DESIGN FOR ELECTRIC LIGHT AND POWER PLANT

BY

THOMAS PHILIP COWLEY

AND

FRANK BERNARD COLLIS

THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE 1902

UNIVERSITY OF ILLINOIS

May 29, 1902. 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Frank Bernard Collis and Thomas Philip Cowley

ENTITLED Design for an Electric Light and Power Plant

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering.

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

CENTRAL HEAT LIGHT AND POWER PLANT.

This Power Plant shall be for supplying heat, light and power for a Manufacturing Company, using five hundred (500) horse power in machinery and using one thousand (1000) incandescent, sixteen (16) candle power lamps, and twenty five (25) arc lamps.

All machinery will be driven by motors; one motor driving several machines.

The electrical apparatus and engines and accessories, will be chosen in regard to their adaptability to this special plant; location and natural and artificial resources being duly taken into consideration. Such accessories as feed water heaters economizers, mechanical draft, condensers, mechanical stokers, and etc., shall only be used in case a practical saving can be madeby their installation.

The location is such that sufficient water may be had by drilling from to feet. Railroad facilities will be such as to provide sufficient facility for transportation of supplies and material needed in the construction of this plant.

Land of a desirable location is cheap enough, so that space need not be considered.

HORSE POWER REQUIRED FURNISHED TO ENGINE DUE TO THE MOTORS.

There is to be five hundred (500) horse power furnished to the machines by the motors in the Works.

The efficiency of the transmission system is as follows:--

Efficiency of engine	=	86%
" " generator	=	94%
" " induction motor	=	87%

Hence, the efficiency of the combination equals (86 x 94 x 87) = 70%.

The horse power required at the engine will therefore be equal to 500 ÷ .70 = 714 horse power.

HORSE POWER REQUIRED FURNISHED TO ENGINE DUE TO ARC LIGHTS.

Enclosed arcs require 9.6 amperes at 50 volts. Hence the watts per lamp equals (50 x 96)= 480. Total watts equals (25 x 480)= 12000, required for the lamps. Total length of line equals five thousand (5000) feet. The wire used for line is number six (#6) B. and S. Resistance per foot of #6 B & S at 68° F.= ·0003944 ohms. Total resistance of line = 5000 x .0003944 = 1.97 ohms.

The I^2 x R loss=9.6^2 x 1.97 = 181 watts. equals:--Total watts required for lamps and line equals (12000 + 181) = 12181.

Total horse power therefore equals 12181 ÷ 746 = 16.4 (electrical horsepower).

The Efficiency of The Arc System is as Follows:

Efficiency of engine	=	86%
" " generator	=	94%

Therefore the efficiency of the system equals (86 x 94)=80%.

Hence the horse power required will be(16.4 ÷ 80) = 20.

HORSE POWER REQUIRED FURNISHED TO ENGINES DUE TO INCANDESCENT LAMPS.

Required one thousand (1000) lamps; one-half (1/2) ampere; one hundr d and ten (110) volts,

Total watts =1000 x 110 x 1/2 = 55000

" horse power = 55000 ÷ 746 = 74 electrical horse power.

The Efficiency of The Incandescent System is as Follows:

Efficiency of generator = 94%

" " engine = 86%

Therefore the efficiency of the system equals (94 x .86) = 80%

Hence the indicated horse power required at the engine will be equal to (74 ÷ .80) = 92.

The Total Horse Power Required Furnished to Engine Due to Motors, Arc Lamps and Incandescent Lamps equals:--

714 + 20 + 92 = 826.

The Boiler Horse power Required To Furnish Eight Hundred and Twenty Six Indicated Horse Power To the Engines.

The steam consumption per indicated horse power equals twenty two (22) pounds for the type of engines chosen.

Therefore the total consumption will equal (826 x 22) = 18172 pounds of steam per hour.

The standard boiler horse power is based upon the evaporation of 34.5 pounds of water from and at 212° Fahr.

Hence the total boiler horse power required will equal

18172 x factor of evaporation necessary to reduce to basis of from and at 212° F. ÷ 34.5= $\frac{18172 \times 1.2}{34.5}$

DIVISION OF POWER.

Engines and Boilers.

After considering all possible arrangements for dividing up the eight hundred and twenty six (826) horse power required of the engines we adopted the Arnold System of power Station Construction.

We decided to install two four hundred and fifty (450) horse power tandem compound corless engines. The kilo watt capacity of the generator for each of these engines was found by the handy rule:-- 450 x 6 ÷ 10; which equlas 270 K. W. We therefore decided to install two generators of two hundred and seventy (270) kilo watt capacity.

The Arnold System which is described in detail in the Arnold Bulletin #3 permits of the following connections and arrangements. Each generator is always available from either engine. If for example as an illustration of the flexibility of the System one of the engines become disabled; then the second engine which should be able to carry one hundred (100) per cent over load could run the generators and develop the necessary power. Supposing farther that the generator nearest this one driving engine should become disabled; it can be disconnected and allow the second generator to p rform directly from the first engine. The gemerators are designed to carry fifty per cent over load for an hour and twenty - five per cent for three hours.

Therefore by the use of this system it is possible to have a reliable direct connected plant without being compelled to carry

the investment of an extra engine and generator to stand idle most of the time in order to meet the emergencies caused by accidents which seldom occur. The six hundred and thirty-five horse power required of boilers we divided as follows:--four one hundred and fifty horse power boilers would generate steam enough to run the engines at normal load; one one hundred and fifty horse power boiler will be kept in reserve.

We decided that five one hundred and fifty horse power boilers would be the best arrangement. If one boiler became disabled it would only necessitate the connecting up of the reserve boiler wh ch is of such a size as not to envolve much expense for the purpose of providing for any immergency which very seldom occurs but which must be provided for.

ESTIMATE OF COST OF PLANT COMPLETE.

Cost of Building	$10,000.00
" " Chimney	1,500.00
" " Engines	20,000.00
" " Generators	16,000.00
" " Boilers and Stokers	17,000.00
" " Feed Water Heater	750.00
" " Boiler Feed Pump	200.00
" " Condenser Pump	850.00
" " Condenser	1,700.00
" " Economizer	5,000.00
" " Piping	2,000.00
" " Coal and Ash Machinery	4,500.00
" " Mechanical Draft	2,500.00
" " Switch Board	500.00
Total	$82,500.00

900 / $9.16 per H.P.

decimal pt?

CENTRAL HEAT LIGHT AND POWER PLANT FOR A MANUFACTURING CO.

Mechanical Engineering Dept. Thesis

by

T. P. Cowley F. B. Collis.

Part 1. Five 150 H. P. Water-tube Boilers.

" 2 Grates and Mechanical Stokers.

" 3 Two 450 H. P. Corliss Engines.

" 4 Two Alt. Cur. Generators.

" 5 One 700 H. P. Jet Condenser.

" 6 One exhaust Feed Water Heater.

" 7 Boiler feed Pump and Condenser Pump.

" 8 Economizer.

" 9 Steel Stack.

" 10 Mechanical Draft.

" 11 Coal and Ash Handling Apparatus.

" 12 Boiler-house piping, Valves etc.

" 13 Switch-board and Instruments.

CENTRAL POWER LIGHT AND HEATING PLANT FOR MANUFACTURING CO.

Champaign, Illinois.

Specifications for material and labor required in the installation of the equipment of the Central Power, Light and Heating Plant for Manufacturing Co. Champaign, Ill.

Prepared, as a thesis for B. S. in Mechanical engineering University of Illinois by T. P. Cowley and F. B. Collis.

GENERAL DESCRIPTION.

LOCATION.-The work herein specified is for a Manufacturing Co. at Champaign, Ill., on the line of the I. C. R. R. also on the C. C. C. & St. L. R. R. and the Wabash R. R. Located 120 miles south of Chicago. The distance of the plant from the depot is less than one mile.

Return of Plans:-All plans and specifications are to be returned to the company's office.

Drawings:-Plate No. 1. Plan and elevation of plant showing arrangement of boilers, engines, generators, piping, valves, separators, heater, condenser, return tank, coal bunkers, ash and coal handling apparatus and other miscellaneous fixtures. Plate No. 2 complete view of piping with all dimensions. Plate No. 3 Switchboard wiring.

Subdivision of Specifications:-These specifications are subdivided in several parts as outlined on the title page. All bids must be so divided so that any part may be omitted from the contract if deemed advisable or necessary by the company.

GENERAL CONDITIONS.

These specifications and the accom anying drawin s are hereby made a part of the contract between the contractor and the company.

SUPERVISION OF WORK AND MATERIALS:

The consulting Engineer will exercise general supervision for the Company over all materials and work, and will reject any defective material or work whenever found. No portion of either work or materials will be finally accepted until the final acceptance by the Company and the discharge of the contractor from his responsibility therefor.

Omissions:-Any work drawn and not specified or specified and not drawn or particularly mentioned, necessary to the full completion of the work according to the spirit and intent of the drawings and specifications is to be done without extra charge.

Damage by Accidents:-The contractor shall put up and maintain such barriers and red lights as will prevent accidents in consequence of his work: and he hereby assumes all liabilities for all damages occasioned in any way by his neglect or that of his agents, employees or workmen.

Interpretation:- Upon all questions concerning the execution of the work, the interpretation of the drawings and concerning the com letion of the work, the decision of the Consulting Engineer shall be final and binding.

PART 1.

BOILERS.

Number and Type.

There will be five (5) water tube boilers set two in a battery with the odd one set alone at the end.

Pressure.

Boilers to carry safely a working pressure of 160 pounds per sq. in.

Heating surface and grate area.

Each boiler shall have at least 1500 sq. ft. of prime heating surface and 35 sq. ft. of grate area.

Material and Workmanship.

All material and workmanship must be in every particular first-class.

Support.

Each battery of boilers is to be supported independent of the brick work by wrought iron beams and columns resting on cast-iron bases.

Valves and Fittings.

The boilers are to be supplied with all the necessary valves and fittings of proper size and strength. The main steam connection will end with and include a companion flange for the boiler flange.

Tools.

A full set of stokers tools, and all other necessary appliances for properly caring for boilers, are to be furnished.

Erection.

The five boilers are to be erected in batteries of two each with the odd one alone at one end.

Boilers will be set on foundations furnished by the company. All safety valves, water columns, gauges, grates, fire brick lining and all other usual equipments are to be put in place and made ready for operation by boiler contractor.

Tests.

The boilers are to be tested by a hydrostatic pressure of at least 220# when erected and all joints to be tight before bricked in. This test is to be made in the presence of the buyers representative.

Grates.

Mechanical stokers with chain grates will be used and boiler fronts must be made to fit these stokers, the drawings of which will be furnished the boiler contractor.

PART 2.

GRATES AND MECHANICAL STOKERS.

There will be five (5) mechanical stokers of the chain grate type with complete mechanical apparatus for operation of same.

Area of grate surface to be 35 sq. ft.

Contractor must furnish drawings with complete dimensions for the boiler contractor's use.

PART 3.

ENGINES.

Number and type.

There will be required two engines of the tandem compound corliss, condensing, direct connected, side crank type, with cast iron sub-bases and heavy duty frames. Both engines alike except one is to be right handed and the other left handed.

Speed.

Generator proposals are asked for 270 K. W. dynamoes, running at 90 R. P. M. and propositions on engines should be for this speed.

Capacity.

Each engine is to be directly connected to a 270 K. W. 220 volts A. C. dynamo. The engine shall develope its best economy when indicating 450 H. P. at the stated speed when taking steam at 125# gauge pressure, and exhausting against a back pressure of 2# absolute. Each engine shall be capable of standing an initial pressure of 150# gauge and shall be capable of operating continuously at an overload of 50% without unduly wearing or straining any of its parts.

Regulation.

provide each engine with durable and efficient governor which shall be quick to respond to sudden changes of load without tendency to race. With a constant steam pressure the drop in speed from no load to one third above rated load shall not exceed 2 1/2%. The engines shall not vary more than 2 1/2% with a steam pressure varying between 110 pounds and 125 pounds when working

with constant load. The speed of the engines will not vary more than 3% with combined changes of load and steam pressure above specified.

Economy.

The engine bidder will state the least consumption of dry steam (2% moisture) which he will guarantee his engine to use I. H. P. when working at full load conditions.

Connections.

The engines and generators are to be connected up by the Arnold System. (See description and specification of system accompanying this).

Design of Parts.

Engine bidder is to submit a specification describing in detail the material and design of various parts of the engine he proposes to furnish. This description will include the weight and size of fly-wheel size of main bearings, etc., and a list of wrenches and tools which will be furnished for adjustment of engines.

Provide oil and water shields with suitable drains.

provide drains from both cylinders.

Provide throttle valve which will admit of either quick or gradual closing or opening and when closed shall exclude all steam from cylind-r.

Piston rod packing to be self adjusting metallic.

Provide ample space around all parts for erection, repairs, lubrication, inspection and adjustment.

All details are to be of the best workmanship and material in accordance with the best engineering practice of the day.

PART 4.

GENERATORS.

There will be two (2) alternating current multipolar compound wound, constant potential directly connected electric generators; each having a capacity of 270 K. W. at a potential of 220 volts when running at 90 R. P. M.

These generators will be connected with the "Arnold System" (See accompanying drawins and specifications).and all bids must be for generators built to couple up according to this system.

Contractors will submit with their bids complete drawings of the generator which they propose to install, giving all special features of construction. They will also state the guaranteed efficiency at different loads, and the guaranteed regulation and amount of heating.

Generators will be mounted on foundations provided by the company.

PART 5.

CONDENSER.

Number and Type.

There will be one(1) indepent driver jet condenser.

Capacity.

Suitable in capacity to handle two 450 H. P. compound engines when said engine shall be consuming not to exceed 17000# of steam per hour and to maintain a sea level vacuum of not less than 26 inches, with steam pressure of plant not less than 120# injection water not over 70° temperature and all piping tight.

Material and workmanship.

All details to be of best material and workmanship in accordance with the best engineering practice of the day.

Manufacturer will state with bid the steam consumption of the condenser engine.

PART 6.

FEED WATER HEATER.

There will be required one horizontal, closed, exhaust feed water heater suitable for heating 22500# (750 H. P. at 30# water per H. P.). Heater to have at least 1/2 sq. ft. of heating surface per horse power. Heater will be placed between engine and condenser. It must be furnished with all necessary attachments for cleaning, inspection and blow offs for both scum and mud. A grease extractor attachment will be accepted.

PART 7.

PUMPS.

Number and Type.

There shall be one (1) duplex, outside packed, boiler feed pump.

Capacity.

Pump shall have a capacity of 300# per minute, running at not more than 60 feet per minute.

Working Conditions.

Under ordinary conditions the pump will receive its supply from a well, the water level of which will be 15'-0" below pump. It will also be required to take its supply from the return tank of the steam heating system located on floor with pump, water level 24" to 36" above pump. Temperature of water 150° or it may take its supply from the mains under a pressure of thirty to one hundred and at a temperature of from 50° to 80° and the pumps is to be able without alteration or adjustment to take the water under any of these conditions.

Steam Pressure.

Usually 120# Maximum 160#.

Construction.

Material and workmanship to be first-class. Bronze rods preferred. If shipped from factory, it shall be tapped 1/2" for indicator connection steam and water ends.

CONDENSER PUMP.

Number and Type.

There shall be one(1) condenser pump, of the outside packed, duplex type.

Capacity.

Pump to have a capacity of 9500# per minute delivered to the condenser without running at more than 60 feet per minute.

Working Conditions.

Water pumped from well with never more than 15 feet suction. The discharge will be into a 700 H. P. jet condenser located at the same level.

Steam Pressure.

Usually 120# Maximum 160#.

Construction.

Material and workmanship to be first-class. Bronze rods. If shipped from factory, it shall be tapped 1/2" for indicator, steam and water ends.

PART 8.

ECONOMIZER.

There will be one economizer of a size suitable for 700 H. P. of boilers. Temperature of entering water about 160°. An induced draft system is used.

Contractor will furnish detailed drawings of the economizer he manufactures giving heating surface of the particular economizer he proposes to install.

PART 9.

STACK.

There will be one (1) steel stack 6 feet in diameter and 60 feet high.

Material.

The stack shall be built of soft steel plates 5/16" thick.

Joints and Riveting.

The joints are to be in and out lap joints with conical inverted sections so that the top end of each section rests outside of the section immediately above it. All vertical seams are to be lap joints with single row of rivets and with lap scarfed down at horizontal seams.

Ladders and Cleanout Doors.

A ladder shall extend from the top 20 feet down to the roof, care being taken to have the ladder truly in line both horizontally and vertically.

A cast iron clean-out door complete with frame and latch is to be furnished by the stack contractor.

Base and Top.

A suitable cast-iron base to rest on the foundation, and some form of cast-iron top, which will give the stack an ornamental and finished look, must be furnished.

Painting.

Before leaving the shop all material should receive on all sides a heavy coat of Dixon's Graphite Stack Paint applied to the material before rusting is allowed. After erection is

completed all parts are to be painted on the inside and outside with a heacy coat of approved paint well brushed into joints. Color of final coat as selected by company.

The work throughout shall be done with the best material in a complete workmanlike manner and when complete shall present a neat finished appearance.

PART 10.

MECHANICAL DRAFT.

There shall be one induced draft system of mechanical draft, guaranteed to burn 30# of Illinois bituminous pea coal per ft. of grate surface per hour on 175 sq. ft. of grate area. There are five boilers with 35 sq. ft. of grate area each.

The fan shall be independently driven by directly connected steam engine, shall not run over 225 R. P. M. when fan is running under maximum load.

Fans shall be equipped with water cooled bearings and one end of shaft fitted with a 12" pulley for belting to an induction motor in case of accident to engine.

Location.

The apparatus will be placed on the boiler room floor with the base of stack set at any height to accommodate fan.

The gases pass through short flues to the main flue (10′ high by 11′ wide) in which are situated the economizers. Location plan will be furnished bidders.

Paint.

All iron work to be given at least two coats of black paint approved by the company.

PART 11.

COAL AND ASH HANDLING APPARATUS.

There will be a system of coal handling apparatus suitable for conveying the coal from the lower bin to the upper as shown on the plans. Conveyor to run about 60'-0" horizontally raise about 25'-0" and arranged to dump coal every 10 feet.

Gates.

There will be six (6) se s of gates and levers on front of bin for discharging to boilers.

Spouts.

There will be five (5) steel spouts 13'-0" long from above gates to hoppers of furnaces.

Ash Conveyor.

There will be one (1) screw conveyor 60' long consisting of cast-iron blades on a 2" square iron bar, with hangers at suitable distance case, hardened boxes and driving and complete. This screw conveyor will pass out side of building connecting with a bucket conveyor which lifts the ashes 14'-0" and discharges them to the ground.

See drawing No. 1 for dimensions and arrangements.

PART 12.

SPECIFICATIONS FOR BOILER HOUSE PIPING VALVES SEPARATORS ETC.

Contractor to furnish and erect all piping valves and separators as shown on drawing.

Testing.

All pipe lines are to be tested after erecting by applying 60# water pressure and under this pressure all joints must be tight. No calking of joints will be allowed but defective or leaky joints must be made tight by screwing tight. This test must be made in the presence of the company's representative.

Changes.

Any changes made necessary by any cause whatever shall be made without extra expense, providing it does not involve the use of any extra material.

Painting.

Give all pipes and fittings one coat of black asphaltum after testing. Also paint with same material tanks, separators and other fixtures erected under this contract.

Valves.

All valves to be iron body gate valves above and including 3" . Use brass body gate valves below 3".

Exhaust Head.

Furnish and erect one 12" exhaust head of approved design.

Separators.

Furnish and erect two (2) 8" steam separators of approved design.

Packings.

Pack all flanges in low pressure mains with Rainbow packing; all flanges in high pressure mains with corrugated copper gaskets. Pack all valve stems with asbestos wick soaked in oil.

PART 13.

SPECIFICATIONS FOR SWITCH-BOARD WITH COMPLETE SET OF INSTRUMENTS.

Contractor will submit bids for a three panel switch board of grey marble erected, wired and connected to generators and circuits. The switch board shall be wired according to drawing 3 and furnished with the following instruments.

Switches.

Three (3) double throw switches, ten (10) four poled switches and eight (8) two poled switches for synchronizing lamps.

Ammeters.

There will be eight (8) ammeters connected as shown and one(1) current indicator marked (I) on drawing.

Voltmeters.

There will be one (1) volt meter marked (V) and two (2) recording volt-meter as shown on drawing.

Rheostats.

There will be two (2) concentric rheostats connected as shown.

Fuses and Lightning Arresters.

All circuits shall be furnished with fuses and lightning arresters as shown on drawing. The ground plates of arresters shall be sufficiently well grounded to insure perfect connection.

Lamps.

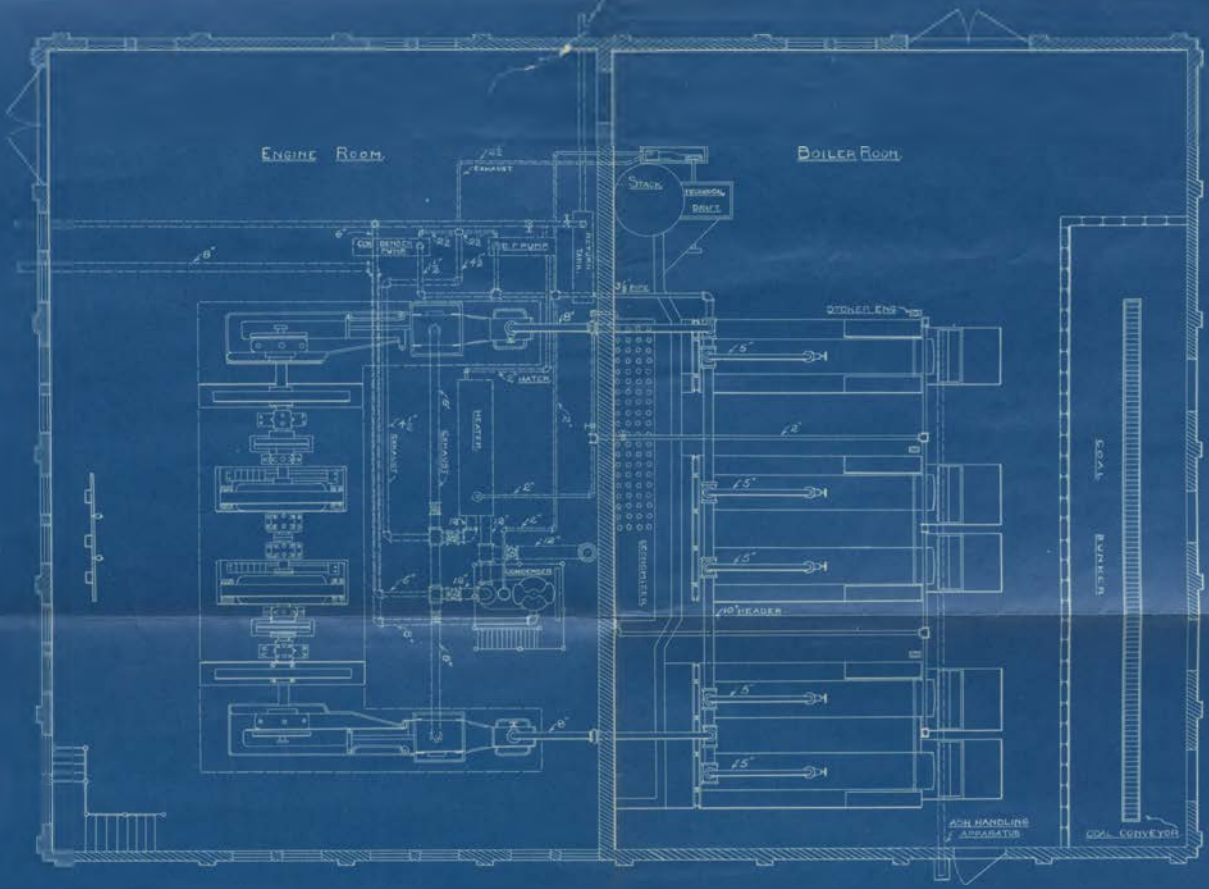
One pilot lamp for each exciter shall be furnished and mounted on switch-board. Synchronizing lamps shall also be furnished and mounted.

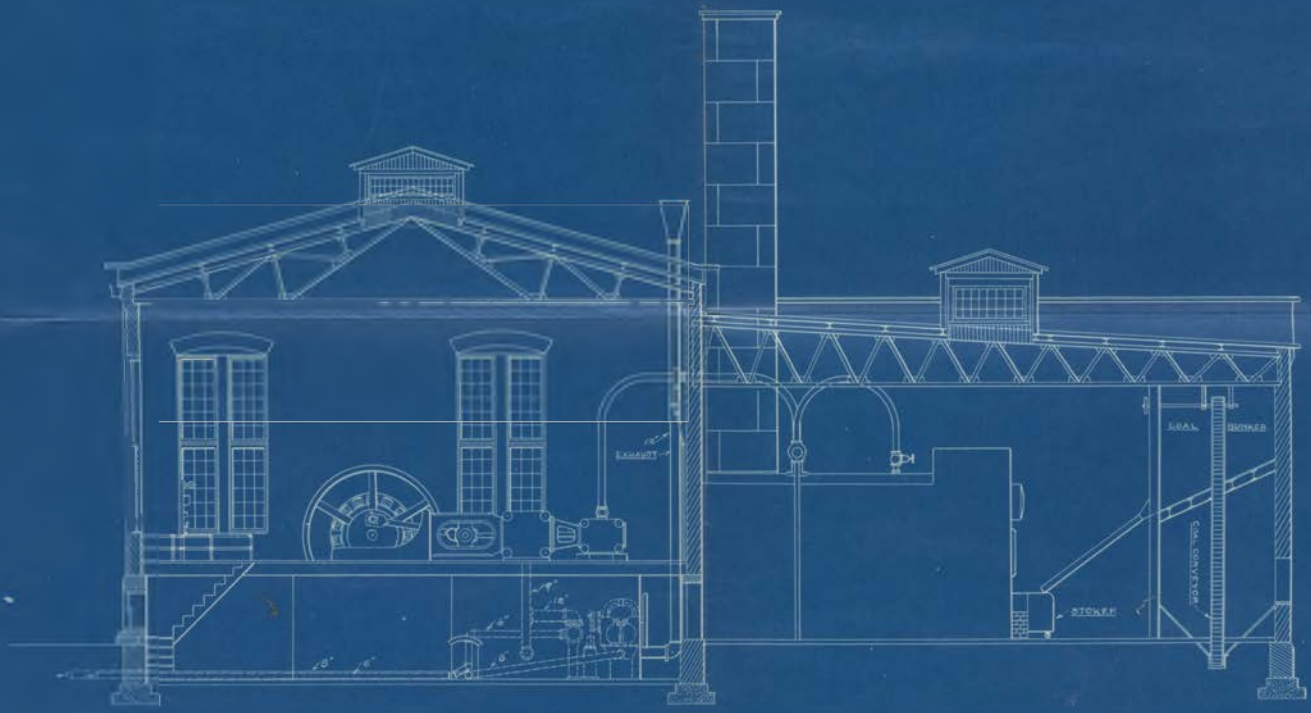
Regulator.

There shall be one (1) reactive regulator for control of arc lighting circuit.

Transformer.

There shall be one (1) ten to one transformer furnished and connected as shown at back of switch-board.





CENTRAL HEAT-LIGHT AND POWER PLANT.

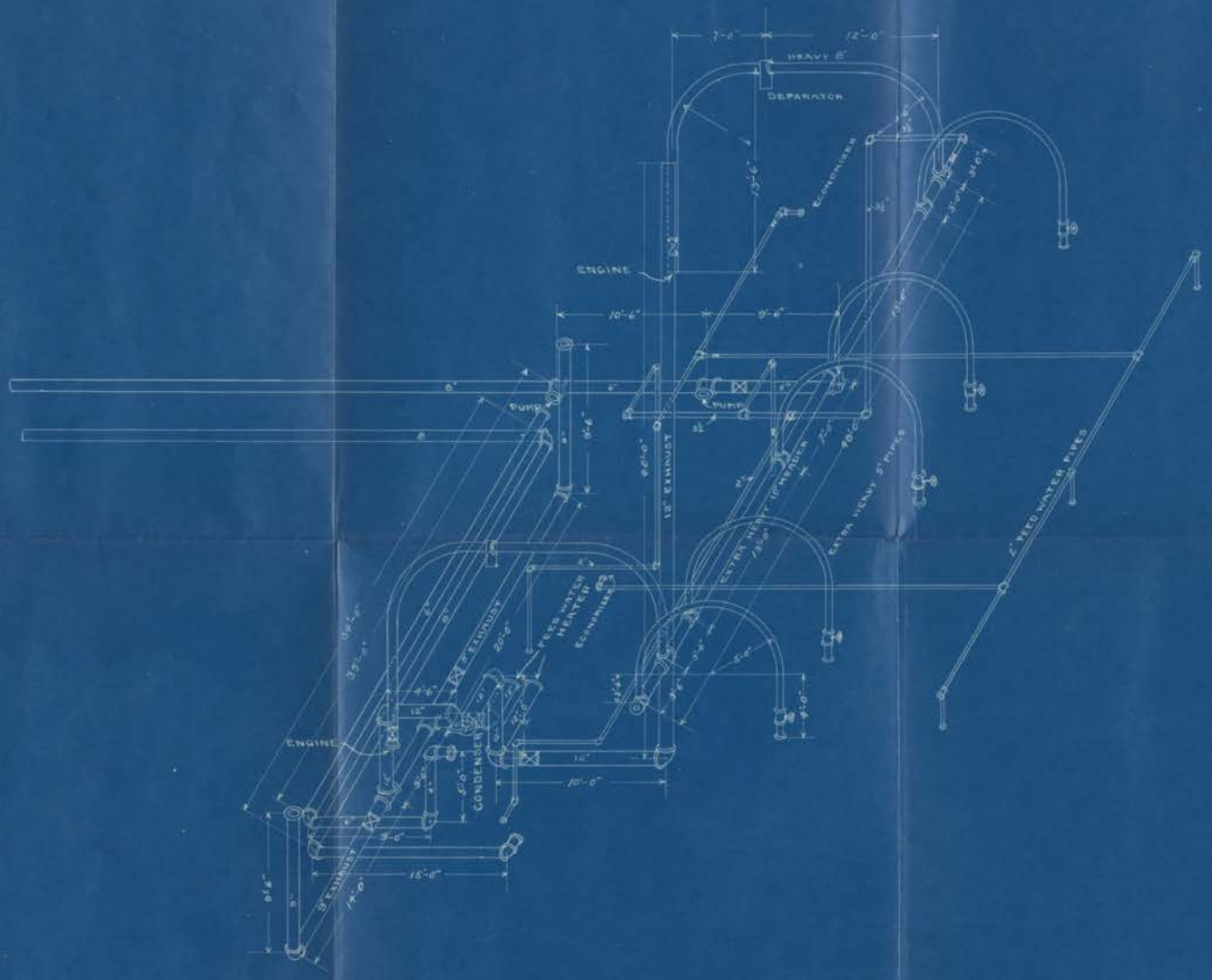
—CORLISS ENGINES—
2-450 H.P NORMAL, 675 MAXIMUM.

90 R.P.M.

SCALE - $\frac{1}{8}$" = 1'-0"

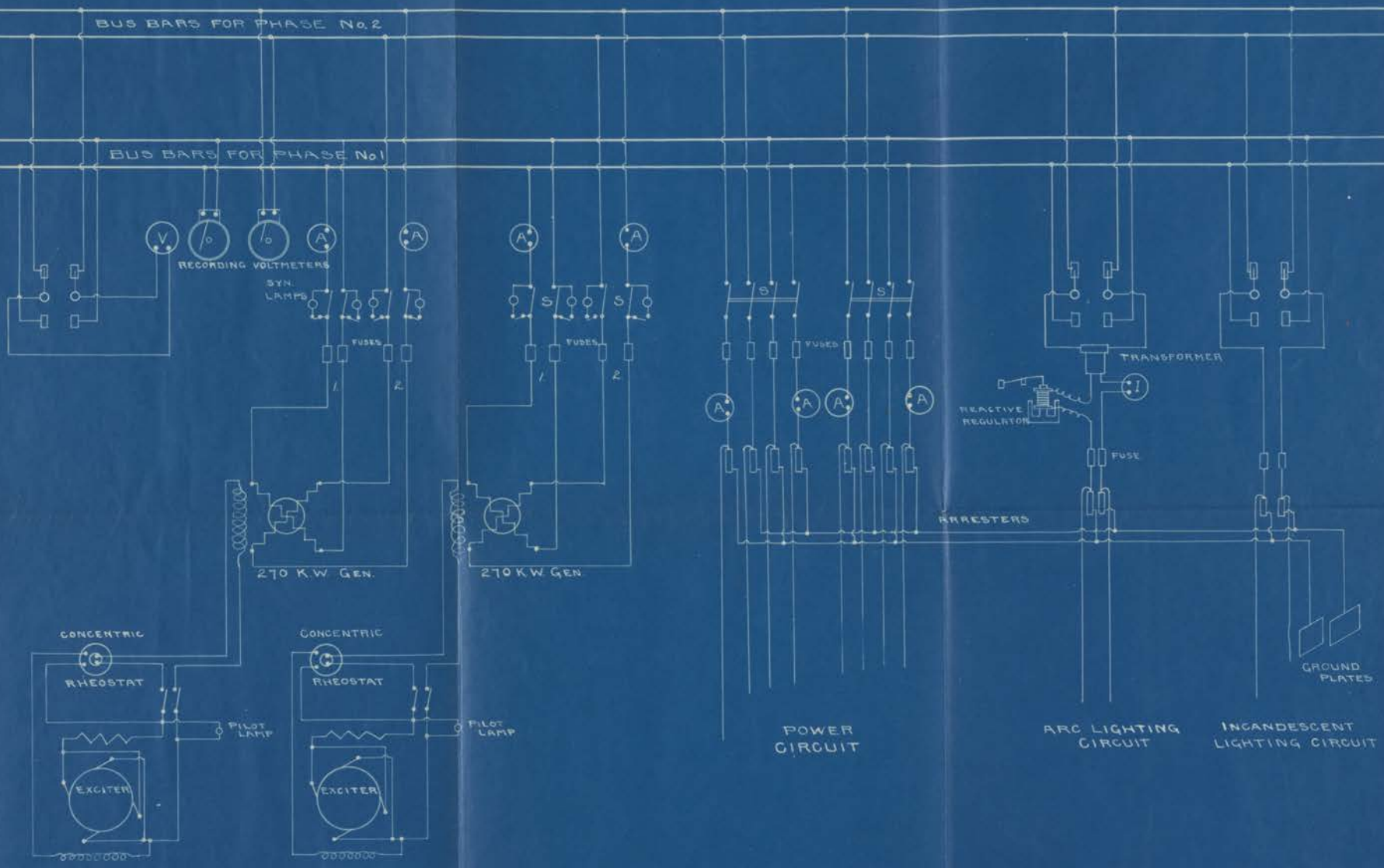
—GENERATORS—
2—270 KW A.C. 220 VOLTS.

—THESIS—
MECHANICAL ENG. DEPT
UNIV. OF ILL.
—1902—



STEAM PIPING SYSTEM

CENTRAL HEAT-LIGHT AND POWER PLANT



SWITCHBOARD WIRING

CENTRAL HEAT-LIGHT AND POWER PLANT