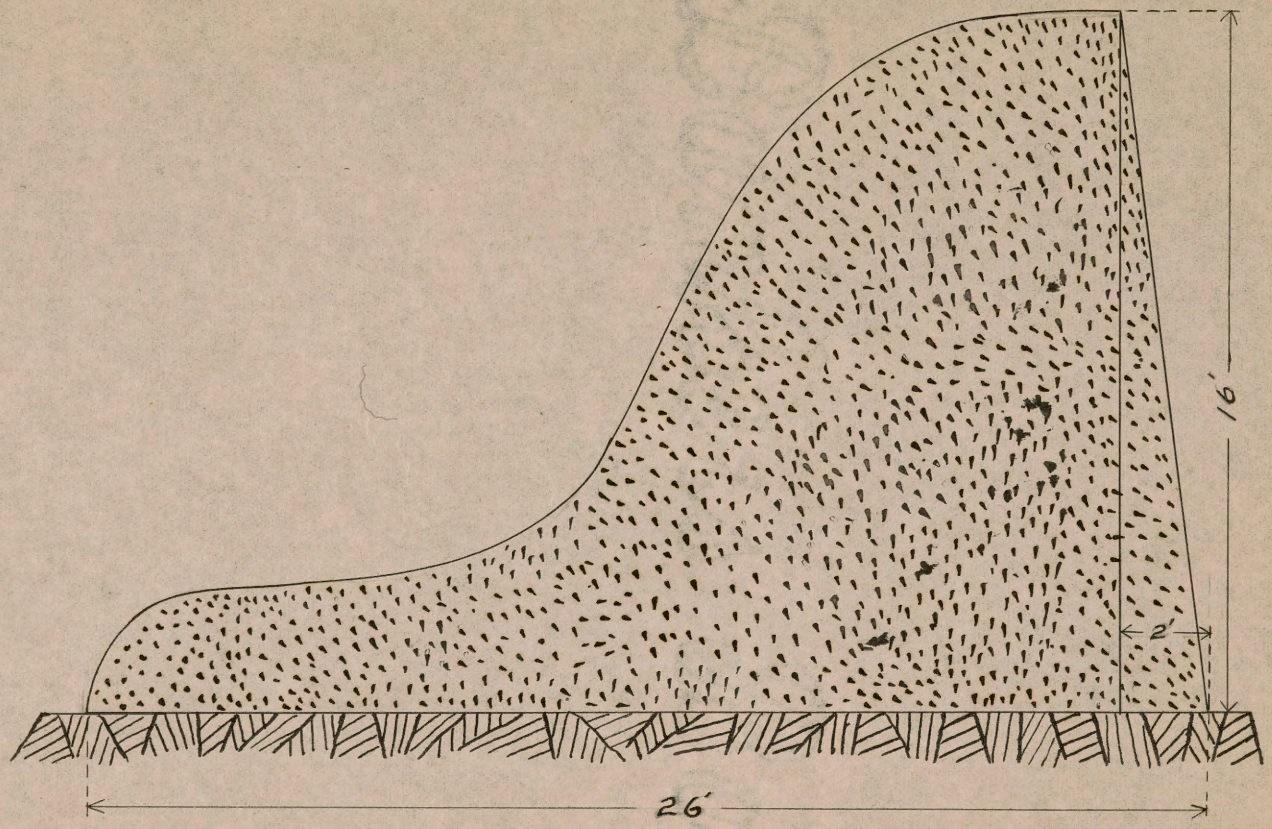
To be able to determine any of the details we must first consider that the value of the power that can be developed by means of the proposed dam, limits the amount that can be expended for its construction. In our case a dam is necessary to turn the water into the tunnel, and the height is limited by the fact that the amount received for a further increase in power, by increasing the height of the dam, will not be equal to the additional cost, interest and depreciation. The height is directly limited by (1) the overflow of valuable lands; (2) the interference with public rights; (3) and the cost of the structure. After due consideration of the various types of dams, we have selected a low solid concrete gravity dam. The principle reason being the decrease in cost over other types of dams owing to the cheapness of the material. Here sand and rock can be gotten almost without cost, while to use a reinforced dam the iron reinforcement would cost excessively, owing to the distance from the rail-

road. The rock out of the tunnel can all be used in the dam and other concrete construction, and the sand is very plentiful all along the river. Estimating the cost of concrete at $4.00 per cubic yard, a dam 5 feet wide at the top and 16 feet high (which allows for a foundation in solid rock and 8 feet above low water level) will cost about $100.00 per linear foot and the length is 250 feet, making a total cost of $25000.00 for the dam.

In connection with the dam comes into consideration the trash-racks to keep floating substances out of the wheels. They are to be made out of metal slats designed so as to be arranged in vertical sections from 2 to 4 feet wide. As a part of the rack-house equipment a small differential chain-hoist, designed to run on an elevated track so that it may be brought directly over each rack-section, is to be used to remove a rack-section. This arrangement allows sufficiently light sections to be comfortably handled when out of position, thus greatly facilitating cleaning and repairing. The cost of the track-rack and rack-house is included in the cost of the dam by making a liberal estimate on the length of the dam.

The Tunnel.

In determining the size of the tunnel or penstock through the mountain we must first assume an approximate tunnel and calculate for the size under the given conditions, In this particular case the minimum flow is 720 cubic feet of water per second, with a 12¼ foot natural head and an 8 foot dam, making a total head of 20¼ feet. But in this case we will not have the tunnel come out on a level with low water mark, but the bottom of the tunnel will come 10 feet above low water mark at the site of the power-house. (See Appendix Plate V.)



Section of Dam.

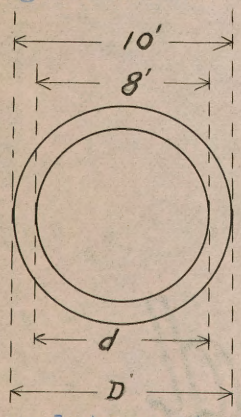
This leaves a head of 10¼ feet on the bottom of the tunnel. These conditions were chosen in order to increase the efficiency by shortening the vertical shaft from the turbine to the generator (since the generator must be above high water mark) as much as would prove profitable, and to give room for the header and turbines to be above low water, so as to give easy access to them in case of need of repairs. The 20¼ foot head is maintained by means of draft tubes as shown in the plans and drawings of the power-house. (See Appendix plate V and VI.)

By assuming a 7 foot tunnel the head on the center is 7½ feet so then in the formula $V = (2gh)^{\frac{1}{2}}$ we have V = 8.02 X7.5 = 21.8 feet per second, which is the velocity of the water flowing through the penstock under the given conditions. Allowing 2% for the loss of velocity due to entrance and friction, we have 21.4 feet per second from which to calculate the area of the cross-section. Since the area is equal to the volume divided by the velocity, we have 720/21.4 = 32.8 square feet which gives a tunnel whose diameter is 6.4 feet for low water. But to allow for high water and an increase in the capacity of our plant it is necessary to make the tunnel 8 feet in diameter. Then at any stage of the river the capacity of the tunnel is great enough to carry a sufficient amount of water to run all the turbines at full load.

This tunnel must be protected against water-hammer occasioned by the sudden release of the load on the station, which would, by means of the water-wheel governors, shut off the passage of water through the wheels, thus leaving no outlet for the water at the lower end of the penstock. This water-hammer or hydraulic-ram effect is

tremendously large, and must be overcome in one or two ways; first, by the use of a relief valve at the lower end of the tunnel, which is set to operate at a slightly higher pressure than the normal operating pressure of the tunnel; secondly, by the use of a standpipe at the lower end of the tunnel whose height is great enough that it will not overflow under the normal operating pressure of the tunnel. Since this latter method is impractical owing to the tunnel being through a mountain, we must use the former. The relief valve is situated in the end of the header under the power-house with its discharge pipe into the tailrace.

The cost of excavation varies so greatly that we can only anticipate results that will be probably within 20% of correct. The cost per unit for excavation varies with the size of the tunnel, so after many inquiries and investigations we found that $10.00 per cubic yard, assuming all excavations through stone, to be an ample estimate. A tunnel 10 feet in diameter and 180 feet long has a volume of 525 cubic yards, making the cost of excavation $5250.00. The lining is made of concrete with a neat cement finish and is one foot thick. From figure 1 we calculate the volume of the lining in the following manner:



$$\frac{\pi D^2}{4} - \frac{\pi d^2}{4} = 78.5 - 50.2 = 28.3$$ square feet in the cross sectional area of the tunnel making 188.4 cubic yards at $10.00 per cubic yard, which is $1884.00. This makes a total of $7134.00 for the complete cost of the tunnel including the excavations for the power house and tail race. This last assumption is based on the fact that

a liberal allowance is made on the length of the tunnel, and that $10.00 per cubic yard for excavation is too large since it is not likely to all be through solid rock.

THE POWER-STATION DEPARTMENT.

Now that the power-station has come into consideration it becomes necessary to go to the other end of the line and study the nature of the load, for this must determine the characteristics of the generating units. We assume the load to include electric railway service, factory power, and street and commercial lighting, thus carrying a direct, as well as a synchronous and inductive load. Without question the current will be an alternating three-phase current.

The transmission voltage is of next importance and is determined by the length of the line, which in this case, is about 25 miles. The voltage is usually a little over 1000 volts per mile according to the best practice, so we adopt 30,000 volts as our transmission voltage. By using a higher voltage, say 60,000, we find that a much less wire is necessary, but we find this impractical since the tensile strength of the wire would be too small to withstand the pull. Another reason for not using a higher voltage is the difficulty of manipulation and the excessive cost of insulators.

It is now necessary to return to the turbines to select the type and size of water-wheel, thus obtaining what speed may be gotten from them. At low water we have 41000 cubic feet of water per minute under a head of 20¼ feet, so after due consideration we found that two 54 inch turbines of the S.M.Morgan Smith make were more effic-

ient and better adapted to this particular place than any other. A third turbine of the same size and type is necessary for an auxiliary unit and for secondary power during the high water months. The vertical type of wheel was selected because in this way we can have the power-house situated directly over the water-wheels, and high enough to prevent high water from flooding the power house and equipment. The turbines are directly connected to electric alternators of special design with vertival shafts, so that the loss of power between the turbines and generators is reduced to a minimum. The only objection to this direct connection would be that the speed of the turbine and rotor of the generator must be the same. However, this is entirely feasible since the speed of the turbine is 137 revolutions per minute and the generator can easily be so designed as to give 60 cycle current at this speed. The loss in belting or in using bevel gears to connect to an alternator on a horizontal shaft would be from 10 to 15 per cent. The length of this vertical shaft is about 14 feet which puts the power-house above the high water mark.

Our minimum indicated horse-power of the river is 1450 H.P. so we find that the 54 inch vertical Smith turbine under a 20 foot head, using 20,000 cubic feet of water per minute, would give 612 H. P. with an efficiency of about 85 per cent. By having three units of this size we have two to operate under our minimum load, with the third as an auxiliary and for secondary power during high water months. In this way we will be able to cut off the secondary power should we need the third unit as an auxiliary in case of a breakdown. The units were selected of uniform capacity so that a minimum number of duplicate parts may be kept in stock. The cost of wheels, bear-

ings, casings and header as obtained from the turbine manufacturers, are as follows, these prices including installation.

3 - 54 inch turbines $3300.00

3 - Step bearings 1500.00

3 - Iron casings and header 2700.00

which makes a total cost of $7500.00 for the water-wheels and equipment.

The following estimate on the electrical apparatus was furnished by the Westinghouse Electric and Manufacturing Company.

3 - 360 K.W. 2300 volt, 3-phase, 60 cycle revolving field, vertical A.C. generators, for direct connection to water-wheels operating at 135 revolutions per minute.

1 - Horizontal type, 125 volt, compound wound, 50 K.W. direct current exciter for direct connection to a water wheel by means of a bevel gear.

1 - 50 K.W. motor generator set for exciter purposes, complete with starting device and rheostats.

3 - Generator panels, each to be equipped with the necessary apparatus for the proper control of the generator, including necessary instruments, switches, etc.

1 - Exciter panel, complete, for the control of the above two exciters.

3 - Transformer panels, to control the three banks of transformers.

9 - (Three per bank) 125 volt, 2300 to 30,000 volt transformers, complete with necessary oil, etc.

The approximate price on the above apparatus delivered and installed would be $30,000.

Next to come into consideration is the power-house and its

inside arrangement. The house has its south wall built entirely of concrete which also acts as a retaining wall built along the side of the mountain. This wall is 65 feet high while the other two foundation walls are only 40 feet high. The power-house is a one story frame building, with concrete floors and foundations, 84 x 40 feet, with a two story high tension switch room on the west end extending only 24 feet in length, and is to be built at an estimated cost of $5000. The turbines are under the house 11 feet below the floor and 14 feet above the low tail-water level. The alternators are on the same vertical shafts as the turbines, with a six foot space between units and between each unit and the south wall. (See Appendix plate V & VI).They are conveniently arranged in a single row, having the electric controlled water wheel governors between them with ample room for the operator to pass. One exciter is connected directly to the vertical shaft of the first turbine by means of a bevel gear. This gear may be disconnected and the exciter run by either of the other turbines by connecting with a belt. The other is a motor generator set placed opposite the interval between the second and third units. Each exciter is capable of carrying the total exciter load. The switch board is situated on a gallery 12 feet high opposite the generators where the operator at the switch board is in sight of the exciters and generators. The switch board is best situated in the center of the gallery and far enough back to enable the operator to pass in front of it without danger to his clothing coming into contact with any apparatus on the board; so he can safely turn his back on the swicth board when he is watching the action of the equipment on the floor of the station. All cables are carried through conduits

under the station floor and along the walls.

Since our conditions have permitted a gallery, a very comfortable layout may be proposed. The low-tension bus-bars are well out of the way and easy of access if placed over head at the back of the gallery. Therefore, for convenience we propose to have each set of bus-bars at different heights from the floor but not over one another.

Between the machine and bus-bars there are to be knife-switches and oil switches, the former to protect the latter, as sometimes an oil switch fails to act promptly. The oil-switches are placed on the gallery under the low tension bus-bars in individual chambers of cement. To prevent the action of the switch from being concealed, a thick glass panel is placed in front of the switch chamber, thus making it possible for the attendant to see the switches at all times, which is desirable for mechanical as well as personal reasons. The voltage-regulators are to be situated on the exciter-panel in the switch-board.

The schronizing device is to be placed on top of the center of the switch board so as to be visible from the switches of every unit.

The step-up transformers are to be situated in a single row across the west end of the power-house, and are equipped with low trucks. The cables from the line oil-switches terminate in a sort of bus-bar arrangement to which will be connected the low tension leads of the step-up transformers. These bus-bars are to be placed on the end wall back of the transformer.

The high-tension switch-room is situated on the second floor directly over the step-up transformers. Between the step-up trans-

formers and high tension bus-bars are situated the multiple oil-switches which enable the operator to cut in any bank of transformers on any out going line. To the high-tension bus-bars are connected the transmission lines through knife-switches. Just before the line leaves the room are the taps for lightening-arresters with choke-coils between the arrester taps and the high-tension bus-bars. This very often saves the bus-bar insulator and transformer lead. The line leaves the building through a hole in the west end wall just under the eave of the roof. The conductors are to be surrounded by a glass insulator which will fill up the hole in the wall to keep out cold and to prevent small birds from making the power station their home. Since it is strictly essential to take the best of care of the line from the time it leaves the switch-board, care must be taken to allow no dripping eaves over it. To prevent this a small shelter is necessary to extend for a short distance out over the wires from the building.

TRANSMISSION DEPARTMENT.

The simplest and most widely used method of building electrical circuits uses bare wire conductors supported upon poles set in the ground and excepting within the densely settled portions of the larger cities this type of circuit is universally employed. It is evident that in this case, where the voltage (30000) is high, insulation would be no protection.

The first step to be taken is the selection of the route. In general the shortest way is the best. In this case the public highway is about the shortest distance between the point from which the power

is to be transmitted and Rogersville, the point to which the power is to be delivered. (See Appendix plate VII.) This route without question can be secured much cheaper than a private right of way for the ordinary farmer in this section of the country is glad enough to sell the right to set a pole for from $3 to $5. We, therefore, propose to build the line along the public highway, assuming of course that we have the permission of the counties through which it passes.

As the continuous operation of the plant is considered of great importance it is nece ssary to have two separate and distinct lines, each capable of carrying the total load, so that in case of trouble on one, the other being in readiness, may be used. By operating these two lines in parallel the losses and drop in voltage are just half as great as in the case of one line. Now it becomes a question of whether to use steel towers, iron, concrete or wooden pole construction. A few years ago the question of material for a pole line was scarcely given a thought, as wooden pole construction was a universal practice. Experience has shown, however, the wooden poles are subject to attacks from insects of various kinds, and the high voltage, coming into contact with the wooden poles when an insulator failed, set the poles on fire and so metal poles became desirable and in many cases a necessity. Generally speaking, it is economical today to construct a metal pole line. In the present case, however, it is without question, more economical to use wooden poles than to use iron poles or steel towers owing to the fact that good chestnut poles can be bought delivered on the ground for not more than the exceptionally low price of $1.25 per pole, while the steel tower costs from $175 to $250. Of course the steel towers could be placed much farther apart than the wooden poles

but the cost even then would be much greater than the cost of keeping up the pole line. We propose, therefore, to use chestnut poles.

Practice shows that the proper length of the poles should be about 35 feet and the diameter at small end should be seven inches but we are proposing a 40 foot pole with a diameter of seven inches at the small end so that when the ground end decays it can be cut and reset, thus doubling the life of the pole. To further lengthen the life of the pole it is well to char and tar the butts.

Practice shows that for high tension transmission lines the spacing of the poles varies from 100 to 125 feet, and on account of the extremely rough country through which the line is to pass we think it more expedient to advise the minimum. In considering the tension in the wires the cost of poles, insulator, etc. it is good practice to place the poles 100 feet apart.

The cross-arms are to be made of hard maple, a wood which is common to this part of the country and which can be had at a price not to exceed 20 cents. The pins are to be made either from oak or hickory and well boiled in paraffin or linseed oil so as to keep them from decaying. They will not cost over 4 cents delivered. The cross-arm braces are to be made of hard maple wood and will cost about 5 cents apiece.

In selecting the proper insulator, choice must be made between glass and porcelain. Glass is cheaper, more easily and cheaply manufactured; owing to its transparency, it can be more easily and reliably examined; the same property detains insects from building cocoons under the petticoats, and enables line men to inspect more easily. Porcelain, if well made is stronger both mechanically and electrically, is a better insulator and does not readily collect a condensing film

of moisture. For these reasons porcelain insulators are used above 5000 volts. They will cost about $600 per thousand.

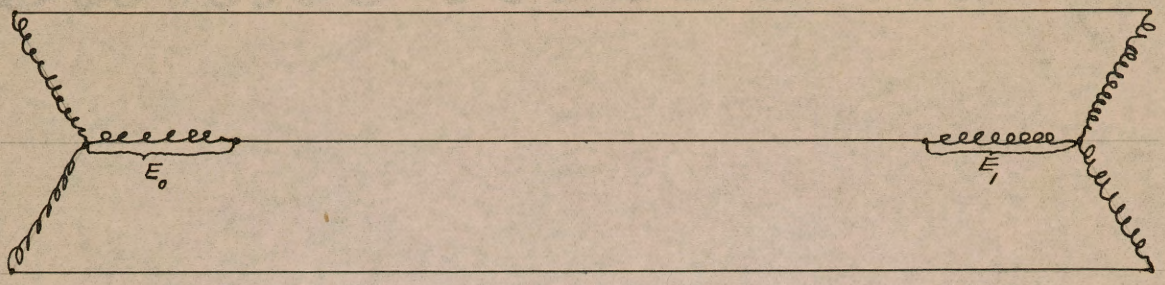
The next question to decide is whether to use copper or aluminum conductors. The tensile strength of aluminum is 25000 pounds and that of copper is 50,000 to 60,000 pounds. The conductivity of aluminum is about 60 per cent of that of hard-drawn copper, so that for the same conductivity, the area of the cross-section of the aluminum would have to be 60 per cent greater than that of copper and then the ultimate strength of the total section on this basis would be about 64 per cent of that of copper while the weight would be only about one third of that of copper. Therefore aluminum can compete with copper as long as the price per pound does not exceed two times that of copper, since the specific gravity of aluminum is 2.68 and that of copper is 8.89. There is never any great saving in the use of aluminum, as the market price is governed by the market price of copper. Aside from cost there are many points in favor of each.

Copper is more quickly obtained on orders, but aluminum is more quickly put in place, as it is so easily handled on account of its lightness. According to practice a copper conductor will remain intact at the point of an arc for a longer time than will aluminum. This is a good feature on a wooden pole line for it may burn off the cross-arm and thus clear the trouble. On the other hand this is impossible with metal towers as there is nothing to burn off and a sustained ground on the line may bring trouble elsewhere in the system. Then in addition to this, the life of aluminum is very short due to impurities in the metal. From the above consideration it therefore, seems advisable for us to use a copper conductor. The wires are to be 6 ft. apart so that

the wings of birds can not span them and also to prevent sticks from lodging on them. The farther the wires are apart the less will be the leakage across the intervening air but on the other hand, the induction and, therefore, the drop in voltage will be greater. But notwithstanding this drop in the voltage, we are for the above reasons, justified in placing the wires 6 ft. apart.

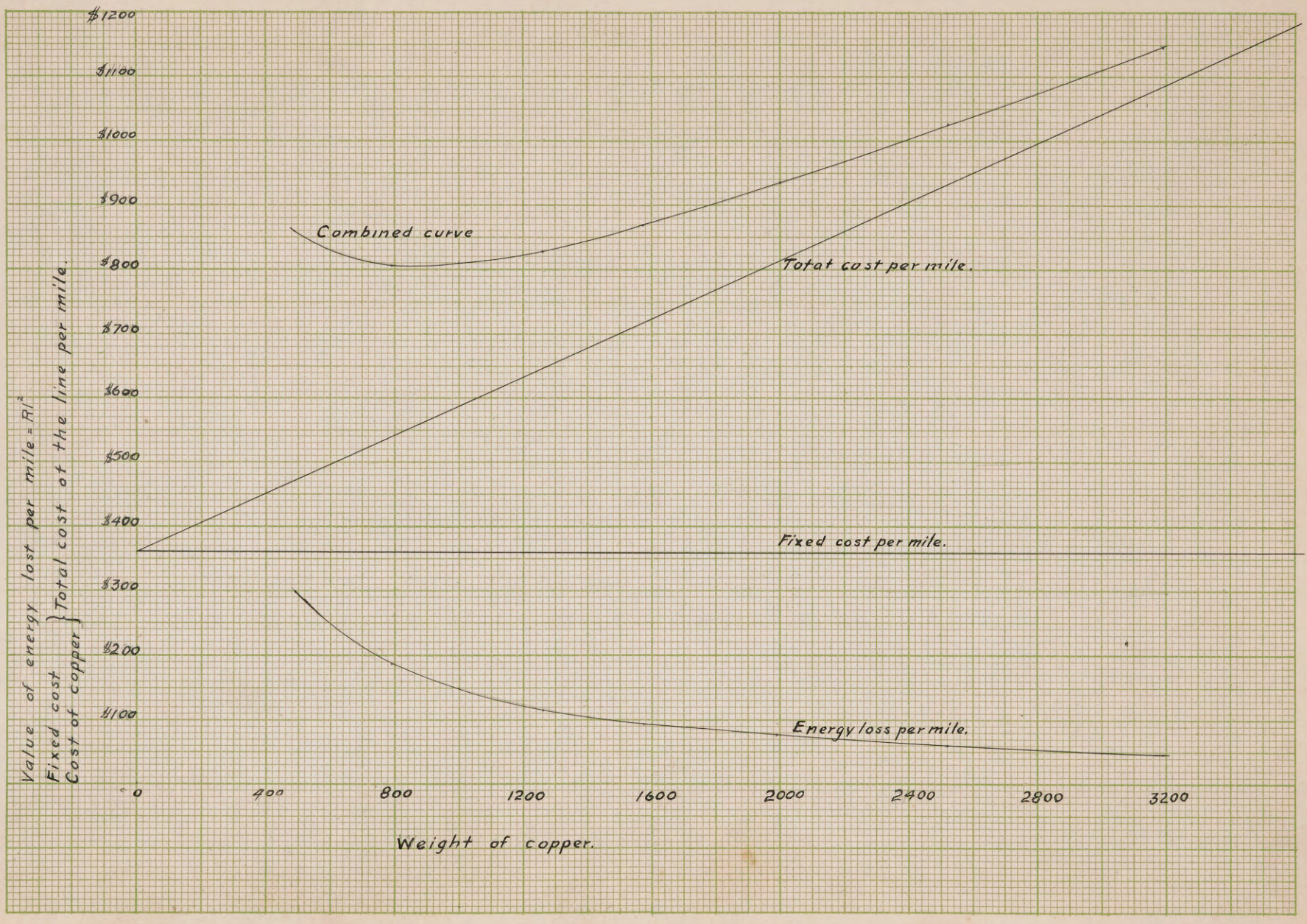
The consideration which determines the most economical section of the conductor is this: The larger the conductor the less the waste of energy in transmission, and the less will be the cost of producing that energy. On the other hand the larger the conductor the greater will be that part of the cost of the transmission which depends on the section of the conductor, and the greater the annual charge on that part of the capital expended. In such a case, then, the most economical section of conductor is that for which the annual cost of the energy wasted in transmission is equal to the annual interest and depreciation on that part of the cost of the transmission, which is proportional to the section of the conductor. To calculate this economic section the first step is to ascertain what current must pass through each conductor, knowing the total power to be delivered, the voltage and the power factor. The load is about equally distributed between rotary converters and induction motors, and since for efficient operation the power factor of either is not less than 90% (the arc and incandescent light load being too small to effect the power factor) it seems advisable to adopt this as the combined power factor in this case. Now by using Y connection for both the generator and the receiving circuit, and by having the neutral grounded, the voltage between mains may be divided by the square root of 3 to give the values of E_0 and E_1. The former

being the highest voltage in any one wire as shown in the figure below:



Let cos θ be the power factor of each receiving circuit, P the total power to be delivered, E_1 the electromotive force between the terminals of each receiving circuit, and E_o the electromotive force of each armature winding on the generator. Then assuming an average drop of 5 percent for the rough approximation we have by the formula, $P = 3 E_1 \cos \theta$, in which P is 1262000 watts, E_1 is 16400 and cos θ is .9, I equal to 28.5 amperes, which is the average full load current for the line.

Now that we have the current, we may determine the most economical section of conductor by drawing and combining two curves in the following manner. One curve is drawn using the weight of copper per mile as the abscissa and the fixed cost plus the cost of copper at 20 cents per pound per mile as the ordinates. The other is drawn using the weight of the copper per mile as the abscissa and the value of the $R I^2$ losses per year for the various sizes of wire as the ordinates remembering that the two lines are to be operated in parallel and hence the $R I^2$ losses being only half as great as that for a single line. These two curves are combined and shown in the following page. The lowest point on this curve or the point giving the least cost per mile as the ordinate shows for its abscissa about 800 pounds for the weight of copper per mile of single line. This gives approximately a number 8


$1200
$1100
$1000
$900
$800
$700
$600
$500
$400
$300
$200
$100
Combined curve
Total cost per mile.
Fixed cost per mile.
Energy loss per mile.
Value of energy lost per mile = RI²
Fixed cost
Cost of copper } Total cost of the line per mile.
0
400
800
1200
1600
2000
2400
2800
3200
Weight of copper.

wire as the size for the most economical operation of the two lines in parallel. It is now necessary to determine whether or not this wire is strong enough in tension, due allowance being made for changes in temperature, the tension of course being greatest in cold weather. From table 68 in Beardsley's Hydro-Electric plants, we find that if a wire is stretched when the temperature is 80°F and giving it a certain sag, that when the temperature falls to 10° below zero the sag, on account of the contraction of the wire decreases to a very much smaller amount, thus increasing the tension in the wire. From the formula $T = \frac{H^2W}{8\,d}$, in which T is the tension in the wire, H the distance between the poles, d the sag at the middle of the span, and W the total weight of wire (including wind, sleet, etc.) in pounds per foot, the tension was found to be about 500 pounds while the tensile breaking strength is only about 800 pounds, so it becomes necessary to use a larger wire to get a sufficient tensile strength, regardless of the economic section.

By the above formula it was found that a number 5 wire is the least that can be used, the calculations showing the factor of safety being shown below. In order that the tension may not be too great it is necessary to assume a sag of at least one foot when at a temperature of -10° F, which gives for the additional length of the wire due to the sag, at that temperature $L - H = \frac{8d^2}{3\,H} = .027$ ft. where L is the length of the wire and the other symbols are the same as used above. From the coefficient of expansion the expansion at 80°F is calculated to be .084. Then the total increased length, L - H, due to the sag at a temperature of 80°F is .084 + .027 = .111 foot. Then substituting in the formula, $.111 = \frac{8d^2}{300}$ # $d^2 = 4.16$.: $d = 2.04$ feet, the sag. Now knowing the sag by solving for T in $T = \frac{H^2W}{8\,d}$, we get T = 550, by assuming a wind of 20 miles per hour and making due allowance for

sleet, we have .08 pounds per foot acting vertically due to the weight of the wire, .30 pounds of sleet per foot acting downward, and a horizontal wind force on the wire, which is now twice as large in diameter of .23 pounds per foot. The resultant of these forces is .44 pounds per foot equal to W. This 550 pounds stress is the greatest to which the wire will be subjected under the most unfavorable conditions. Since the tensile strength of this wire is $\frac{60000}{.027}$ = 1560 pounds, we have a factor of safety of nearly 3. This is a rather low factor of safety, but as a matter of fact these adverse conditions would never all come at one time.

To find the voltage drop, substitute in the equation below, the values of the reactance and resistance corresponding to a number 5 wire, and we have:

$$r = \frac{(E_o^2 - (E_1 \sin\theta + \frac{X}{2}I)^2)^{\frac{1}{2}} - \cos\theta}{I}$$

$$32.5 = \frac{(300710281 - (E_1 \sin\theta + 239)^2)^{\frac{1}{2}} - .9\,E_1}{28.5}$$

$\therefore E_1 = 16410 \qquad E_1 (3)^{\frac{1}{2}} = 28390$

$E_o - E_1 = 30000 - 28390 = 1610$ volts which is a 5.4% drop. This drop is for a single line but since the lines are to be operated in parallel, the drop will be only half as great, 2.7%.

The cost per mile of the transmission line is given in tabular form as follows:

Cost Per Mile of Transmission Line.

Chestnut poles at $1.25 (40 ft. with diam. of 7")	=	$66.25
Miscellaneous (Foreman)	=	25.00
Cross-arms at 20 cts.	=	10.60
Pins at 4 cts.	=	6.36
Cross-arm beams at 5 cts.	=	5.30
Cross-arm bolts at 10 cts.	=	10.60
Insulator pins at 15 cts.	=	23.85
Carriage bolts at 4 cts.	=	12.74
Setting arm, insulator pins at 50 cts.	=	26.50
Porcelain insulators at $600 per 1000	=	95.40
Number 5 wire at 20 cts. per lb.	=	316.80
Stretching wire	=	20.00
Right of way at $3 per pole	=	158.40
Total cost per mile	=	$777.80

Since there are two transmission lines it will be equivalent to having one line 40 miles long and the total cost is 777.80 x 40 =$31112.

THE COST AND SALE OF THE POWER.

In order to determine the cost per horse power of development it is necessary to know what H.P. is delivered and to know this we must point out the various losses encountered in the generation and transmission of the energy, and for this purpose attention is called to Appendix plate VIII. In this diagram is traced the losses from the time the water enters the forebay until the power is available at the point where the power is to be used. The energy in the forebay before it

enters the penstock is 2340 H.P. and for a 2% friction loss and a 20% loss in the turbines we find that they deliver 1836 H.P. to the generators. The loss in the transformation of the power in the generator is given by the Westinghouse Electric Co. as 5%. Then the generator gives out 1744 H.P. and the current generated is at 2300 volts. The step up transformers have an efficiency of 97% delivering, therefore, 1690 H.P. to the line. There is a line drop of 5.4% in voltage, with only a $R I^2$ loss of 3¼% which gives 1635 H.P. as the amount of power delivered to the step-down transformer. These have an efficiency 97% delivering 1585 H.P. to the sub-station at Rogersville. As we only sell to wholesale customers, and are not concerned about the distribution of load, the cost and selling prices are both based on the amount of power delivered to the secondary circuit, which as stated above is 1585 H.P. Having determined the amount of power delivered, we are able now to calculate the cost of development for horse power by summing up the various costs as follows:

Estimate of Total Cost of Development.

Dam	$25000.00
Tunnel	7134.00
Turbines (complete)	7500.00
Electrical Equipment	30000.00
Power House	5000.00
Transmission lines and right of way	31112.00
Site and water rights	1254.00
Total cost of development and transmission	$107000.00
Total cost per H.P.	$67.50

In order to determine the annual cost of the developed power we

must take into consideeation, interest on the investment, depreciation or reduction in value due to ordinary operation, maintenance and repairs, insurnace, taxes and operating expenses. Each of these items of course, vary with the duration and the conditions under which the power plant is installed and operated. We shall not be far from right in quoting below the ordinary rates of practice as modified by our own special case.

Estimate of Annual Cost.

Interest on the investment at 6%	$6420.00
Taxes	200.00
Depreciation on buildings at 1%	50.00
Depreciation on turbines at 2%	150.00
Depreciation on generators, etc. at 8%	1600.00
Depreciation on pole lines at 3%	143.00
Total fixed charges	$8563.00
General Superintendent	2000.00
Line superintendent	800.00
Line men	600.00
Two attendants at$800. each	1600.00
Two assistants at 500. each	1000.00
Repairs and incidental expenses	1037.00
Total annual cost	$15600.00
Cost per H.P. of 1585 H.P.	$9.85
Cost per H.P. of 1040 H.P.	$ 15.00

The above cost per H.P. per year was calculated on the basis of the total capacity of the plant, however since the minimum flow of the

river only permits of a guarantee of two turbines, which is 1040 H.P., this must be the basis on which we determine the cost per H.P. per year which is $15.00. On this basis the power obtained from the third turbine is gotten absolutely without cost, and is known as secondary power, for the reason that it is only possible to funish it when the flow of the river is sufficiently great to run three turbines, which i is on an average of about ten months per year. So then the power of the third turbine, which is off say for two months a year on account of low water, and also which may be cut off at any time in case of accident or a breakdown, to supply the primary or guaranteed power, is known as secondary power and must be sold at a much cheaper rate, and to factories or mills that already have a steam plant installed or who are not seriously hindered by having their power cut off at any time.

Upon investigating the cost to run and maintain steam plants of various sizes, against which we will have to compete, it was found that to operate a 500 H.P. steam plant would cost under favorable conditions from $40 to $50 per H.P. per year, while for a 200 to 300 H.P. plant it would cost from $60 to $80 per H.P. per year, increasing in as great or greater proportion as the plant decreases in size. Now since these are the conditions against which we are to compete we think it wise to propose to sell power at a flat rate of $35.00 per H.P. per year for 24 hours, - this rate being cheap enough to have a ready sale and yet it allows for an ample profit for the owners of the plant.

The probable distribution of power from the sub-station at Rogersville is suggested in the following table and since the load factor is so variable, we determine the cost of primary power per H.P. per hour, on which we regulate the selling price of the power, neglecting

entirely the secondary power, which will all be net profit whatever it may be.

COST OF POWER

Primary	Time during which power is used	Days per year	Hours per day	H.P.	H.P. hrs. per year	Cents cost per H. P. hr.	Total cost per year
Southern Railway	5 A.M. to 10 P.M.	365	17	500	3102500		
Inter-urban Railway	5 A.M. to 10 P.M.	365	17	200	1241000		
Marble mill	6 A.M. to 6 A.M.	365	24	200	1752000		
Rogersville Electric Co. (arc	6 P.M. to 6 A.M.	365	12	100	438000		
Rogersville Electric Co. (incandes.	6 P.M. to 9 P.M.	365	3	40	43800		
Cost of total primary power				1040	6577300	.22	$14373.12

Secondary

Flour Mill at Bull's Gap	6 A.M. to 6 P.M.	310	12	75	279000		
Rogersville Ice Plant	6 A.M. to 6 A.M.	365	24	60	525600		
Planing & Furniture Factory	6 A.M. to 6 P.M.	310	12	100	372000		
Lyon's Flour Mill	6 A.M. to 6 P.M.	310	12	75	279000		
Hale's Saw Mill	6 A.M. to 6 P.M.	310	12	50	186000		
Unsold				160			
				520	1641600	0	

SALE OF POWER

Primary	H.P.	Hrs. per day	H.P. hrs. used per year	No. cents per H.P. hr. per year for 24 hrs. per day.	$ income for power per year.
Southern Railway	500	17	3102500	.56	$17374.00
Inter-urban Railway	200	17	1241000	.56	6949.60
Marble mill	200	24	1752000	.40	7008.00
Rogersville Electric Co., (arc	100	12	438000	.94	4117.20
Rogersville Electric Co., (incandes.	40	3	43800	3.20	1401.60
Total income from primary power					$36,850.40

Secondary

Flour Mill at Bull's Gap	75	12	279000	.25	697.50
Rogersville Ice Plant	60	24	525000	.11	577.50
Planing & Furniture Factory	100	12	372000	.25	930.00
Lyon's Flour Mill	75	12	279000	.25	697.50
Hale's Saw Mill	50	12	186000	.25	465.00
Unsold	160	12	897000	.25	2242.50
Probable income from secondary power					$5610.00
Total income					$42,460.40

APPENDIX.

L E E

S C O T T

NEWMANS RIDGE

NEWMANS RIDGE

H A N C O C K

VIRGINIA BOUNDARY
TENNESSEE LINE

H A W K I N S

PLATE II.

U.S. TOPOGRAPHY MAP

Scale 2 mi = 1 in.



Contour map showing location of Plant of Clinch River Power Co.
(The contours were taken from the U.S. Topography map).

PLATE I.

TABLE I.

The average 10-year horse power of the river with an 8 foot tunnel and a 20.3 foot minimum low water head.

Month	H.P.	Head in feet	Discharge cu. ft. per min.	Rise in feet	Minimum H.P. for 10 years.
Jan.	3000	21.8	72500	1.5	2280
Feb.	3500	23.3	76000	3.0	2250
Mar.	3540	24.0	78000	3.7	2890
Apr.	3180	22.6	74500	2.3	2790
May.	3020	21.9	72700	1.6	2775
June	2930	21.7	71500	1.4	2200
July	2820	21.5	71400	1.2	1640
Aug.	2600	21.4	71300	1.1	1440
Sept.	1670	20.5	43200	.2	1470
Oct.	1590	20.3	41000	.0	1440
Nov.	3100	22.0	73200	1.7	1500
Dec.	2990	21.6	72400	1.3	1720



PLATE III.

Horse power curve of the river for a 20 ft. head through a 8 ft. tunnel, taken from data furnished by the U.S Weather Bureau.

PLATE IV

TABLE II.

The annual indicated horse power of Clinch River at the site of the Clinch River Power Co. plant from 1895 to 1904.

Month	Year							
	1895-6-7	1898	1899	1900	1901	1902	1903	1904
Jan.	3660	3060	3240	2820	2550	3280	2890	3680
Feb.	3700	2800	3830	3300	2900	3510	3580	3690
Mar.	3750	2800	3770	3600	2890	3710	3680	3090
Apr.	3800	3110	3100	2800	3700	2890	3610	2770
May	3500	2900	3240	2690	3590	2710	2690	2770
June	3520	2900	2810	2810	3490	2800	3670	2680
July	3540	2960	2660	2800	2730	2640	1640	2670
Aug.	3530	2280	2650	2650	2550	2620	1480	1530
Sept.	1465	3270	2690	2650	2800	1640	1430	1460
Oct.	1500	2660	1500	1530	2600	2180	1420	1420
Nov.	1500	2760	1640	2800	1570	1550	1500	1590
Dec.	2790	2690	2690	2800	3680	2820	3600	3790

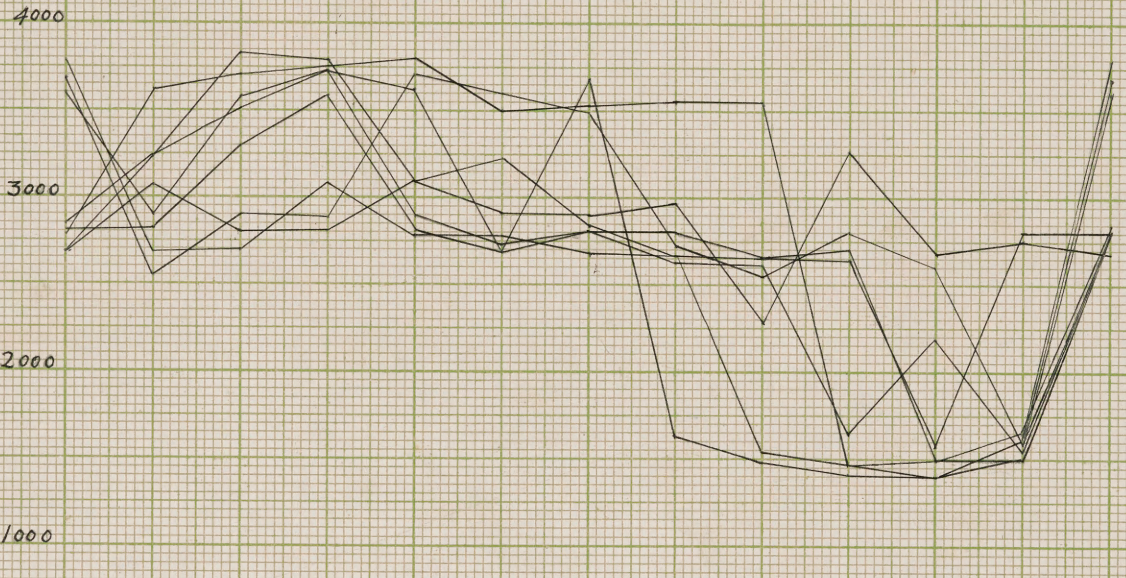
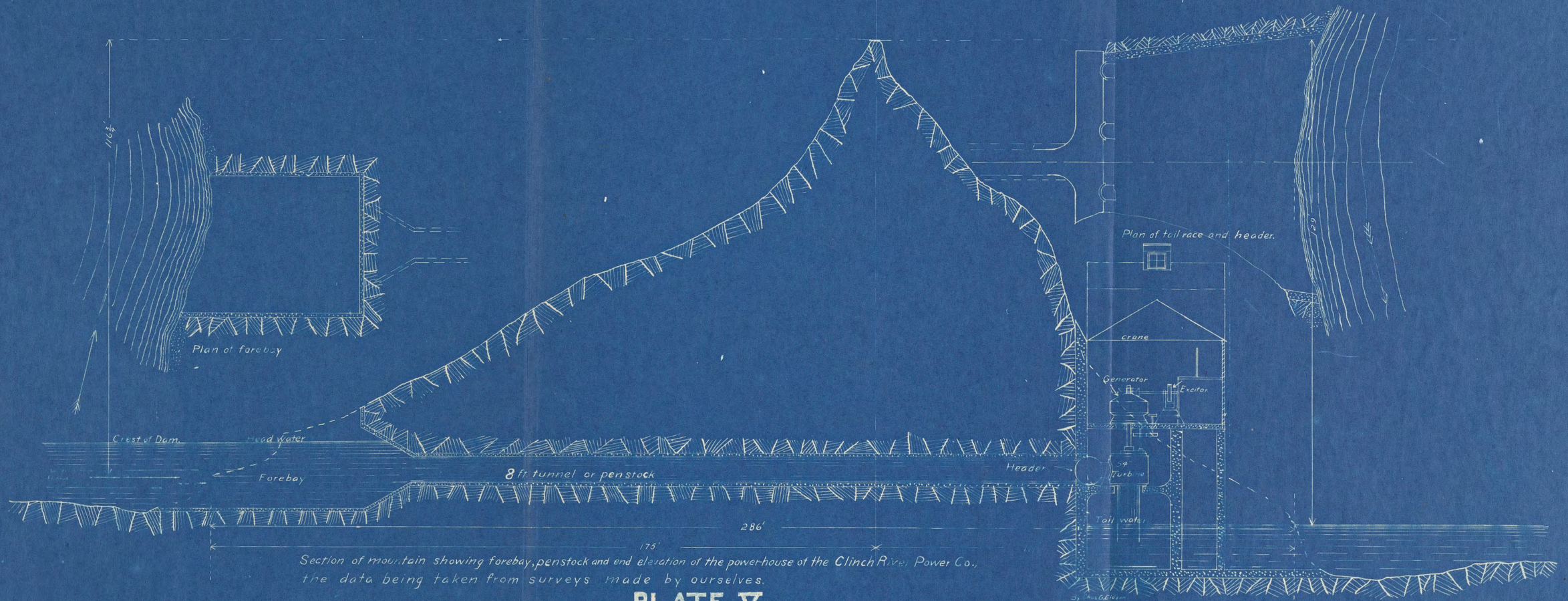


PLATE IV

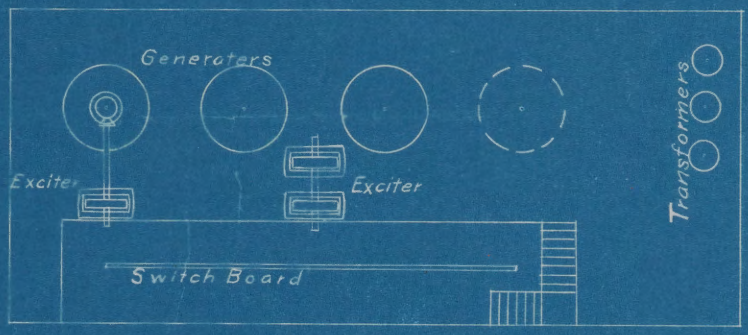
Annual horse power from 1895 to 1904, taken from data furnished by U.S. Weather Bureau

NO 345.
EUGENE DIETZGEN CO. CHICAGO-NEW YORK.

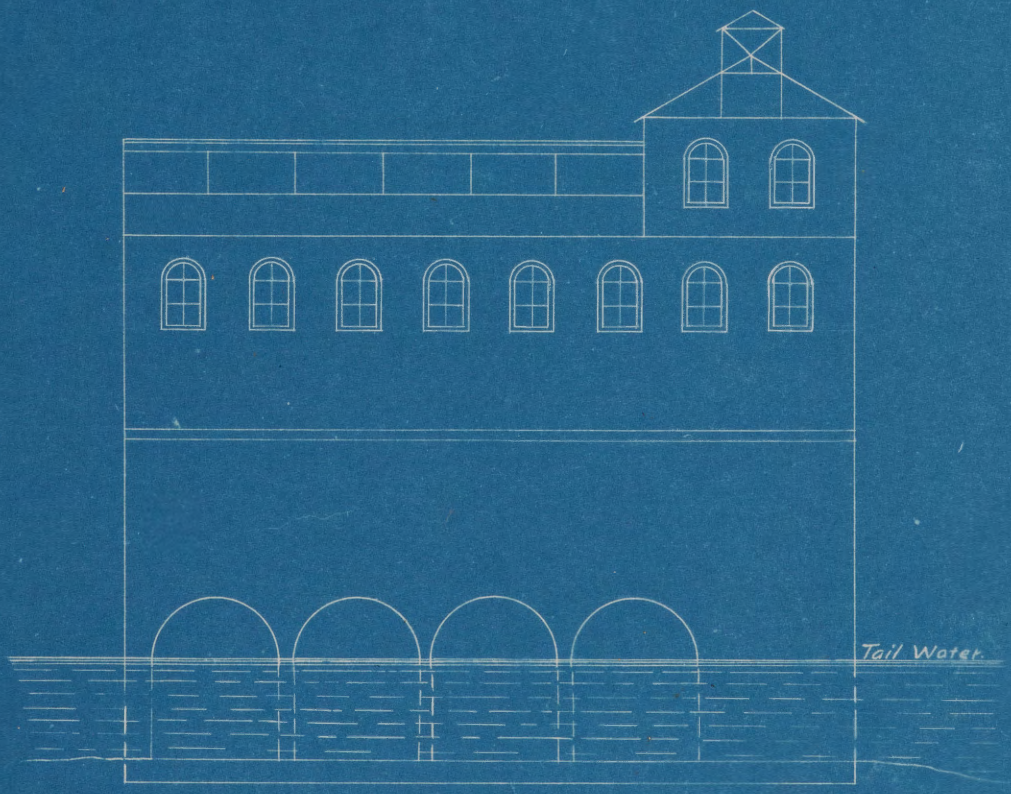


Section of mountain showing forebay, penstock and end elevation of the powerhouse of the Clinch River Power Co., the data being taken from surveys made by ourselves.

PLATE V.

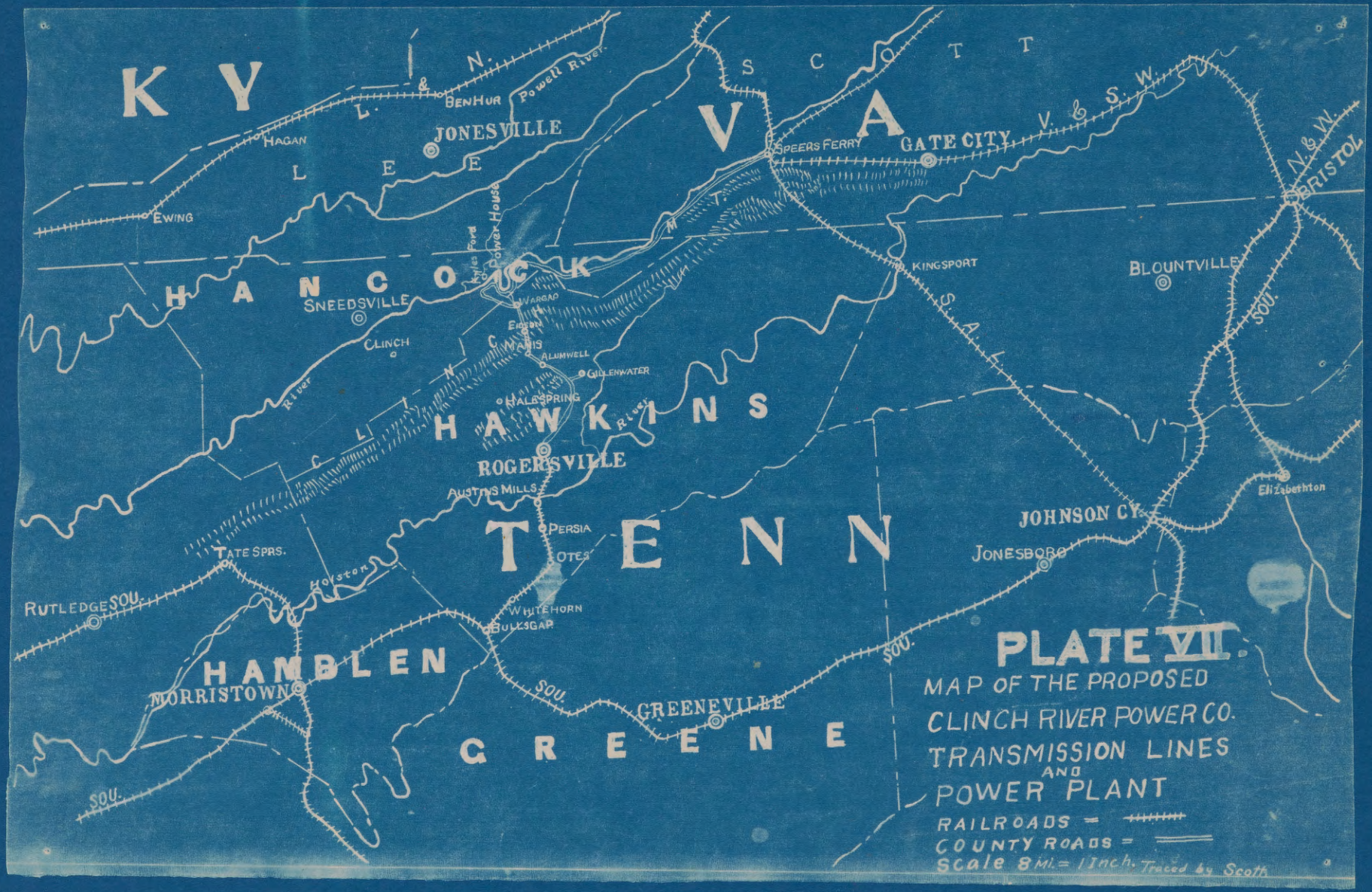


Plan of Power House.



Front Elevation.

PLATE VI.


KY
VA
TENN
L. & N.
BEN HUR
Powell River
JONESVILLE
HAGAN
EWING
LEE
SCOTT
SPEERS FERRY
GATE CITY
V. & S. W.
N. & W.
BRISTOL
Byles Ford Power House
HANCOCK
SNEEDSVILLE
KINGSPORT
BLOUNTVILLE
SOU.
CLINCH
River
WARGAP
EDSON
WANIS
ALUMWELL
GILLENWATER
HALSPRING
HAWKINS
R. Riv.
ROGERSVILLE
AUSTINS MILLS
Elizabethton
JOHNSON CY.
PERSIA
OTES
TATE SPRS.
JONESBORO
Holston
RUTLEDGE
WHITEHORN
BULLSGAP
HAMBLEN
MORRISTOWN
GREENEVILLE
GREENE
PLATE VII.
MAP OF THE PROPOSED
CLINCH RIVER POWER CO.
TRANSMISSION LINES
AND
POWER PLANT
RAILROADS =
COUNTY ROADS =
Scale 8 Mi. = 1 Inch. Traced by Scott

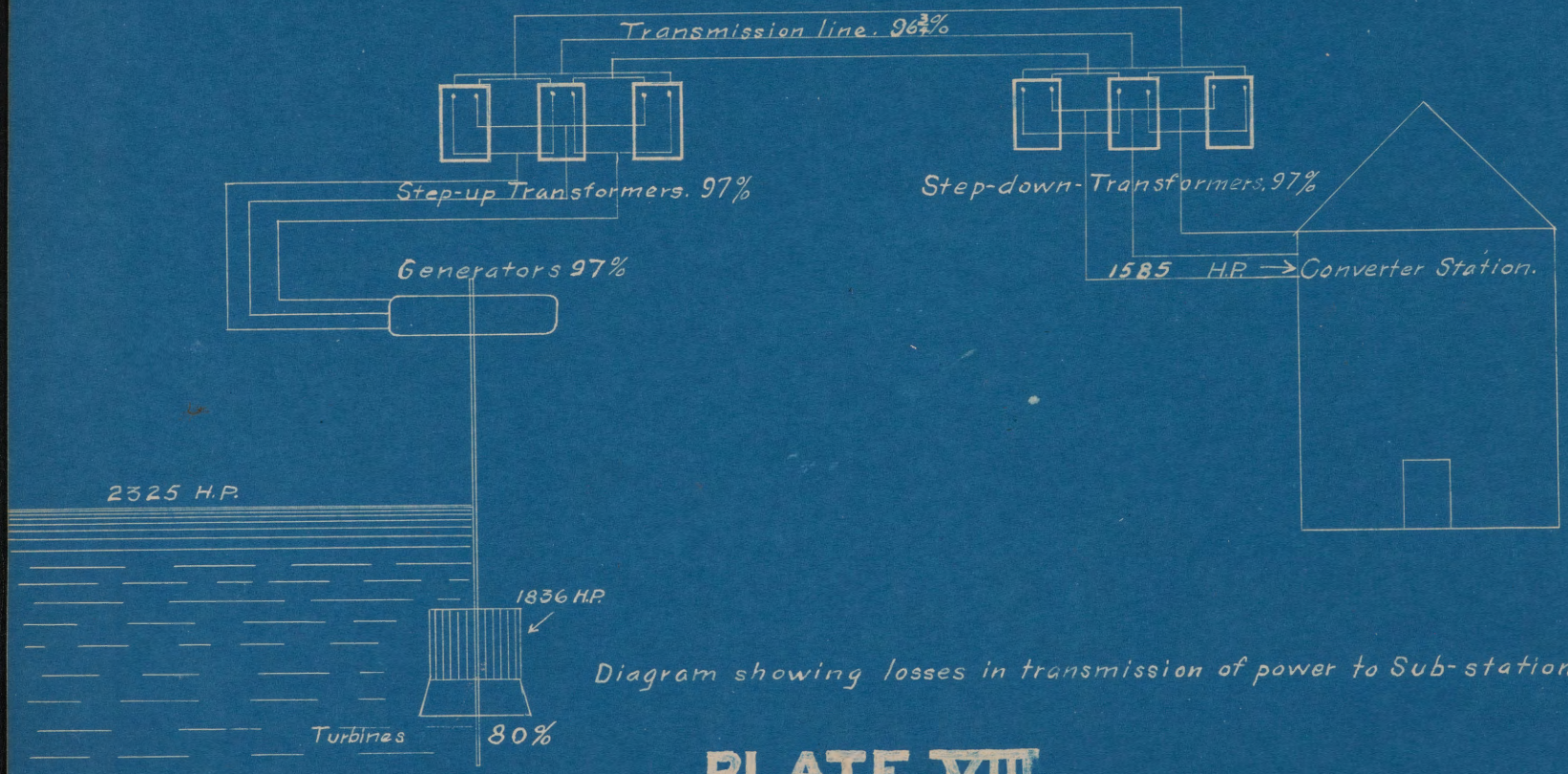


Diagram showing losses in transmission of power to Sub-station.

PLATE VIII.