THESIS

CEDAR STREET POWER
STATION

BY

ERNEST D MENKEE

1921

An Investigation of the Cedar Street Power Station, Lansing, Michigan.

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By

Ernest Danola Menkee

Candidate for the Degree of

Bachelor of Science

June, 1921

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Drawings and Illustrations

Foreword-

In the preparation of this thesis, I gratefully acknowledge here my obligations to Supt. O.E. Bulkely of of the Lansing Board of Water and Electric Light Commissioners, who gave me permission to enter the plant and gave me some of the data and drawings; and to Mr. Renz, operating engineer of the plant for his explanations of various plant features, and to Mr. Reed of the Firm of Woodwell and Resler, Consulting Engineers, for the loan of several drawings and permission to get photographs from the firm's negatives.

Object-

The object of this report is to make an investigation of the Cedar Street Power Station in Lansing, Mich., with the idea of the writer obtaining more information, especially, first hand information concerning power stations, their layout, equipment, cost data, and characteristics of operation. This report might be said to be supplementary to the course in Power Plant Design of the Winter Term, namely to find out some of the things studied in the course. The benefit of this thesis will not be so valuable, perhaps to the reader as to the writer himself, who has had the experience of looking over the plant in considerable detail.

The things to be determined in this investigation are as follows:

1. Find out nature and position of equipment-
   a. Type.
   b. Size.
   c. Cost as far as possible.

2. Capacity at which the plant operates.

3. Operating data-
   a. Load curves.

4. Calculations to find out at what loads various machines are operating, and to find out cost of their operation per day.

5. Economic characteristics-
   a. Curves.

Description of the Plant-

General.

The city of Lansing is located in the south central part of the state of Michigan, on the banks of the Grand River, one of the longest and largest rivers in the state. Lansing is the Capitol City of Michigan and also the center of important industries that have developed greatly since the advent of the automobile. The population has been steadily increasing since the beginning of the city until now it contains about 60, 000 inhabitants.

Due to the great growth of the city, the water power available is not sufficient to supply the need of industrial demands, and for that reason recourse was had to steam power.

At the present time there are three main stations in the city for supplying the lighting and power circuits. The street railway systems are supplied from other sources of power. The three stations above mentioned are the Ottawa Street Station, the Cedar Street Station, and the hydro-electric plant back of the property of the Oldsmobile automobile factory.

It will not be the purpose of this report to touch upon facts such as the time of building the plants, reasons for their being built or being enlarged, or reasons for any changes that may have been made from time

to time.

The plant selected for this investigation as has already been stated is the Cedar Street Station. This plant was selected because of the better standardization of equipment as compared to the Ottawa Street Station, and because the general layout of the plant conformed more nearly with modern high grade engineering principles.

The station sets back just a little way from Cedar Street, (south, about one half block from Mich. Ave. E.) and to be exact is on Jay St. It is a very short way from the Grand River to which it is connected by two large intake tunnels for circulating water and by sewers. Thus, by the close proximity of the river, the plant is assured of water for condensing purposes. A siding from the N.Y. Central R.R. permits the coal to be brought directly to the power house. The blue print of the property map shows the holdings of the plant and the relation of the various buildings to each other. The streets of the city are also shown in their proper relation to the plant. As can be readily seen from the blueprint, it shows that the boiler house is parallel to the engine room and to the coal bunkers, and that both are practically parallel to the railroad track.

Coal Storage and Coal Handling-

There are two main coal storage sheds, and the bunker over the boiler room. The capacity of the coal storage is sufficient for about a months run when the plant is running at full capacity. The coal storage shed next to the boiler room is filled by machinery and the other one is filled by hand. We will next describe the manner of filling the coal storage shed in which the coal is handled by machinery.

The coal is delivered, when possible, in bottom dumping cars. After arriving at the plant the car is located over the track hopper, thus permitting the coal, when the bottom of the car is dropped, to fall directly into the track hopper. From the track hopper the coal is taken by a coal feeder to the coal crusher. After being crushed, the coal goes to the elevator and thence to the overhead bunker. The coal is distributed in this overhead bunker by a distributing conveyor. The manner of distribution is as follows: the conveyor scrapes the coal along a shallow metal trough in which there are small holes at regular intervals for the coal to drop through. The coal, as it is scraped along the trough, falls through the first hole in the trough until the bunker underneath is so full that no more coal can fall through. In like manner, the coal falls through the next hole, and so on, until the bunker is filled. Any more coal than is necessary to fill the bunker falls into the coal storage shed underneath the bunker.

There are chutes on the underside of the overhead bunker to let the coal into the coal storage.

As was stated before only one coal storage shed can be filled in this manner.

The coal in this bunker is taken out by means of a reclaiming conveyor. This conveyor is in a passage way

under the coal storage. The coal storage floor has holes in it to permit the coal to drop into the conveyor.

This reclaiming conveyor takes the coal from this storage and delivers it to the elevator, and thence to the overhead bunker. From the foregoing statements it can be seen that the elevator handles some of the coal twice; once coming from the coal crusher; and again, that part of it that goes to the coal storage.

The coal in the other coal storage shed is shoveled directly there from the coal cars. The coal is taken out by hand and not by machinery. It is dumped into the hopper of the elevator, and then taken to the overhead bunker. This coal is used for emergency purposes.

The coal bunkers and coal storage sheds are constructed entirely of brick and concrete except the roof which is of wood and steel

Boiler House----Buildings.

The provisions in the boiler house for getting coal to the boilers are of rather heavy construction and take up considerable space. The overhead coal bunker is made of reinforced concrete and is very heavy. It is of 300 tons capacity. The distributing conveyor is over the bunker as is shown in the accompanying blue print which shows the coal handling machinery, being in the passage way under the roof monitor. The passage way, and in fact all of the coal handling machinery are enclosed as much as possible to keep

Things of interest on the opposite page:--

This picture was taken in the boiler room from the S. end. It shows the fronts of the Murphy stokers very plainly In front of the furnace doors on the floor may be seen the iron cover to the ash pit. Over in the far left of the picture may be seen a man who is standing near the weighing larry. Above may be seen the I beams that the hand operated ool buckets run on.

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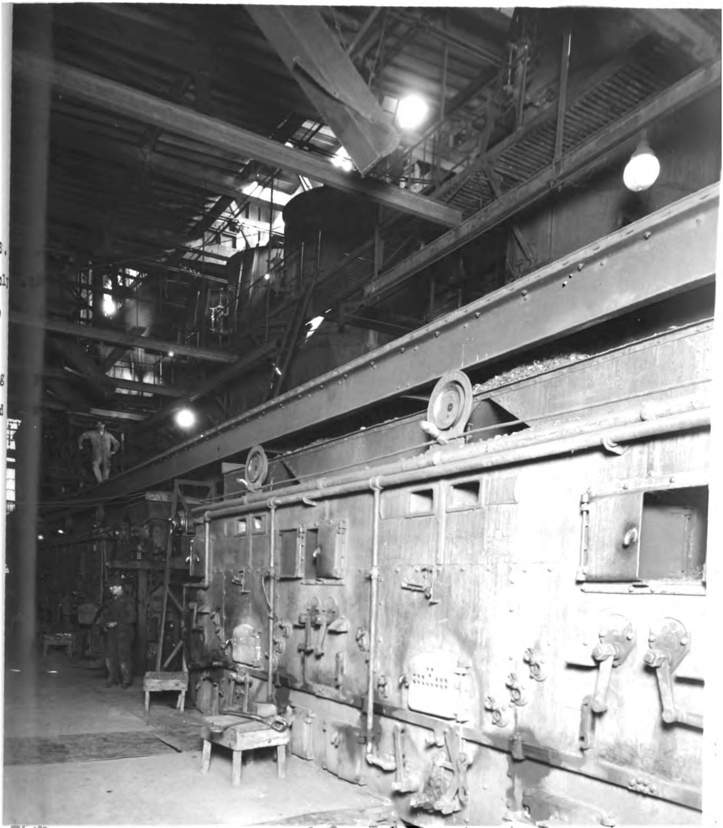


the coal dust from getting into the boiler room. Chutes run from the overhead bunker into the boiler room. As can be seen from the blue prints, there is a small track on top of the stoker settings for the 1 ton weighing larry to run on.

The boiler house itself is of the usual construction, being of brick, concrete and steel work, the steel being used in places where greater strength is needed. The roof is supported by both steel and wood trusses, the wooden being in that part of the plant which was first constructed.

Boiler House----Boilers

In the boiler house are six 400 h.p. Wickes vertical water tube boilers, and two 740 h.p. Sterling water tube boilers. The room is approximately of an area 55ft.x 125ft. and equal to 6875 sq. ft. The boilers have a maximum output of steam, if all boilers are running at 200% rated capacity, of 116,000# per hour. The weight of steam produced per sq. ft. of boiler room floor area equals about 17#. This is just about one half of the amount that was produced per sq. ft. of floor area per hour according to the first layout at the Markische Electricity Works, but it must be remembered that this plant is an exceptionally well designed plant, and for that reason the comparison probably is not of much value.

The Wickes boilers are encased in metal sheeting to prevent air infiltration. The Sterling boilers are bricked in and their tops are completely covered with heat insulating material. Only one front is used for the two boilers.

The Wickes boilers use natural draft and the Sterling boilers use forced draft. The forced draft used is equal to about 3" of water. 0.2" draft is used over the fire beds and about 0.6" is used in the back breeching. The chimneys are are large size, one being 9'x 200' and of radial brick construction, and the other 9'x 187'-6"and of reinforced concrete.

For the pressure or forced draft system on the Sterling boilers, there are two pressure fans in the basement,one of which is electrically operated,and the other by a steam engine. The fan operated by the steam engine is a Sirocco fan of about 28" dia. and the other is and ordinary blowing fan of about 30" dia.

The ash from the furnace of the Sterling boilers is handled and disposed of by letting it drop into a pit under the boiler, this pit being on the level of the basement floor. From this pit it is hoed into the opening of the ash conveying system, the system being of the air suction type. It then goes to the ash bin outside of the plant.

The ash from the Wickes boilers is raked,in the same manner as in the previous explanation, from a pit which is under the furnace setting, the pit being about 1/2 foot below the level of the boiler room floor. The ashes are then conveyed to the ash collector.

The gases from the Wickes boilers enter the chimney at an average temperature of less than 400 degrees F. and from the Sterling boilers at a temperature a little less than 500 degrees F. A recording thermometer is installed for recording the temperature of the stack gases coming from the Wickes boilers.

The feed water temperature, due to the abundance of exhaust steam from the feed water pumps and other auxilliary apparatus, especially, when the plant is running at full capacity, is close to 212 degrees F. The condensate water and make-up water are heated in two open feed water heaters. A Hoppes feed water measuring weir is in the circuit, but at the time of writing this is not in operation.

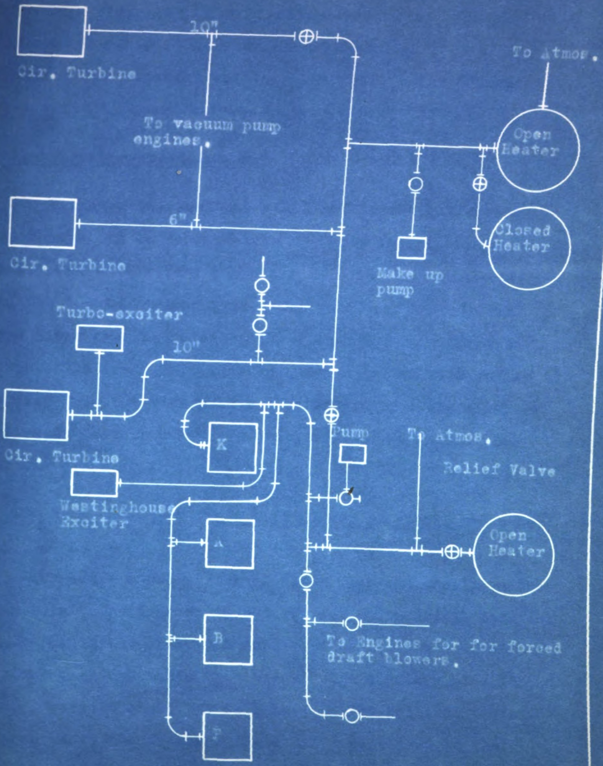
All of the boilers have the S-C feed water regulator for maintaining the proper water level in the boilers. They can be set so that water level can vary from 2 to 8 inches before acting. The feed water pumps also have governors for maintaining the proper pressure in the feed mains. The latter are the Fisher Feed pump governors. In case that the water regulators should not work for some reason or other, there are whistles on the boilers to show high and low water.

Boiler Room----Stokers

Stokers are used for firing the boiler furnaces of which there are two types in the equipment. The Wickes

EXHAUST STEAM PIPING --- CEDAR STREET STATION

DIAGRAMATIC PLAN



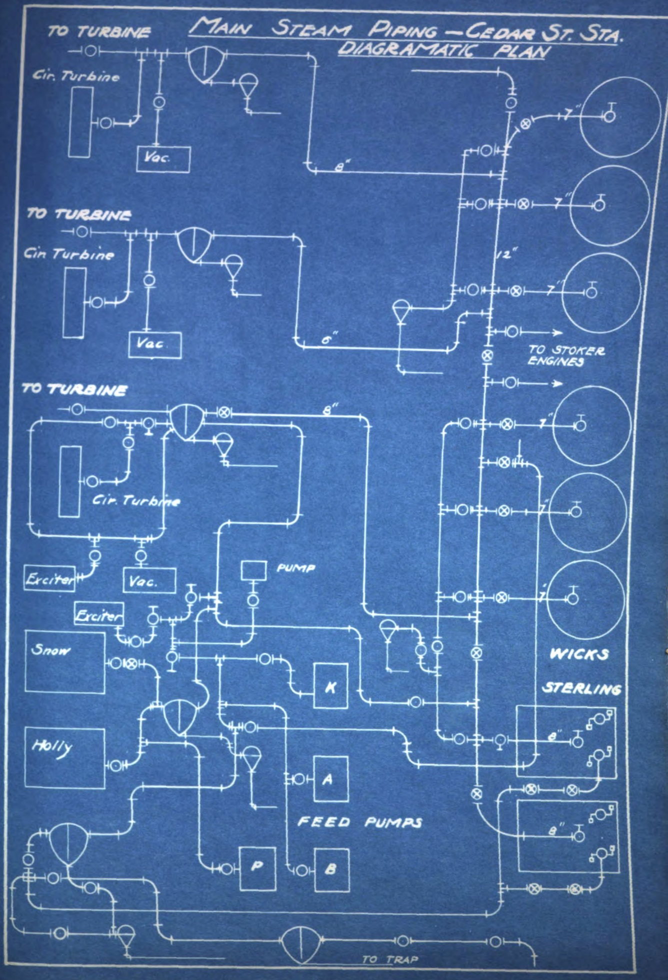
boilers have Murphy stokers in dutch oven settings, and operated by either a steam engine or electric motor at the operators pleasure. The Sterling boilers are equipped with Taylor underfeed stokers which are operated from a line shaft on the basement ceiling, the shaft being connected to a variable speed motor.

Boiler House----Feed Pumps

Although the feed pumps are not in the boiler room it was thought to be best to take up their description at this time. The boiler feed pumps are of both the reciprocating and the turbine driven type. The water pressure in the feed lines are regulated by the Fisher governor for feed pumps. The feed pumps take up quite a lot of room as may be seen from the blue prints. Three pumps, among which is included the turbine driven pump, are in the engine room and the other is in the basement.

Boiler House----Steam pipes, auxilliary pipework, and water supply.

The main steam piping is shown diagramatically on the blue print. The drawing is not correct as to actual location of the parts,but shows the manner of connecting in the various machines. The main steam range consists of a 12" header carried along the wall back of the boilers. It is connected to the Wickes boilers by 7" pipes and to the Sterling boilers by 8" pipes. The pipes going to the main units are either 6" or 8". Steam separators are in all the main steam line connecting in the various units. There is


MAIN STEAM PIPING — CEDAR ST. STA.
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E.D. MENKEE

no cross connecting of the steam mains to form a complete loop.

The main steam piping is of steel, and is fitted with both the gate and globe valves. There are no devices to show when the valves are open although there ought to be, because some of the valves are not readily accessible.

There is one expansion joint in one of the large pipes leading to the basement. The fixed point is on an elbow in the basement.

The main steam piping and the feed water piping are lagged with a heat insulating compaund that is about 1 1/2" thick.

The exhaust steam piping is as shown in the accompanying blue print. The main lines are of 10" dia. The operating engineer of the plant declares that even with exhaust pipes of this size, there is considerable back pressure in the piping, especially, when the plant is running with full load. The exhaust steam piping leads to the feed water heaters.

The feed water and condensate piping is connected in as shown in the blue print. The condensate piping is mostly of cast iron although there is some steel pipe used. When the plant is in full operation, water does not go thru the feed water heaters fast enough to supply the boilers, so a by-pass is connected in to let the water go directly thru the water meter. There is also a roof tank from which feed water may be obtained. The water in the roof tank comes from the condensing apparatus and from the steam traps. The water from this tank is used either for feed water or for the water seal on the bearings of the Allis-Chalmers turbines. Feed water may be obtained from the city mains in an emergency.

The condensate piping is not lagged due to the low temperature of the water in the pipes. As before stated, feed water pipes are well lagged. The feed water pipes are of steel in order to stand the high pressure of the water inside of them(180#/sq. in.). The pipes are in duplicate as far as possible to guard against breakdowns. The pipes vary in diameter considerably. The pipes that connect into the boilers are 2 1/2". The main feed water pipes are 3 1/2" and 4 1/2".

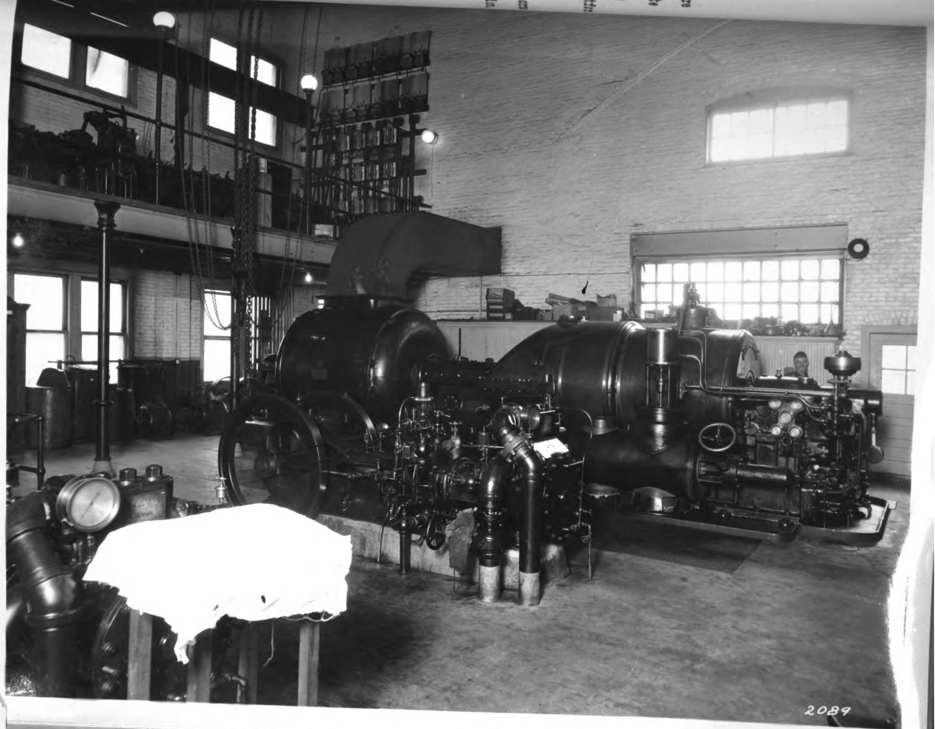
There is a small make-up pump used to supply the water loss. The water is quite hard; so a water softening compound is pumped into the feed water system twice a day by means of a small pump.

The intake and discharge pipes are shown in the property map of the plant. The main intake pipe is of 24" diameter. There is also another smaller one. These two pipes supply the condensing water. The outlet pipe is of cast iron, 18" in diameter. There is also a 10" tile sewer.

One of the feed water heaters is placed on top of the semi- underground flue from the Wickes boilers, and the other is hung from the roof trusses. The water measuring device is with the latter. To get the water from the lower feed water heater to the upper, a small pump is used. From

Things of interest on the opposite page:--

This is a picture looking to the south. In it are shown the reciprocating dry vacuum pump in the immediate foreground and the 2000 K.W. Allis-Chalmers unit in the background. Over on the left the raised switchboard platform may be seen. On the platform may be seen some of the constant current transformers. On the wall over in the corner may be seen some of the equipment for lightning protection.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Things of interest on the opposite page;--

This picture shows the engine room when looking from the south. In the immediate foreground is shown the 1000 K.W. Allis-Chalmers unit. Over in the background may be seen the fly-wheels of the pumping engines. This picture shows the switchboard to good advantage. The switches on the far end are the power switches and those on the near end are for the lighting circuits. One motor generator set is shown under the platform. The crane track is seen to be just over the top of the switchboard.

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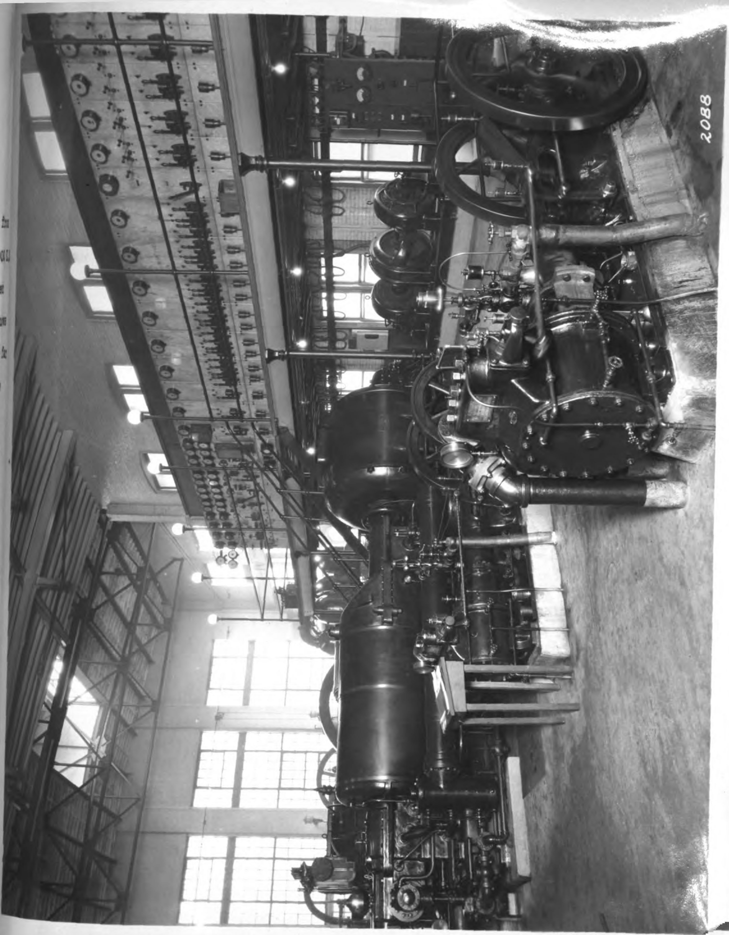

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the measuring tank the feed water flows under a positive head to the feed water pumps. The piping is neither in as good shape as it could be, nor is it laid out as well as it could be if there was more room.

The piping, considering the plant as a whole, is not in very good shape. This is probably due to the fact that there has been so many changes and alterations in the plant. The plant is not laid out on generous enough principles, and due to the lack of room the piping suffers for lack of space to put it in right.

Engine Room--

The dimensions of the engine rooms considering the space that the steam turbines occupy are: length 80' and breadth 42'; height of roof 34'; height of basement 12'.

Engine Room----Steam Turbines

Steam is supplied to the steam turbines at a pressure of 150#/ sq.in. and is saturated. The units installed are one 2000 K.W. Allis-Chalmers, one 1000 K.W. Allis-Chalmers, and one General Electric-Curtis unit of 2000 K.W. capacity. The machines are standard units of their respective manufactures and need not to be further described here.

Engine Room----Condensers-

The condensers are located immediately below the steam turbines and they rest on large concrete blocks. The circulating and condensate pumps which are driven by a small steam turbine are along the side of the condenser in

Things of interest on the opposite page;-

This is a picture of the plant looking at it from the southeast and shows what might be called the back yard. The picture shows the ash collector just to the left of the chimney in the center. In the foreground are the transformers used to connect the plant with the others that it is interconnected with. The smoke flue from the Wickes boilers may also be seen running along the side of the building to the center chimney. The picture also gives a general idea of the appearance of the building.


2083

a shallow pit made in the floor. The condenser and auxiliary pumping equipment are of Alberger make. The condensing plant does not take up very much room. Each turbine has its own condensing equipment. There are some openings in the floor of the engine room around each turbine for the purpose of inspecting the condensing apparatus or moving parts of it by means of the crane.

The condenser itself is of the surface type, and for a 2000 K.W. unit contains 6000 sq. ft. of surface for cooling. A small turbine drives the circulating and condensate pump, all being on the same shaft. There is also a reciprocating vacuum pump attached to each condenser for exhausting air out of it , and thus bettering the vacuum. The condenser and its auxiliary apparatus are in the basement of the plant, while the main units are on the ground floor.

The circulating water is pumped from a well in the basement floor that connect with the river, and is discharged into the sewer. The condensate water goes to the feed water heaters and to the roof tank.

Engine Room----Generators

The main generators supply 3 ϕ alternating current at a pressure of twenty three hundred volts, and this is voltage is regulated by means of a Tirril regulator. These generators are of standard contruction, regular types as manufactured by the respective companies.

The cables from the generators run to the switchboard in conduits.

The air required for cooling the generators comes in through openings in the foundation walls of the building. The air comes in on the under side of the machines and leaves on the top side.

The switchs and meters for the various units are on the main switchboard in full view of the operator.

Engine Room----Building Details

The building is of ordinary construction and design. The plant has been altered three or more times; so there is some variation in the architecture of the building. The building is faced with red brick,and in the new part with both red brick and while tile. The roof of the new part is held up by rigid steel trusses while the old part has wooden trusses reinforced by steel rods. The engine house walls are built of solid brick, but in the boiler room there are some steel columns in with the brick and concrete. Both engine and boiler rooms have skylights; however the boiler room is rather dark even on a light day. The engine room has a large number of windows to give the necessary light. The wallsof the engine room are painted a light color.

The switching gear is in the engine room, being on a platform raised about 10' off the floor level and reached by a steel stairway.

There are two stairways in the engine room leading to the basement, and another two stairs leading from the engine room to the boiler room. These last mentioned steps are necessary because the level of the boiler room floor is a little lower than the engine room floor.

One of the photographs shows the general appearance of the plant looking at it from the southeast. It is not a very good picture due to the fact that it is hard to find a place where where a good photograph can be taken.

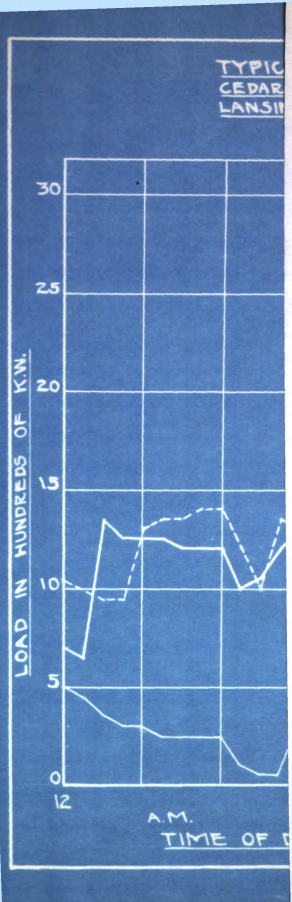
Engine Room----Electrical Apparatus

As mentioned above, the switching gear is on a raised platform in the engine room. For the main power circuits there are 10 marble panel switchboards, and for the street lighting circuits there are 17 marble switchboards. All the marble panels are arranged in a straight row. All of switches are of the oil type. There are two main types of circuits, lighting, and power. The main lighting circuit is for street lighting.

There are 7 constant current transformers for street lighting.

The electrical sw.-gear is of various makes and types and will be taken up in more detail in another part of this thesis.

To measure the current output, there are two totalizing watt hour meters, one on the main bus bar, and the other on line connecting this station in with the other stations. The management of the plant is going to install more meters in order to get a check on the present meters. At the time of writing this thesis the management of the plant was very eager to have more meters installed, because then they could determine more accurately what the various units were doing when loaded, and how much current was generated.



how the load varies. It is ...

peak in the morning and in the evening.

Engine Room----Pumping Equipment-

This plant contains both the electrical machinery and pumps for the city water supply. That part of the blue-print, marked"Water Pumping Machinery", is where the pumps are located. The pumping machinery consists of one Snow 10,000,000 gallon or 41,000,000 ft. lb. duty pump of the horizontal compound type; one 4,000,000 gallon Alberger centrifugal pump; one old Holly horizontal steam pump that is used no more, because of small capacity. There is also a deep well pump of 12" size made by the American Well Works of Aurora, Ill.

In preparing this report not so much attention was paid to the pumping equipment of the plant, for the purpose of this work was to investigate more particularly the power equipment of the station,such as boilers and electrical machinery.

Operating Data----General

Conditions of Operation

Due to the unsettled conditions at the present time the plant is not running at its full capacity. This is caused by the present business depression that causes some of Lansing's largest plants to run only part time, thus not requiring so much power. The blue print showing the load curves of three typical days gives the reader an idea of how the load varies. It is readily seen that there is a peak in the morning and in the evening.

The peak in the morning is due to the factory load and the one in the evening is due to the residential lights and street lights. The blue print shows that the evening peak is nearly constant for the different days shown on the curve.

The maximum peak is about 3100--3200 k.w. The full rated capacity of the plant is 5000 k.w. The operators at the plant said that peaks as high as 6300 k.w. have been successfully carried at times during the years of the war.

Due to the fact that this is a municipal lighting plant, not as good records are available as could be wished for. There are no records of water consumption, for the measuring device is not in running order. There are no steam meters to measure the steam flow to the various machines. No tests have been carried out lately to see if the steam consumption of the various machines still agree with their respective manufacturers guarantee. Owing to the low rating at which the plant is running at the present time it would be difficult to make satisfactory tests of the plant as a whole.

There are several recording meters such as a flue gas temperature meter, steam pressure meter, and one or on the switchboards.

Because of the pumping engines being on the same boilers with the electrical machines, it is a little more difficult problem to find out the exact cost of the electrical energy. The way this is taken care of is to allocate a certain amount for the cost of running the pump per week and charge it to the Water Works Dep't. This is shown in the following list showing the weekly station charges for a certain week.

Weekly Station Charges----Specimen of a Weekly Report

Cedar Street Station

Cost per K.W.Hr. for week ending April 15, 1921.

Coal---588.9 tons at $5.30		$3121.00
Oil, waste, and packing		20.00
Supplies & Miscellaneous		200.00
Labor:-		
Supervision	$125.-	
Repairs	400.-	
Firemen	124.-	
Firemens Helpers	116.-	
Ash Handling	218.-	
Coal Handling	78.-	
Operators	230.-	
Miscellaneous	50.-	1341.00
Total cost		4682.00
To Water Dep't.(Snow Pump)		50.00
Net Cost		4632.00

Total K.W.Hrs. generated	314,000
Station cost per K.W.Hr.	$0.0147
Use factor	37.4%

By use factor is meant the ratio of the number of K.W.Hrs that are actually generated in a given length of time to the number that the plant could generated if running at rated capacity. From the above data it is seen for the week endingApril 15, 1921 that the plant only generated one third of the power that it was able to generate.

Following are two monthly analyses of the Cedar Street station. One is for December 1920 and the other forMarch 1921. They are given on the next page.

Analysis of Operating Expenses----Monthly

For December 1920 and March 1921.

	Dec.1920	March 1921
Superintendance	$275.00	
Labor-Boiler	3230.-	$2589.99
Labor-Engine	612.50	613.-
Labor-Miscellaneous	467.10	830.97
Fuel	34,443.97	17,264.23
Lubricants	85.28	46.01
Supplies	773.76	136.24
Re-sale Supplies		
Distribution		
Supplies	22.23	8.84
Inspection	153.50	150.-
Setting and removing Transformers		578.92
Maintenance		
Ash		224.54
Repairs to Conductors & Pole Lines	1255.08	1349.04
Electrical Machinery	141.13	1869.75
Service and Meters	197.70	69.01
Transformers	68.75	4.79
Buildings and Grounds	234.16	110.47
Boilers	887.59	1102.40
Coal Handling Equipment	786.12	45.62
Stokers	659.30	776.42
Transportation Equipment	721.75	661.41
Injuries and Damages	5.-	
Street Lighting System	1823.70	767.77
Boulevard Lighting System	491.18	126.97
Furnaces		1738.57
Administrative		
Executive Salaries	342.22	923.32
Clerical Salaries	1940.87	2588.97
Office Expense	69.53	139.56
Stationary and Printing	93.29	150.53
Telephones and Telegraph	14.40	74.82
Interest on Funded Debt	1468.75	1468.75
Insurance	131.92	131.92
Uncollectable Bills	35.81	26.19
Depreciation	4359.94	3945.53
Postage	53.48	
Total	$56242.03	$40826.56

Following are the K.W.Hrs. output of several months including the two months given in the analyses. This table shows the amount of coal burned per month and its cost, besides the cost per K.W.Hr.

Cedar Street Station

K.W.Hrs. generated per mo.	Month	Coal burned in tons and cost.	Total Cost of coal.	Total cost per mo.	Cost per K.W.Hr.
2,084,000	Nov. 1920	4658 at $8.55	$54,000	$65,693.30	$0.0315
2,083,000	Dec. 1920	4550 at $7.30	$33,200	$56,242.03	$0.0259
1,671,000	Jan. 1921	3603 at $6.30	$22,100	$44,867.51	$0.0268
1,674,000	Feb. 1921	3633 at $5.60	$20,350	$42,697.76	$0.0255
1,471,000	March 1921	4545 at $5.30	$24,100	$40,836.56	$0.0277

The following data gives the manner in which the boilers are banked for the loads carried on April 14th and 15th. The boilers are numbered from 1-8 beginning from the south end.

April 15,1921.

#2 Banked from 11:00 A.M.-6:00 P.M.

#4 Banked from 12:00 A.M.-6:00 A.M.

Banked from 11:30 A.M.-12:00 P.M.

Continued from preceding pg.

#6	Banked from 12:00 A.M.- 6:00 A.M.	
	Banked from 8:00 A.M.- 9:30 A.M.	
	Banked from 10:00 P.M.- 12:00 P.M.	

April 14,1921.

#2	Banked from 12:00 Noon- 8:00 P.M.
#3	Banked from 10:00 A.M.- 11:15 A.M.
#4	Banked from 12:00 A.M.- 6:00 A.M.
	Banked from 11:15 A.M.- 12:45 P.M.
	Banked from 5:00 P.M.- 6:00 A.M.
#5	Banked from 12:00 A.M.- 6:00 A.M.
#6	Banked from 11:30 A.M.- 7:00 P.M.
	Banked from 10:00 P.M.- 12:00 Mid.N.

The following data gives the number of men employed around the plant and their pay. From the data it is seen that the men working in the plant receive good pay. Working conditions are good so there is not much complaining on the part of the men employed. At the time of writing this, the plant management was thinking of giving a cut in pay. This is the pay the men received before their cut.

Men Employed in Plant and Their Pay

1-Boiler washer at	$140.00 per mo.
4-Firemen at	$165.00 per mo.
2-Firemen (six days a week) at	$155.00 per mo.
1-Coal Unloader at	$155.00 per mo.
1-Engine Room Sweeper at	$150.00 per mo.
1-Operating Engineer at	$275.00 per mo.

1-Assistant Operating Engineer at $200.00 per mo.

3-Operators at $175.00 per mo.

1-Operator(Spare) at $ 87.50 per mo.

7-Ash Handlers at $0.65 per hr.-8 hrs per day and 7days per week.

2-Repairmen at$0.85 per hr.-8 hr day.

1-Repairman at$0.80 per hr.-8 hr day.

6-Repairmen at$0.65 per hr.-8 hr day.

31 men are employed in the plant. The repairmen handle coal wheneve necessary.

One half of the time of the spare operator is charged to the Water Works Dep't.

There are two machinist and a blacksmith and their time is charged to whichever dep't. they happen to work for.

It is seen that the men are mostly well paid when in most cases the day is only 8 hrs.

The amount of coal, oil, and waste used per day is hard to determine. The amount of coal used per day depends on the heating value of the coal. Some of the coal was bought a long time ago when poor coalflooded the market. At the present time with a maximum peak load of about 3000 K.W., the coal consumed per day amounts to 85 tons per day. The coal bunkers hold about 4000 tons of coal; so it is seen that the plant can run better than a month on the reserve supply of coal.

Turbines do not use much oil; so the oil used is not much of an item of expense. Sometimes the oil in the turbines is changed once in several years. The pumps use most of the oil consumed. The oil used amounts to about 4or 5 bbls. per ~~week~~ month.

The plant uses rags instead of waste. No exact figures were obtained for the amount used per day.

The water costs nothing except for the coal used to make the steam for the pump.

Operating Factors----Definitions

There are several fundamental terms used in power plant work to show efficiency of the plant in operation. They are as follows:

1. Total Connections equals capacity of all plants supplied with energy from a power station.

2. Hours of full use of power station equals ratio of K.W.-hours per annum supplied to feeders to peak load of power station in K.W.

3. Load factor referred to power station equals ratio of K.W.hours per annum generated to highest peak load of power station in K.W. x 8760 equals ratio of average load generated, to peak load of power station.

4. Load factor referred to consumer.

a. Ratio of K.W. hours sold per annum, to peak load on feeder x 8760 equals ratio of average load sold to peak load on feeder.

b. Ratio of K.W.hours sold per annum, to consumers' installed capacity x 8760 equals ratio of average load sold, to consumers' installed capacity.

5. Diversity factor equals ratio of peak load on

feeders to sum of consumers' or group of consumers' maximum demands.

6. Utility factor of power station equals ratio of K.W.hours generated per, to capacity of plant installed in power station x 8760 equals ratio of average load generated to installed capacity.

The utility factor is determined by the load factor and the available standby plant. It is reduced each time an extension is made, and will become equal to the load factor when the whole of the installed plant is made use of and no spare plant is left.

7. Running factor equals ratio of sum of hours per annum during which the plant was running, to the possible maximum; the latter is obtained by multiplying the number of sets installed by 8760.

Owing to lack of sufficient data we will make use of only two of the above factors and in the following we will show their application.

We will figure out the load factor and the utility factor for each day represented by the load curves on the blue print sheet. The days represented are Saturday, April23,1921; Sunday, April, 24, 1921; Wednesday, April, 27, 1921. The terms having been already defined it is nothing but a matter of arithmetic to get the desired results and they are tabulated below. The results were obtained by dividing the average load of the day in question by the maximum half hour peak.

Utility and Use Factors

Day	Load Factor-%	Utility Factor-%
Wed.,April 15, 1921	67	39.15
Sat.,April 23, 1921	70.8	28.35
Sun.,April 24, 1921	50	15
Wed.,April 27, 1921	58.2	36.7

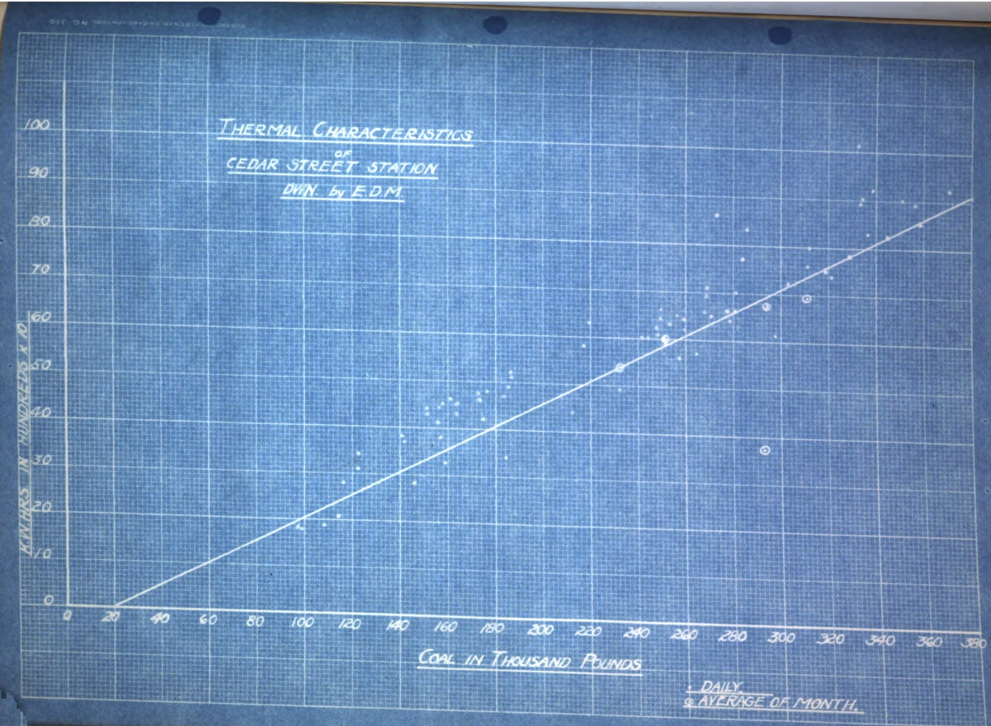
In the paragraph preceding the tabulated data the method of obtaining the load factor was described. To get the utility factors, the daily station output in K.W.Hrs was divided by the station's rated capacity in K.W. x 24.

It is seen from the above data that considering only a short space of time that the load factor is good, but that the utility factor is poor, being only about 33%. This means that a smaller return is being made on the investment than could be made, for the higher the utility factor the cheaper power can be generated. To get very accurate factors, the average should cover a long period of time. In this case it was impossible.

Characteristics----Thermal

The greater part of the thermal characteristics represents fuel consumption. To show the relation of fuel consumption to current output, the thermal characteristic curve is drawn, and from this the relation may be ascertained. To what extent the coal consumption depends on the utility factor may also be shown on the above mentioned curve.

The curve representing the thermal characteristic moves along a straight line. This curve cuts the abcissa


THERMAL CHARACTERISTICS
OF
CEDAR STREET STATION
DWN. by E.D.M.
K.W.HRS. IN HUNDREDS x 10
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
COAL IN THOUSAND POUNDS
. DAILY.
⊙ AVERAGE OF MONTH.

at a point that represents the coal consumption necessary to supply the constant losses.

The thermal characteristic plotted on the blue print gives the reader an idea as to the thermal characteristics of this plant. It was plotted from data taken over a long time, and in this data I tried to get the largest and also the smallest fuel consumption per day that was possible to get. I was disappointed in not finding a day with smaller coal consumption. The reason for so many of the points being so far away from the curve is because of the great variation of fuel used. Probably the pumping equipment also has something to do with it. The small dots represent daily coal consumption and the dots with a circle around them are the average for the month. It was rather hard to determine just where the line should be drawn. If the points could have been obtained where the curve crosses the abcissa it would have been an easy matter.

From the curve of coal consumption the following table was determined. The heat consumption in B.T.U. may be found by multiplying the proper values in the table by the heating value of the fuel in B.T.U.

Utility Factor n	Coal Consumption per K.W.Hr.
0.1	5.16
0.2	4.75
0.3	4.47
0.4	4.37
0.5	4.30
0.6	4.25
0.7	4.22

The values in the above table show that as the utility factor increases the coal consumed per K.W.Hr. increases. The values obtained seem to be a good average for a power plant of the average type. On some days the coal consumed per K.W.Hr. will be less than the above, but on other it will be more, all depending on the nature of the fuel.

Comparing the above values obtained with some mentioned in the book "Engineering of Power Plants" by Fernald and Orrok, we find the following: That 5# of coal per K.W.Hr. with low load factor is good. Good practice is 2# and 3# of coal per K.W.Hr., and very few reported are under 2# per K.W.Hr.

Economis Characteristics

Similarly, the expenses for oil, waste, etc., and up to a certain point, the staff expenses are dependent on the load on the station. A portion of the repair costs are likewise constant and independent of the load, the remaining part being proportional to the latter. The total cash payments can thus be separated into a constant part and a part proportional to the load, and, therefore, to the hours of full use or the load factor.

The indirect expenses consist of the amount allowed for depreciation of the plant and the sum required for providing the interest and amortization of the capital expenditure.

The amounts to be written off are as a rule definitely determined in advance according to the probable life of the

different part of the plant.

The economic characteristics of the power station can be obtained from the monthly working accounts of the station. Certain values will of course vary to a certain extent according towhether large sums for taxes, repairs, etc., happen to have been paid out during any month. The extraordinary amounts should be distributed thruout the year.

In figuring out the curve interest and amounts put into the reserve fund are not taken into account.

To plot the curve for determining the daily working costs, the generating costs are plotted on the X axis and the load in K.W.Hrs. on the Y axis. To do this the daily cost over a long period should be calculated, but in this example only two or three points were determined in order to get the slope of the line. To do this the following figure must be computed.

The daily fixed charges are found from the two monthly analyses, for March 1921 and December 1920. For December 1920 the fixed charges less the reserve fund and interest are $7039.46 and for March 1921 are $7980.84. The average amount for the two months is $7510.15. The fixed charges per day is equal to 1/31 of the above amount or $242 per day. To the fixed charges must be added the station charges which amounts to more than the fixed charges. The station charges are made up of money paid out for supervision, fuel, oils, waste, labor, supplies, etc.

For this problem we will assume the following figures.

Coal at $5.30 per ton.

Oil, waste, and packing at $3.00 per day.

Supplies and Miscellaneous at $30.00 per day.

Labor, repairs, and miscellaneous at $192.00 per day.

From the above figures it will be seen that the coal and labor make up the bigest items of daily expense. The item for labor will remain constant within certain limits of power output. The daily costs will vary more or less in accordance with the amount of coal burned per day.

We will figure out the daily working costs for several days considering that the costs of daily operation vary with the amount of coal consumed.

April 15, 1921.

Fuel 87.85 tons at $5.30 per ton	$465.-
Oil, waste, and packing	3.-
Supplies and Miscellaneous	30.-
Labor, supervision, etc.	192.-
	690.-
Less $7 for Snow Pump	7.-
Station charges for the day	683.-
Fixed Charges for one day	242.-
Total Charges for the day	925.-
K.W.Hrs. 47,000	

April 27, 1921

Fuel 82.25 tons at $5.30 per ton	$436.-
Oil, waste, and packing	3.-
Supplies and Miscellaneous	30.-
Labor, Supervision, etc.	192.-
	661.-
Less $7 for Snow Pump	7.-
Station charges for the day	654.-
Fixed Charges for one day	242.-
Total Charges for the day	896.-
K.W.Hr. 44,000	

April 23, 1921

Fuel 61.15 tons at $5.30 per ton	$324.-
Oil, waste, and packing	3.-
Supplies and Miscellaneous	30.-
Labor, supervision, etc.	192.-
	549.-
Less $7 for Snow Pump	7.-
Station charges for the day	542.-
Fixed Charges for one day	242.-
Total Charges of the day	784.-
K.W.Hrs. 34,000	

In plotting the daily load curve, time is plotted along the X axis and K.W. load on the Y axis. The corresponding K.W.Hrs. per day at the various loads is also plotted on the Y axis. The unit of cost as figured out above is laid out along the X axis to the left. Having plotted the dalily load curve, it is transferred to the fourth quadrant as is shown by the dotted lines on the blue print. The new curve is the cost curve, and from it the hourly working cost at any hour of the day may be found, or both the variable and fixed costs per hour. The costs per hour are also plotted on the Y axis. The cost per K.W.Hr. could also be plotted there if desired.

The area under the curve represents cost of operation and its area is equal to the cost of operation for the day whose load curve is plotted in the first quadrant. The curve as plotted represents the load curve for April 15, 1921. The area under the curve was measured as nearly as possible with a planimeter to check on the accuracy of the work. Not knowing how the load curve varies from reading to reading, it is not to be expected that the area will exactly represent the cost of operation of the day in question.

By scaling the curve it was found that 1sq. in. of area equals $15.40. The total area under the curve equals approximately 59 sq.in. Therefore. the total daily working cost from the curve is equal to 59x $15.4o or $910.00. The cost of operation for the day whose curve is plotted as figured out before was $925.00. This is an error or 1.62%.

The purpose of the daily cost curve is for finding the cost of producing power at different times of the day when supplying different loads. Thus we will investigate the cost of power at two different loads to find difference in cost per K.W.Hr. Suppose that we take the 1100 K.W. load and the 2900 K.W. load. According to the curves, at the 1100 K.W. load it costs $26.00 per hour and at the 2900 K.W. load $53.00 per hour. Then at the 1100 K.W. load, in one hour there are generated 1100 K.W.Hrs., and at the 2900 K.W. load 2900 K.W. Hrs. The cost per K.W. Hr. at the 1100 K.W. load is $0.0236 and at the 2900 K.W. load $0.01825. A curve of this kind could be made use of to find suitable rates to charge consumers of power when operating at different loads and taking power at different loads.

In plotting a daily cost curve, the fixed charges should be sumed up for a sufficiently long time so as to be apportioned more evenly to the days of the year, for in some days or weeks more is paid out than in others.

Calculations To Find Out At What Loads Machines Are Operating At

It was not thought to be worth while to figure out the loads that the various machines were operating at. The following will give the reader an idea of how the machines are manipulated.

As far as possible a main unit is chosen that will give the most economical water rate for the load being carried. This will necessitate either a 2000K.W. machine or a 1000 K.W. machine or sometimes both as the case may be.

Most generally more feed pumps are used than are needed. This is done for the purpose of keeping the water hammer in the pipes down to a minimum. When only one feed pump is running at its full capacity there is considerable strain on the piping due to the intermittent surges of water. By putting on several pumps at the same time the individual surges are made smaller and the time in between shorter and with less strain on the pumps.

The condensing equipment runs at a constant speed and its load depends on that of the turbine.

The boilers are not overloaded ordinarily. Carrying such a load on the station as is shown by the blue prints, there is really no need of any boilers being overloaded. At one time however, it was said by the operators, 2000 K.W. were handled on one 740 h.p. Sterling boiler.

The cost of their operation per day was not computed.

I was disappointed in not being able to procure more cost data than is given below. Supt. Bulkely of the Water and Electric Light Commissioners promised to let me take the detailed list of the appraisal that the Consulting Engineering Firm of Woodwell and Resler had compiled. The detailed report did not come back in time to be included. The preliminary report came back from N.Y. and I have included it in this report. It is not in much detail.

Cedar Street Station.----Cost Data

Item	Cost to Reproduce. Jan. 1921.	Per Cent Good.	Accrued Dep.	Present Value
Land	$33,625	100	-------	$33,625
Buildings	$158,048	90	$14,805	$143,243
Mechanical Equip.				
Turbines and Acces.	$218,297	97	$6,765	$211,538
Boilers	$119,461	97	$15,697	$103,764
Stacks	$15,400	97	510	$14,890
Coal & Ash System	$80,759	75	$19,892	$60,861
Piping System	$70,471	83	$12,181	$58,290
Electrical Equip.				
Switchboards	$24,004	98	360	$23,644
Exciters and Motors	$18,130	90	813	$17,317
Wiring and Cabling	$6,300	95	240	$6,060
Lighting	733	98	10	713
	$745,212		$71,273	$673,939
Scrap	$169,850	88.5		$168,850
	$576,362			$505,089

Electrical Equipment includes switchboards, panels, exciters and motor generators, regulators and wiring and cable.

List of the Main Plant Equipment

Boiler Room

1-500 h.p. Cookson Feed Water Heater. Open type.

6-400 h.p. Wickes Vertical Water Tube boilers.

2-740 h.p. Sterling Water Tube boilers.

1-Hoppes F.W. Heater and V-notch meter.

6-Murphy Stokers.On Wickes boilers.

2-Taylor Stokers.On Sterling boilers.

1-Burnham Steam Pump used for makeup. Reciprocating type.

1-Burnham Steam Pump used to pump water from Cookson F.W. Heater to the V-Notch meter.

1-1 ton weighing larry on track on stoker settings.

Ellison Draft Gauges on Murphy Stokers.

1-Reciprocating pump for injecting boiler compound into the feed water system.

S-C boiler water level regulator. S-C Regulator Co.,Fostoria, O.

Diamond Soot Blowers.

Coal buckets and pulleys for hand operation in case coal handling machinery breaks down.

Semi-underground flues for the Wickes boilers.

Steel breeching for Sterling boilers.

Geco ash handling system m'f'g. by Green Eng. Co.

1-Radial Brick chimney installed by Kellog Eng. Co.(9'x200').

1-Reinforced Concret chimney installed by Kellog Eng. Co. Size 9'x 187-1/2'.

Engine Room Equipment.

1-Burnham Feed Water Pump. Mfg. by Union Steam Pump Co., Battle Creek, Mich. Reciprocating Pump. Size 14 x 9 x 16 inches.

1-Feed Water Pump for boilers. Mfg. by the American Steam Pump Co., Battle Creek, Mich. Size 16 x 10 x 20 in. Reciprocating pump.

1-Knowles Boiler Feed Water Pump. In basement used as a spare. No size given on pump.

1-Boiler Feed Water Pump. Mfg. by the Am. Well Wks.,Aurora,Ill. Type 124 D-No.273-60 h.p.-3600 r.p.m. Pump direct connect to American-Kerr Turbine.-Type BFTD-Size 4-Shop No. 26303- r.p.m. 3600.

1-Deep Well Pump-Mfg. by Am. Well Wks.,Aurora,Ill. 12" size. Direct connected to 50 h.p. 3∅ induction motor-Speed Full load 1160-Type KT-6-50-1200-FormA.-Cycles 60-2200 V-12 Amp-50 h.p. continuous 40°C- 25% overload 2 hrs-55° C-General Electric Co.

1-Holly Water Pump(not used)

1-Alberger Pump and Condenser Co's. 12"-2 stage volute pump used for emergency purposes. Direct connected to induction motor-Type PM-6-200-1200-Form C-Cycles 60-3 ∅-200 h.p.-2200 V-46.5 Amp-Speed no load 1200-full load 1175- Ft.Wayne. Motor.

1-Worthington Horizontal Pumping Engine of the Compound Type. Size H.P 20"-L.P. 44"-Water 19"-Stroke 36". 10,000,000 gallons- 41,000,000 ft.lbs. duty.

1-Exciter-Mfg. by Westinghouse Electric and Mfg. Co.

D.C. Generator-25 K.W.-125 V-200 Amps-375 r.p.m.-

Direct connected to Westinghouse Std. Engine of

Vertical Type 6 1/2" x 8".

1-Exciter-Mfg. by Allis Chalmers Co.,Milwaukee, Wis.-

Motor driven-Volts no load 120-Full load 120-

R.p.m. 850-Motor-H.P. 60-Volts 1200-Amps 14.8-

3ø-60 cycles-850 r.p.m.

1-Allis-Chalmers Turbo driven exciter-Generator-Volts no load

120-Volts full load 120-Amps 416-2400 r.p.m.-

Turbine-No. TIN-13- Normal K.W. 50-Speed 2400.

I-Motor Generator Set:-

Motor-100 K.W.-Form PB-Type ATl-8-Amps 25-Volts 2300-

Cycles 60-H.P. 125-Speed 900-P.F. 1-General Elect.

Generator-D.C.-Type MPL 1-6-25-325-Form 2-F-K.W. 75-

Amps 125-Speed 900-Volts No Load 600-Full Load 600-G.E.

Generator-D.C.-Type MPL 1-6-25-325-Form 2-F-K.W. 75-

Amps 600--Speed 900-Volts no load 125-Full Load 125-G.E.

3-Alberger Dry Vacuum Pumps-Reciprocating Type-Steam Cyl.

8" dia.-Vacuum cyl. 2o" dia.-Stroke 12".

1-Main Unit:-

Turbine-Curtis-General Elect. Co.-K.W. 2000-Speed 1800-

Form G-Steam Press.150#/in^2.-Condensing-P.F. 0.8.

Alternator-Type ATB-4-2500M-1800-Form HT-K.W.2000-

Volts 2300-Ampes 628-Speed 1800-G.E.Co.

1-Main Unit:-

Turbine-Allis-Chalmers Co. Parsons Type-K.W. 1000-

1800 r.p.m.

Generator-Volts 2300-Amps 251-3ø-Freq.60-1800 r.p.m.

1-Main Unit:-

Turbine-Allis-Chalmers Co.-Parsons Type-No.452-Max K.W. 2000-0.8 P.F.-1800 r.p.m.

Generator-Volts 2300-Amps 628 Max-3∅-Freq 60-Speed 1800.

2-Condensing Units consisting of:-

Alberger Condenser-6000 sq.ft. of condensing surface.

Alberger-Curtis Turbine 75 h.p.

Volute circulating pump. 3"

Volute condensate pump. 14"

1-Condensing Unit consisting of:-

Alberger Condenser-3000 sq.ft. of condensing surface.

Alberger-Curtis Turbine 50 h.p.

Volute circulating pump. 14"

Volute condensate pump. 2 1/2"

The condensing equipment and the Knowles feed pump mentioned above are in the basement. The following equipment is also in the basement.

1-Ingersoll-Rand Air Compressor for compressing air used in cleaning machinery-4 1/2"x 5" cylinder belt connected to a 5 h.p. 3∅ induction motor-Volts 440-Amps 7.1-Mfg. by Western Elect Co.

1-Blow Off Tank used for blowing off the boilers-2 1/2'x 12'.

1-Forced Blower Equipment:-

Fan 30"-American Blower Co.-Plate Fan Wheel-

Motor-440 Volts-60 Amps-3∅-60 cycles-50 h.p.-Type KT-336-6-50-1200-Form B-50°C-Speed full load 1155.

1-Forced Draft Blowing Equipment;-

Fan-No.7 Sirocco-American Blower Co. Detroit, Mich.

Steam Engine-9"x 8".American Blower Co.

2-12 h.p. motors-91 Amps-110 volts-940 r.p.m. to 100 r.p.m. adjustable speed.

Coal Handling Machinery

Coal Handling Equipment installed by the Guarantee Construction Company of Chicago. No name plate on the Coal Crusher. The elevator is made by Stephens-Adamson Co. and has a capacity of 30 tons per hour. The coal crusher has a capacity of 35 tons per hour. By suitable gearing the reclaiming conveyor may be thrown in or out of operation. The coal crusher, feeder, and the reclaiming conveyor are run by a motor of the following capacity: Motor-Type 1-6-15 A-15-Form K-Amps 19-Volts 440-Speed no load 1200-Full load 1145. The Stephens-Adamson Co's. plant is located at Aurora, Ill. The elevator and the distributing conveyor are operated by one motor. The distributing conveyor is also manufactured by the Stephens-Adamson Co. The motor is of the following size:-

Motor-15 h.p.-3ϕ-Induction motor-Type KT-440 Volts-26 Amps-Speed 855 r.p.m.-Western Electric.

1-Capstan along the railroad tracks for pulling the coal cars over the coal hopper.

The ash handling machinery consists of the receiving tank and blowing machinery. The fan is of the centrifugal type and operated by a motor of the following size:-

50 h.p.-3600 r.p.m.-440 volts-3ϕ induction motor.

Electrical Equipment

Electrical Equipment

The electrical equipment is manufactured by several different concerns, and no attempt was made to get a list of equipment in any great detail. The equipment consists primarily of 10 power switchboards and 17 used for the lighting circuits. The switchboards are of marble. There are 7 constant current transformers.

Some of the bigger electrical units have been described in detail in the preceding pages, and to describe the small parts of the switchboard would take up more space than is allowable; so it will be neglected here.

The meters on the switchboards are mostly of the Westinghouse manufacture while the switches(knife) are nearly all of the Cutler-Hammer make. The oil switches are of General Electric manufacture. The transformers are made by several concerns including the large and a few of the small concerns.

The electrical equipment was installed by the B.Baily Engineering Co. of Toledo, Ohio.

Miscellaneous Equipment

1-Foxboro Recording Flue Gas Thermometer 0-800^{o}F.

Manufactured at Foxboro, Mass.

Most of the pressure and vacuum gages are manufactured by the Alberger Co.

1-Northern 15 ton crane.

Conclusion

In concluding this report the following things might be well worth con sidering. In starting on this report, the idea was for the writer to obtain a better understanding of power stations and their operation by going to one and observing what took place; also to get some data from a plant actually working, in order to find out some of the characteristics of operation. As far as cost data was concerned, not much was obtained. This does not mean much anyway on account of the unsettled business conditions and rapid fluctuations in prices.

It would probably not be amiss to give the writers opinion on some of the good and bad features of the plant, and in the succeeding paragraph he will endeavor to point out a few of the good features of the plant.

The plant is very compactly arranged and does not take up much space for the amount of power generated. It would probably be better if the plant had been laid out on more generous principles. Most of the main generating sets are easily accessible and well arranged. As far as the coal handling equipment is concerned, it takes up little space and appears to be efficient. Some changes could probably have been made in it when installed for the better, but they will not be taken up here. The plant is near a good water supply which is nearly always necessary. The feed water piping is in duplicate in most cases so as to prevent a shutdown on account of the water supply breaking down. The basement of the plant is kept in good order and it contains lockers for the workmens' clothing. Operating conditions are good,which being conducive to (conducive) to well satisfied men causes little dissatisfaction among them. In opposition to the good features some of the bad features are mentioned in the next paragraph.

One of the very noticeable bad features of the plant seems to be that too many men are needed for handling ashes; the cause of;this lies in the way that the setting of the Murphy stokers are arranged, which makes it hard for the ashes to be hoed into the ash conveyor. It would be better if the Murphy stokers were arranged as the Taylor stokers in which case the ashes fall down on to the basement floor. Another bad feature is the position of the Hoppes F.W. Heater which is because it is hung from the boiler room roof trusses, a place where it is very hot and crowded. Due to the above mentioned facts it is hard to repair anything around it when it breaks down. Lack of steam and water flow meters are noticeable. It would be very much more easy to find out how the plant was running if more flow meters were installed and also some more electrical measuring instruments. It would be better for the plant as a whole if it were laid out on more generous principles. As it is now the piping suffers from lack of sufficient room. Due to the many changes in the plant from time to time, to say the least, the pipes have been put in any way to get them in. They are a terrible mess. Another bad feature is the low power factor of the station. Some of the consumers have a P.F. as low as 50%. The Reo factory in the morning has a P.F. of from 50-60%.

This low P.F. makes itself known in the heating effectso on the station apparatus. The consumers should have some way to raise the power factor; a synchronous motor will do it and also permit power to be taken from it.

The writer feels that he has received considerable benefit from the work by being around a large power station. He had never been around a power station of this size before and this gave him an opportunity to find out just what there is to a power station and how it is arranged.

The writer craves the readers indulgence for any typographical errors that may be found. The typewriting was done by the writer himself, and thruout the work may be found several mistakes where a word has been put in or left out, but it also must be remembered that even the better grades of books often contain typographical errors in their first editions.

E.M.

Bibliography

The books used in the preparation of this Thesis are:

Electric Power Stations	Klingenberg
Engineering of Power Plants	Fernald and Orrok