THESIS

DESIGN AND CONSTRUCTION
OF POWER PLANT
MARQUETTE CEMENT MFG. CO.

GEO. W. WILLIAMS

1909

THESIS

THE DESIGN AND CONSTRUCTION OF A POWER PLANT

for the

MARQUETTE CEMENT MANUFACTURING COMPANY,

La Salle, Illinois.

A

T H E S I S

presented to

The Faculty of the Michigan Agricultural College.

by

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George W. Williams

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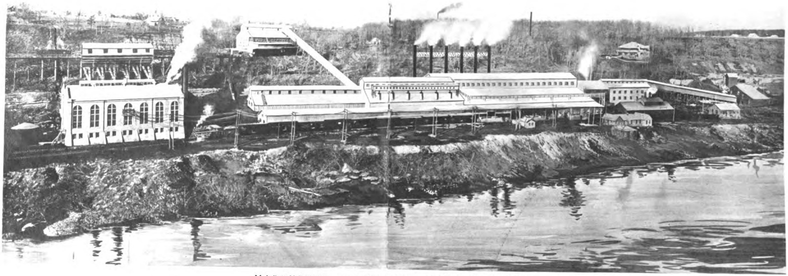
THESIS



MARQUETTE PORTLAND CEMENT WORKS

ANNUAL OUTPUT 1,000,000 BARRELS

In choosing this subject for a thesis, it is not with the idea of being able to present anything new or of great magnitude, but rather to bring out the numerous problems involved in the design and construction of a modern power plant as encountered in actual practice. In this particular case, however, there were features involved in the location and arrangement seldom encountered in the average plant and it was these that made it seem of sufficient interest to warrant its description.

As industries are constantly being developed, the requirements for motive power are being increased and to economically keep pace with these conditions, the matter of careful engineering becomes of more and more importance.

In the summer of 1905, the business of the Marquette Cement Mf'g. Company had reached such proportions that radical alterations in and extension to their plant became necessary and to meet the constantly increasing demand for cement coupled with the keen competition between manufacturers, the matter was one calling for thorough consideration and planning.

The Company's plant is located near La Salle, Illinois, in the valley of the Vermillion river, on a narrow strip of land between it and a range of rock bluffs paralleling its course. The average elevation of the strip is about thirty feet above the river at this point, while the bluffs are forty feet higher at their edge, rising to a height of one hundred and fifty feet above the river some four hundred feet farther back. A line of the Chicago, Burlington and Quincy Railroad follows along the river on the lower level, while a branch of the Illinois Central runs along the top of the bluff.

The product of this Company is made from a natural cement rock quarried from a mine in the bluff adjacent to the mill. From the mine the rock is hauled in dump cars by an electric locomotive to the crushers where it is broken into small pieces, then conveyed by means of a belt to storage bins over the grinders. The grinders, or ball mills as they are called, reduce the rock to a powder which is fed into the rotary kilns, where it is burned with pulverized coal blown into the kilns by specially designed fans. This burning produces what is known as a cement clinker which, after cooling, is crushed and reground to an impalpable powder and passed on to the storage bins where it is allowed to age or season before packing.

The process is a continuous one and the plant is in operation twenty-four hours a day during the whole year with the exception of about ten days when it is shut down for general repairs.

At the time mentioned the mill was grinding about one thousand barrels of cement per day and the existing market conditions and outlook for the future were such

that it seemed advisable to double its capacity and, at the same time, provide for future growth. Such an increase in capacity would necessitate a complete overhauling of the plant and its operation from the mining of the raw material to the storing and shipping of the finished product.

Up to the time of remodeling, the plant had been served by only one of the railroads, namely, the Chicago, Burlington and Quincy, although the branch of the Illinois Central ran close by. To get the latter to run a spur onto the property would open a way to other sources of fuel supply and points of disposal for the finished product and would materially affect the cost of plant operation as will be later explained. To bring this about required the purchase of additional property and the usual amount of time consumed by railroad companies in such cases, but both of these matters were, in due time, satisfactorily settled and the attention of the Company was turned to the main problem, that of remodeling the plant.

The general requirements and plans for the changes in the mill proper were taken in hand by the Company themselves, who were guided by the experience gained in the operation of the old one, and assisted in the engineering features by the builders of the apparatus entering into its make-up.

While the process itself is a simple one and standard apparatus had been developed to carry it out, a large amount of power is constantly required for each of the various steps and upon the reliability of its source depends, in a large measure, the successful operation of the whole plant.

When the matter of providing for the power was reached, it became necessary to call in outside engineering assistance and Mr. George M. Brill was selected to carry on that feature of the undertaking. The conditions then existing together with the general requirements for the new plant were made a subject for an investigation which resulted in a report setting forth the recommendations covering a new power installation.

The old plant was being operated both electrically and mechanically, but experience and common practice indicated the advisability of complete electrification in the new one. This is more easily understood when it is considered that the process is carried on by units of mills, grinders, rotary kilns, etcetera, each requiring a large amount of power and so arranged that to drive them by mechanical transmission would necessitate the use of long lines of heavy shafting, gears, chains and belts, which, in such a gritty atmosphere, would consume a large amount of power and entail considerable expense for maintenance and loss due to break-downs.

The old power plant was located in one end of the mill proper and as the latter was hemmed in by the railroad and bluff on its sides and the entrance to the mine and the storage bins on its ends, this space was not only valuable for other purposes, but actually required to carry out the plans for the new arrangement. There was, however, sufficient space available at one end of the property for the erection of a new power plant, and as the power was to be electrical, the small extra distance to the center of distribution was immaterial.

In the majority of power plants using coal as a fuel, hand labor or special apparatus are required for unloading and storing the coal and disposing of the ashes, these conditions being looked upon as fixed and the necessary charges or costs resulting therefrom borne and considered as a matter of course.

The natural conditions which existed at this particular site, make it possible and practical, without undue expense, to so locate, design and equip a boiler plant that the common source of annoyance and expense in handling the coal and ashes could be almost eliminated and gravity employed to deliver coal to the boilers and remove the ashes from them. With the Illinois Central spur extended onto the property to a point above the proposed power plant, coal could be delivered in drop-bottom cars to a storage bin above the boilers, from which it could be drawn through chutes to the grates which in turn would discharge the ashes into suitable hoppers underneath. These hoppers could be placed at a height that would permit of cars on the Burlington track being placed under them for the purpose of conveying the ashes away from the plant. By the use of properly constructed chutes and ash hoppers, regulated and operated by the boiler room attendants, the coal could be passed from the cars to the grates and the ashes removed with practically no hand labor or power operated apparatus. The difference in the cost of operating such a boiler plant and one built along the lines of the old one, where hand labor was employed, is shown by the following calculations.

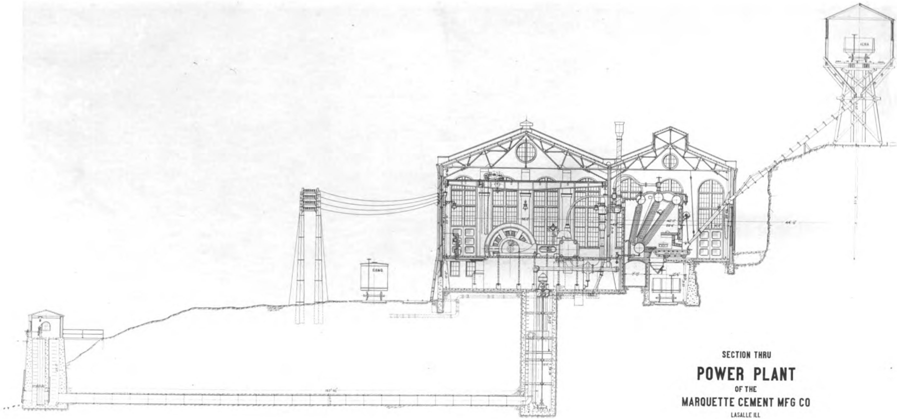
Assuming that 2000 boiler horse power would be the average capacity in use and burning coal at the rate of 4.5 pounds per boiler horse power per hour, 9000 pounds of coal per hour or 108 tons per day of twenty-four hours would be required and if the ashes amounted to 15%, there would be 16.2 tons of them per day.

HAND METHOD.

Unloading 108 Tons of Coal at 7½¢	=$8.10
Firing 108 Tons of Coal at 15¢	=16.20
Removing 16.2 Tons of Ashes at 12¢	= 1.94
Total	$26.24

GRAVITY METHOD.

Unloading Coal and Dumping Ashes	$1.75
Firing Boilers, two shifts at $3.00	= 6.00
Total	$7.75



SECTION THRU
POWER PLANT
OF THE
MARQUETTE CEMENT MFG CO
LASALLE ILL

With a gravity system and automatic stokers, the coal could be delivered to the plant in drop-bottom cars which would make it possible for one man or his equivalent to unload the coal and dispose of the ashes, and one man in each shift could care for the firing of the boilers. To realize this it might require an extra expenditure of $10,000, but even so, the saving affected would in a few years pay off the extra first cost.

With the river close by, a sufficient quantity of water for the operation of the plant could be obtained with but a small expense for pumping.

The location relative to the mill, the location of railroads, the elevations and the nature of the soil all contributed to conditions practically ideal for the purpose of a power plant and with proper design of the building or buildings and the selection of equipment, properly installed, there should result a plant of exceptional economy in operation and maintenance.

Without going into the detailed requirements for increased power at that time, we were given to understand that an installation of 2400 horse power of water tube boilers, equipped with automatic stokers, and the same horse power of cross-compound condensing engines direct connected to generators of suitable capacity would satisfactorily meet the requirements. Two ways of providing for this capacity were open for consideration. One was to purchase new boilers,

engines and generators of the type mentioned for the whole equipment; the other was to use the old horizontal tubular boilers and the belted engine-generator units then in service as far as they would go and supplement them with new apparatus.

The water tube type of boiler would be in larger units than the tubulars, somewhat more economical in the production of steam, more easily and therefore cheaply operated and less expensive to maintain. More important, however, was the fact that the old boilers were built to carry pressures not to exceed 110 pounds, while the water tube type could carry 150 pounds or more with a consequent material improvement in the engine economy.

While the old engines might have been continued in service in the new plant, they were in units of 400 horse power, rather small for use in a new plant of the proposed size. Aside from this and the low pressure for which they were designed, they were far less economical than first class cross-compound units.

If the old apparatus were used, the building would have to be considerably larger to house it on account of the greater space required by the low pressure tubular boilers and the belted engine-generator units. There would be the expense of moving it, some repairs would doubtless be necessary and sooner or later it would have to give way to apparatus of the more modern type considered for

the balance of the equipment.

Continuous operation during the period of changing over was also an important factor, as each day's shut-down involved a loss of profits amounting to approximately one thousand dollars, and by leaving the old equipment intact until the new plant could be started, this loss could be avoided. Considered from every standpoint, if the new plant was to be made strictly first class, it would be better to install such new apparatus throughout as might be necessary to properly meet the requirements and thereby gain the extra efficiency from the start.

The first plan considered was to erect two separate buildings to house the boilers and engines, locating them at different elevations. The boiler house would be placed on the top of the blmff, which would bring it at such a height that a larger hopper holding a car or more of ashes could be cut in the rock under the boilers and the cars run under it through a tunnel cut in from the side of the bluff. Practically all of the excavated material could be used in the manufacture of cement so that the expense of excavation chargeable to the power plant would be small. The engine room would be located at a lower level and nearer the plant.

Upon further consideration this plan was abandoned and it was decided to place all of the apparatus in one building with the boilers and engines on the same level. The floor would be at such a height that cars could be switched into the boiler room basement and clear the ash hoppers, one of which would be provided for each boiler. This latter plan was by far the better one as the first cost and operating expense would be much less than would be the case were separate buildings provided and the apparatus spread out over a larger area.

When the general location of the power house had been fixed, a survey was made and levels taken covering the area under consideration from the river to the top of the bluff including the floor line of the old mill and the Burlington and Illinois Central roads where they passed the plant. From these levels a profile was prepared to serve in determining the exact location and elevation of the new power plant and its apparatus.

As a large quantity of water would be required for the plant, the means of economically supplying it from the river was an important consideration. Two methods of doing this presented themselves, one being that of locating the pumping apparatus at the river, which was about 150 feet away. The other was to place the apparatus in the power house and bring water to it by means of an intake. As the river during high periods reached an elevation from eighteen to twenty feet above normal, it would be nedessary, were the first method employed, to place the apparatus at the extreme elevation to insure it from flood.

This would necessitate lifting the water this height during the greater portion of the year which, added to the necessary discharge head and the friction of the long discharge line, made it the least economical from an operating standpoint. Again, isolated apparatus is liable to receive little attention and under such circumstances may become a source of much expensive annoyance. To carry out the second method, it would be necessary to sink a shaft in the power house to a depth corresponding with low water in the river and by means of a tunnel connect the latter with the former. Pumps could then be placed in the shaft with their water ends submerged and with their power ends, whether steam or electrical, located at such an elevation as to be operated from the basement floor. This method would eliminate the suction lift, the friction of a long discharge line, the cost of the line and the pump house, and place the apparatus where it could receive proper care without extra effort. If barometric condensers were used this shaft would serve a second purpose by affording space below ground for their discharge legs, thereby materially reducing the height of the condenser heads and consequently the lift of the condensing water.

Estimating the cost of installing the first method, exclusive of the pumping apparatus, as $3000.00 and that of the second as $5000.00, the initial expenditure favored the former, but when considered from an operating standpoint, the latter was the more economical. The amount of water required to condense the steam from 2400 horse power of engines using fourteen pounds of steam per horse power hour and thirty pounds of water per pound of steam would equal $\frac{2400 \times 14 \times 30}{60}$ or 16,800 pounds of water per minute. By a reduction in head of twenty feet a saving of $\frac{16800 \times 20}{33000}$ or say ten horse power would be affected, which, at $25.00 per year, would equal $250.00 per year, considerable more than the interest at five percent on the difference in first cost and enough to warrant the construction of the shaft and tunnel.

The use of barometric condensers, already mentioned, had been considered from the start as they had successfully served in the old plant. Experience there had demonstrated them to be by far the best type for the service, owing to their ability to operate with water containing much foreign matter and scale producing constituents. A surface condenser,with its numerous small tubes, would soon become clogged with dead leaves or scale and rendered useless, a condition calling for continual attention and expense to keep it in working order. With an almost inexhaustable supply of water close by, jet condensers could be operated without this trouble and the barometric type, owing to the high lift and the absence of moving parts, would be the most economical and simple to operate.

The electrical current in use in the old plant was 220 volt, direct and was originally adopted on account

of the use of variable speed motors driving the rotary kilns and the mine locomotive. While the use of direct current motors is unusual in modern cement plants, owing to the gritty atmosphere in which they must operate, this Company had gradually increased the amount of such apparatus and, strange though it may seem, their experience with it had been entirely satisfactory. A record of maintenance expense had been carefully kept covering a period extending over several years and this failed to furnish any evidence to their discredit. To discard the old motor equipment and replace it with alternating current machines would mean the sacrifice of a greater portion of its cost to say nothing of the more serious loss in the time required for changing over. The need for some direct current for the kiln motors and the locomotive would still remain when the plant was remodeled and this, together with the loss involved were the old equipment replaced, were strong arguments in favor of continuing its use. The extra first cost of generators and transmission line, using the low voltage direct current, was thoroughly considered, but even this was not sufficient to bring about the change.

The old engines, which were belted to jackshafts, were indicated and the motors throughout the plant tested to determine the power being used and to this was added that necessary to operate the extra apparatus which would be installed in the new arrangement.

TEST OF ENGINES.

Compound (Corliss)

Three Tube Mills One Ball Mill One Counter Shaft Elevators and Conveyors	345 H.P.

Simple (Bates Corliss)

Three Tube Mills Counter Shaft Elevators, belt driven from jack-shaft, Electrical Load, 950-1000 Amperes	554 H.P.

Simple (Allis Corliss)

Electrical Load, 1100 Amperes	350 H.P.
Total Full Load	1249 H.P.

TEST OF MOTORS.

Location	Use	Size H. P.	Amperes
Coal House	Coal Crusher	25	97.5
	" Conveyor	15	57.0
	" Dryer	10	39.5
	" Speeder	6	23.0
	" Elevator	5	23.0
Quarry	Locomotive	40	135.0
Raw End	Rock Crusher	75	250.0
	" Belt	15	58.0
	" Fan	10	38.5
	" Conveyor	25	97.5
	Grit Mills	125	450.0
	Ball Mill	190	700.0
	Blower Fan	10	97.5
	#1 Kiln	10	39.2
	#2 Kiln	10	39.2
	#3 Kiln	10	39.2
	#4 Kiln	10	39.2
	#5 Kiln	10	39.2
			2262.5

TEST OF MOTORS (con't)

Location	Use	Size H.P.	Amperes
	Brought Forward		2262.5
Finish End	Pan Conveyor	5	21.0
	Clinker Pit Fan	10	38.0
	Cooler Fan	35	153.0
	Kent Mill	30	113.0
	Kent Mill	30	113.0
	Cement Belt	15	58.0
	Sacking	5	21.0
	Sacking	5	21.0
	Sacking	5	21.0
	Sacking	5	21.0
	Emery Wheel	6	21.0
			2863.5
Lights			200.0
	Total		3063.5

The requirements of the extra apparatus which was to be installed were as follows:

One Tube Mill in coal room	360	Amp.
Two #8 Ball Mills with Dryer and Elevator(raw end)	350	"
Three 5 x 22 Tube Mills (raw end)	1080	"
Three 5 x 22 Tube Mills (finish end)	1800	"
Three Kent Mills (finish end)	480	"
Extra Separators, Conveyors and Elevators	150	"
Four Cooler Fans	480	"
Sacking Motors	50	"
Extra power for Rock Crushers	100	"
Extra lighting in Quarry and Mill	100	"
Total	4950	"

Adding the total amperes obtained from the individual motor readings to the total required by the extra apparatus, we have 8013.5 amperes, which at 220 volts is equal to 2363 H.P. Deducting the electrical load of 610 H.P. from the total of the engine tests, we have left a mechanical load of 639 H.P. Adding these results, we have a total of 3002 H.P. By comparing the collective electrical load as shown by the engine tests and the total of the individual readings, we find the collective load is about two-thirds that of the total individual.

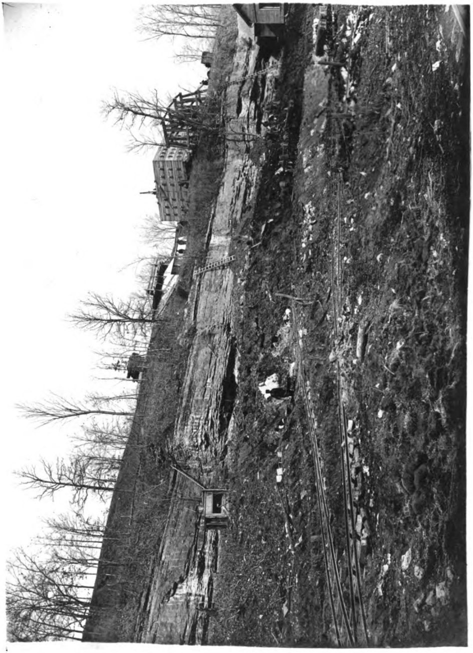
In view of the above, it was decided to provide 1800 electrical horse power in two equal units for the first installation and arrange the building and auxiliary apparatus to care for an additional installation of 900 H.P. As the load would be steady, large units, all of a size, would make the best arrangement and with machines designed to carry a fair overload, one unit could be temporarily shut down if necessary.

The current was to be carried from the power house to the mill on nine circuits arranged as follows:

800	Amperes	to	Coal Room.
600	"	"	Crushing House and Locomotive.
1000	"	"	Ball Mills.
1800	"	"	Raw Grit Mills.
800	"	"	Rotary Kilns and Fan.
600	"	"	Kent Mills.
1800	"	"	Finish Grit Mills.
300	"	"	Sacking Platform.
300	"	"	Lights.

The lines supplying current for the raw grits, rotary kilns and fan were to be connected to the old switchboard in the mill where the power would be divided and distributed over the old circuits.

The boiler equipment was planned in the same manner as the engines and divided into three batteries with



two 400 H.P. boilers in each, making a total of 2400 H.P,, 1600 H.P. of which was to be installed at first. On account of their being out of service more often for cleaning and the requirements of the auxiliary apparatus for steam, the total horse power of the boilers was made nearly equal to that of the engines, although the latter would require but half the steam that the former could produce.

Next came the matter of providing sufficient draft for the boilers and, under ordinary circumstances, this could best be accomplished with a chimney of moderate height. In this case, however, it would be necessary to build a chimney much higher than usually required to obtain the desired unbalanced atmospheric conditions, owing to the proximity of the bluff. Induced draft was being employed in the old plant for this purpose and as the apparatus was in first class condition, it would answer for part of such an installation in the new plant. The new apparatus could be installed first and arranged to do the work until the old plant could be dismantled and the old apparatus moved. If run with engines, most of the heat in the steam would return to the boiler by way of the heater so that the expense of operating it would not be great and its first cost would be about half that of a suitable chimney.

The use of economizers in connection with the induced draft apparatus naturally suggested itself as an ideal arrangement from the standpoint of economy. Of course

this point was somewhat offset by the fact that there was sufficient exhaust steam from the auxiliary apparatus to heat all the boiler feed water. Again as the water was very bad considerable trouble would doubtless be experienced in the tubes. These facts coupled with the first cost of the apparatus made the installation of economizers seem unwarranted.

Samples of water taken from the river for analysis were found to contain the following substances:

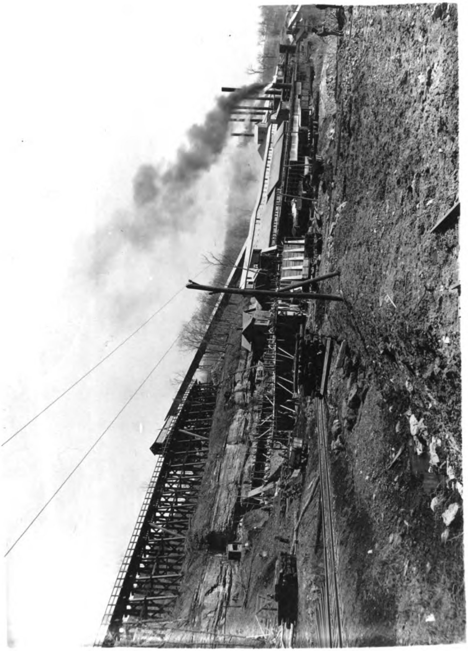
Silica	0.28	grains per gallon
Iron Oxide and Alumina	0.12	" " "
Calcium Sulphate	16.58	" " "
Calcium Carbonate	2.04	" " "
Magnesium Carbonate	10.81	" " "
Sodium Sulphate	7.08	" " "
Sodium Chloride	3.85	" " "
Organic Matter	0.93	" " "

This analysis shows a large percentage of sulphate which would not be separated from the water by temperatures found in heaters, although a large portion of the carbonate would doubtless be precipitated. To render the water suitable for boiler feed purposes would require the installation of chemical purifying apparatus and it was possible to find such apparatus on the market, the makers of which would guarantee its successful operation at the nominal cost of two and one-half cents per thousand gallons of water treated. A heater could be arranged in conjunction with the purifier and be supplied with exhaust steam from the auxiliary apparatus in the plant.

It was planned to draw the water for the boilers from the condenser hot well and in this manner save some of the heat contained in the engine exhaust. To render this water suitable for the purpose, it would be necessary to insert vacuum oil separators in the exhaust connections between the engines and condensers to extract the oil contained in the steam. To lift the water from the hot well, located about twenty feet below the basement floor level, it was decided to use deep well pumps, the water end of which would be submerged in the well and the steam end placed on the floor, the two being connected by wooden pump rods.

In order to supply two sources of power to operate the automatic stokers, an engine and motor were to be installed. The latter, on account of the low cost of the electrical power, would be used most of the time.

While the engine load would be quite steady when once the new mill had settled down to a working basis, there would necessarily be need for some adjustment before this would be realized. The centrifugal pumps supplying the condensers would operate steadily although furnished with means for hand regulation and to take care of the fluctuation between the amount of water required by the condensers and that supplied by the pumps, storage tanks were to be installed on the ground level at one end of the plant to act as a cushion. At the same time this storage of water above the river would serve as a limited supply for the



fire pump should anything occur which would put the centrifugals out of service. In addition to these a 55,000 gallon tank was to be placed on the highest point of the bluff to be used as a gravity tank in connection with the fire protection system.

A cross compound steam driven compressor, which supplied air to the rock drills in the mine, was to be moved from the old plant, as was the duplex steam driven pressure pump which supplied the mill with water. The former was to be placed on the engine room floor while the latter would be placed in the basement and serve as a general fire and service pump.

An electric hoist, hand traveled crane was to be placed in the engine room to facilitate the erection of the engines and generators and to handle such parts as might be removed for repairs after the plant was in operation.

Having settled upon the general type and capacity of the power equipment and laid out, in the rough, the necessary water storage tanks, steam and water piping, toilet facilities, sewerage and plumbing entering into the make-up of a complete plant, it only remained to purchase suitable apparatus, carefully plan its arrangement and properly install it in a substantial building to obtain a first class and economical result.

The following specifications were prepared submitted to the respective makers of apparatus and proposals solicited.

Boilers.

There shall be furnished four 400 H.P. water-tube boilers, delivered and erected on foundations built by the Company, and left ready for brick work, steam and water connections.

These boilers are to be set in two batteries and arranged for mechanical stokers, which are to be furnished under another contract.

The rating of the boilers shall be based on an allowance of ten square feet of heating surface per horse power.

With each boiler shall be furnished a pop safety valve, set to blow at 150# pressure, one safety water column connected, blow-off valve, one 12" pressure gauge, and one set of firing tools. The contractor shall also furnish one flue cleaner to be operated either by steam or water.

Proposals shall state quality of steel used in drums and tubes, number, thickness, size and riveting of drums, number of fire and common brick necessary for setting and dimensions of battery and single setting. The contractor shall furnish and put in place all special brick for arches, baffles, etc. other than the fire and common brick used in the setting.

After the boilers are erected and before brick work is commenced they shall be tested and made tight under a cold water hydrostatic test of 200# per square inch and a Hartford Steam Boiler Inspection and Insurance Company policy for $500.00 shall be furnished for each boiler.

ENGINES.

There shall be furnished two engines which shall be alike in all particulars. Each shall be horizontal, cross compound, heavy duty type, arranged for operating a continuous current generator direct connected. Each shall be of such size that when operated at a speed of 100 R.P.M. with initial steam pressure of 150# and vacuum of 25" it will develop 950 I.H.P. when cutting off at the most economical point in the high pressure cylinder. Each shall be equipped with double eccentrics to operate efficiently and satisfactorily through a wide range of loading. Disc cranks shall be used. Each low pressure cylinder shall be arranged to run on live steam independently of the high pressure cylinder during emergency requirements.

Proposals shall include for each engine a quick acting throttle valve, drain valves, water relief valves of ample capacity, a complete automatic pressure oiling system, steam separator, metallic packing on piston rods and valve stems, shields over cranks, three 12" gauges suitably mounted and connected to indicate the pressure on high and low pressure cylinders and the vacuum, all necessary wrenches,

and each cylinder shall be equipped with indicator connections with three-way cocks. The low pressure piston shall be babbetted. The makes of separator, metallic packing and gauges shall be approved by the consulting engineer for the purchaser.

The engine builder will furnish the foundation bolts with nuts and square washers for the engines and deliver them at the purchaser's plant within twenty days from date of contract.

The engine builder shall co-operate with the builder of the generator and the consulting engineer regarding the details of the engine and generator arrangements and shall furnish the engineer blue prints promptly after such arrangements shall have been agreed upon, the prints to show fully the essential features of the apparatus including all dimensions necessary for the design of the foundations and the arrangement of piping.

Proposals shall include with each engine a re-heater of ample and stated capacity, with all material necessary to connect it to the cylinders. The purchaser will furnish the necessary piping to supply live steam to them and for removing the condensation.

Material and workmanship shall be first class and proposals shall definitely specify what materials are to be used and the character of the workmanship which will be furnished under the contract and state the following

Diameter of cylinders and length of stroke.
Diameter, weight and width of fly-wheel.
Diameter and length of main bearings.
Diameter and length of cross head and crank pins.
Diameter of piston rods.
Size of connecting rods at center and near ends.
Bearing surface of cross head shoes.
Diameter of steam and exhaust pipes.
Weight of engine complete and floor space occupied.
Guaranteed steam consumption.
Guarantees on regulation.

The engine builder will furnish the shafts, base plates and either put the armatures upon the shafts or deliver the shafts to the generator builder for that purpose.

Proposals shall include the services of an expert erector to supervise the unloading, installating and starting of the apparatus. The purchaser will furnish all necessary foundations and ordinary labor for unloading and erecting but in so doing will assume no responsibility for the safety of the apparatus until it shall have been completed, started and accepted.

GENERATORS.

There shall be furnished two generators which shall be alike in all particulars. Each of the two generators will be approximately 700 K. W. capacity, direct driven, continuous current, compound wound, operated at approximately 100 R.P.M. The full load voltage shall be about 250 and the no load 220 volts.

Proposals are requested upon standard apparatus and shall include guarantees on efficiency, compounding, overload capacity and heating, together with a statement of

the weight of each armature and commutator and total weight of each generator.

The engine builder will furnish the shafts, and either put the armatures upon the shafts or deliver the shafts to the generator builder for that purpose. The delivery is to be F.O.B. cars the plant of the Marquette Cement Manufacturing Company, via. the C.B. & Q Ry.

Proposals shall include the services of an expert erector to supervise the unloading, installating and starting of the apparatus. The purchaser will furnish all necessary foundations and ordinary labor for unloading and erecting but in so doing will assume no responsibility for the safety of the apparatus until it shall have been completed, started and accepted.

SWITCHBOARD.

There shall be furnished, delivered and erected one switchboard which shall consist of two generator and six feeder panels. Each panel shall consist of two slabs of Blue Vermont marble, free from flaws, the main one to be 62" high with sub-base 28" high. These are to be mounted on a suitable angle iron frame work securely fastened to a channel iron base with adjustable bracing rods to support board five feet from the wall.

Connections on back of the board are to be of hard drawn copper having a sectional area such that current density will not exceed 800 amperes per square inch.

Bus-bars shall be laminated and provided heavy enough to take care of three 750 K.W., 250 volt generators operating in multiple. The third generator with its panels will be added later. Current density for bolted contacts must not exceed 200 amperes per square inch. All connections shall be furnished including suitable lugs for connecting feeder circuits. All instrument connections to be run in straight horizontal and vertical lines with right angle turns.

Proposals shall state the price per foot for which the contractor will furnish the necessary lead covered paper insulated cable for connecting the generators to the switchboard and between equalizer pedestals and shall include the labor for making these connections, the necessary conduit or trenches to be furnished by the purchaser. The size of the generator leads shall be 3,750,000 C.M., the field connections No. 0, and the equalizer connections 2,000,000 C.M.

The panels shall be as follows:

2 - Generator panels, each of 750 K.W. capacity, and upon each of which shall be mounted,
1 - D.P. Independent arm, overload and reverse current, 3,000 ampere, I.T.E. circuit breaker.
1 - Type "B", illuminated dial, 4,500 ampere, Station Ammeter.
1 - Rheostat operating mechanism furnished by purchaser.
1 - Ground detector push button.
1 - Pilot lamp.
1 - Four point voltmeter receptacle and plug.
1 - Type "G" Thomson Astatic recording wattmeter, 4,500 ampere capacity mounted on sub-base.

1 - Feeder pannel with
2 - 1,800 ampere, auto-directite D.P., tandem non-closing circuit breakers.

1 - Feeder panel with
1 - 1,000 and 1 - 800 ampere auto-directite D.P., tandem, non closable circuit breakers.

1 - Feeder panel with
1 - 800 and 1 - 600 ampere auto-directite D.P., tandem, non closable circuit breakers.

1 - Feeder panel with
1 - 600 and 2 - 300 ampere auto-directite D.P., tandem, non closable circuit breakers.

2 - 2,000 ampere, quick break switches, each mounted on separate cast iron pedestals, for equalizer connection.

2 - 300 volt, type "B", illuminated dial voltmeters mounted on swinging bracket.

It is the intention of this specifications to cover a complete switchboard, furnished, delivered and erected and connected to the generators ready to receive feeder connections.

If the makes of instruments and equipment specified are deviated from in proposals, attention shall be called to the substitutions with a full statement of those offered.

INDUCED DRAFT APPARATUS.

There shall be furnished one induced draft outfit with capacity for 2000 H.P. water tube boilers on the basis of 5# of coal per horse power hour. It is proposed to use an underground flue from the boilers to the fans, which flue will be constructed under another contract and to meet the requirements and conditions decided upon.

In the old power plant now in operation, a special 12' wheel 5' in width is in use. Proposals are requested on installing the new apparatus complete with double connection to the underground flue, removing the old apparatus, with such reconstruction as will be necessary to meet the new conditions, and connecting it to the new apparatus in such a manner that either fan may be used at will. A 50' stack of ample size with double up-take fitted with dampers, for connecting to the fans shall be included, thus making the final arrangement embody duplicate apparatus complete in all parts.

The work shall be so handled that the new apparatus may be put in use before the old is disturbed. It is desired to get the best and most compact arrangement possible without obstructing or eliminating more of the window area than necessary.

Proposals shall state fully what is offered, together with a sketch of the outfit, and guaranteed time of completion of the new outfit and the re-arrangement of the old.

BOILER FEED PUMPS.

There shall be furnished and delivered two duplex, outside end packed plunger pumps. They shall be brass fitted and suitable for pumping hot water for boiler feed purposes.

The pumps shall be alike in all particulars. Each pump shall have a capacity of five gallons per cycle of both plungers. The steam pressure will be 150# and the exhaust pressure 5# per square inch. They will be used for feeding the boilers from which the steam is taken.

Companion flanges of suitable strength shall be furnished on suction and discharge connections and with each pump shall be furnished two sets of packing suitable for hot water.

Proposals shall give the following information:

Diameter of cylinders and length of stroke.
Diameter of suction and discharge connections.
Details and arrangement of valves.
Space occupied by one pump.

The material and workmanship on these pumps shall be first class and all parts of ample strength and so designed as to safely meet the requirements. The proposals shall definitely state and fully guarantee these features

CRANE.

There shall be furnished, delivered and erected on runway provided by the purchaser, one twenty ton electric hoist hand travel crane, equipped with trolley and fitted with a direct current motor for hoisting with the necessary devices and facilities for controlling it. Current for the motor will be supplied by the purchaser at 220 to 240 volts. The trolley and bridge travel shall be operated by hand from the floor.

The conditions and requirements under which the crane will operate are as follows:

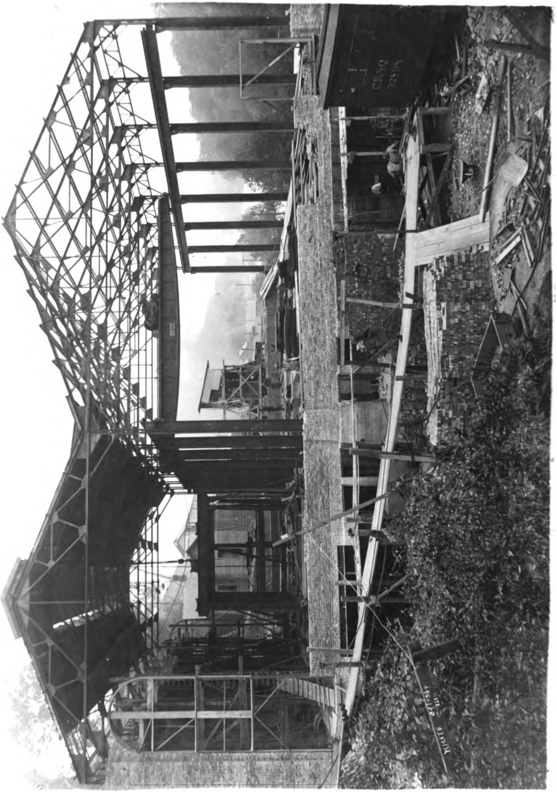
Span, c. to c. runway rails.	54'0"
Distance from floor to top of rails.	27'0"
Distance from top of rail to lowest point of roof trusses.	5'8"
Distance from center of rails to inside of walls.	10"
Distance from inside of walls to intersection of braces with roof trusses.	4'0"
Distance from under side of roof trusses to intersection of braces with walls.	3'0"
Total lift.	24'0"

While giving the essential features it is intended that the crane shall be of standard make and if necessary some details of the building may be modified to that end.

The crane shall be given one coat of paint before leaving the shops of the maker and another coat after erection of such color as may be indicated by the purchaser. Proposals shall embody a full description of the crane offered together with make of motor and such information as may be necessary to indicate its type, speed and capacity.

It is expected that the building in which the crane is to be installed will be ready to receive it about March 1st, and it is desired that the crane be erected immediately following the completion of the building. The power plant will be erected along the C.B. & Q. Ry. with side track to the building.

Proposals shall include price, date of delivery and guarantees on the successful operation of the crane in all particulars.



For the remainder of the apparatus, with the exception of the piping, no specifications were prepared, but a memorandum of requirements was furnished the respective bidders who submitted proposals setting forth the details of construction together with guarantees of performance and efficiency.

After all proposals had been received, the information contained therein was tabulated in form for a comparative study of the various makes of apparatus submitted and the capacities, size of parts, materials of construction, weights and efficiency were carefully considered.

In the case of the boilers, the general design, heating surface, accessibility for cleaning and floor space required were main factors in making a selection. In deciding upon the engines, the matter of general design, size of cylinders, materials used, size of bearings, pins and rods, size and weight of fly-wheel, economy and regulation were of most importance. The most important points in deciding the selection of the generators, were the accessibility to rotating parts, windings, efficiency and heating guarantees.

All of the auxiliary apparatus was considered in the same manner and it may be superfluous to add that in each case the matter of price was of no small importance. Each of the items were weighed in conjunction with the price for which the apparatus was offered and the selection made to the end that the best equipment might be obtained for the least money.

It is difficult to describe the many factors entering into the selection of apparatus so as not to leave the impression that the engineer acts simply in the capacity of a purchasing agent, since the time has passed when he designs all of the apparatus entering into the make-up of a plant. The reputable concerns making standard apparatus cannot, from a practical standpoint, change their designs to suit every whim of the engineer, but at the same time minor features can and often are altered to conform with what he considers to be best for the work in hand. In this particular case, it was found desirable to alter some features of the selected apparatus,such as increasing the size of the engine crank shaft and pin bearings and to substitute a special type of quick opening throttle valve for the one proposed. The windings of the generators were changed to increase the over-load ratings and several minor points in the equipment of the proposed switchboard were altered to improve its efficiency.

The final choice of boilers lay between two makes, namely, the Babcock and Wilcox and the Stirling. These boilers are of quite different types. The Babcock and Wilcox has straight tubes with a hand hole and cover plate opposite each end of each tube which has to be removed when the tubes are cleaned, while the Stirling has tubes bent at the ends and all connected into drums with manholes in the ends. With the former type, if the water is bad and the tubes have to be often cleaned, considerable expense is involved in grinding the seats of the cover plates to make them tight, while with the latter all tubes can be cleaned with a turbine cleaner from the inside of the drums with but three manholes to pack. The Stirling type is a good steamer and in this instance, as is often the case with its lower first cost due to the smaller amount of labor necessary in its construction, there seemed no real reason for paying the additional price necessary to procure the Babcock and Wilcox boiler.

The equipment finally selected for this plant consisted of the following makes and sizes of apparatus:

4 - Stirling Company, 410 H.P. water-tube boilers with
4 - Green Engineering Company chain grates.
2 - Fulton Iron Works, 1100 H.P., 22"x46"x48" heavy, cross compound, condensing Corliss engines.
2 - Western Electric, 800 K.W.D.C. comp. wound generators.
1 - Western Electric, eight panel switchboard.
1 - B.F. Sturtevant Co., 240" three-quarter housed fan direct connected to a 10" x 12" horizontal engine.
1 - Vater, 2400 H.P. heater and purifier.
2 - Fairbanks, Morse Company, 10" x 6" x 10" outside end packed, pot valve, duplex feed pumps.
2 - Hill, 6" x 30" deep well pumps.
2 - Baragwanath, 18" barometric condensers.
2 - Lawrence Machine Company, 8" vertical submerged centrifugal pumps direct connected to 50 H.P. Jenney Electric vertical motors.
2 - Vater, 26" vacuum oil separators.
1 - Whiting, 20 ton electric hoist hand travel crane.

Drawings of the selected apparatus, giving the general outline, with dimensions and the location and details of all connections, were obtained from the builders and the information incorporated into a general layout.

The building which resulted from this had one

working story with a basement and was divided into two main parts, one to contain the boilers and their auxiliaries and the other the power generating equipment. A one story addition, joined to the main building at one end, was provided to house the induced draft apparatus, the condenser pumps with their driving motors and the deep well pumps. The floor of this part and that of the engine room basement were on the same level. The floors of the boiler and engine rooms were placed at an elevation of fifteen feet above the rail of the Burlington tracks. The whole area under the engine room was excavated, while under the boiler room only sufficient space was provided for the cars and the smoke flue. Steel ash hoppers of about seven yards capacity were suspended from the basement ceiling under the boilers and so arranged that there was a clear height of ten feet above the rail.

The condenser heads were located in the engine room about ten feet above the floor with their discharge legs running along a trench in the basement and down the pump shaft into the hot well. The reheaters, oil separators and service pump were located in the basement under the engine room, where also was placed bath and toilet facilities for the plant operators. Most of the live steam and feed water piping was above the main floor while the exhaust connections, blow-off and sewerage were in the basement.

The bottom of the pump shaft was fixed at such an elevation as to insure a submergence of the pumps at low water periods which made it about forty feet below the pump house floor. The hot well, made of steel, was located about half way down the shaft on a ledge formed by a contraction in the size of the shaft. The shaft and the river were connected by a tunnel of sufficient size to permit of a person entering for the purpose of cleaning it out. The overflow from the hot well was carried down the shaft in an iron pipe and thence through tile laid along the side of the tunnel to the river on the down stream side of the intake. As the river water contained a large amount of floating material which might clog the apparatus, a gate house was placed on the river end of the tunnel to control the inlet. This house was divided into two duplicate compartments fitted with gates and screens and connected by a third to the tunnel. By closing the outer and inner gates of one compartment, its screens could be removed for cleaning without shutting off the water supply to the plant. The operating floor was located above the high water so that the inlet would be under control at all times. The shaft, gate house and tunnel were all to be constructed with concrete walls. Owing to the peculiar shifting of the bore for the tunnel during excavation, it was found necessary to abandond the use of concrete in its construction.

When the general layout has been completed and the amount of space required determined, detail plans were prepared for the building, machinery foundations, pump shaft,


WHITE
Oglesby Ill.

tunnel, gate house and piping.

The building was to be constructed of non-combustible materials as far as practicable, keeping in mind the advantage of using cement as an advertising feature. To this end, the building was planned with the lower portion, from the ground to the main floor, of concrete; the walls of brick with the joints left unstruck to receive a cover of rought cement plaster; the main floor of stone concrete reinforced and the roof of cinder concrete reinforced. The roof and crane runway were supported on a steel frame work, leaving the wooden doors, window sash and frames the only combustible in the whole construction.

The lower portion of the building, being in reality its foundations, was massive enough to permit of concrete being economically used in its construction, while the walls above the main floor were so cut up with large openings for windows and doors that the extra cost of the forms for concrete made their construction of brick much cheaper, and when coated with plaster would not only present a pleasing appearance but carry out the cement plan. For floors and roof, nothing would so well meet the requirements as concrete.

The detail designing of the building began at the top or roof. First it must be covered with a waterproof roofing, as the concrete itself would not be impervious and would cause a great amount of annoyance by sweating underneath if not protected on the outside. A thorough canvass of the various materials used for this purpose was made with a view to their durability and first cost with the result that a composition roof made of asphalt, felt and gravel was selected.

The steel work was laid out with a view towards the economical distribution of the material and the detail plans submitted to bidders with the following specifications.

Proposals are requested for furnishing, delivering and erecting all steel work shown on drawing #3, which accompanies and forms a part of this specification. Proposals shall contemplate the execution of the work according to the details and to meet the requirements shown. If the details shown on the plans are deviated from or other sizes of material used, the allowable unit compressive stress is to be $16000 - \frac{70L}{R}$ lbs. per square inch and the tension stress 15000 lbs per square inch, and no metal of less thickness than 1/4" shall be used except for fillers, and no angles less than 2 1/2" x 2" x 1/4". Rivets shall be so spaced and of such size that the shearing stress shall not exceed 10000 lbs. per square inch or the bearing value 20000 lbs.

Field rivets shall be spaced for stresses two-thirds of those allowed for shop rivets and field bolts are to be spaced for stresses two-thirds of those allowed for field rivets.

All steel shall be of such quality as to meet the Manufacturers Standard Specifications for medium structural steel. All riveting is to be well done with the holes true, well filled and the heads well formed concentric with the holes. Where several pieces are brought together they must fit closely and when riveted shall be free from twists, bends or open joints. All surfaces in contact shall be painted before they are put together and before leaving the shop the material shall be thoroughly cleaned of all loose scale and rust and given one coat of pure boiled linseed oil. After erection the work shall be given a coat of Pitkin's Graphite Red Lead or Detroit Superior Graphite paint of such color as may be selected.

The contractor shall furnish at his own expense, all necessary tools, staging and material required for the erection of the work and remove the same when the work is completed. The contractor shall assume all risks from storms or accident until the work is completed and accepted.

In planning the piping layout, safety and economy in operation were the results to be obtained and to this end all of the high pressure steam and water lines were made up with full weight pipe and extra heavy fittings. The pipe and fittings used for the low pressure steam and water were of standard weight, except the exhausts from the condenser relief and heater back pressure valves which were made of spiral riveted galvanized iron pipe and malleable fittings. Each boiler was connected to the twelve inch header with an eight inch goose neck to insure dry steam and a globe valve was placed in each connection at the header. An automatic non-return valve was located on top of the boiler to protect the men when it was being cleaned or in case of accident to it. The connections to the engines, compressor and auxiliary apparatus were taken off the top of the header and each, in additon to the throttle valve, had a globe or angle valve at the header.

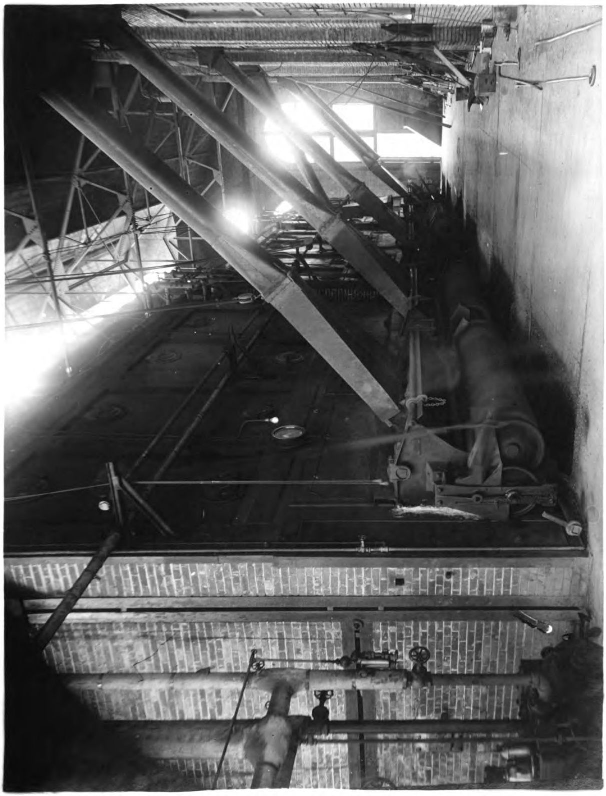
All the header valves six inches and larger were by-passed and the header and all low points in the piping were drained with traps of ample size.

To further insure the reciprocating apparatus against damage from water, large receiver separators were provided for each unit. These also were drained by traps.

All of the piping was laid out, supported and the connections made in such a manner that no undue strains would be caused by expansion.

A fourteen inch discharge line from the centrifugal pumps ran through the basement of the power house and just back of the condenser legs to the storage tanks outside. The condensers were so located that their throats were eight feet above the mean level of the water in the tanks and each was supplied from the pump discharge line by a seven inch connection carried up to the inlet just above the throat. The discharge legs from the condenser were carried down along side of the supply pipes,thence in the trench to the hot well in the pump shaft. At a point below the normal water level in the tanks, a by-pass was connected across from the injection supply pipe to the discharge leg and a valve placed in it and in the supply pipe above the cross connection. This arrangement was adopted in order that the condensers could draw their supply when in full operation and at the same time provide a means for starting them when the engines were put in run. In starting up an engine, the exhaust steam could escape through the relief valve to the atmosphere and the engine run non-condensing. The valve in the supply line being closed, that in the by-pass would be opened and the water flowing down the drop leg would form a partial vacuum which would draw over some exhaust steam. The condensation of this steam would increase the vacuum sufficiently to raise the water in the injection pipe when its valve was opened. After the supply had reached the head of the condenser, the by-pass would be closed forcing all of the water through the head.

The flange joints in the high pressure steam lines and in the connections between engines and condensers were to be made up by screwing the pipe through the flange and peening it in, then facing off the pipe and flange together. All other flanged joints were made in the same manner with the omission of the peening. All piping three inches and above was to have flanged joints, all under that



size to be made up with couplings and unions.

All steam valves except for some of the exhaust lines were to be globe or angle and those in the water lines were to be gate. All flanged valves were to be iron body, bronze fitted and all screwed valves were to be bronze throughout. The valves on the header and those used as throttles on the auxiliary apparatus were to be of the "Crosby" make, the automatic non-return valves "Foster" and the remaining ones "Crane Company". "Jenkins "96" gaskets, which are rubber treated with graphite, were to be used in all live steam and high pressure hot water lines and "Rainbow" (rubber) on the exhaust and low pressure water lines.

The high pressure steam piping was to be covered with H. W. Johns-Manville Company's asbestos sponge felt and the exhaust steam and hot water piping was to be covered with one inch asbestos air cell. A two inch covering of asbestos sponge felt was to be applied to the steam separators and the heater was to be covered with magnesia blocks two inches thick.

In general, the artificial lighting of the plant was to be done with arc lamps, incandescents being used in the basement, car tunnel and around the pumps and fans. A cabinet box was located in the engine room near one of the doors leading to the boiler room and from this box circuits were run in conduits to the motors around the power house and to the lights. Each arc was on an individual circuits while the incandescents were grouped.

Each generator was connected to the switchboard by rubber covered cables, supported from the steel beams on the ceiling of the basement by "Fletcher" porcelain clams in iron frames. The cross section of one cable sufficient to carry the current would be too large for convenient handling, so three cables, 1,250,000 C.M. each, were used for each line, their ends being joined at the generator and switchboard by a specially designed clamp.

The cables for carrying the current to the mill were made up of soft drawn stranded copper wires covered with three closely woven braids of jute, thoroughly impregnated with a high grade of waterproof compound. These cables were strung on wooden supports made up of two - forty-five foot cedar poles, set seven feet apart and connected with four double sets of 6" x 4" yellow pine cross arms, securely bolted and braced to the poles. One and one-half inch oak pins set in tandem were spaced twelve inches apart on the cross arms and each carried a #3 Knowles glass insulator on which the cables rested. The supports were spaced one hundred feet apart and thoroughly braced with stranded galvanized iron guy wires.

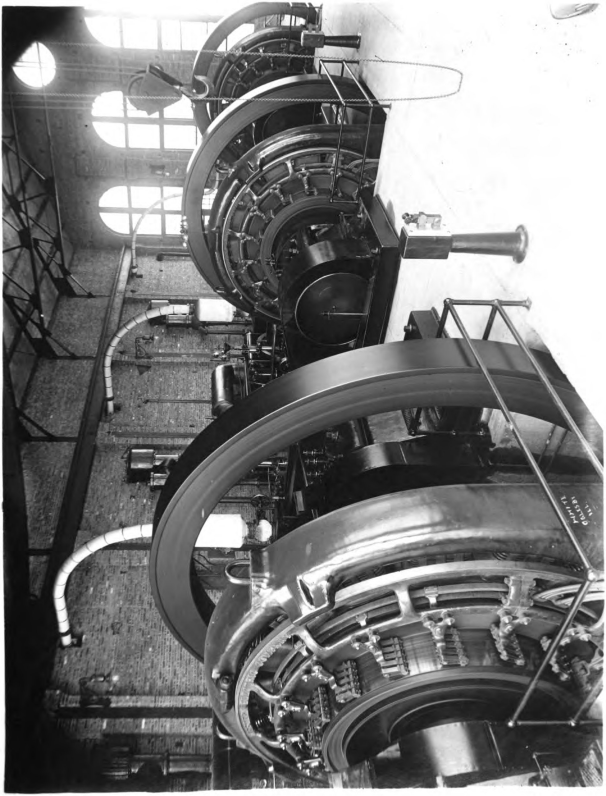
The first installation of cable consisted of four circuits run as follows: To the old switchboard, two 1,250,000 C.M. cables; to the crusher house, two 850,000 C.M. cables; to the raw end one 1,250,000 C.M. cable and to the finishing end, one 850,000 C.M. cable.

It was the intention of the Company to let all work of construction to contractors, but owing to the extremely high figures covering some features, principally the excavation, tunnel and foundations, due no doubt to a large element of uncertainty, and the Company's desire to push the work with all possible speed, they finally decided to carry on as much of the construction as possible themselves.

The site which had been chosen for the building had a very irregular surface covered with trees, underbrush and large boulders. The latter were originally a part of the bluff, but had become loosened by the elements and broken away. To reduce this area to the required level was an arduous task requiring the removal of approximately ten thousand cubic yards of material and to loosen both rock and earth, blasting was resorted to throughout the work of excavation. The material was shoveled into dump cars by laborers and hauled away and deposited on the low ground along the river bank.

The foundations of the building had been designed for a bearing value determined by average conditions, but when the excavation had been completed, it was found that they would have to be redesigned to make allowance for the wide range of soil conditions, which in a width of one hundred feet, varied from a firm hard rock to a black loam.

During the excavation for the building



foundations, work was started on the pump shaft and tunnel, the latter being worked from each end. A working shaft about seven feet square cribbed with plank and timber was sunk near the river just back from the proposed location of the gate house, a hand winch was placed over the opening for hauling up the buckets of excavated material and a pulsometer was used to keep the work free from water. The work at the river progressed much faster than that at the pump shaft owing to the smaller size of the bore and the lesser amount of care necessary in its excavation. As soon as the desired depth had been reached, a drift was started from each end towards the center, the work of excavation being followed by timber shoring. A narrow gauge track was laid on the bottom of the tunnel on which to run a small flat car which was used to carry the buckets between the head of the drift and the hoisting shaft.

In order to prevent undue settling in the surrounding soil, the sinking of the pump shaft had to be done with great care. The excavation was carried down in steps of no greater depth than that which would leave the earth walls standing intact. That much of the concrete wall of the finished shaft was then built and after sufficient time had been allowed for it to set, the forms were removed and another section excavated. In this manner the required depth was reached without disturbing the surrounding soil. The material encountered in the excavation of the shafts and tunnel was principally clay, although a flat ledge of rock was found near the bottom of the pump shaft, which extended some ten or fifteen feet into the tunnel. When it was found necessary to abandon the construction of a concrete tunnel, a 36" cast iron pipe was substituted and owing to the difficulty of handling this heavy pipe in the restricted space if furnished in the usual twelve foot lengths, six foot lengths were procured. These were lowered down the shafts and skidded along the tunnel on rollers into place. All of the joints were leaded and caulked, the 18" tile line for the overflow laid along side, and then the earth backfilling thoroughly tamped around both. When all of the pipe was in place, the shaft at the river was filled up.

Next came the construction of the gate house. In order to build this, it was necessary to keep the water back with a coffer damp which was done by means of a double wall dam of heavy planking, built in the form of a V with the apex pointing out into the river and the two legs running into the bank. The space between the walls was filled and puddled, and earth from the gate house excavation was banked up around the outside.

When the foundations for the building and machinery had been completed, the steel contractor was called upon to start the erection of the building frame work and the floor beams. After these were in place, the crane was

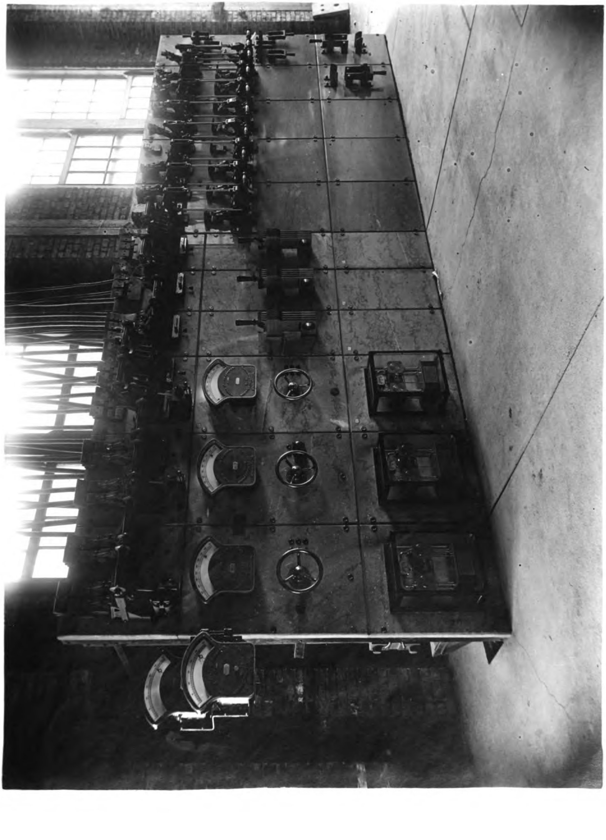
erected and the plant made ready to receive its first installation of machinery.

The supporting frame for the boilers was the first item to be installed, after which the boilers themselves were erected and their brick work carried along with that of the building.

The erection of the engines followed along in the course of a short time, some parts, however, being left until the roof had been completed.

A contract had been made for the concrete floor and roof and the roof was started as soon as the steel work was in place. In designing this roof it was so arranged that the underside would be flat and rest on the top of the purlins, being anchored to them with clips. This made the forming very simple as the planking would extend from the edge of one purlin to that of another and could be supported by joists resting on their lower flanges. Little cutting or nailing being necessary, the forms could be easily and quickly erected or removed. The forms were left on for a couple of days, after which the concrete was sufficiently strong to permit of their removal. The work was carried on in sections and the same forms used several times.

After the engine room had been covered, the generators and switchboard were erected and in the meantime the auxiliary apparatus had been installed. The plant was



now ready for connecting up and the piping, which had already been contracted for and delivered, was put in place. All of the large piping down to and including six inch, was made up with flanges and fittings in the shop where ordered, closing-in pieces being left for final measurements on the job. The cutting and fitting of the smaller sizes and the erection of the whole job was done by the Company's own men under the supervision of a competent foreman, who furnished the necessary tools with his services on a per diem basis.

The connections between the generators and switchboard were made and the power house wired for power and light, this being followed by the construction of the transmission line to the mill.

The sewer from the plant was run across the tracks and down to the river on the down stream side of the gate house and an 8" water line was carried from the fire pump in the basement to the gravity tank on the hill and connections made to the mill and the warehouse on the bluff.

With the finishing touches, such as roof covering, sheet metal work and interior trim finished, the plant was ready to be put in run and the opportunity had arrived for determining whether or not it was a success and would result in the saving expected.

From the start the plant operated without a hitch and in a short time following the completion of the re-arranged mill, it was demonstrated that it could operate economically under an exceedingly heavy overload.

In conclusion, is given the itemized cost of the new plant, the cost of operating it and the old one each for a period of one year and the amount of cement produced in the respective periods.

COST OF PLANT.

Building	$41,692
Gate House, Tunnel and Well	3,575
Boilers and Flue	14,772
Stokers	4,800
Coal Chutes and Ash Hoppers	1,701
Induced Draft Apparatus (old $1,050)	3,897
Deep Well Pumps	641
Boiler Feed Pumps	750
Heater and Purifier	2,950
Engines	25,500
Generators	20,020
Switchboard and Generator Cable	7,550
Condensers	1,000
Centrifugal Pumps and Motors	2,450
Storage Tanks	1,254
Oil Separators	1,100
Piping including cast iron	12,500
Crane	2,750
Pole Line and Lighting	11,029
Trestle	1,000
Miscellaneous moving and erection	4,500
Total Original Installation	$165,431

Adding $41,235, the cost of the third unit including two boilers, one engine and generator with their appurtenances, another centrifugal pump and motor and the necessary piping and cable for connecting them with the first installation, we have a total cost of $206,666, making the cost per horse power $68.89

Below is the operating expense of the old power plant in 1905 and that of the new one in 1907.

OPERATING EXPENSE.

	1905	1907
Labor	$19,700	$14,900
Supplies	298	321
Coal	33,773	38,000
Oil	1,373	1,990
Repairs	12,576	4,560
Total	$67,720	$59,771

Comparing these figures and considering that with the old plant there was produced not to exceed 500,000 barrels of cement per year while the present yearly output is about 1,000,000 barrels it becomes evident that the Company is saving a trifle over six cents per barrel in the cost of power alone.

The above gives ample proof that the building of this plant was warranted and that its location and arrangement were large factors in bringing about the results.