HYDRO - ELECTRIC DEVELOPMENT ON THE SNAKE RIVER, OREGON

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HYDRO-ELECTRIC DEVELOPMENT

ON

THE SNAKE RIVER

AT

OXBOW BEND, OREGON

A THESIS

PRESENTED BY

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HYDRO-ELECTRIC DEVELOPMENT ON THE SNAKE RIVER AT OX BOW BEND, OREGON.

The western part of the United States contains a large percentage of the total water power of this country. That portion, which required little money for development and which was near to a market, has been made use of. The greater part, however, is located at large distances from the populous manufacturing centers.

One of the large undeveloped water powers is at Ox Bow Bend on the Snake River. There is little market for the energy in this locality and hence the development of a hydroelectric plant was considered impractical. However, during the last few years, great strides have been made in high tension power transmission and it is now possible to economically carry power large distances to a market. Thus, the output of a plant at Ox Bow can be transmitted to a market at Boise.

At Ox Bow, the Snake River describes a huge bend which has the shape of an ox yoke. The water is to be backed up at this point to create a head of 52 feet, and delivered to the wheels at the lower end of the bend through a tunnel across the narrow neck of land inside of the bend.

A gate is to be placed at the entrance to the tunnel and a settling basin will be located at the discharge end. The minimum stream flow of the Snake River at this point is 6,500 cubic feet per second, so that the minimum theoretical power will be 38,200 H.P. This is determined from the following equation:

$$H.P. = \frac{r\ h\ q}{550}$$

where r = weight of 1 cu. ft. of water in lbs. = 62.5

h = head in feet.

q = discharge in cu. ft. per second.

The station has been designed for 37,200 H. P. at the water wheels. It is proposed to install six units, each consisting of two twin turbines direct connected to a 3,750 K.V.A., 60 cycle, three phase alternator. The water wheels which develope 6,200 H. P. at full gate opening are controlled by oil pressure governors. The power factor of the system is estimated at 85%. From the above it is seen that the capacity of the water wheels is about 50% greater than the generator. This is due to the fact that a turbine can not stand the overload which the alternator can. The excitation for the generators is to be furnished by two water wheel driven exciters. Either of these exciters, which are of 300 K.W. capacity, is capable of supplying all the direct

current required by the alternators, control circuits and auxiliary apparatus. The voltage of the exciters is 125. The water wheels are 500 H. P. in capacity and are placed in separate bulk heads. The intake gates are motor operated but in case of emergency can be controlled by hand.

The three phase current from the alternators is stepped up from 2,300 volts to 66,000 volts by theee single phase transformers. Both sides of the transformers are connected in delta. Only the high side of the transformers are paralleled since all of the energy is to be sent out of the station at the high voltage. An extra transformer is available for use in case of breakdown. Electrolytic lighting arresters are used to prevent trouble due to storms and other static disturbances.

All the apparatus in the station is controlled from a switch board placed upon the gallery. The board is of the bench type and is very compact.

DAM.

In the design and construction of a hydro-electric project, the dam is of great importance. Upon its stability depends not only the continuous operation of the plant but also the lives and property of the people living the valley below. The financial success of the enterprise, too, depends to a considerable extent upon the amount of money expended in damming up the stream. For these reasons, the dam should be carefully looked into and a type and design selected that will insure maximum safety at the minimum expense.

Of the many types of dams which have been built, the most common form of a permanent type is a solid masonry structure. With an abundance of good stone near at hand and high freight charges on steel, this class of dam will probably be as cheap as the reinforced type which is of lighter section.

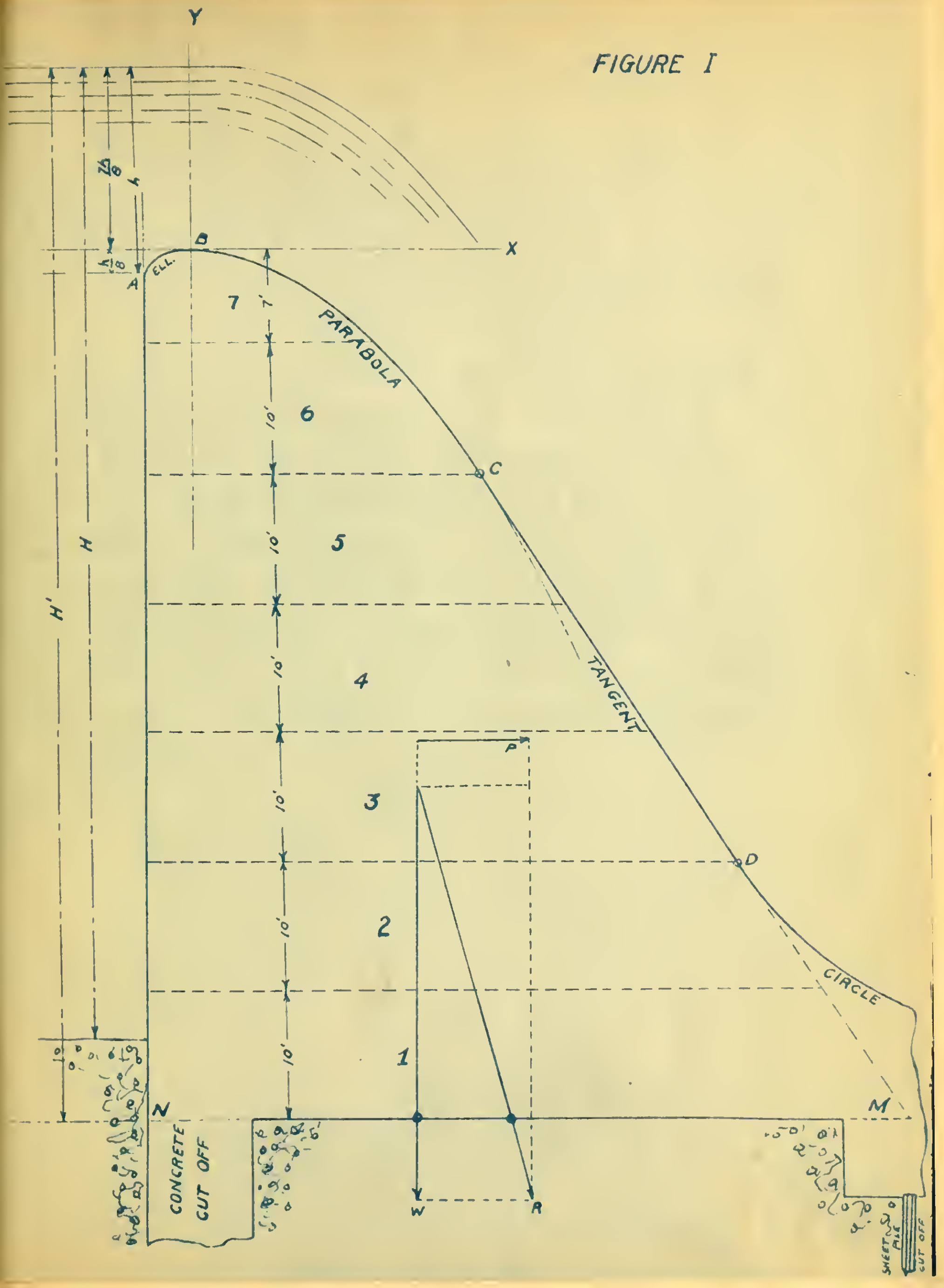
The solid section has proven very reliable, for of all those that have been built, only a few have fail- to stand the test of time and floods. Of the failures, most can be attributed to one of two faults in design. Either the dam was overturned because the spillway section was not large enough to take care of an unusual flood, or it was floated away because improper foundation allowed seepage underneath the dam.

To design a dam at Ox Bow Bend it is necessary to know the maximum stream flow of the Snake River at this point. A record of the principal rivers of the United States is kept by the United States Geological Survey. From this record, the maximum flow over a period of years was determined to be about 70,000 cubic feet per second. The maximum amount of water used by the turbines is 6,500 cu. ft. per second. On account of this vast quantity of water to be wasted, it was decided to build the entire dam a spillway. The main spillway which is 393 feet long will take care of the total 70,000 seconds feet, and a shorter spillway at one side will act as a factor of safety in case of an unusual flood. It is essential to look out for floods in the Snake River Valley as the trees which help hold back the spring freshets are fast being removed, due to forest fires and lumbering. An earth retaining section, with a concrete core, has been constructed to prevent seepage at the end of the dam.

With the assumption that the 393 feet of main spillway takes care of the 70,000 cubic feet per second, the water will rise to the height of 14.2 feet above the dam. This is determined by Francis' formula

$$Q = 3.33\ Lh^{\frac{3}{2}}$$

FIGURE I



Y
X
B
A
ELL.
PARABOLA
C
TANGENT
D
CIRCLE
H
H'
7
6
5
4
3
2
1
7'
10'
P
W
R
N
M
CONCRETE
CUT OFF
SHEET PILE
CUT OFF

$$h^{\frac{3}{2}} = \frac{Q}{3.33\ L} = \frac{70,000}{3.33\ \ 393} = 53.5$$

$$h = 14.2$$

Where h is the head of water above the dam, in feet

Q is the flow in cubic feet per second

L is the length of the overflow section, in feet.

To obtain the smallest amount of action on the dam by the falling water and to obtain an extra amount of head in draught times, the section of the spillway should be the natural curve of water running over a sharp edged weir. This section is shown in figure I. Curve AB is an ellipse having a major axis equal to $\frac{h}{2}$ = 7.1 feet, and a minor axis equal to $\frac{h}{4}$ = 3.55'. Curve BC is a parabola the equation of which is

$$X^2 = 2\ py$$

where $p = .99\ h$

so $X^2 = 2 \times .99 \times 14.2\ y = 28.1\ y$

Solving this equation the following values of X and Y were determined.

X	Y
0	0
5	.89
10	3.56

X	Y
15	8
20	14.2
25	22.2
30	32
35	43.6

The next portion of the curve is a straight line, CD, drawn tangent to the parabola through the point M. M is one extremity of the base of the dam and it is so located that the length of the base NM is equal to 75% of the maximum head of water above this base. The last portion of the curve of the section is a circle DE drawn tangent to the line CM. Its purpose is to direct the water horizontally and its radius may be any convenient distance. It was chosen at thirty feet.

As the gravel which forms the river bottom is a layer of very great depth, it would make the dam of enormous cost if the foundation were taken to bed rock. To prevent erosion at the toe of the dam, a very long apron is carried out. As seepage is likely to occur with a gravel foundation two sheet pile cut offs were decided upon, one at the end of the apron and the other at the toe of the dam. A concrete cut off was also placed at the heel.

The stability of vertical wall against water pressure on one side depends upon three things, for proper security.

First, the resultant of the water pressure, acting horizontally through the center of pressure, and the weight of the dam, acting vertically through the center of gravity, must fall within the middle third of the base.

Second, the maximum pressure per cent area on the base must not exceed a safe value.

Third, the water pressure must be less than the sliding friction on the base.

In a dam of the solid type, the weight of the dam, and the area of the base must be of such a magnitude, if the first condition holds, that the third condition will be absolutely safe, so that it is unnecessary to investigate the strength against sliding.

To determine the line of pressure in the dam the following method was used. The dam was first divided into seven sections, six of which were ten feet each, and the seventh was 7.2 feet high. The center of gravity of the dam was then determined, first for the whole section, then with section 1 removed, then with sections 1 and 2 removed and so

on until only section 7 remained. The line of pressure with no water in the reservoir can be determined by projecting the centers of gravity for the different sections upon the base line of those sections and then connecting points. It was found that the resultant line of pressure lay well within the middle third of the dam.

To determine the line of pressure with any water behind the dam it is necessary first to determine the weights of the different sections. This was done by drawing the section to scale and measuring the area with a planimeter. The following results were obtained with the dam drawn to a scale of 1 inch equal to ten feet.

Section	Area sq. in. (by planimeter)	Vol. of Sect. 1 ft. wide. (cu.ft)	Wt.of Sect. 1 ft. wide #.
1-7	24.12	2412	361,500
2-7	18.68	1868	280,200
3-7	13.86	1386	207,900
4-7	9.53	953	142,950
5-7	6.05	605	60,750
6-7	3.12	312	46,800
7	.93	93	13,950

The material of the dam which is granite was assumed to weigh 150 pounds per cubic foot. The forces shown in the fourth column represent the weights of the various sections acting down through the centers of gravity of the respective sections. It is now necessary to obtain the force and the point of application of the force due to the water. The center of pressure, X_c, was determined by the equation

$$X_c = \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}$$

The force, P, due to the water acting at X_c, was determined by the equation

$$P = \frac{1}{2}\, b h h_3\, r$$

r is the weight of one cubic foot of water and is equal to 62.5#, b is the width of the section and was taken as one foot. The remaining terms are explained by figure II.

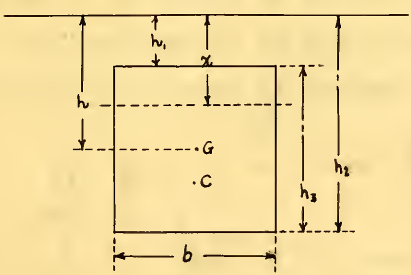


Fig. II.

The following results were obtained.

Sect.	h_1	h_2	X_c	h	h_3	P
1-7	14.2	75.2	51.6	44.5	61	84,800
2-7	14.2	71.4	49.1	42.6	57.2	76,100
3-7	14.2	61.4	42.6	37.6	47.2	56,700
4-7	14.2	51.4	36.2	32.6	37.2	36,700
5-7	14.2	41.4	30	27.6	27.2	23,500
6-7	14.2	31.4	23.8	22.6	17.2	12,150
7	14.2	21.4	18.0	17.6	7.2	3,960

By combining P acting horizontally thru C and the weight of the dam acting vertically thru the center of gravity as previously determined, the resultant pressure may be determined for each section. By connecting the points where this pressure acts on the bases of the respective sections, the line of resultant pressures may be obtained. This line was found to be very close to the center of the dam.

It is now necessary to determine the maximum pressure acting on the base of the dam.

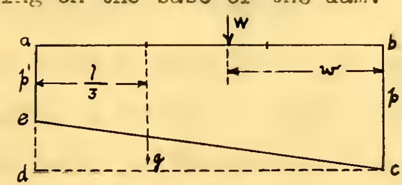


Fig. III.

Figure III represents the trapezoid of pressure on the base of the dam.

W = the total pressure acting on ab

w = the distance of W from the nearer edge, b

p = the maximum intensity of pressure

p^1 = the minimum intensity of pressure

l = the width of the base ab

g = the C.G. of the triangle Ced.

Trapezoid abce = the reaction of the foundation

$$= abcd - ced$$

$$= pl - \frac{1}{2}(p-p^1)$$

Since W and the reaction of the foundation are in equilibrium, the algebraic sum of their moments about any point must be equal to zero. Taking moments about, we find the moment of ced = 0.

$$\frac{l^2p}{6} - W\left(\frac{2}{3}l - w\right) = 0$$

$$p = \frac{2W}{l}\left(2 - \frac{3w}{l}\right)$$

$W = 361{,}500 \quad l = 58.8 \quad w \;\; 28.4$

$$p = \frac{2 \times 361{,}500}{58.8}\left(\frac{2-3 \times 28.4)}{58.8}\right)$$

$$= 12300 \times .55 = 6760\# \text{ per sq. ft.}$$

This value is within the safe limit for coarse gravel which forms the foundation of the dam.

It was previously determined that the line of pressure, with the reservoir both empty and full, was well within the middle third of the dam. As the unit pressure is found to be within the safe working limit of the material of the foundation, the dam will be safe in every respect.

TRANSMISSION LINE.

The line is one of the most important parts of the system, for on it depends the continuity of service without which the best apparatus is useless. On this account it is important to consider carefully not only electrical details, but also methods of construction.

In the design of a transmission system, the line must be considered, first, in its general relations to the plant, second, as a special problem in engineering, third, as a mechanical structure. The first has to do with the proper proportioning of the line as a part of the system, its function as a distributing conductor, and its bearing on the general efficiency of the plant of which it is a part. In connection with this, it must be remembered that much depends on the type and adjustment of the station apparatus in controlling the line voltage, loss and power factor. The second deals with the electrical difficulties, and the third with the materials of construction and methods of applying them.

In the passing of energy over a line there is first the loss due to resistance. The two conductors with the air between them act as a condenser.

This condenser action tends to cause the generator voltage to rise, while the inductance of the line has the opposite effect.

The charging current is constant and, flows as long as voltage is applied to the line. Its importance diminishes as the load increases for when the load is heavy, it is not only overcome by the lagging current of the load, but is also rendered unimportant by the presence of a large current in place with the e. m, f.

In the case of large excess lagging current, the effect on the capacity and regulation of the generator is well known. The lagging load current can be balanced by synchronous machines. Where synchronous machines are not used, a large line capacity current may be desirable. The capacity may be increased by dividing the conductors into two or more wires, separated from each other, but mounted on the same insulator or adjacent insulators. This will at the same time decrease the inductance.

The line which it is proposed to construct in connection with the generating station at Ox Bow Bend will be approximately one hundred and seventy-five miles long.

The voltage has been fixed at 66000 since this is the standard in this locality and it is probable that in the future this station will be tied in with some of the existing plants.

The main line will be run in duplicate on steel towers to insure continuity of service. Three-phase transmission has been decided upon, since it is the most economical in the amount of line wire required. The line side of the transformers will be connected in delta to prevent trouble from harmonics.

The location and capacity of the several substations have been determined from estimations made on the amount of power which can be sold in the several towns. There will be eight substations ranging in capacity from 150 K.W. to 5000 K.W. It is proposed to construct a special line six miles in length to a mine which will require 3000 K.W. This line will be of similar construction to the main line, and will be operated at 66000 volts, for it is believed that this line will ultimately be extended. Two short lines from Boise will be operated at 66000 volts for this same reason. The substations on these lines are small, and the income from them will not justify a steel tower construction with duplicate lines. Wooden poles will be used, and only one line constructed.

TRANSMISSION LINE.

Section 1. Oxbow to Weiser.

The power to be transmitted at present is 7400 K.W., but we shall design the line to carry double this amount to allow for future growth.

Length of section - 65 miles.

Current to be carried at an assumed power factor of 85%.

$$I = \frac{15,000,000}{\sqrt{3} \times 66,000 \times .85}$$

$$= 155 \text{ amperes.}$$

For this section we shall use #1 copper B. & S. equivalent aluminum standard cable.

Area in circular miles = 132,300

Diameter = .42 inch

Area = .1039 square inch

Weight per mile = 642.6 pounds

Resistance per mile to 60 cycle current = .7034 ohms

Elastic limit = 1450 pounds.

Inductance per wire per mile $= (80.5 + 740 \log (\frac{d}{R})) \times 10^{-6}$

d = distance between wires $= (80.5 + 740 \times 2.6) \times 10^{-6}$

= 84 inches = .002 henry.

R = radius of wire

= .21 inch.

Capacity between conductors per mile = $\frac{.0388}{2 \log \frac{d}{R}}$ = .0075 m.f.

A convenient method of calculating the regulation of a three-phase circuit is to consider it as two single phase circuits, having the same size conductors, same voltage and spacing, and each carrying one half of the total power transmitted.

We shall consider this portion of the line as two single phase lines, each transmitting 3750 K.W.

Inductance from Oxbow to Weiser = 65 x 2 x .002

= .26 henry

Reactance wL = 2π x 60 x .26

= 92 ohms.

Capacity between lines from Oxbow to Weiser = 65 x .0075

= .49 microfarad.

WC = $377 \times .49 \times 10^{-6}$

= .000185

Resistance of circuit = 65x2x.703

= 91.5 ohms.

In order to calculate the regulation, we shall divide the line into ten sections.

For each section:

$L = .026$ henry $\quad wL = 9.2$ ohms.

$C = .049$ microfarad $wC = .0000185$

$R = 9.15$ ohms.

Let us assume the drop is 10%

Voltage at Oxbow = 66,000

Voltage at Weiser = 59,400.

At present we shall confine ourselves to the regulation of the line when carrying the present load. (7400 K.W. or 3700 K.W. on each single phase line.)

Current in section 1 = 73 amperes.

Resistance drop in section 1, R.I. = 9.15 x 73 = 668 volts.

Inductive drop in section 1, X.I. = 9.2 x 73 = 672 volts.

Voltage at end of section 1, $E_1 = \sqrt{(59400 + 668)^2 + (672)^2}$.

$= 60072$ volts.

Effect of charging current.

The maximum charging current will be that in section 10 where the voltage is 66,000.

$$I_c = 2\pi f\, CE.$$

$$= .0000185 \times 66,000$$

$$= 1.22.$$

Resultant current $= \sqrt{(73)^2 + (1.22)^2}$

$$= 73.09.$$

The error in neglecting the effect of charging current will be $\frac{.09}{73} \times 100 = .12$ of one per cent.

Hence we will neglect the charging current.

Since we have decided to neglect the charging current, the resistance and reactive drops will be the same in all sections.

$$E_2 = \sqrt{(60073 + 668)^2 + (672)^2}$$

$$= 60743 \text{ volts.}$$

$$E_3 = \sqrt{(60743 + 668)^2 + (672)^2}$$

$$= 61413 \text{ volts.}$$

$$E_4 = \sqrt{(61413 + 668)^2 + (672)^2}$$

$$= 62083 \text{ volts.}$$

$$E_5 = \sqrt{(62083 + 668)^2 + (672)^2}$$

$$= 62753 \text{ volts.}$$

$$E_6 = \sqrt{(62753 + 668)^2 + (672)^2}$$

$$= 63424 \text{ volts.}$$

$$E_7 = \sqrt{(63424 + 668)^2 + (672)^2}$$

$$= 64095 \text{ volts.}$$

$$E_8 = \sqrt{(64095 + 668)^2 + (672)^2}$$

$$= 64765 \text{ volts.}$$

$$E_9 = 65346 \text{ volts.}$$

$$E_{10} = \sqrt{(65346 + 668)^2 + (672)^2}$$

$$= 66107 \text{ volts.}$$

This is within .16 of one per cent, hence the drop assumed is satisfactory.

THE LINE AS A MECHANICAL STRUCTURE.

Weight per foot of cable = .121#

Area of conductor = .104 square inch

Diameter of conductor = .42 inch

Elastic limit of cable = 1450#.

We shall assume that the line is covered with 1/2 inch of ice, and that the wind pressure is 15# per square foot.

S_1 = span in feet = 500

D = sag in feet

W = weight of conductor and ice in pounds per foot

W_2 = resultant of W and wind pressure in pounds per foot

T = maximum allowable tension in conductor = 1450#

K = temperature coefficient of linear expansion per degree Fahrenheit = .0000128

t = temperature in degrees Fahrenheit above minimum (-40°) = 125.

E_1 = stretch modulus of elacticity = 9,000,000.

L_s = length of single span of strung cable at minimum temperature, in feet.

L_u = length of unstressed single span of cable at minimum temperature.

$$L_s = S_1 + \frac{S_1^3}{24} \frac{W_r^2}{T^2}$$

$$L_u = \frac{L_s}{1 + \frac{T}{AE_1}}$$

$$D^3 - \frac{3}{8} S_1 (L_u(1+Kt) - S_1) D = \frac{3 S_1^3 L_u W_r}{64 AE_1}$$

$$D^1 = \frac{DW}{W_r}$$ vertical sag.

Weight of ice per cubic foot = 57#.

$$\text{Weight of 1/2 inch of ice} = \frac{12 \pi \left(\left(\frac{1.42}{2}\right)^2 - \left(\left(\frac{.42}{2}\right)^2\right)\right) \times 57}{1728}$$

= .57# per foot of cable.

Weight of cable and ice = .691# per foot.

$$\text{Wind pressure on ice covered cable} = \frac{1.42 \times 12 \times 15}{144}$$

= 1.78# per foot of cable.

$$\text{Resultant, } W_R = \sqrt{(.691)^2 + (1.78)^2}$$

= 1.91# per foot of cable.

$$L_s = 500 + \frac{(500)^3 \times (1.91)^2}{24 \times (1450)^2}$$

= 509.04 feet.

$$L_u = \frac{509.04}{1 + \frac{1450}{9{,}000{,}000 \times .104}}$$

= 508.25 feet.

$$D^3 - \frac{3 \times 500}{8} (508.25 \times 1.0016 - 500) D = \frac{3 \times (500)^3 \times 508.25 \times 1}{64 \times .104 \times 9000000.}$$

$$D^3 - 1690 D = 6080.$$

$$D = 42.8 \text{ feet.}$$

$$D^1 = \text{vertical sag} = \frac{42.8 \times .691}{1.91}$$

$$= 15\text{-}1/2 \text{ feet.}$$

The lowest portion of the cable must be a sufficient height above the ground to prevent accidental contact. This distance should be 20 or 25 feet. We shall use a tower having the lower cross arm 40 feet from the ground. The minimum clearance will then be 24-1/2 feet.

Forces acting on the Towers.

The main line from Oxbow to Boise will be built in duplicate. Two three-phase lines arranged in delta, one on each side of the tower will be strung.

Weight of conductors and ice = 6 x 500 x .691

= 2075#

Force due to wind on conductors = 6 x 500 x 1.78

= 5350#.

Surface of tower exposed to wind will be about 30 square feet.

Wind pressure on tower = 30 x 15.

= 450#.

This acts at the center of gravity of the tower, but let us assume that 300# acts along the line of the wind pressure on the conductors. Wind pressure acts through the center of gravity of the delta, about two feet above the lower conductors, or 42 feet from the ground.

Total force due to wind = 5350# + 300#

= 5650#.

The towers must support a weight of 2075# and a force of 5650# acting 42 feet from the ground.

SUMMARY.

Length of line - 65 miles.

Transmitted power - 7500 K.W.

Conductors - #1 Equivalent Aluminum Stranded Cable.

Length of span - 500 feet.

Spacing - 7 feet.

Maximum sag - 15-1/2 feet.

$$\text{Approximate number of towers} = \frac{5280 \times 65}{500}$$

$$= 690$$

Approximate number insulators = 690 x 6.

= 4140.

TRANSMISSION LINE.

Section 2, Weiser to Horseshoe Bend.

On this line are located four substations, ranging in capacity from 150 K. W. to 600 K. W. We shall consider this section as carrying 6800 K. W., since the substations are small, and the difference between the currents in the several sections, will be slight.

Length of line - 65 miles.

The power to be transmitted is 6800 K. W.

$$I = \frac{6800000}{\sqrt{3} \times 59400 \times .85} = 78 \text{ amperes.}$$

59400 = voltage at Weiser.

To allow for a growth of load, we shall use #1 copper B. & S. equivalent aluminum standard cable.

Line constants are the same as for section 1.

Let us assume a drop of 10%.

Voltage at Horseshoe Bend = 59400 volts. x .9 = 53460

The method of calculation followed was that used in calculating section 1.

A ten per cent drop is satisfactory.

We shall use the same span and towers as used on section 1.

SUMMARY.

Length of line - 65 miles.

Transmitted power - 6800 K. W.

Conductors - #1 Equivalent Aluminum Standard Cable.

Length of span - 500 feet.

Spacing - 7 feet.

Maximum sag - 15-1/2 feet.

Weight to be supported by towers 2075#.

Force acting due to wind = 5650#.

Arm of above force = 42 feet.

Approximate number of towers = $\frac{5280 \times 65}{500}$

=690.

Approximate number of insulators = 690 x 6.

= 4140.

TRANSMISSION LINE.

Section 3. Horseshoe Bend to Boise.

The section of the transmission line from Horseshoe Bend to Boise is 26 miles long. There are no substations between Horseshoe Bend and Boise. The power to be transmitted at present is 5450 K. W.

We have found that at full load, the voltage will have fallen to 53460 at Horseshoe Bend. We shall assume 60,000 volts at Boise, then calculate the voltage at Horseshoe Bend. Regulators will be installed at Horseshoe Bend to raise the line voltage to that required.

The Horseshoe Bend plant at present is of 1500 K. W. capacity. This plant will be operated in parallel with the Oxbow Bend station.

line current, $I = \frac{5450000}{\sqrt{3} \times 60000 \times .85}$

$= 61$ amperes.

We shall use #2 equivalent aluminum cable, which will allow for an increase in load of about 75%.

Line Constants.

Inductance per wire per mile = .00197 henry.

Capacity between conductors per mile = .0073 microfarad.

Resistance per mile per wire = .8873 ohm.

Area of cable = .0824 square inch.

Diameter of cable = .37 inch

Elastic limit = 1155#

Weight per foot of cable = .0965#

The result of the calculation of the voltage required at Horseshoe Bend was 62700 volts. Hence the regulator at Horseshoe Bend must raise the voltage from 53460 volts to 62700 volts.

This section of the line is to be run in duplicate, as were sections 1 and 2. We shall use a span of 500 feet.

The results of the calculations are shown below in the summary.

SUMMARY.

Length of line - 26 miles.

Transmitted power - 5450 K. W.

Conductors - #2 equivalent Aluminum Standard Cable.

Length of span - 500 feet.

Maximum sag - 13 feet.

Weight to be supported by towers - 1910#.

Force acting due to wind - 5450#.

Arm of above force - 42 feet.

Approximate number of towers $= \frac{5280 \times 26}{500}$

$= 275.$

Approximate number of insulators = 275 x 6 = 1650.

TRANSMISSION LINE.

Section 4, Boise to Meridian.

A ten mile branch line is to be constructed from Boise to Meridian. At present the power to be transmitted is only 300 K. W. The line current at 60000 volts is so small that the size of conductors used depends on the mechanical strength required.

We shall use #4 B & S. hard drawn copper wire.

Breaking stress - 133#.

Diameter - .204 inches.

Weight per foot - .126#.

Resistance per 1000 feet - .3172 ohms.

Inductance per wire per mile - .0024 henry.

Capacity between conductors per mile - .00665 microfarads.

The result of the calculation of the voltage at Meridian at full load is 59894 volts.

Line Construction.

On this part of the line we shall only run one three-phase line, one conductor on top of the poles, other two on cross arms. The results of the calculations are given below in the summary.

SUMMARY.

Length of line - 10 miles.

Transmitted power - 300 K. W.

Conductors - #4 copper B. & S. hard drawn wire.

Length of span - 75 feet.

Spacing - 7 feet.

Maximum sag - 1.29 feet.

Weight to be supported by poles - 125#.

Force acting due to wind - 488#.

Arm of above force - 25'.

The size of pole required will be a 26 foot white pine pole at least 2 feet in diameter at the butt.

$$\text{Approximate number of poles} = \frac{5280 \times 10}{75}$$

$$= 700.$$

$$\text{Approximate number of insulators} = 700 \times 3.$$

$$= 2100.$$

TRANSMISSION LINE.

Section 5. Boise to Neal.

The distance from Boise to Neal is twenty-one miles. The size of conductors are determined by the mechanical strength required as on section 4. The power to be transmitted is 150 K. W.

We shall use #4 copper B. & S. hard drawn wire. The line constants are the same as for section 4. Line construction is the same as for section 4.

SUMMARY.

Length of line - 21 miles.

Transmitted power - 150 K. W.

Conductors #4 Copper B. & S. hard drawn wire.

Length of span - 75 feet.

Spacing - 7 feet.

Maximum sag - 1.29 feet.

Weight to be supported by poles - 125#.

Force acting due to wind - 488#.

Arm of above force - 25 feet.

The poles to be used are as on section 4.

Approximate number of poles $= \frac{5280 \times 21}{75}$

$= 1470.$

Approximate number of insulators = 1470 x 3.

= 5410.

TRANSMISSION LINE.

Section 6. Branch from Oxbow to Mine.

This line is to transmit 3000 K. W. a distance of six miles. We have decided to run two 66000 volt lines as on the main line. The intention is to ultimately extend this line hence we are using a high voltage line and steel tower construction.

$$\text{Line current } I = \frac{3000{,}000}{\sqrt{3} \times 66000 \times .85}$$

$$= 31 \text{ amperes.}$$

We shall use #2 equivalent aluminum cables.

The line constants are as for section 3.

The line construction is the same as on section 3.

The voltage at the mine a t full load will be 65400.

SUMMARY.

Length of line - 6 miles.

Transmitted power - 3000 K. W.

Conductor - #2 equivalent aluminum cable.

Length of span - 500 feet.

Spacing - 7 feet.

Maximum sag - 18 feet.

Towers - 40 feet to lowest insulator.

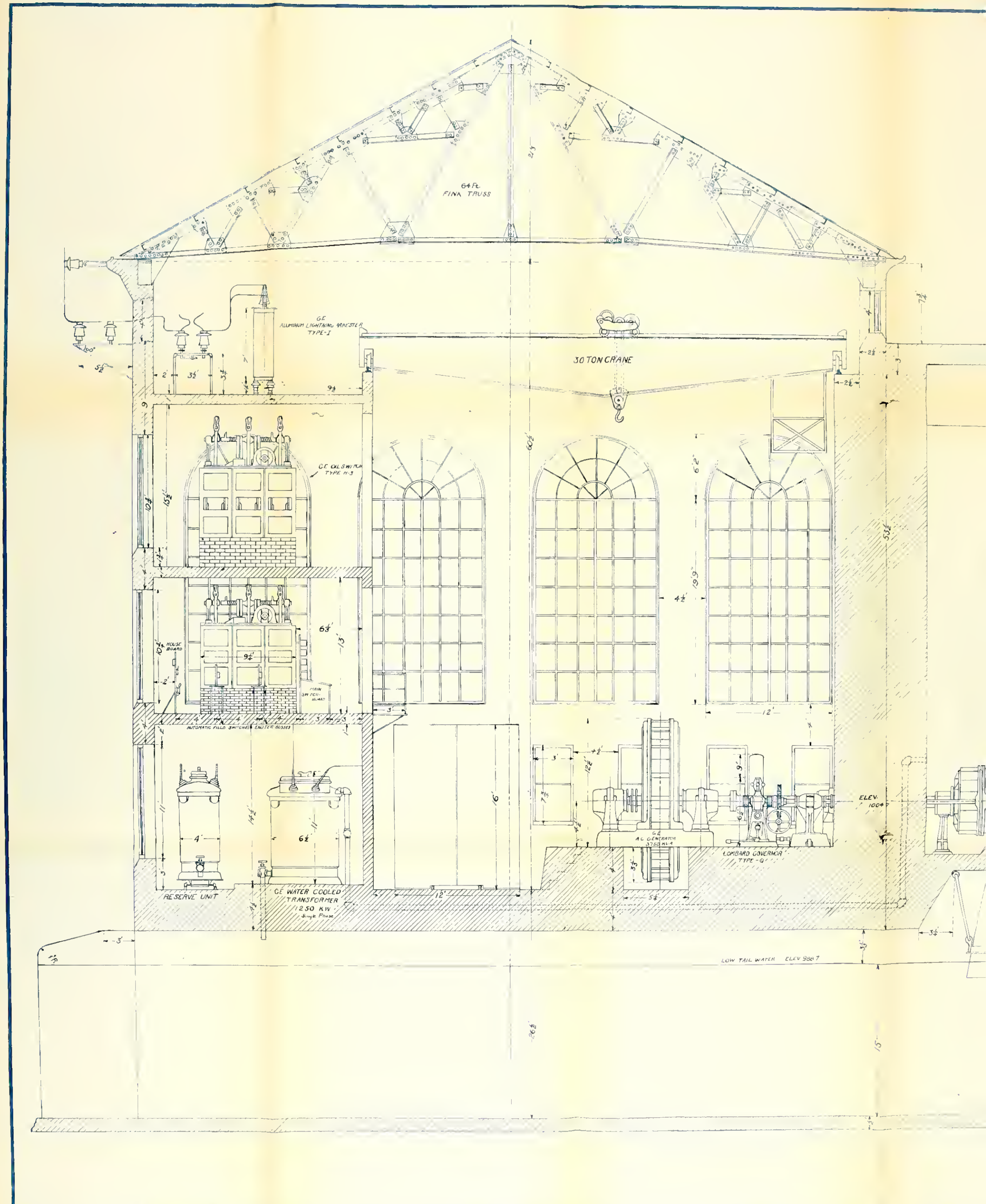
Weight to be supported by towers - 1910#.

Force acting due to wind - 5450#.

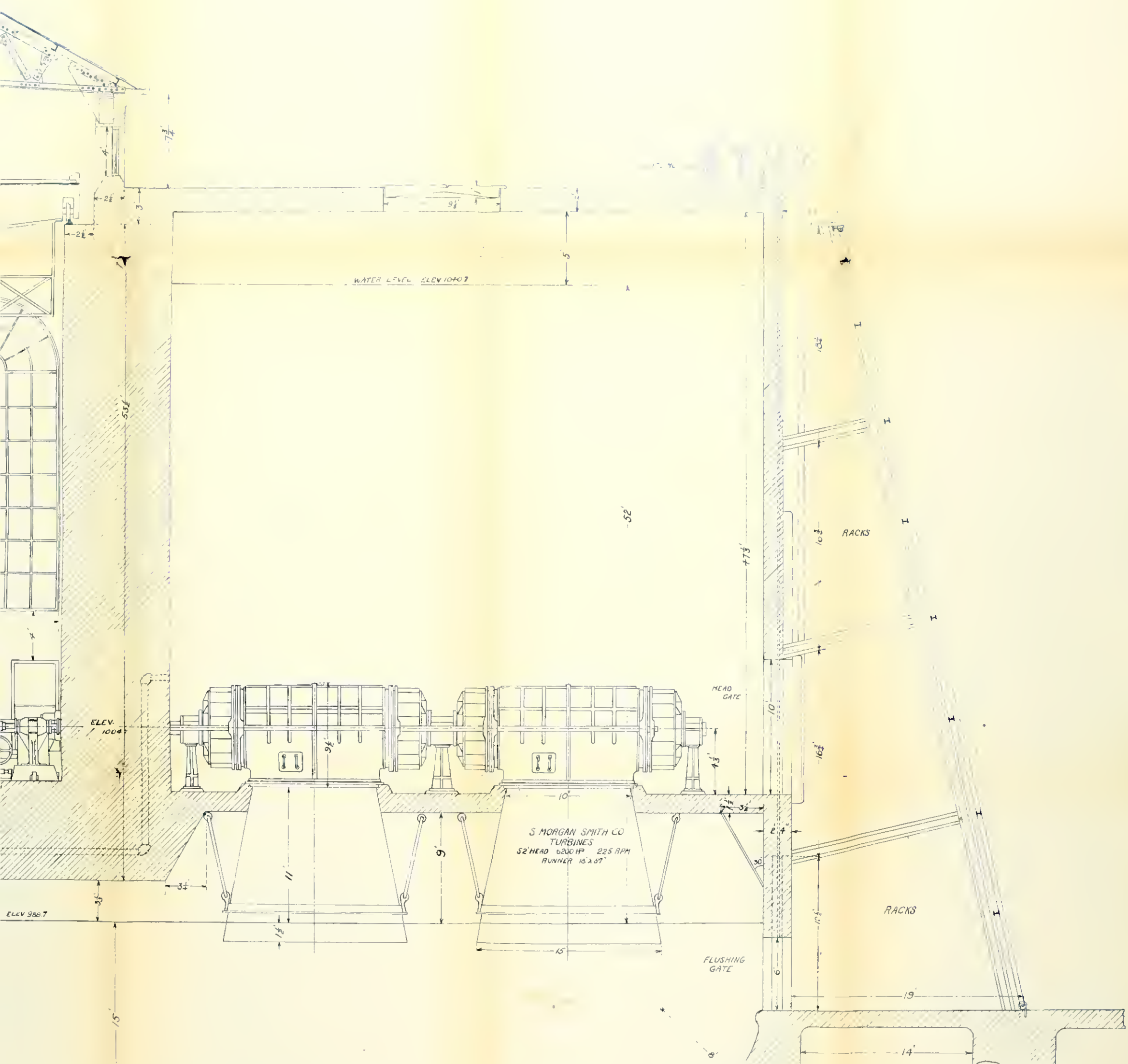
Arm of above force - 42 feet.

Approximate number of towers $= \frac{5280 \times 6}{500} = 65$

Approximate number of insulators = 65 x 6 = 390.



64 Ft. FINK TRUSS
G.E. ALUMINUM LIGHTNING ARRESTER TYPE-I
30 TON CRANE
G.E. OIL SWITCH TYPE H-3
HOUSE BOARD
MAIN SWITCH-BOARD
AUTOMATIC FIELD SWITCHES EXCITER BUSSES
RESERVE UNIT
G.E. WATER COOLED TRANSFORMER 1250 KW. Single Phase
G.E. A.C. GENERATOR
LOMBARD GOVERNOR TYPE-Q
ELEV. 1004
LOW TAIL WATER ELEV 988.7



ELEVATION

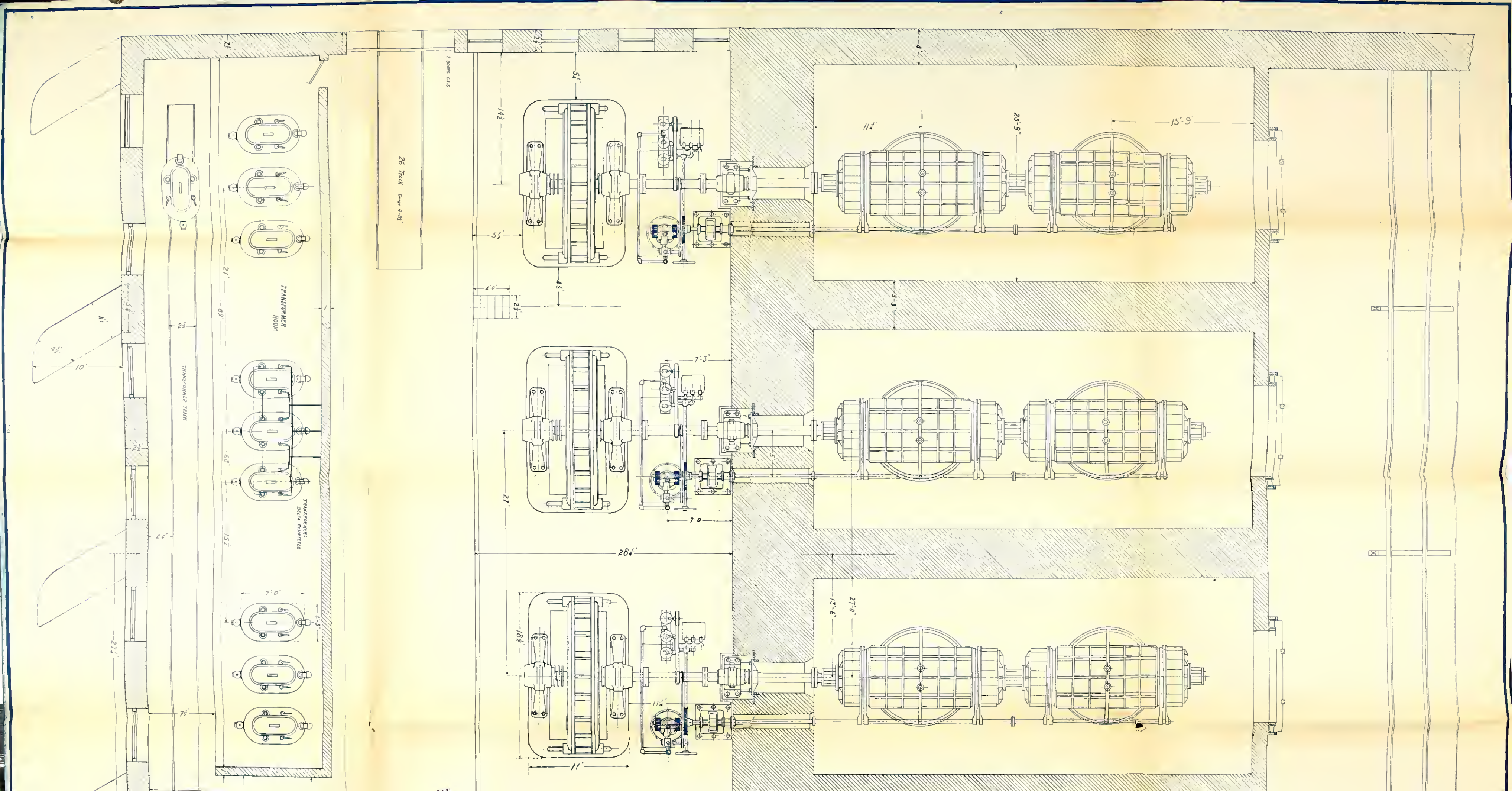
OF

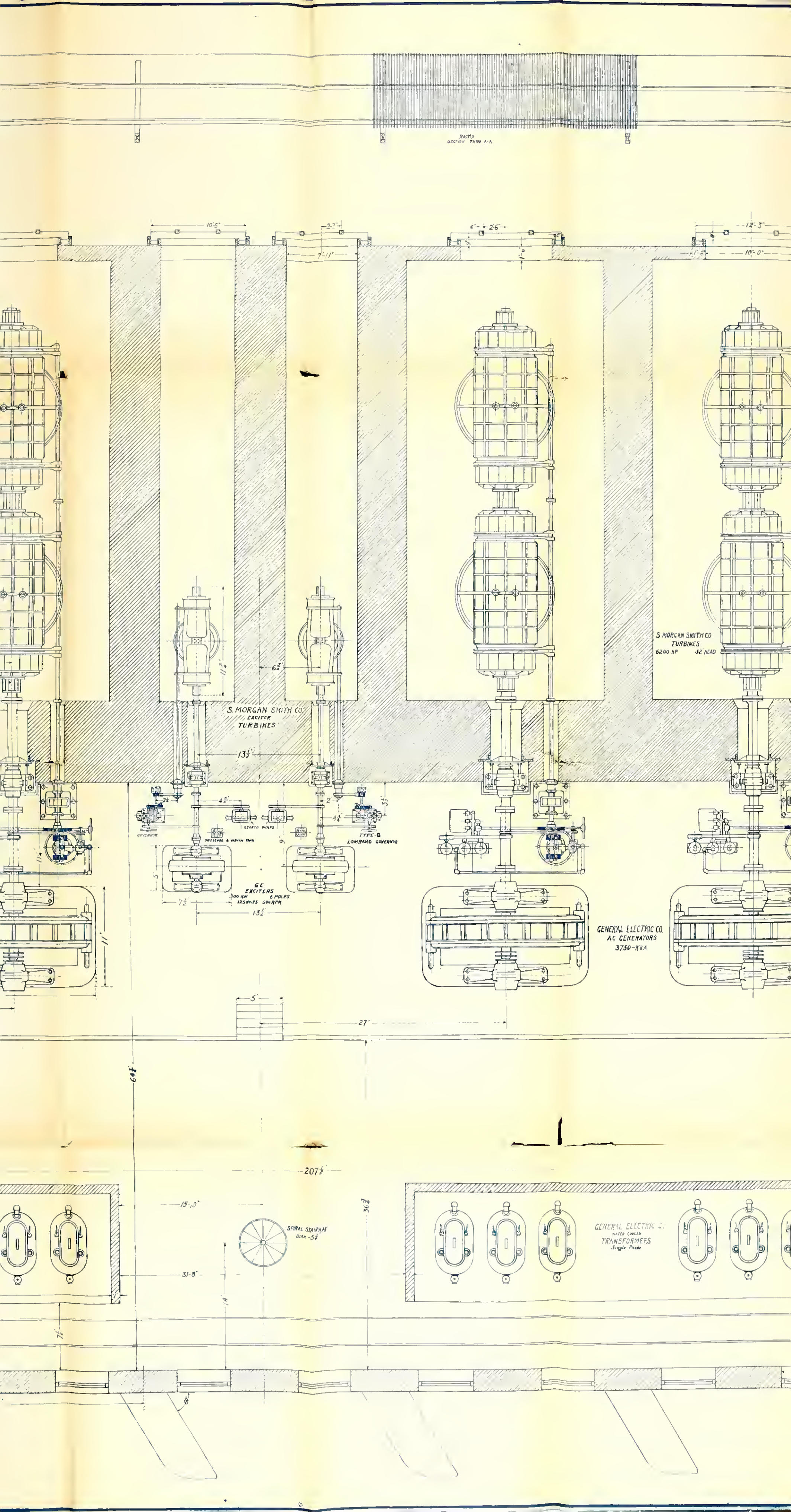
PROPOSED POWER PLANT

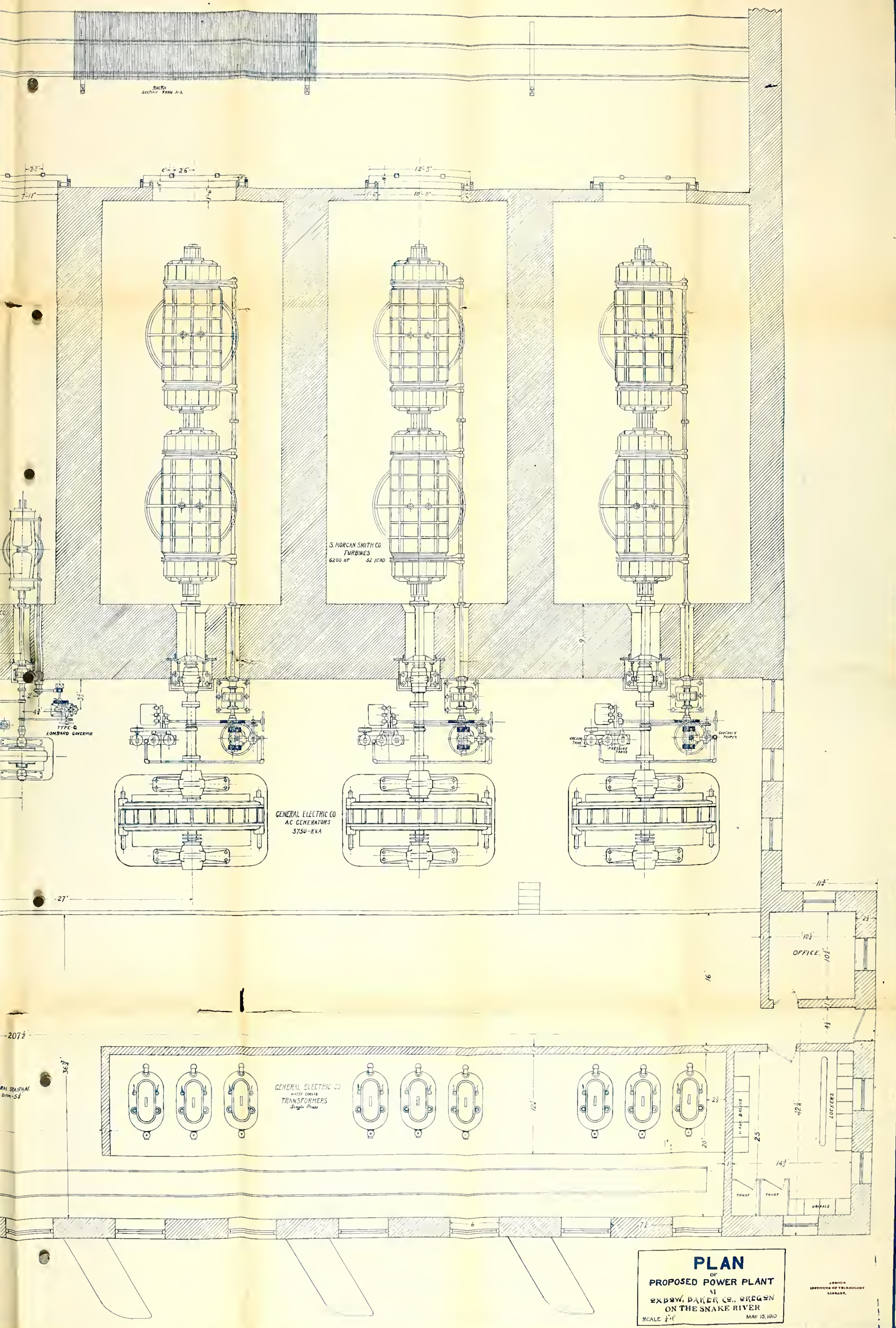
AT

OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER

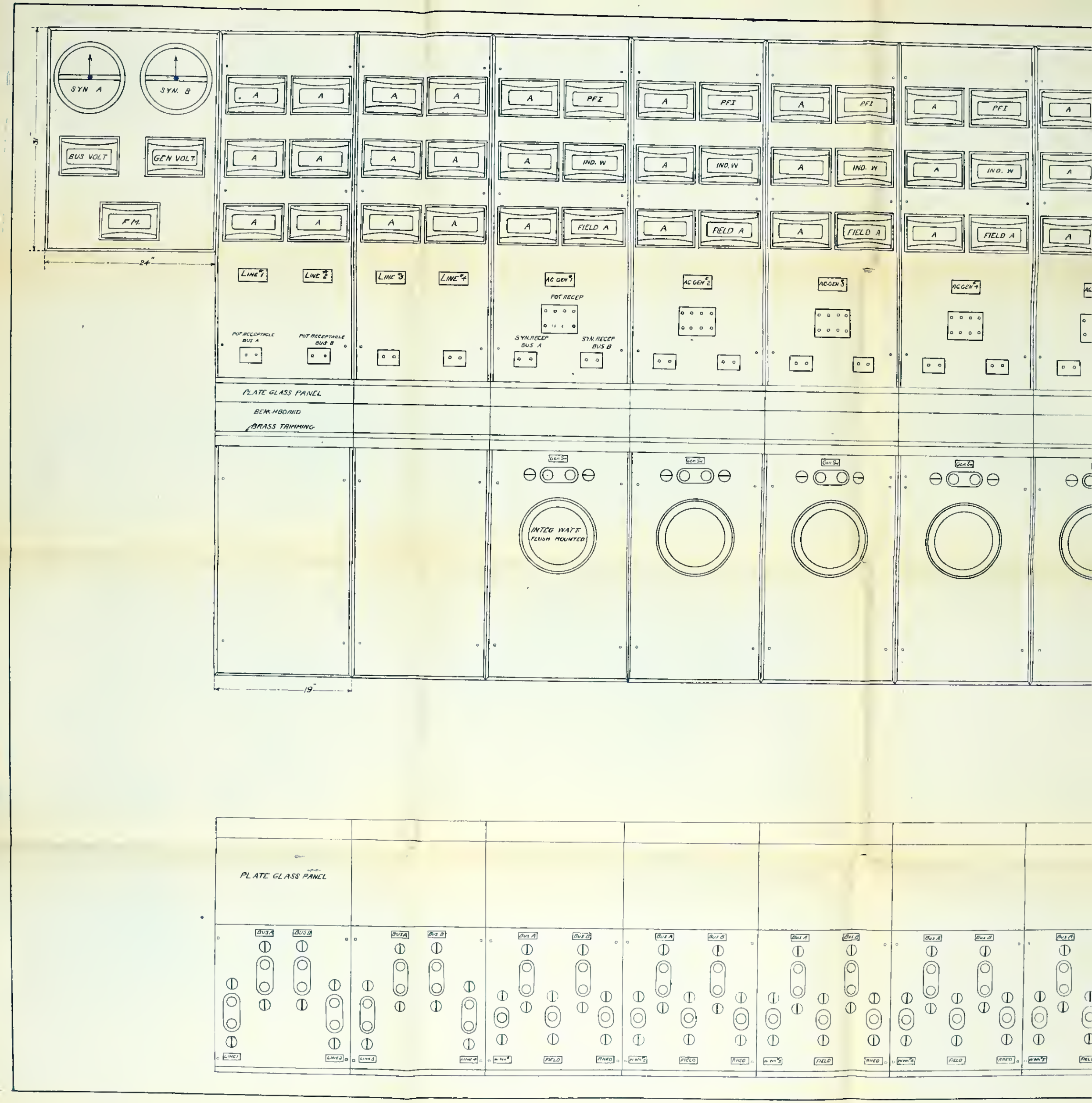
SCALE $\frac{1}{4}$"=1' MAY 15 1910

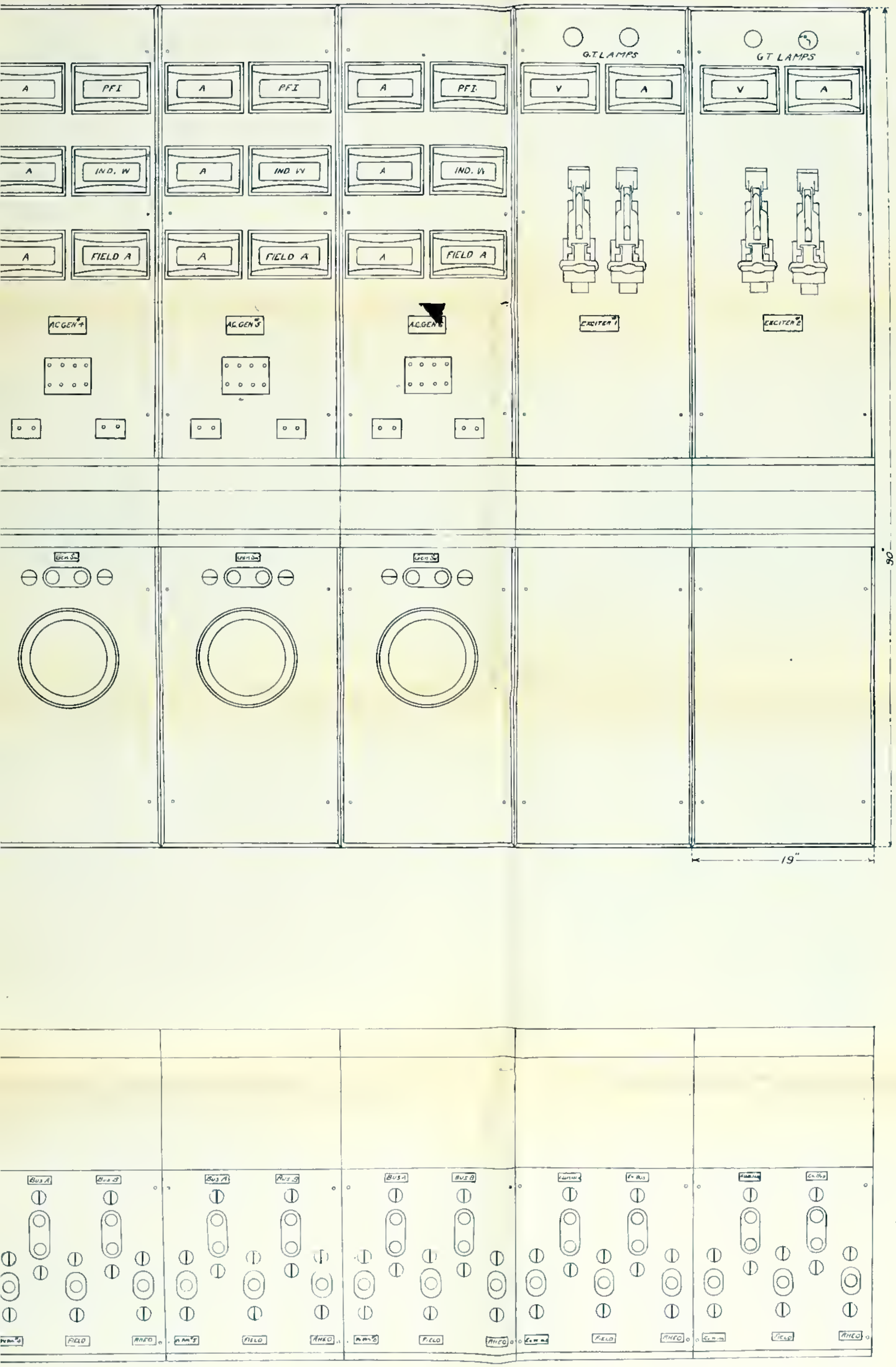

TRANSFORMER ROOM
TRANSFORMER TRACK
TRANSFORMERS DELTA CONNECTED
26 Track
15'-9"
23'-9"
28¼'
27'-0"
13'-6"
7'-0"
7'-3"
11'

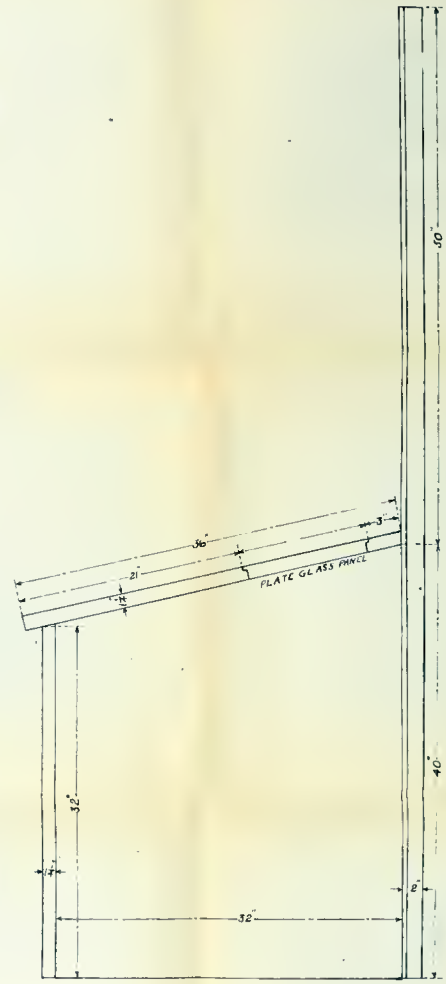

RACKS
SECTION THRU A-A
S. MORGAN SMITH CO.
EXCITER
TURBINES
S. MORGAN SMITH CO
TURBINES
6200 HP
52' HEAD
GOVERNOR
GEARED PUMPS
TYPE-Q
LOMBARD GOVERNOR
GE
EXCITERS
300 KW
6 POLES
125 VOLTS
500 RPM
GENERAL ELECTRIC CO.
AC GENERATORS
3750-KVA
SPIRAL STAIRWAY
DIAM-5½'
GENERAL ELECTRIC CO.
WATER COOLED
TRANSFORMERS
Single Phase
207½'
64⅛'
27'
36¾'
31'-8"
15'-0"
14'
5'
13½'
6¾'
11'
10'-5"
7'-11"
12'-3"
10'-0"



PLAN
OF
PROPOSED POWER PLANT
AT
OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER
SCALE ⅛"-1' MAY 15, 1910


SYN. A
SYN. B
BUS VOLT
GEN VOLT.
F.M.
31"
24"
19"
LINE #1
LINE #2
LINE #3
LINE #4
POT RECEPTACLE BUS A
POT RECEPTACLE BUS B
AC GEN #1
AC GEN #2
AC GEN #3
AC GEN #4
POT RECEP
SYN. RECEP BUS A
SYN. RECEP BUS B
PFI
IND. W
FIELD A
PLATE GLASS PANEL
BENCHBOARD
BRASS TRIMMING
INTEG WATT FLUSH MOUNTED
PLATE GLASS PANEL
BUS A
BUS B
FIELD
RHEO





SWITCHBOARD

FOR

PROPOSED POWER PLANT

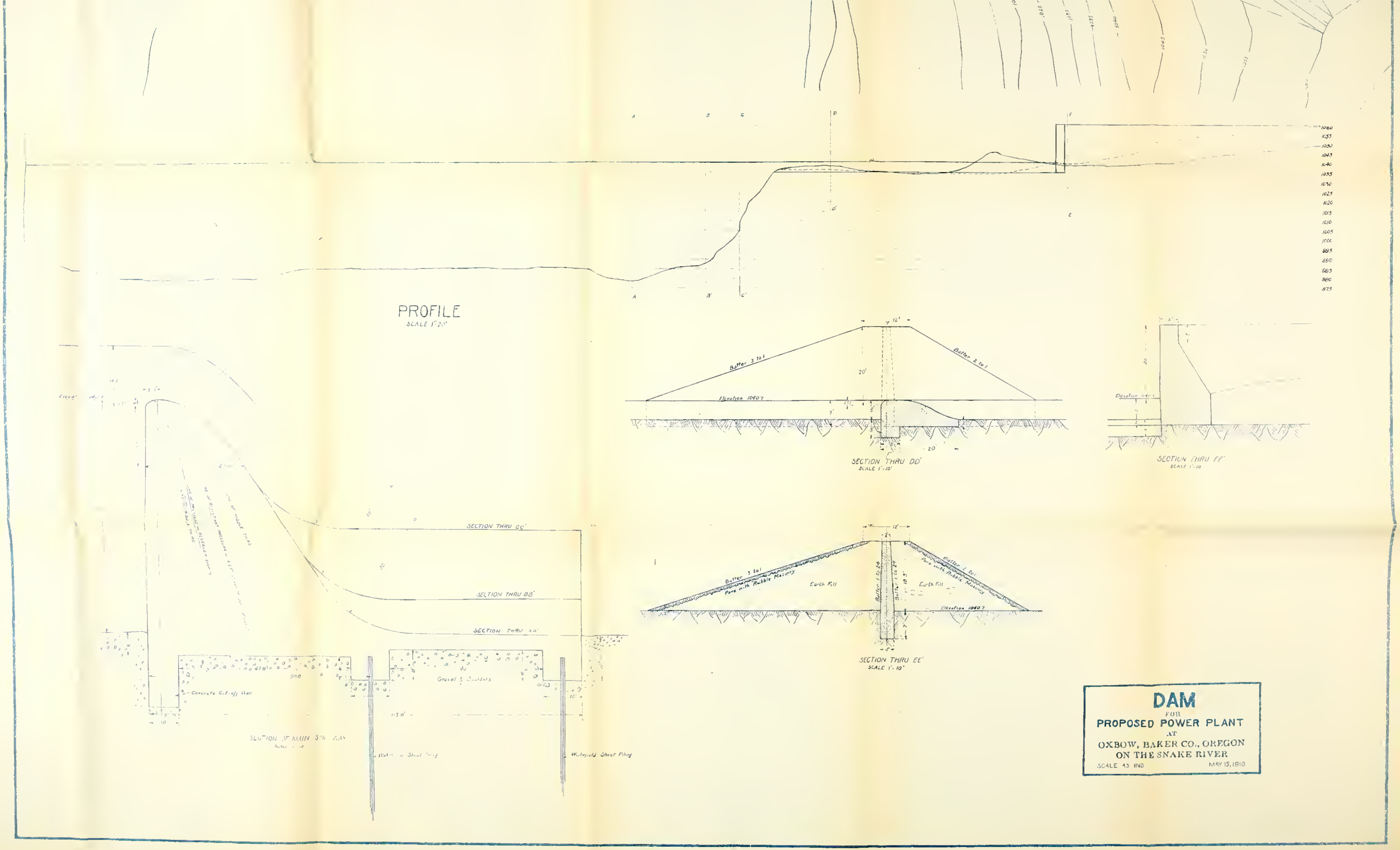
AT

OXBOW, BAKER CO., OREGON

ON THE SNAKE RIVER

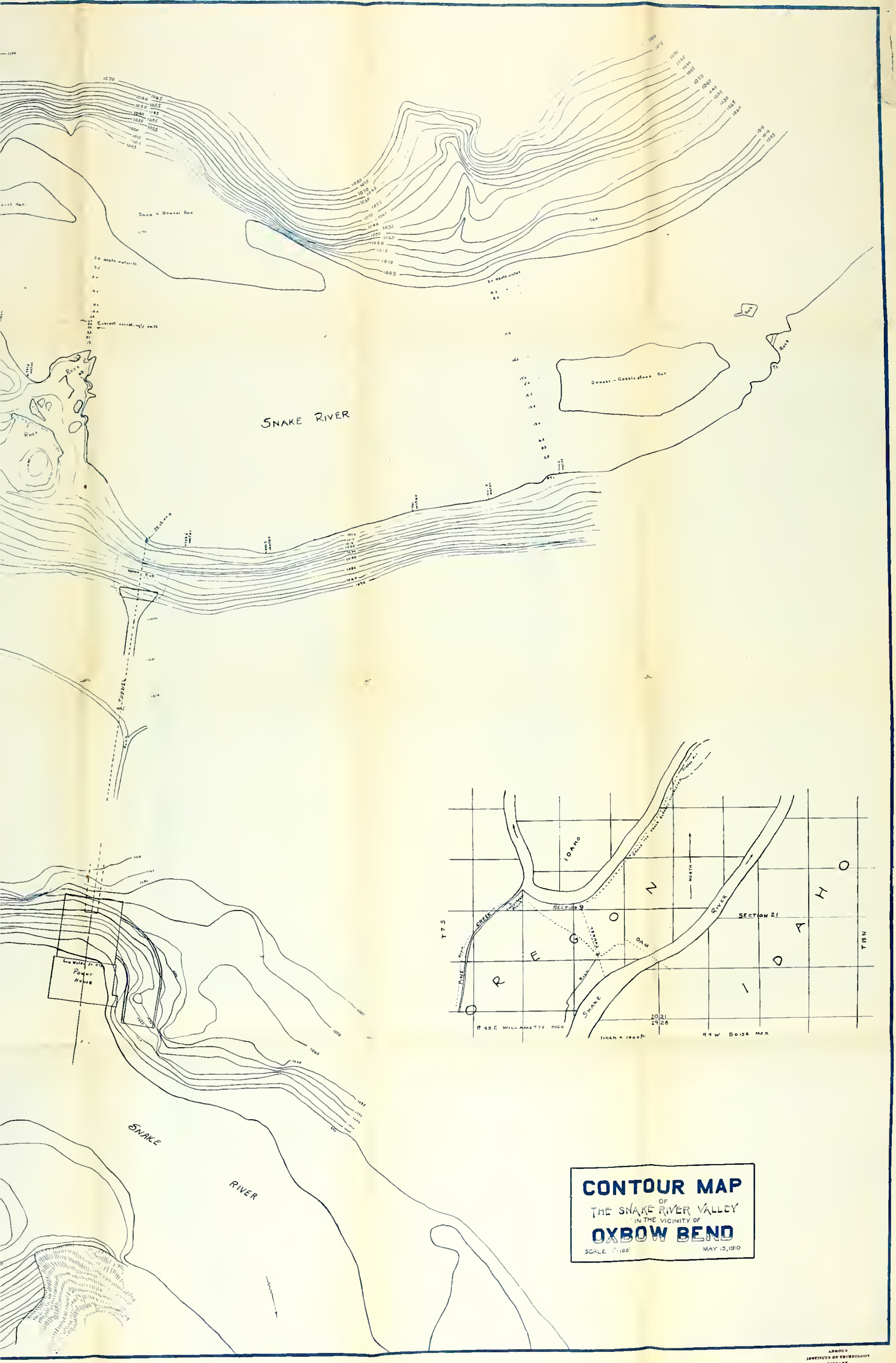
SCALE 2" = 1'　　MAY 13, 1910

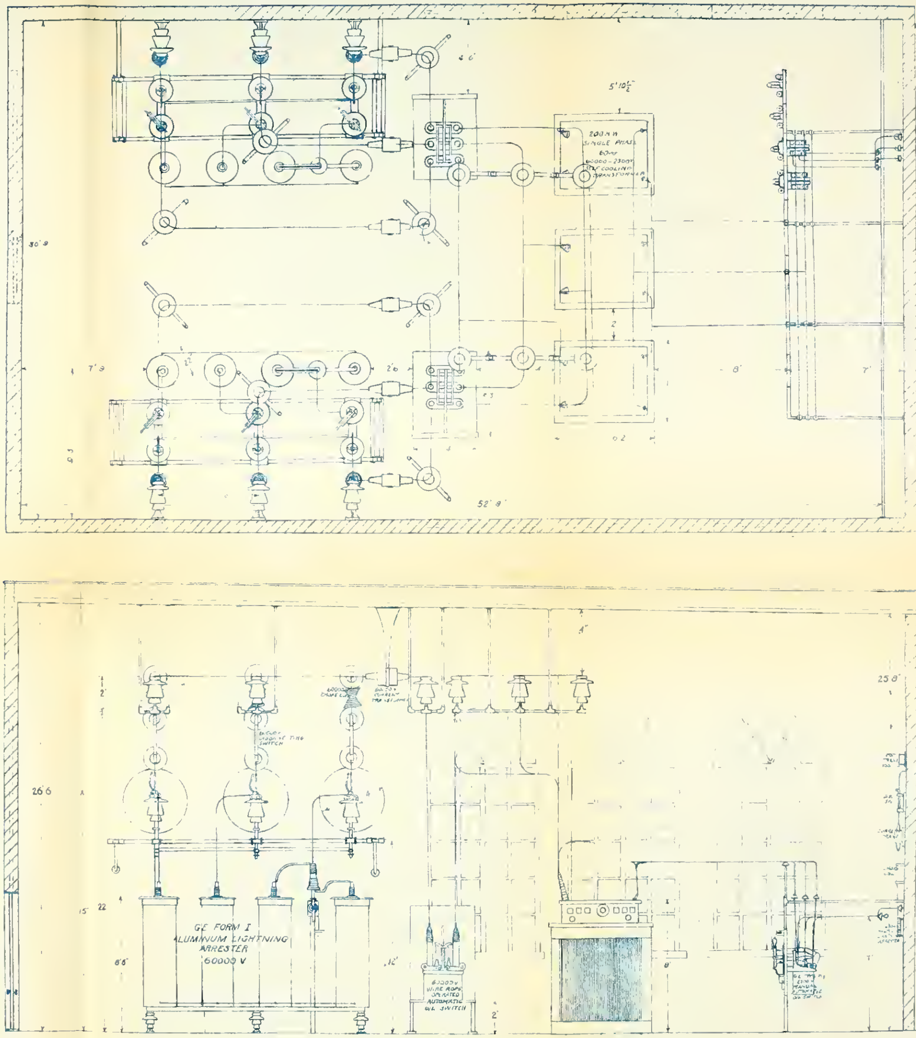

PLAN & TOPOGRAPHY
SCALE 1"-20'



PROFILE
SCALE 1"-20'
SECTION THRU DD'
SCALE 1"-10'
SECTION THRU FF'
Batter 3 to 1
Batter 2 to 1
Elevation 1040.7
SECTION THRU EE'
SCALE 1"-10"
Pave with Rubble Masonry
Earth Fill
SECTION THRU CC'
SECTION THRU BB'
SECTION THRU AA'
Concrete Cut-off Wall
Gravel & Boulders
Wakefield Sheet Piling
DAM
FOR
PROPOSED POWER PLANT
AT
OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER
MAY 15, 1910


IDAHO
SNAKE
RIVER
SNAKE


CONTOUR MAP
OF
THE SNAKE RIVER VALLEY
IN THE VICINITY OF
OXBOW BEND
SCALE 1"-100'
MAY 15, 1910
SNAKE RIVER
SNAKE
RIVER
TUNNEL
Power House
Gravel – Cobblestone Bar
Sand & Gravel Bar
T 7 S
T 19 N
R 46 E WILLAMETTE MER
R 4 W BOISE MER
PINE CREEK
OREGON
IDAHO
SECTION 9
SECTION 21
TUNNEL
DAM
NORTH
RIVER
1 inch = 1000 ft.
20 21
29 28



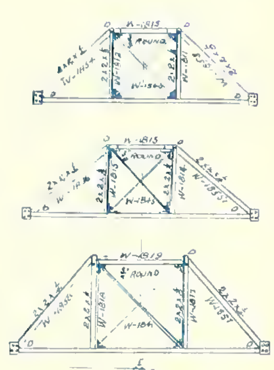
600 K.W. SUBSTATION

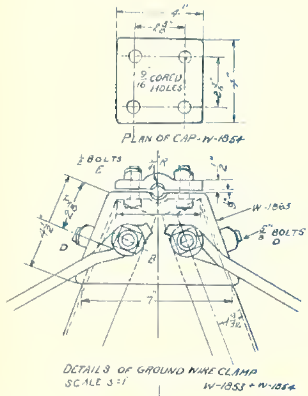
TO BE USED AT

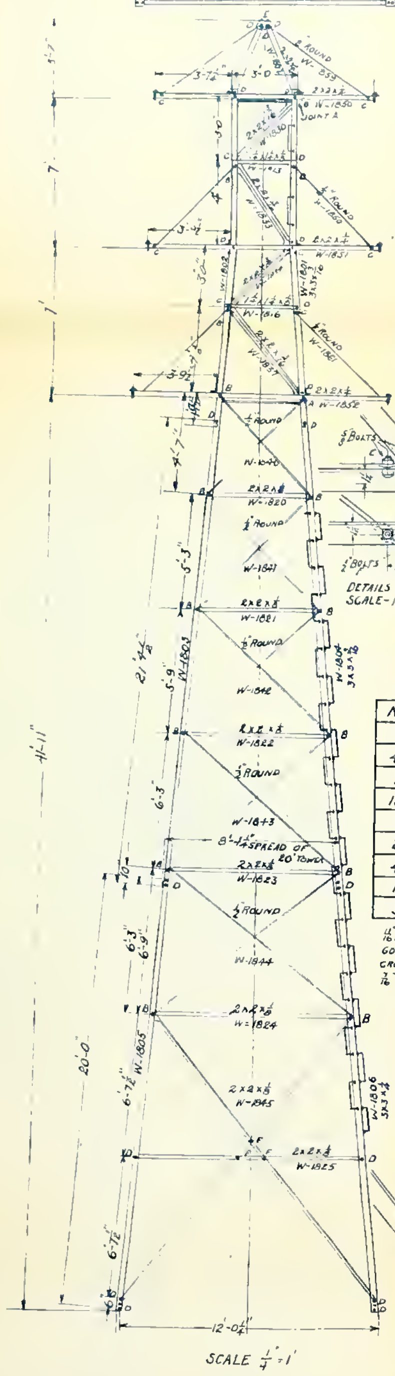
WEISER, IDAHO

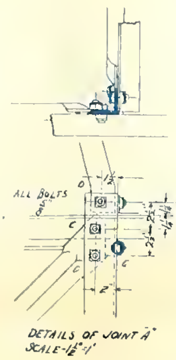
ONTARIO, IDA.

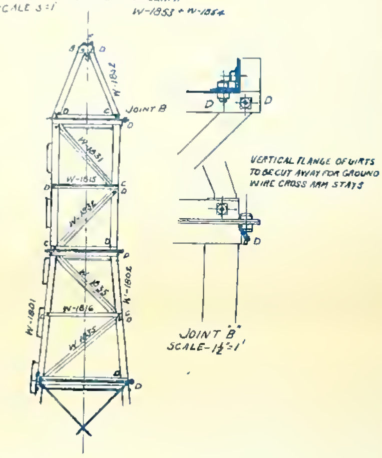
SCALE ¼" = 1'   MAY 15, 1910

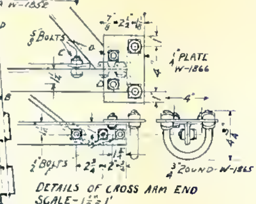










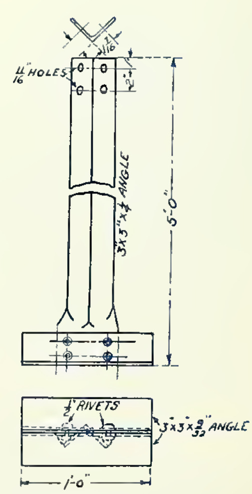


BOLT LIST

NO.	SIZE	LOC
2	$\frac{5}{8}\times 2$	A
48	$\frac{5}{8}\times 1\frac{3}{4}$	B
25	$\frac{5}{8}\times 1\frac{1}{2}$	C
132	$\frac{5}{8}\times 1\frac{1}{4}$	D
4	$\frac{1}{2}\times 1\frac{3}{4}$	E
24	$\frac{1}{2}\times 1$	F
46	$\frac{11}{16}\times 1\frac{1}{2}\times\frac{1}{8}$ WASHERS	
12	$\frac{7}{16}\times 1\frac{1}{8}\times\frac{1}{8}$ WASHERS	
30	LOOP STEPS 12 RIGHTS 18 LEFTS	

$\frac{11}{16}$" WASHERS ARE TO GO ON ALL BOLTS GOING THRU WIRE BRACES EXCEPTING AT CROSS ARM ENDS

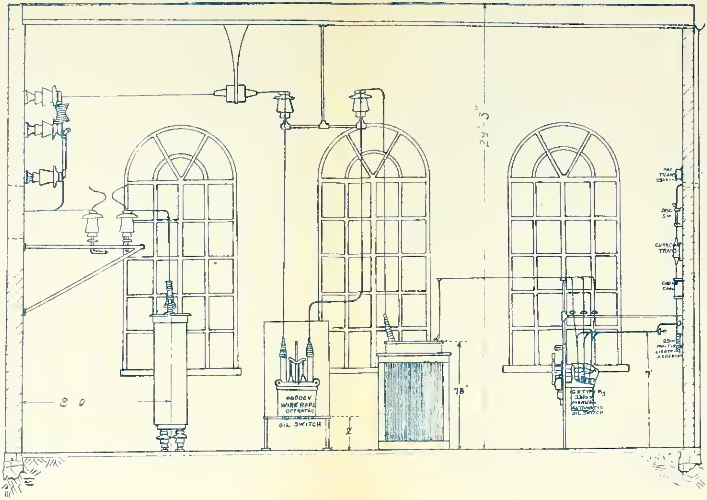
$\frac{7}{16}$" WASHERS ARE TO BE USED ON CROSS BRACES

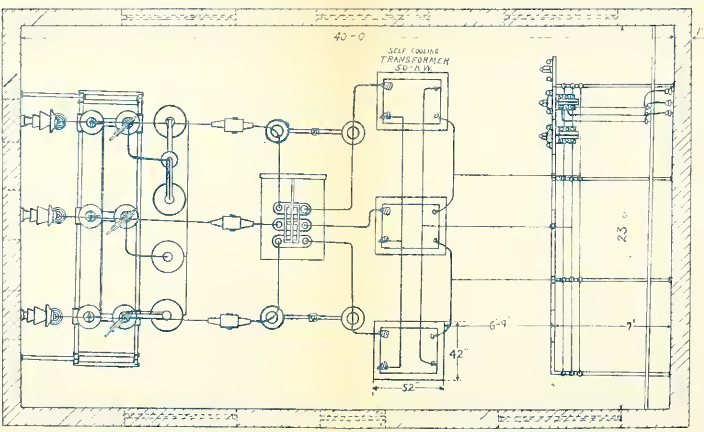


DETAILS OF ANCHOR POST
SCALE 1$\frac{1}{2}$"=1' W=867

TRANSMISSION TOWER
FOR
PROPOSED POWER PLANT
AT
OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER

SCALE AS IND. MAY 15, 1910





150 K.W. SUBSTATION

TO BE USED AT

NEAL, IDA.

SCALE $\frac{1}{4}"=1'$ MAY 15, 1910

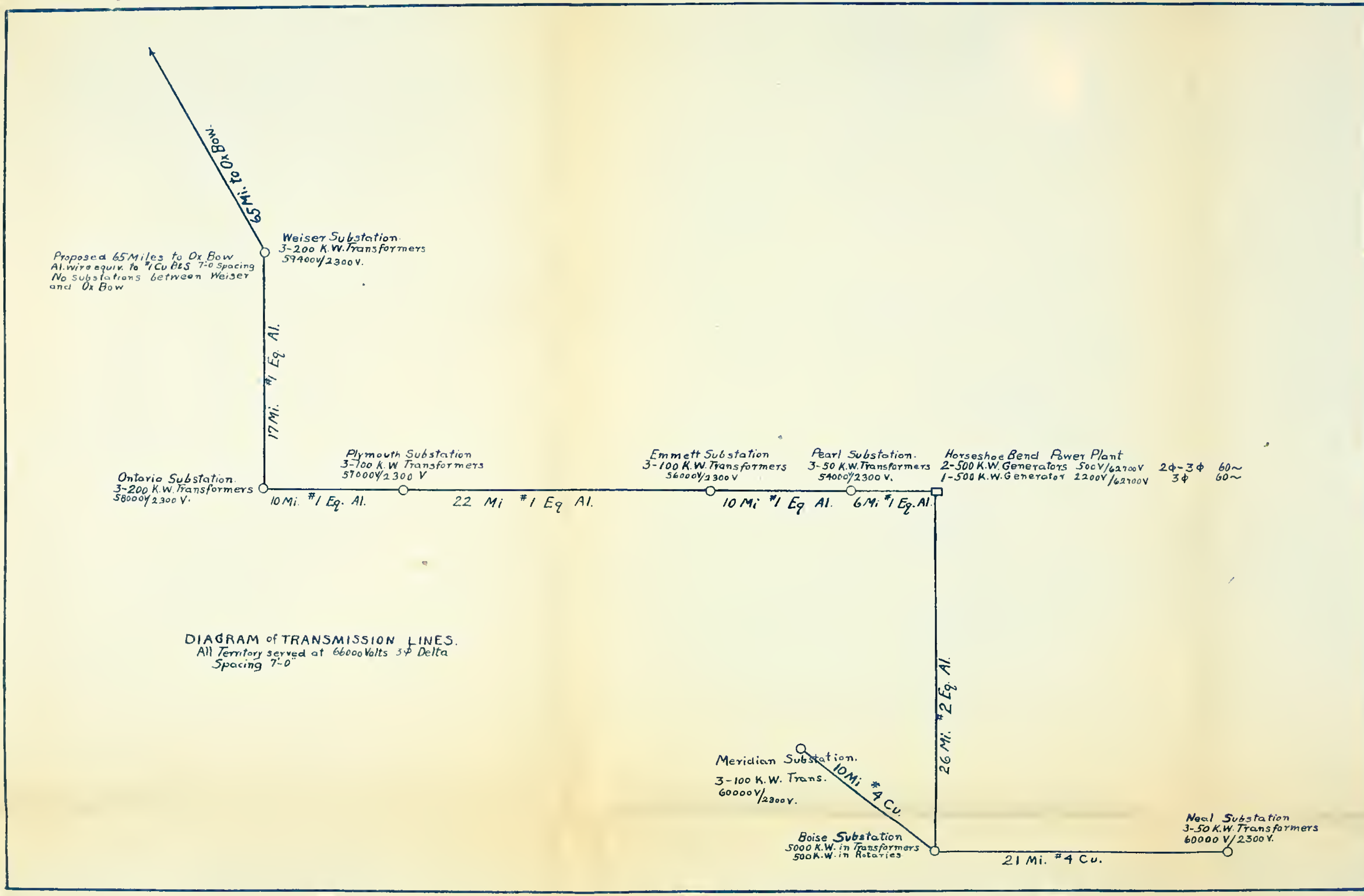
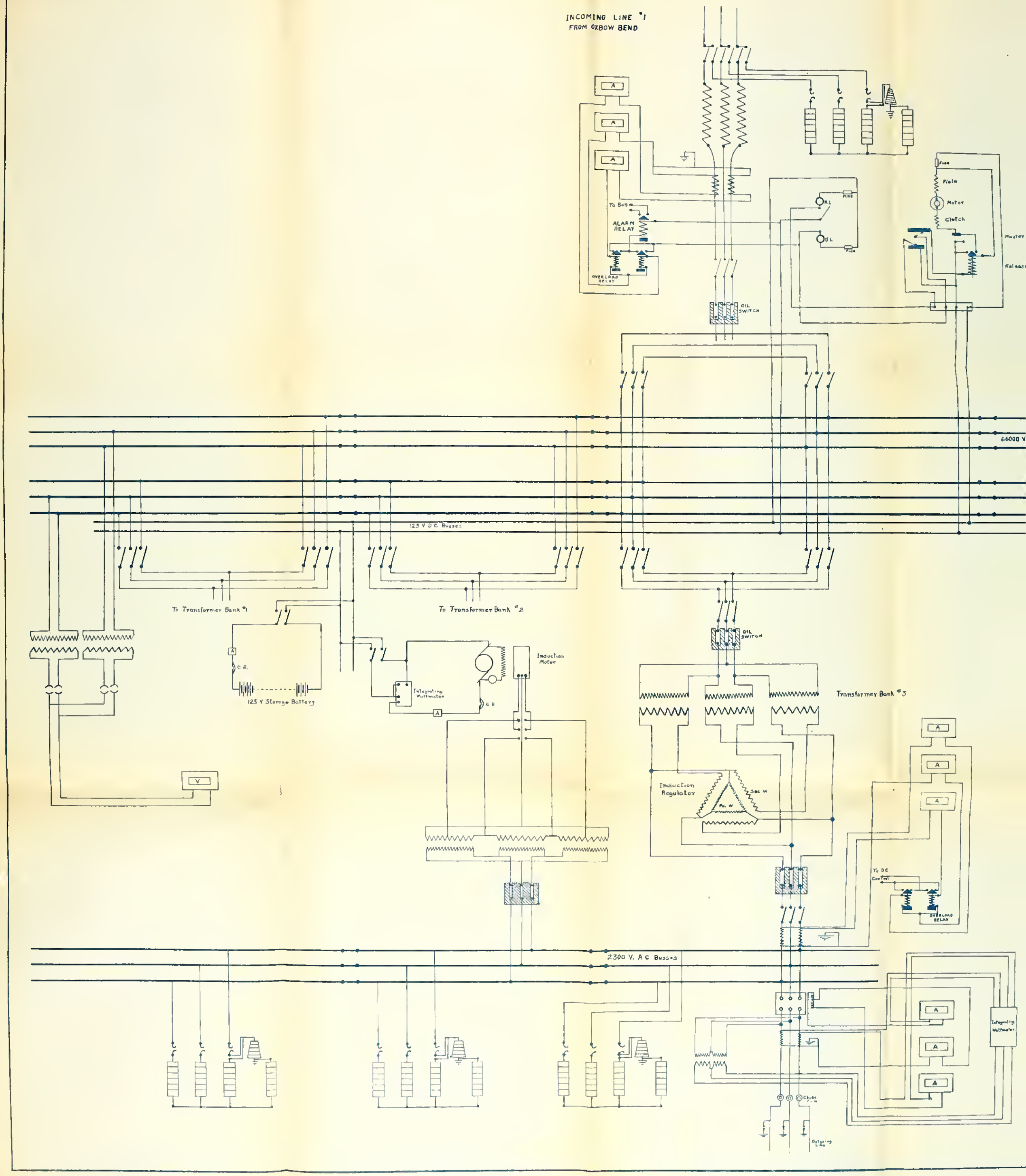
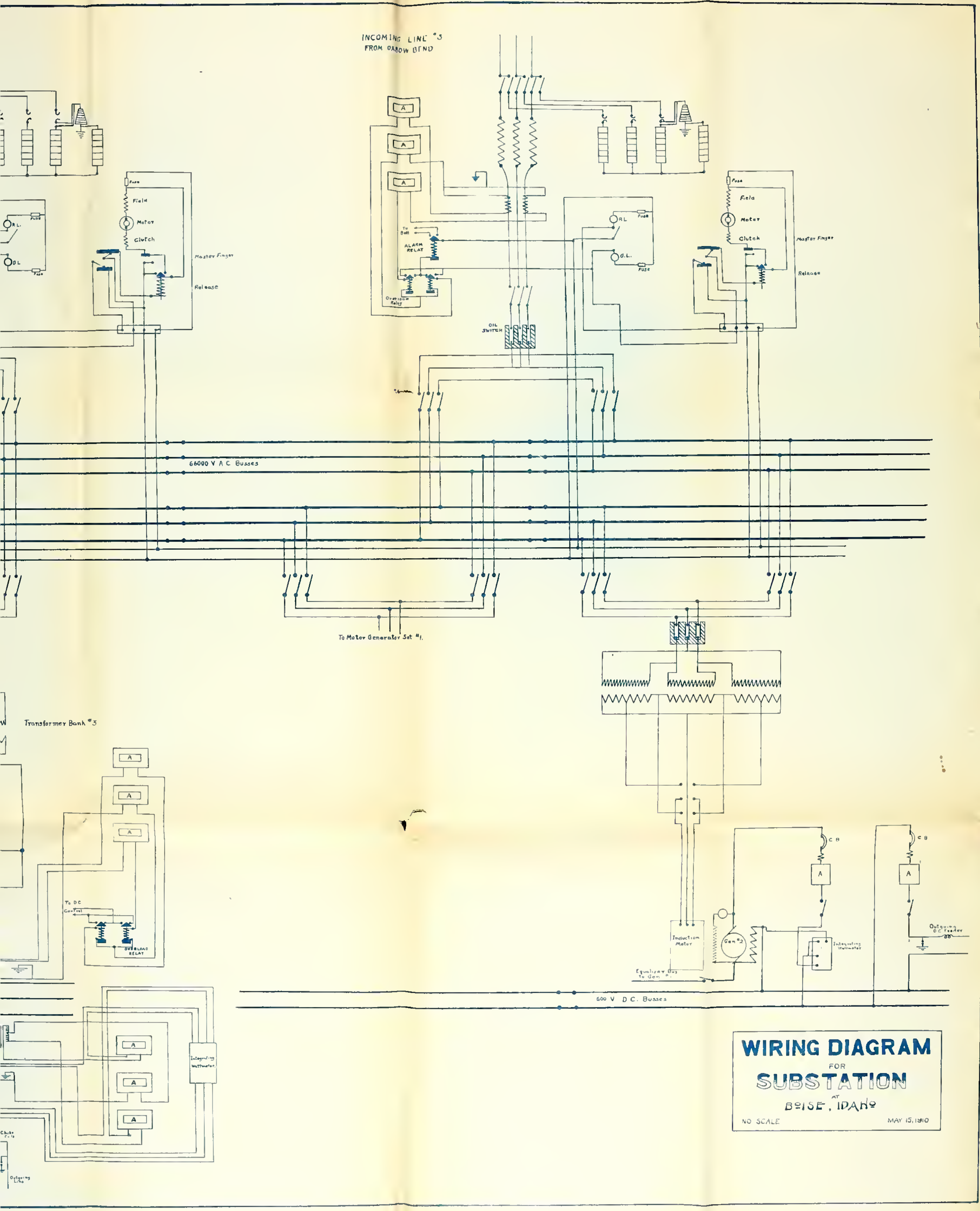


DIAGRAM of TRANSMISSION LINES.
All Territory served at 66000 Volts 3ϕ Delta
Spacing 7'-0"



INCOMING LINE #1
FROM OXBOW BEND
To Bell
ALARM RELAY
OVERLOAD RELAY
OIL SWITCH
Fuse
Field
Motor
Clutch
Master
Release
R.L.
O.L.
66000 V
125 V D.C. Busses
To Transformer Bank #1
To Transformer Bank #2
C.B.
125 V Storage Battery
Integrating Wattmeter
Induction Motor
Transformer Bank #3
Induction Regulator
Sec W
Pri W
To DC Control
2300 V. A C Busses
Integrating Wattmeter
Outgoing Line



WIRING DIAGRAM

FOR

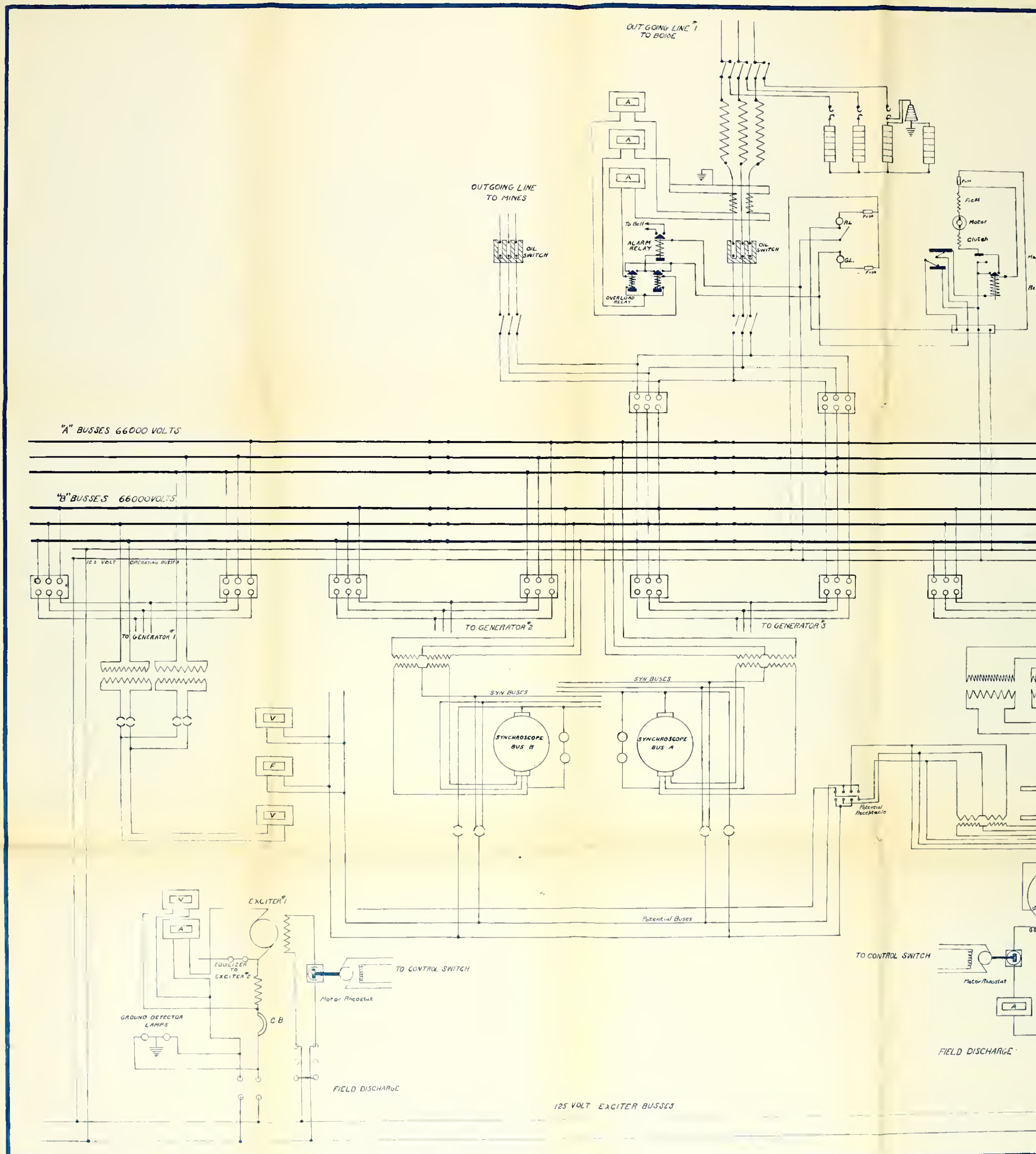
SUBSTATION

AT

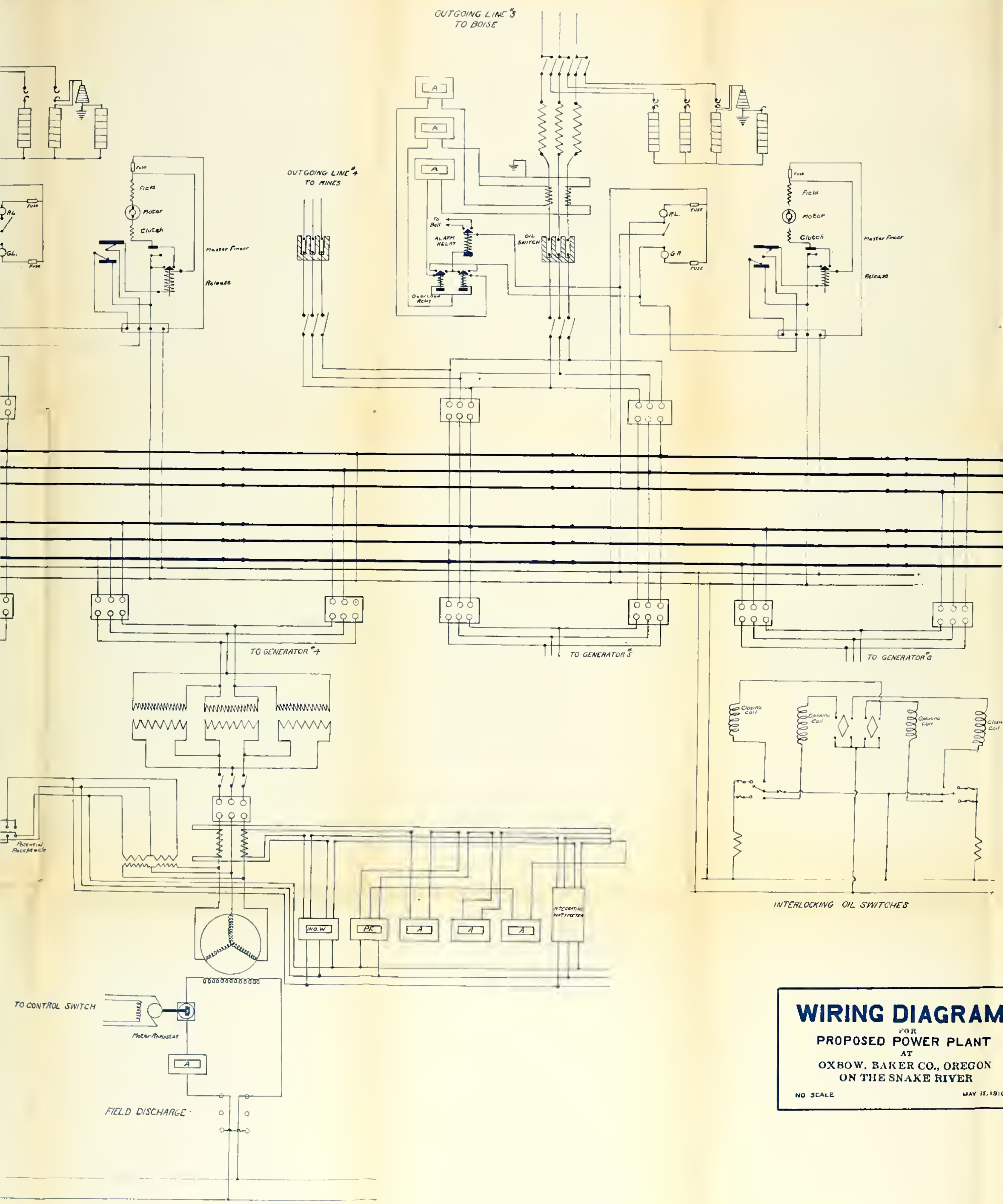
BOISE, IDAHO

NO SCALE

MAY 15, 1910



OUTGOING LINE #1 TO BOISE
OUTGOING LINE TO MINES
OIL SWITCH
ALARM RELAY
OVERLOAD RELAY
To Bell
Fuse
Field
Motor
Clutch
"A" BUSSES 66000 VOLTS
"B" BUSSES 66000 VOLTS
125 VOLT OPERATING BUSSES
TO GENERATOR #1
TO GENERATOR #2
TO GENERATOR #3
SYN BUSES
SYNCHROSCOPE BUS B
SYNCHROSCOPE BUS A
Potential Receptacle
Potential Buses
EXCITER #1
EQUILIZER TO EXCITER #2
CB
GROUND DETECTOR LAMPS
Motor Rheostat
TO CONTROL SWITCH
FIELD DISCHARGE
125 VOLT EXCITER BUSSES



WIRING DIAGRAM

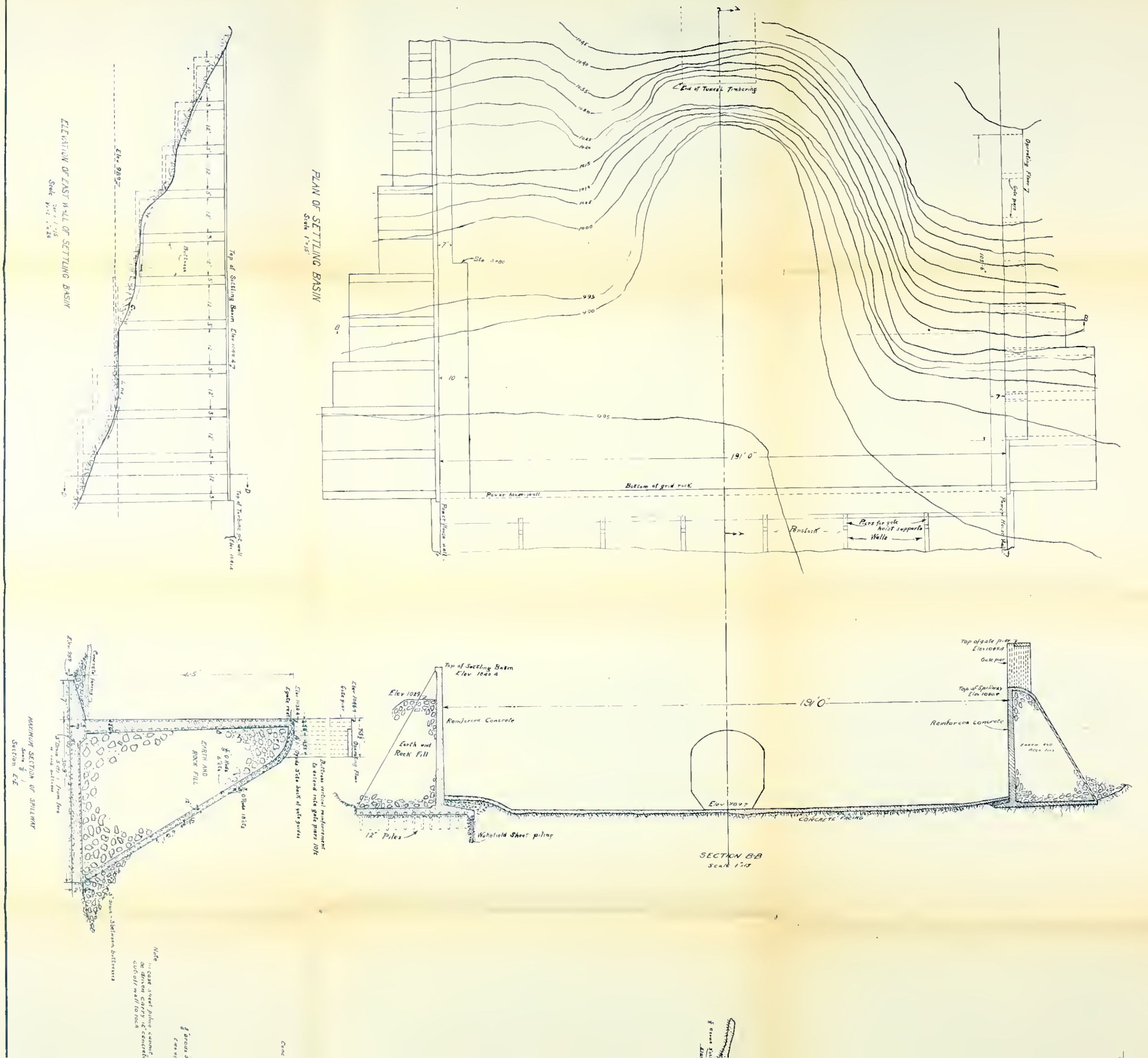
FOR

PROPOSED POWER PLANT

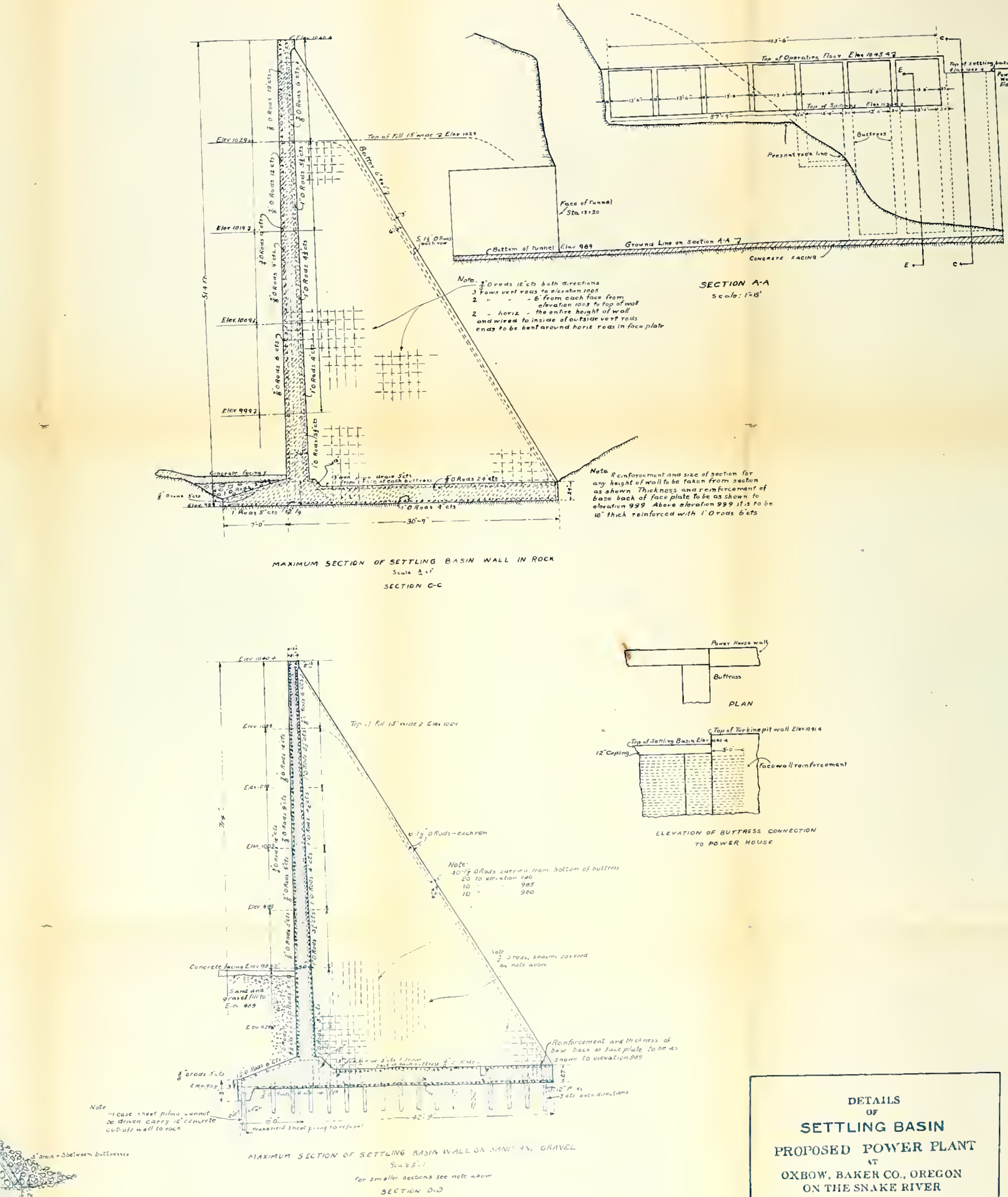
AT

OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER

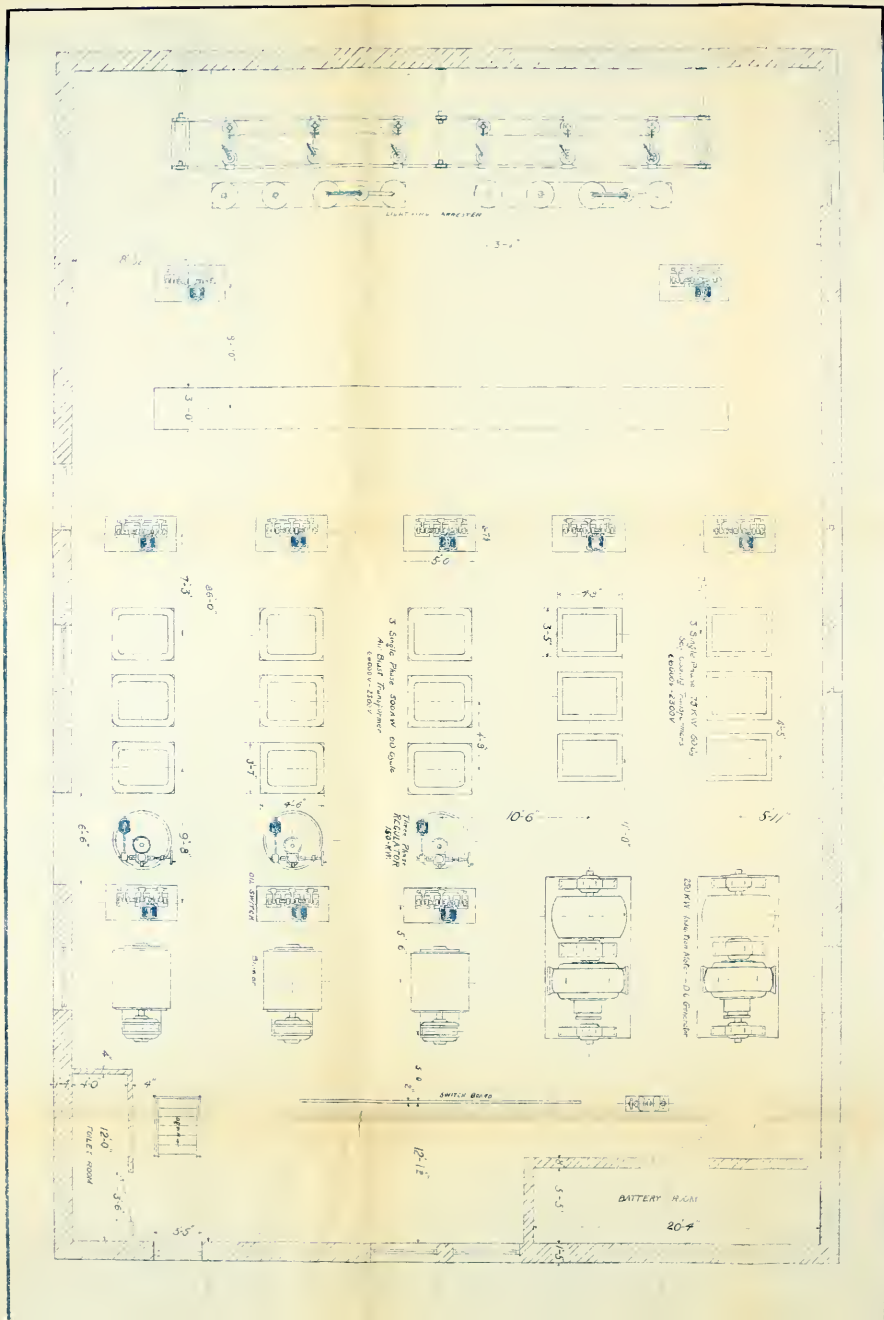
NO SCALE MAY 15, 1910



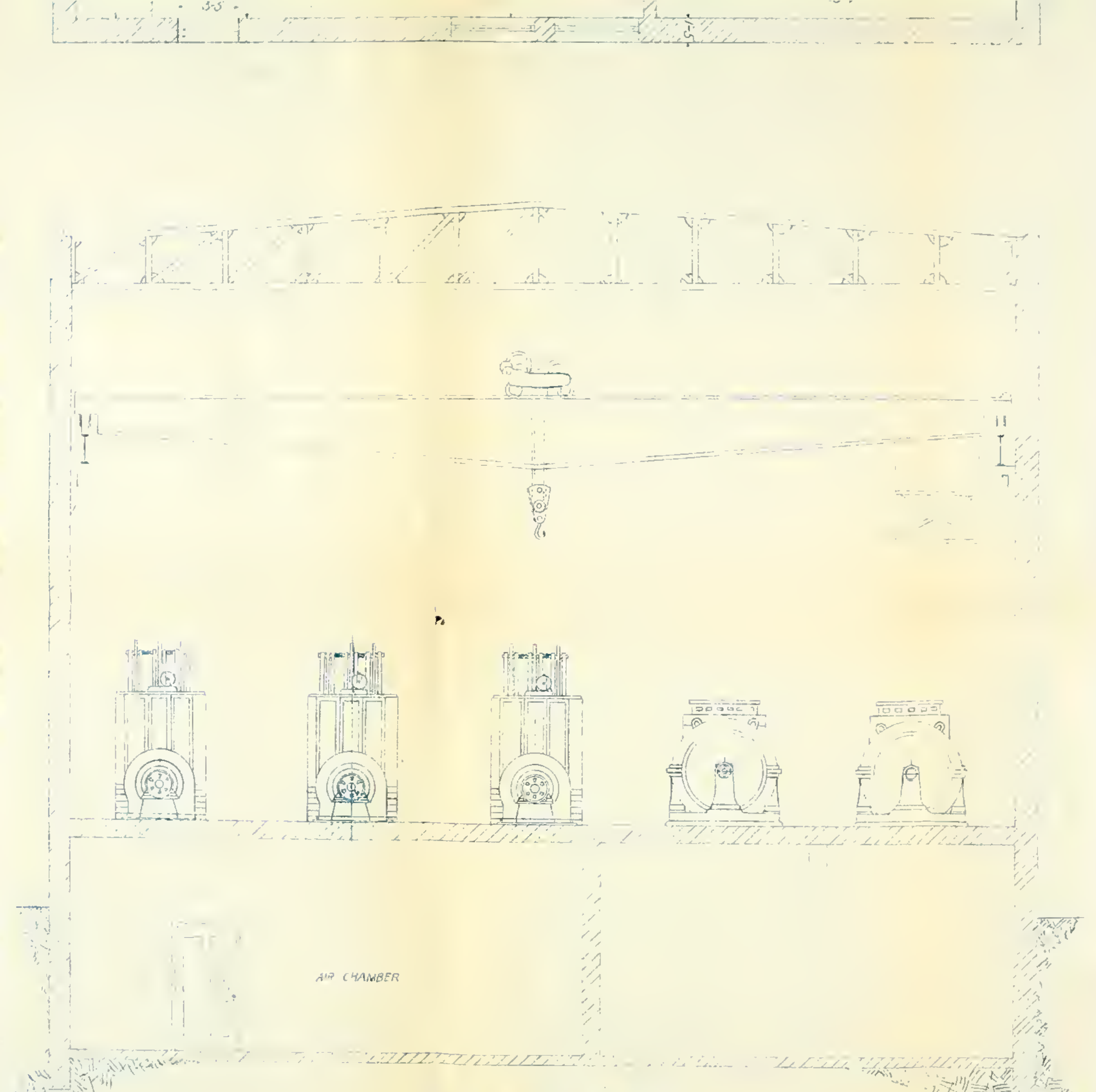
PLAN OF SETTLING BASIN
ELEVATION OF EAST WALL OF SETTLING BASIN
End of Tunnel Timbering
Operating Floor
191' 0"
Bottom of grid rock
Power house wall
Penstock
Piers for gate hoist supports
Walls
Top of Settling Basin Elev 1040.4
Elev 1029
Reinforced Concrete
Earth and Rock Fill
191' 0"
Top of gate pier
Gate pier
Top of Spillway
Reinforced Concrete
12" Piles
Wakefield Sheet piling
CONCRETE FACING
SECTION B-B
Scale 1"=15'
EARTH AND ROCK FILL
MAXIMUM SECTION OF SPILLWAY



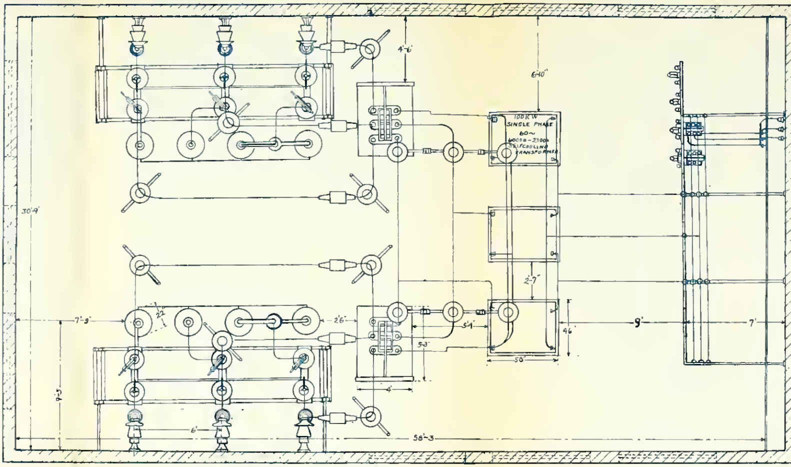
DETAILS
OF
SETTLING BASIN
PROPOSED POWER PLANT
AT
OXBOW, BAKER CO., OREGON
ON THE SNAKE RIVER

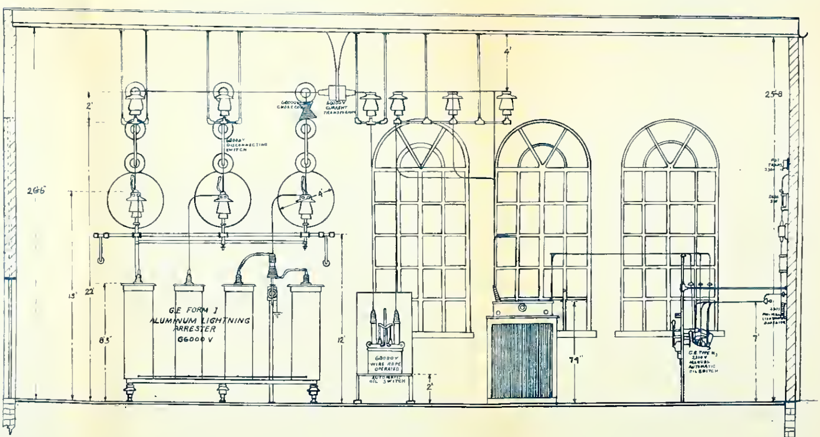


SWITCH BOARD
BATTERY ROOM
TOILET ROOM
OIL SWITCH
Three Phase REGULATOR
10'-6"
5'-11"
20'-4"
12'-0"



5000 K.W.
SUBSTATION
TO BE USED AT
BOISE IDA.
SCALE $\frac{1}{4}$"=1' MAY 15, 1910





300 K.W.
SUBSTATION

TO BE USED AT

PLYMOUTH. IDA.

EMMETT. IDA

SCALE $\frac{1}{4}$"=1' MAY 15 1910