A STUDY OF METHODS FOR CARRYING INCREASED LOAD ON THE M.A.C. POWER PLANT

THESIS FOR THE DEGREE OF B. S.
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A Study of Methods For Carrying Increased Load on the M.A.C. Power Plant.

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THESIS

OUTLINE

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3. Study of installations.

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INTRODUCTION

In connection with the present power plant, there are two well known facts that must be considered, first, that the plant must be run at maximum capacity to meet the present power requirements; and secondly that because of financial conditions the undertaking of any great changes would be made very difficult.

As a considerable sum of money must be spent it is a wise move to plan ahead and use the money so that it will not be necessary to make further changes in the near future. The power that will be required, say thirty years from now, is the least that should be considered. To secure some definite ideas concerning the probable requirements for power in the future, we used two methods of proceedure. First we obtained records showing the number of students registered at M. A. C. for a number of years back, and also a record of the amount of coal used in a period covering eight years. From the data thus obtained we constructed curves and calculated the average rate of increase in each case.

Coal Consumption.

1907	4,594	Tons
1908	5,427	"
1909	7,044	"
1910	7,465	"
1911	7,409	"
1912	7,238	"
1913	7,923	"
1914	8,622	"

The above data was obtained from the monthly coal consumption record kept at the M. A. C. power house. From these figures a curve on coal consumption was constructed, and from the general trend of the curve the point showing the probable coal consumption by the year 1950 was located at about 30,000 tons per year. This is practically three times the present coal consumption and the present plant has a total boiler horse power of 1320, and the capacity of the generators is 300 Kw.

Number of Students at M. A. C.

1884	171
1890	369
1896	425
1898	469
1899	528
1900	627
1901	652
1902	689
1903	854
1904	917
1905	950
1906	1009
1907	1001
1908	1191
1909	1370
1910	1494
1911	1568
1912	1702
1913	1643
1914	2010
1915	1999
1916	1993

The foregoing record of the number of students registered at M. A. C. for a period of 32 years was obtained from the office of the Registrar. From this data the curve showing the probable enrollment by the year 1950 was constructed. This shows that the enrollment by that time will probably be about 4,200 students. The enrollment for 1917 was about 2,000, or the increase will be about 100 per cent.

Determination of the Probable Power Requirements in the Year 1950.

From the two curves previously constructed it is shown that the growth of M. A. C. in recent years has been rapid and that the probability isthat it will continue to be rapid. With this rapid growth has come a rapid increase in the consumption of coal and power.

The following computations are for the purpose of making use of the curves in getting the probable power requirements for power in the year 1950. The average increase in coal consumption over the period covered by the curve and ending with the year 1914 is 600 tons per year. The increase in years equals 36 years.

36 x 600=21,600

21,600+8,622=30,222 Tons.

8,622 tons being the coal consumption in 1914.

Figuring on the basis of 7 lbs. of water evaporated per lb. of coal, 432,108,000 lbs. of water would be evaporated.

Assuming that 35 lbs. of water is evaporated per sq. ft. of heating surface per hour;

$$\frac{432,108,000}{3.5 \times 365 \times 24} = 13,800 \text{ sq. ft. heating surface.}$$

$\frac{13,800}{10} = 1,380$ Boiler h.p. for the average load in 1950.

In the same way the boiler h.p. was figured for 1914, using the highest coal consumption per month as a basis. This gave a boiler h.p. of 880. The average boiler h.p. for 1914 was figured in the same way and this gave 392 boiler h.p.

Then letting X equal the maximum boiler h.p. in 1950; Then by proportion $\frac{880}{392} = \frac{X}{1,330}$ or X = 3,100 boiler h.p.

Using the data from the curves of increase in growth as maximum data and considering that the boilers can be run under heavy over-load during the coldest portion of the year we figure that the most economical installation would be a total of about 2400 boiler h.p. The units in each case can be added as fast as they are required or as the present boilers wear out.

Power Requirements.

The total rated capacity of the engines and generators in the engine room is now 300 kw. and these units are not generally taxed to their capacity. We decided, therefore, that the most economical power unit to install would be a 250 kw. direct-connected Corliss unit, which would be run so as to save the two larger reciprocating engines which would be retained. The life of those two units would then be lengthened. The use of the 50kw. unit would be discontinued and the unit removed.

In regard to using a Corlisss unit instead of a turbo-generator set there are several things to take into consideration. Fully 90 per cent of the power developed is used for heating purposes and the remainder for lighting and electrical power. The engines, therefore, exhaust into the heating system, and as the engines are not run condensing there is a considerable period in the summer months when they are very uneconomical. A turbine is a very economical unit when it is run condensing but it is even more uneconomical that a reciprocating engine when it is run non-condensing. During the larger part of the year there isno advantage in using a condensing unit as then live steam would have to be used for heating purposes. There is available space in the plant, as altered, for the Corliss unit and condenser, our plan being to supply the power during the summer months by means of the Corliss unit running condensing and during the winter months by means of all three units, if necessary, running non-condensing.

Cost of Installations.

Installation No.1.

Based upon data given in "Engineering of Power Plants" by Fernald and Orrok.

5-350 h.p. Lyons boilers.

Cost of fire tube boilers f.o.b. factory

= 180+6.4 x h.p.

5 x(180+6.4 x 350) = 5 x 2420 = $12,100.00

Cost of setting.

= 140+2 x h.p.

5 x (140+2 x 350) = 5 x 840 = $4,200.00

Total cost of new boilers $16,300.00

Cost of Jones underfeed stokers.

Cost of stoker for 350 h.p. boiler, installation not included, $1400.00

Cost of 5 stokers = 5 x $1400.00 =	$7,000.00
Cost of setting	770.00
Total cost of new stokers	$7,770.00
Cost of repairing old stokers	200.00
Total cost of stokers	$7,970.00

Cost of new stack.

Stack 125 ft. high 7' - 0" dia = $4,000.00

The size of stack necessary was determined from formulas taken from Kent's hand book.

E = effective area of chimney.

A = area in sq. ft.

D = diameter in ft.

$E = A - .6\sqrt{A}$

H.P. = boiler h.p.

$$E = \frac{.3\ H.P.}{\sqrt{H}} = A - .6\sqrt{A}$$

Total H.P. of the plant equals 2450.

Assuming that the new stack isto accommodate one-half of the boilers;

$$H.P. = \frac{2450}{2} = 1225\ H.P.$$

Let the height be the same as that of the present stack or 125 ft.

$$\frac{.3 \times 1225}{\sqrt{125}} = E$$

$$\frac{.3 \times 1225}{11.05} = E \qquad E = 33.22$$

$$E = A - .6\sqrt{A} = 33.22$$

$$d = \text{dia. of } E = \left(\frac{32.22 \times 4}{(\pi)^{\frac{1}{2}}}\right)^{\frac{1}{2}}$$

$$= 6.41 ft. = 6'-5"$$

$$D = d+4"$$

$$= 6'-5"+4" = 6'-9"$$

From this it can be seen that the present stack is not large enough to accommodate one-half of the boiler capacity of the enlarged plant. Therefore, figuring the present stack for accommodating 3-350 h.p. boilers and a new stack for 4- 350 h.p. boilers;

$$D = 6\ ft. \qquad H = 125\ ft.$$

$$E = A - .6\sqrt{A} = \Pi \times 3^2 - .6\sqrt{\Pi x 3^2}$$

$$= 28.3 - 1.8\sqrt{\Pi} = 28.3 - 1.8 \times 1.77$$

$$= 28.3 - 3.2 = 25.1$$

$$E = \frac{.3x\ H.P.}{\sqrt{H}} \text{ or } 25.1. = \frac{.3 \times H.P.}{\sqrt{125}}$$

$$\frac{25.1 \times 11.05}{.3} = H.P. = 925$$

This stack has been used for more than 1200 h.p. This was made possible by the use of forced draft.

The New Stack.

By using forced draft, as isnecessary with the Jones Stokers, the present stack will easily accommodate the 3- 350 h.p. boilers. This leaves 4 - 350 h.p. boilers to be taken care of by the new stack.

$H = 125$ ft. $\qquad$ H.P. = 1400

$$E = \frac{.3 H.P.}{\sqrt{H}} = \frac{.3 \times 1400}{11.05} = 38.0 \text{ sq. ft.}$$

$$d = \left(\frac{38.0 \times 4}{\pi}\right)^{\frac{1}{2}} = 6.96 \text{ ft.}$$

$$d = 6' - 11\tfrac{1}{2}''$$

$$D = 6' - 11\tfrac{1}{2}'' + 4'' = 7' - 3\tfrac{1}{2}''$$

Then for these furnaces using forced draft a 7'-0" stack would be large enough.

Cost of Flues.

The average cost of flues per engine h.p. = \$.55

Assume that 2.5 engine h.p. equals one boiler h.p.

Then the cost of flues $= \frac{.55 \times 2,450}{2.5} =$ \$540.00

Cost of Piping.

The average cost of piping is \$4.25 per engine h.p.

Then the total cost of piping would be

$$\frac{4.25 \times 2450}{2.5} = \$4,170.00$$

As the most of the steam is used for heating and is piped directly to the steam main, this figure should be reduced considerably. Probably $3,000.00 would cover this cost. As a considerable proportion of the present piping can be used, this figure should be cut down still further. We will allow $1500 for the cost of piping.

Cost of a 350 h.p. condensing Corliss engine.

Total cost per h.p. = $21.85

Total cost = 350 x 21.85 = $7650.00

Cost of a 250 kw., 220 Volt, generator.

Cost per kw. = $8.00

Total cost = 8 x 250 = $2000.00

Cost of installation = $200.00

Total cost $2200.00

Cost of building.

The cost of enlarging the building figured at $2.00 per sq. ft. floor area would be $3,440,00. As some of the old brick can be used and part of the fixtures will be already in place, this figure can be cut down to $2500.00.

Cost of coal shed.

Floor space = 200 x 180 = 16000 sq. ft.

At $1.00 per square foot (including the trestle, etc.) = 16000 x 1.00 = $ 16,000.00

Size of chimney for B&W. and Wickes boilers.

The present stack will care for 925 h.p.

The total rated capacity of the plant = 2400 h.p.

2400 - 925 = 1475 h.p. to be handled by the new stack.

Use H = 125 ft. H.P. = 1475

$$E = \frac{.3\ H.P.}{\sqrt{H}} = \frac{.3 \times 1475}{11.05} = 40 \text{ sq. ft.}$$

$$d = \frac{(40 \times 4)^{\frac{1}{2}}}{(\pi)^{\frac{1}{2}}} = 7115 \text{ ft.}$$

d = 7' -2"

D = 7' - 2"+ 4" = 7'-6"

Use 8'- 0" for diameter of the stack.

Cost of stack $4,250.00

Size and cost of feedwater heater. (Open type).

326 + 0.3,787 x 2,400 = 326 + 910 = $1236.00 which is the cost of heaters for 2400 boiler h.p.

As the heater already installed will care for one-half of this the new heater would cost

$\frac{1,236}{2}$ or $618.00

Cost of condenser for Corliss engine.

Surface condenser-- capacity up to 3,000 lbs. per hour. 26 in. vacuum.

Cost = 413 + 0.1015 x (lbs. steam condensed)

Compound, low speed, condensing engine,

steam rate = 17.7 lbs. dry steam per I.H.P.

350 x 17.7 = 6,200

413 + 0.1015 x 6,200 = 413 + 630 = $1,043,00.

Size and cost of new fan.

70 in. to 140 in.-- cost = 6.25 x (size in inches)

Use an 80 in. fan.

Cost = 6.25 x 80 = \$500.00

Installation No. 2.

Cost of water tube boilers.

Cost = 150+ 8.2 x h.p.

8x=(150+ 8.2 x 300) = \$20,880.00

Cost of setting.

Cost - 140+ 2 x h.p.

8x=(140+ 2 x 300) = \$5,920.00

Total cost of boilers - \$26,800.00

Cost of chain grate stokers.

Cost = 5 x (boiler h.p.)

= 5 x 2400 = \$12,000.00

Cost of stack.

8'-0" dia. 125' high = \$4,250.00

Cost of flues.

Cost = .55 x eng. h.p.

$= \dfrac{.55 \times 2400}{2.5}$ - \$528.00

Installation No. 3.

Cost of vertical water tube boilers.

Cost - 900 + 63 x (boiler h.p.)

8x=(900 + 6.3 x 300) = \$22,320.00

Cost of setting = \$ 5,920.00

Total cost of boilers = \$28,240.00

Cost of stockers =3.6 x 2,400 = \$ 8,600.00

Total Costs

Total Cost of Installation No.1.

Boilers	$16,300.00
Stokers	7,970.00
New stack	4,000.00
Flues	540.00
Piping	1,500.00
Corliss engine	7,650.00
Generator	2,200.00
Building	2,500.00
Coal storage	16,000.00
Coal handling apparatus	4,000.00
Feed water heater	618.00
Condenser	1,043.00
Fan	500.00
Incidentals	6,354.00
Total cost	$71,175.00

Total Cost of Installation No.2.

Boilers	$26,800.00
Stokers	12,000.00
Stack	4,250.00
Flues	528.00
Piping	1,500.00
Corliss engine	7,650.00
Generator	2,200.00
Building	3,000.00
Coal storage	16,000.00
Coal handling apparatus	4,500.00
Feed water heater	618.00
Condenser	1,043.00
Incidentals	7,808.00
Total Cost	$87,897.00

Total Cost of Installation No.3.

Boilers	$28,240.00
Stokers	8,600.00
Stack	4,250.00
Flues	540.00
Piping	1,500.00
Corliss engine	7,650.00
Generator	2,200.00
Building	3,400.00
Coal storage	16,000.00
Coal handling apparatus	4,000.00
Feed water heater	618.00
Condenser	1,043.00
Incidentals	6,984.00
Total cost	$85,025.00

Advantages and Disadvantages of the Installations.

Installation No.1.

Advantages.

1. Cheapest.
2. Least changes necessary.
3. Two of the present boilers can be used.
4. Smaller stack sufficient.

Disadvantages.

1. Dirty and smoky boiler room due to Jones stokers.
2. Roof too low for a well ventilated boiler room.
3. Unsafe. (Authorities would impose the following requirement for safety, "Never use anything but water tube boilers").
4. Cannot be over-loaded to the extent that water tube boilers can.
5. Slow steaming.
6. Liability to leak from unequal expansion.
7. Specially skilled men required for repairs.
8. Reduction of pressure necessary after a time.

Installations No.2 & 3.

Advantages.

1. Rapid steaming.
2. Relatively small danger from explosion.
3. Repairs easily made.
4. Respond readily to changes in steam demand.

5. Freedom of expansion.

6. Ease of installation.

7. Large overload capacity.

8. Reduction of pressure not necessary.

9. Positive circulation.

Disadvantages.

1. Smaller steam space.

2. Smaller water reserve.

3. Large number of parts.

A resume of the methods of caring for the increased load on the power plant with the view of using as much of the present plant as possible.

From the above study of the advantages and disadvantages of the three installations under discussion, it is seen that the water tube boilers are far superior to the fire tube boilers. As the present building is very unsatisfactory, and as considerable change in the building would be necessary to meet the condition of increased load; we consider that it would be more satisfactory in the long run to install water tube boilers than to replace the small fire tube boilers with larger ones of the same type.

This will necessitate a greater expenditure on account of more expensive boilers and the necessity of raising the roof of the boiler room.

However, in the case of the Wickes boilers and Murphy stokers, this cost is less than 20 percent higher. Taking all things into consideration, we feel that this setting would be the most economical, efficient, and practical.

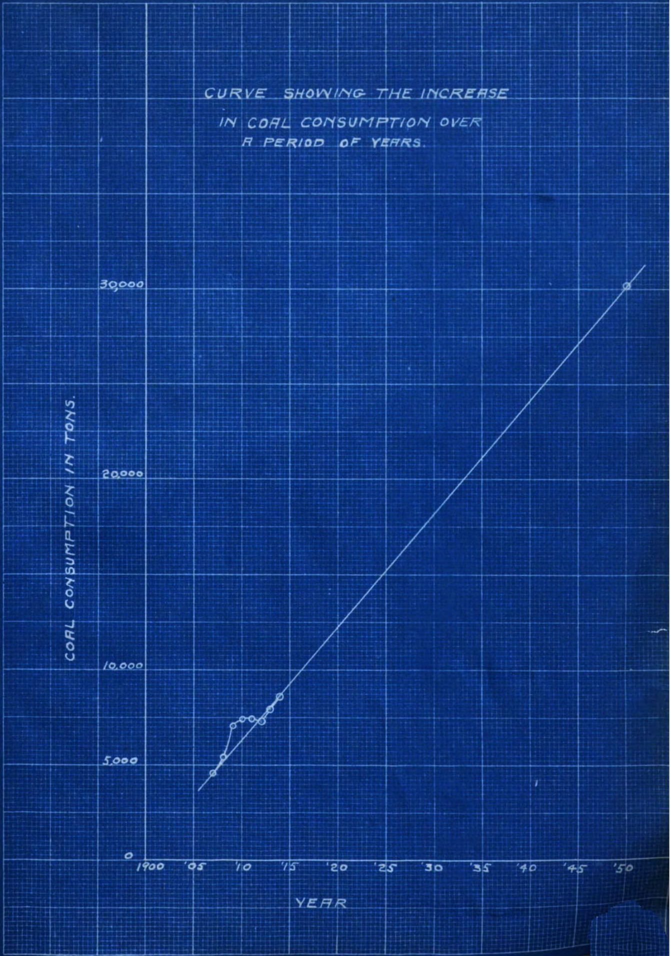
In the line of power, we feel that the addition of a 350 h.p. Corliss engine would be more practical than the addition of a small turbine as when the turbine is run non-condensing it has a very high steam consumption. It would also require the installation of a much larger condenser for the turbine than for the reciprocating engine. A condenser attached to the Corliss engine will allow it to be run condensing when the steam requirement for heating is low. We find that the Corliss engine will generate sufficient power for summer use and that its steam consumptionwill be very low.

In view of the fact that quite a large expenditure must be made, that it will be impossible to enlarge the plant, and that it will be impossible to store sufficient coal to enable the purchase of the entire supply in the summer and thus save a considerable sum of money; we feel that it would be more advisable to make a little greater investment and thus make possible a greater expansion of the plant and the storage of the entire supply of coal for the year. Such a plant would have saved in the neighborhood of $6,000 in the purchase of coal for the year 1917 alone.

It was our plan at the start to make a study of the possibilities of erecting such a plant, but due to the fact that the term was shortened, we did not have sufficient time to carry this study to completion.

We found, however, that such a plant would be possible only by having the boiler and engine rooms at ninety degrees from where they now stand, or in other wordsthe firing aisle would run east and west. This construction would be rather difficult because of the fact that, whatever changes are made, they must be made without interrupting the service. It would probably be possible, however, to do this in the summer by dismanteling part of the stokers and boilers and erecting some of the new ones while the remainder of the old ones were supplying the steam necessary for power and lighting purposes.

A plant erected in this manner would give ample room for coal storage on the south side of the boiler room and an electric crane could be used to unload the coal from the cars into the bunkers and storage, or from the storage into the bunkers. A jib crane could be used for this purpose but it would have to be of the travelling type in order to reach over sufficient storage.


CURVE SHOWING THE INCREASE
IN COAL CONSUMPTION OVER
A PERIOD OF YEARS.
COAL CONSUMPTION IN TONS.
30,000
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10,000
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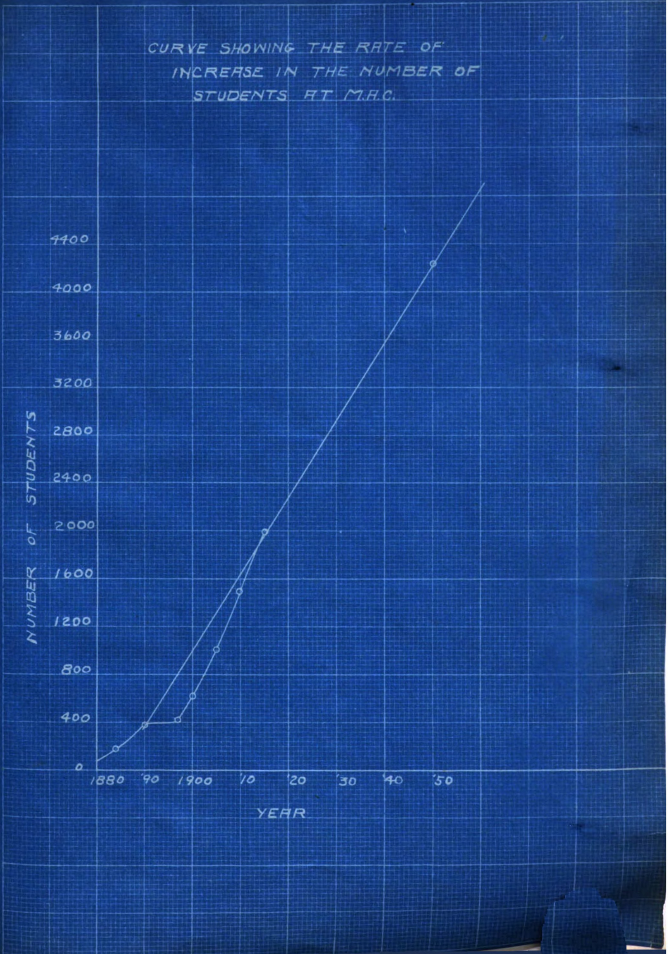
CURVE SHOWING THE RATE OF
INCREASE IN THE NUMBER OF
STUDENTS AT M.A.C.
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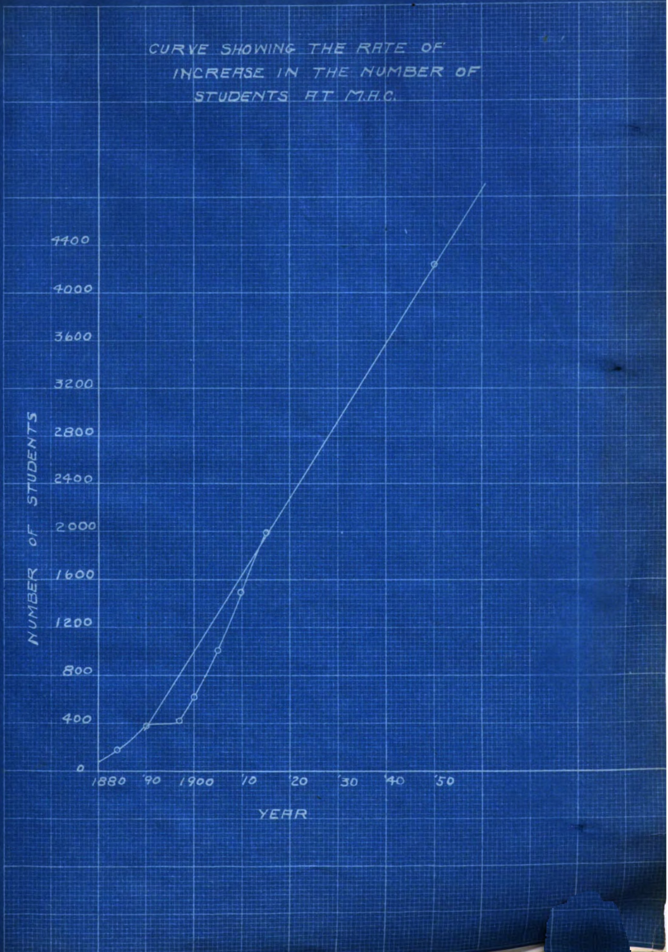
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