DESIGN OF A CENTRAL HEATING AND POWER PLANT FOR THE UNIVERSITY OF TENNESSEE.

BY

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INTRODUCTION.

This thesis consists principally of a series of reports written for the course in Power Plants. These reports have been rewritten and enlarged, but they are rather inconsistent and unconnected. For instance, notably in the decision of type of engines, the conclusions arrived at when the original report was written have been reversed in the revision. The original report has, however, been put in with the first decision, together with the reasons for the wrongness of this decision and its reversal These contradictions might have been left out to the author's credit, but they were left in so that in case any one should read this thesis he will see the blunders into which a beginner may fall.

The sum total of this thesis could probable be put in half the number of words by one skilled in engineering and the use of the English language, but of course this thesis will never be read and lack of time would not permit a rewriting, so that it will have to remain in its present form.

DESIGN OF A CENTRAL HEATING AND POWER PLANT FOR THE UNIVERSITY OF TENNESSEE.

The problem assigned is the design of a 600 H. P. boiler plant with an ultimate increase to 1000 H. P. Also the design of a suitable electric plant for the present needs of the University with provision for future needs. The electric generators will, of course, be driven by steam from the boilers, which are also to heat the buildings of the University.

We now have our problem and must arrive at our results by logical reasoning. We cannot design our building first and then buy our equipment to fit, but must first select our equipment. Now every piece of apparatus almost, in a power plant depends upon every other piece; this is especially true of everything with respect to the boiler, and as our boilers must be chosen both for heating and power we had best select them first. This is true of every boiler plant as everything begins with the coal which is placed in the furnace of the boiler. Next to the boiler both in importance and sequence are the engines or turbines, and hence must be dealt with after the boiler. We also have auxiliary appliances for both the boilers and the engines and these must be taken up somewhat in detail before we put the finishing touches to the building.

Our plant is to be increased in the future and to make a neat job of it we should design with this future extension in view. We must make our housing large enough to accommodate the future plant as well as the present.

SELECTION OF BOILERS.

Now in accordance with our problem our boilers are to be used for both power and building heating. To be sure we might use our boilers for power alone and have other boilers especially designed for heating purposes. But on consideration we can see that this arrangement would be neither pleasurable or profitable: besides two sets of boilers in one room with different pressures and absolutely independent connection would not only be a source of great annoyance, but also of some danger, for the fireman would be more likely to let his water get too low, or to let some other equally unpleasant thing occur, than with one set of boilers. Therefore we had better discard the project of an independent heating system as worthless.

Our problem states that we are to install 600 H. P. of boilers at present. This is not rigid but can be changed if we think another installation better. When selecting the size of our boiler units let us go on the asumption that we want the fewest boilers to do our work well. We could have a battallion of small boilers but this would be absurd, and if we think we see that anything smaller than 100 H. P. is out of the question, and it only takes a few more moments

thought to decide that our plant equipped with 100 H. P. boilers would be the laughing stock of the country. But why do we want to use as few boilers as we can? This question can be answered by several good reasons. The smaller the boiler the greater every item of boiler expense--first cost, maintainance expense, trouble and housing cost. The small boiler is not so economical as the large one. But why go further? The above is a sufficient answer to the question. The next question is,why do we want more than one boiler? Why not have a 600 H. P. boiler with provision for the addition of a 400 H. P. boiler? Undoubtedly every expense for this arrangement would be the lowest possible. But we can answer this question too. A boiler of this size, although suitable for a large plant, would be cumbersome and unwieldy. But the greatest difficulty would be the lack of standby power. It would merely take the bursting of a tube to put the "Hill" at the North Pole, where we would neither have heat nor light, this would be bad, as everyone will agree, so, we must guard against such a contingency. Of course any plant may be subjected to a shut down, but, if proper standby provision is made this is improbable. Our plant will contain 2 to 5 boilers and it is unlikely that more than one of this number shall ever be out of commission at one time. But do we want one boiler to stand idle at all times except in case another boiler becomes disabled? This is not the general practice, either for mill work or central stations, and as a matter of fact is not necessary. The rating of a boiler is only nominal, and most kinds of boilers are capable of being forced, that is they can generate 50 to 150 percent more steam than their rating, and by normally working them at their rated capacity we can generally provide for the loss of one boiler, although we must be careful to select a type of boiler which can be forced to suit our needs.

Another noticeable feature of the modern power plant is the fact that only one size of boiler is used. We certainly would not want to build a plant using more than one size of boiler. It would look bad; the piping and everything else would be out of conformity, and on the other hand this plan of a plant has not a single advantage.

The following principles have been set forth for the selection of the size of boiler units.

1. We want the fewest boilers to do our work well.
2. In case one boiler becomes disabled the remainder must take the load safely.
3. Only one size of boiler is to be used.

Suppose we try 150 H. P. boilers in our plant. At present we would install four boilers. If one goes out of commission each of the other three boilers would have an overload of 33 1/3%

which almost any boiler could do easily. But to get 1000 H. P. with this size boiler we would have to have seven boilers which would be too many for a plant of this size. The cost of these 150 H. P. boilers per H. P. would be considerably more than for either 200, 250 or 300 H. P. boilers. Further the space occupied by them would be much greater than either of the other sizes, making the building cost more. We see that we must use larger boilers.

If we put in 300 H. P. boilers the present plant will contain two and the future plant three or four. This makes the probable overload on each boiler for the present plant 100%. Although an overload of 100% seems high we must consider that we are dealing with boilers, and that the 100% overload comes only during the peak load and will not last more than an hour. I believe that this much overload is permissable with properly selected water tube boilers, which would necessarily be used, as fire tube boilers of this size are not made (except internally fired marine boilers which would hardly be suitable for our plant). For the present plant 300 H. P. boilers would be alright but on investigating their use for the future plant they do not fit very well. We could have a capacity of 900 or 1200 H. P. whereas we want a thousand. If we put in three boilers and build a suitable housing we would not have enough room for our engines, But this is a minor difficulty as we could space our boilers further apart and make it all the better. If we use four boilers we will have more capacity than I believe will be needed and this would be faulty engineering because we can get what we want with another size boiler.

We have two sizes of boilers left, 200 and 300 H. P. We see at once that we cannot get the specified horse power for our present plant with the 250 H. P. boilers. We can get either 500 or 750 H. P. For our future plant however, we will have four boilers giving our required 1000 H. P. Now for our future plant, 250 H. P. boilers give a very nice layout indeed. We would have just about the right sized boiler and engine rooms (Four engines or turbines being used) With the 200 H. P. units we would have three boilers in our present plant and five in our future. The maximum probable overload in the present plant would be 50%, which is reasonable. This size unit gives a nice plant, both for the present and future plants, so which will we use? We cannot get exactly the capacity we want with the 250 H. P. boiler. Apparently if we put in two boilers they would both be subjected to an overload of 16 2/3% during the peak load, and if one goes out the other would have an overload of 140%, which is higher than we could safely design for. Besides it is exceedingly bad policy to design a plant with the intention of being overloaded at any time. However we do not have to discard the 250 H. P. idea for we can put in three boilers and have an excess power of 150 H. P. During the peak we would have an overload of only 20% as against the 50% for the 200 H. P. boilers; but this is of not much consequence as 50% is not a great overload. Apparently there is little to choose between

the two sizes as far as performance goes so we must decide upon other consideration.

In all engineering work the dollar is the measure of everything, so the dollar must make our decision. When dealing with cost the first cost is not the only cost. We want to design a plant for which the total yearly cost is a minimum. This total yearly cost on the boilers consists of the interest on the investment, repair expense, cost of operation, depreciation of value of boilers. We see at once that the cost of operation and the repair expense will be the same or practically so, for both sizes of boilers. This leaves two expenses to deal with. Let us consider the interest on the investment first. The difference in size between a 200 and a 250 H. P. boiler is slight, and the construction is of course almost the same, so the difference in price is not so great as the difference in power. Now the size of the two units is almost the same so that the space occupied by 250 H. P. is very little greater than the space occupied by a 200 H. P. boiler. If we use 200 H. P. boilers we must build a building large enough to house five boilers, as against the four boilers required by the 250 H. P. size. Thus with the first size our building will be something like one fifth larger. Therefore we see at once that increased cost of boilers for our present plant, due to using 250 H. P. boilers, is more than offset by our decreased size of building. Further the cost of boilers in the 250 H. P. size is bound to be less for our future plant.than the 200 H. P. boilers. This argument leaves not a doubt in my mind that the 250 H. P. boiler is more suitable for our plant than the 200 H. P. size. So we will design for a present plant of three 250 H. P. boilers with space for a fourth. By a look at the design of the building it will be seen that five boilers are incompatable, and this is some argument for the 250 H. P. boiler.

The cost of fuel might have been included in the total yearly boiler expense but this would have made little differance as the difference in fuel consumption between the two sizes of boilers would be slight, and if any at all would be in favor of the 250 H. P. boiler as we could take the load for load for most of the day on the two boilers, thus increasing the economy.

Another argument for the choice of the 250 H. P. boilers is the fact that our plant will endure longer without increase, that is the present plant; as time goes on legislative bodies become more reasonable(??) and the longer we can put off the increase in size, the easier can the necessary appropriation be secured.

The next question anter having determined the size is the type of boiler-water tube or fire tube. It is almost imperative that we should use the former since fire tube boilers are hardly ever used or made in sizes greater than 200 H. P. But we will assume that we can have fire tube boilers of 250 H. P. made, or let us consider the marine type.

The marine type can be obviated easily. After 11 P. M. there is no demand for steam and we can either bank the fires or keep a fireman on the job all night. We would have to resort to the latter method with a marine boiler for when once cooled it takes hours to get up steam. We do not want to maintain an all night fireman nor burn coal when we can get out of it, neither do we want a boiler, parts of which contain cold water when steaming under a full load.

The very fact that boilers of the fire tube type are not used in sizes as great as ours is enough to throw them out, because boilers have been used long enough to know what they are. But even were this not so we would not want to install anything but water tube boilers. The fire tube boiler, externally fired, is a slow steamer, especially in so great a size as ours, and the plant under consideration demands a quick steamer, for the boilers will have to be heated every morning and if two boilers only are used during the major portion of the day we would wish to be able to place the third in operation as quickly as possible.

The fire tube boiler is not capable of being forced to such an extent as the water tube boiler and in any central station the greater the overload the boilers can safely take, the better. If so desired a water tube boiler can be operated continously with an overload of 50 to 100 percent. Thus we could put in two boilers at present and get satisfactory results but I would not advise this as we would have the trouble of increasing our size too soon.

The fire tube boiler is inherently dangerous. We have in each boiler a large quantity of water stored under pressure. Furthermore the water is hot and is lying in wait to be liberated for destruction. There would be enough enerby stored in each boiler to blow our whole plant across the river. Of course boiler explosions are rare and are due to carelessness generally, but we had as well be on the safe side as not. The water tube boiler in contrast with the fire tube has not nearly as much water stored per horse power: but this is not all. Only the tubes of the water tube boiler are subjected to the hot part of the fire; the drum is protected by the tubes so that disintegration to such an extent as to cause explosion is not likely to occur. A tube may explode occasionly but this does no harm for it is easily replaced, causing the disabling of the boiler for only a few hours. The added safety of the water tube boiler is almost enough to cause its selection for our plant.

The water tube boiler lends itself to inspection and cleaning more readily than the fire tube boiler. The most important surfaces of a fire tube boiler are the outside of the tubes and the inside of the shell: it is almost impossible to see either, and the cleaning is not very satisfactory. The inside of the tubes can be easily seen and cleaned. With the water tube boiler the inside of the tubes is the important place and it can be seen and cleaned as readily as in the fire tube boiler. Scale formation and the collection of mud are the chief things to be guarded against, and it is readily seen that the chances for either of these occurances in the water tube boiler are much slighter than

in the fire tube boiler, since the circulation is much more rapid in the former. The scale can be cut out of tubes, but if scale collects in the shell of a fire tube boiler we have a job to handle, and will do it when compelled to but no sooner. Wo we see that there is no doubt but that the water tube boiler is the solution to the question of type of boiler.

Now a very important question pops up. At what pressure will we operate our boilers? The boilers in the plant now running operate at 100# pressure and are fed by city pressure. If we raise the pressure we will have to install feed pumps. But this is no great objection as feed water pumps are neither a source of great expense or annoyance, and unless the plans in mind are changed we would want pumps anyway. Not being limited by this question of pumps we must fix our pressure by other conditions in the case. About half of the steam generated is used for heating. Now the pressure of the steam in the radiators is limited to 3 to 5 lbs. above atmospheric, so that the boiler pressure must be reduced before entering the radiators. For this reason we want to keep our boiler pressure as low as we can with our eye on our power side of the question. Without a doubt any pressure from 100 to 200 # would do. But in a plant of this kind generating steam for power only the average practice seems to be about 140# with 100# as a low limit. Now we do not want to be on the extremes unless for some good reasons so let us say 125#. This is not fixed, and in fact if after the plant is built reasons are seen for raising or lowering this pressure we can do so within reasonable limits without making a change except changing the blow off point of the safety valve.

Now about the heating system. At present the pressure is reduced twice, once in the boiler room and again at the buildings to be heated. I believe that this method can be changed to advantage. I propose to make only one reduction and that at the buildings. By doing this we can use much smaller steam mains and these can be insulated well or the difference in cost between the small main and the large main. Thus, although the difference in temperature between the ground and the main is greater in case of the high pressure, the loss due to radiation is found to be smaller. First because we can insulate better and second because the surface in contact with the ground is not nearly so great in case of the high pressure.

But this is not the only reason for this change. When the pressure is reduced the steam is superheated and as this reduction is to be made at the building all the superheat will be available for heating and this is what we want. Furthermore the steam which condenses on its way up the hill can return directly to the boilers without interferance from reduction valves. The size of the steam lines should be such as to give the steam a velocity of about 6000 ft. per minute.

Now having our boiler decided we must select or discard the various boiler and furnace appendages. The first question in

boiler operation is feed water and feeding this water into the boilers. At present the boilers are fed with city water and under city pressure, making a very simple scheme. I presume that our new plant will use city water since a filtering plant of our own could hardly purify our small quantity of water in competiton with the city price. We will only need enough water for the engines or turbines as the heating steam returns to the boilers in the form of condensed steam, except that which escapes from the radiators.

If we raise the pressure of operation to 125# as proposed it will be necessary to establish feed pumps. These feed pumps will only have to pump against a head of 25# so that they will not require very much power and I believe the economy gained by the 25# raise of pressure will greatly offset the additional increase in cost. We can use steam driven reciprocating pumps or turbine driven pumps but I doubt the advantage of the latter if they are built in such small sizes. We can also use a motor driven pump and I am somewhat biased in its favor. Before buying a pump, however, I would get prices from the various makers and select the pump which I thought most servicable. Economy and first cost are minor consideration here because the power used is very small as compared to the total power generated, and the cost is but a fraction of a percent of the total cost. I believe it will only be necessary to establish one pump and also to make this pump large enough to take care of the 1000 H. P. of boilers, for the larger the pump the more carefully it will be built and hence the less troublesome.

We now want to know what capacity of pump to buy. As said before we will only have to supply engine water. Our ultimate plant will have 450 H. P. of engines and the consumption will be 25# of steam per horse power hour--a liberal figure. Thus the pump must be able to pump 11250# of water per hour against a pressure of 25#, or 1350 gallons. If we allow an efficiency of pumps and motor, or steam cylinder, to be 50% the power required to drive the pump will be .66 H. P. This is too low as we know from experience but this is of little import anyway.

As stated before will need to put in only one pump, for if this one pump bets out of commission we will only have to lower our pressure 25# and feed from the city main until our pump is fixed.

We can now deal with the mechanical stoker. If stokers are used the building in mind will not have to be changed in the least. This is some consolation if we decide that mechanical stokers are advantageous. The following advantages are quoted for the stokers.

1. Saving of fuel and hence apparent increased economy.
2. Saving of labor.
3. Smoke abatement if we used a recognised boiler and stoker.
4. Better boiler operation and hence increased life of boiler.

Of course we must know the extent of each of the above advantages before we can make our decision. The decision will be made by weighing the advantages against the disadvantages.

One well known stoker, (The Jones Underfeed), is guaranteed to save 10% of fuel as compared to hand firing, as well as to practically abate all smoke. The price of three such stokers is $4,200.00. This $4,200.00 is practically all the expense extra incurred by the use of stokers.

Now the disadvantage of this stoker measured in dollars is 4200 x .15 = $630.00 per annum, considering the depreciation, interest on the investment, tax and repairs etc., as 15% of the first cost. This figure is about right for such machinery in this country.

Now suppose that 300 H. P. of steam is used for eight hours per day for six months in the year. Suppose that it takes 35# of steam to make one H. P. and that to make each pound requires 1000 B. T. U. Next let the water in the boiler receive 9000 B. T. U. per lb. of coal, then each day we must have

$$\frac{300 \times 35 \times 8 \times 1000}{9000 \times 2000} = 4.7 \text{ tons of coal for heating.}$$

Now we must get the coal per day required for power. Suppose the power factor is 0.3 and that the peak load is 300 H. P. The average load is therefore 90 H. P. Each horse power hour requires 25# of steam and the load is on for 15 hours. Coal required per day for power is

$$\frac{90 \times 25 \times 15 \times 1000}{9000 \times 2000} = 1.4 \text{ tons.}$$

The power load is carried for 300 days per year approximately, and the heating load for 200 days. Total coal used per year is 300 x 1.4 + 200 x 4.7 = 1360 tons. If this coal costs $1.50 per ton the value of coal used each year is $2040.00 If we save 10% of this coal each year the saving will amount to $204.00. If mechanical stokers are not used the plant will require an extra fireman during the day for six months out of the year. This item will amount to $300.00, allowing the fireman $1.50 per day. The total saving due to the use of mechanical stokers is evidently $504.00 plus smoke abatement per year. Thus the smoke abatement must be considered worth $126.00 per year, and in my own opinion it is.

The calculations with reference to saving due to use of stokers are all based on assumptions and for this reason must be taken with a grain of salt. I believe that more coal than this will be used but am doubtful as to the 10% saving of fuel, so that as far as increased economy goes it is about tit for tat. We must however, consider that this plant is for the University of Tennessee and for this reason should be a model plant.

The Kincaid Stoker is about 1/3 cheaper than the Jones Underfeed but it does not have the reputation of the latter, neither is it guaranteed so confidently. The construction, simplicity and modus operandii of the Kincaid Stoker are certainly convincing--to me at least--and if I were actually building a plant I would tra vel several miles to see one in operation for to see one actually firing would be the greatest argument for or against the stoker. The greatest doubt that enters my mind regarding this stoker is its ability to spread the coal uniformly over the grates, but if the makers are to be believed the stoker maintains a more uniform fire than any human fireman.

After all is said pro and con I believe that mechanical stokers can be profitably put in our plant. As mentioned before one big argument in favor of this decision is the fact that the plans for the building will not have to be altered in the least.

Having decided on the type, size, etc. of our boilers it only remains now to choose some make. Of course we will want boilers of proven merit. There are several makes of boilers in the field today which have reputation and are doubtless high grade boilers. The one boiler that strikes my favor is the Babcock and Wilcox Water Tube Boiler, both in theory and construction. Having examined the boiler literature sent me by the various manufacturers, there is not a doubt left in my mind as to the superiority of the B. & W. boiler.

Other boiler buyers seem to be of my opinion, judging from the great horse power of the B. & W. boilers installed annually and these installations seem to be giving satisfaction, almost universal satisfaction in fact.

Only a few boiler builders were written to but a look at the prices quoted by them will show that the boilers do not vary so greatly in cost. The variance is not enough to warrant the purchase of any boiler against ones judgement in any case, and if I were buying boilers I would pay several hundred dollars more for B. &. W. boilers than for any other. So let it be settled that Babcock & Wilcox boilers are to be used.

The size of boiler is 250 H. P. and either two or three are to be installed at present with prevision for an ultimate number of four. If two boilers are put in now let them be put in a single setting, that is we will have a battery of two boilers, and if three boilers are put in let two be set in a battery and the third set in singly, with the intention of being set in a battery with the fourth boiler.

The question of feeding the boilers ought to be settled definately. As mentioned before only enough water will have to be supplied to make steam for the engines. If we comply with power plant practice in general we will use a steam driven, direct acting pump, and as I see no reason for doing otherwise let us follow. The great advantage of this pump is its adjustability

to various rates of feed, for by simply varying the opening of the steam valve, the speed, and hence the rate of pumping, can be varied as is necessary. The exhaust steam from this pump can be turned into the exhaust from the engines and will therefore be used for heating during the day.

When buying a pump we had as well buy one which can supply the demands of the ultimate plant. This plant will have a capacity of 450 engine H. P., and as each engine H. P. per hour demands approximately 3 gallons we will have to supply 450 x 3 = 1350 gallons per hour, or say 1500. We will want to use a duplex pump on account of the simplified valve mechanism.

Selection of Feed Water Heater.

Of course we will want some kind of a feed water heater in our plant. Feed water heaters are not costly and their influence on power plant operation is very marked. Various installations of heaters could be made in our plant and the most suitable one should be selected. On consideration the following solutions will be observed.

1. Closed heater using part of the exhaust steam of engines during day, also during night if plant is operated non-condensing, but if condensing, using steam from auxiliaries. This heater will only heat water from the city mains, the water from the buildings being heated, returning to the boiler thru a trap.
2. Economizers heating only water taken from mains, water from "Hill" being returned to boiler thru trap.
3. Economizers heating only water coming down the Hill, exhaust steam heater to heat water taken from mains.
4. Economizers to heat all water going into boiler.

Some of the above statements had best be qualified. For instance an open heater is not mentioned. The reason for this is self evident. If an open heater were used we would use no part of the city to help the feed pumps also this installation would be difficult to operate. Exhaust steam heaters cannot be used to heat the water returning from the Hill because this water is only a little below boiling temperature and hence only a little below the temperature of the exhaust steam.

To make each solution clearer the general arrangements of the heaters and pumps might be given.

1. If operation is condensing the exhaust steam must be piped both to heater and condenser with proper valves. The heater may be connected either as a thru heater or as a vacuum heater. The exhaust of the pumps must also be connected to the heater. It is not however necessary to run them into the atmosphere as the steam from the pumps can be used for heating at all times. The only change in the above for non-condensing operation is the abandoning of the exhaust connection to condenser. For both condensing and non-condensing operation a feed pump must be used to feed water from mains. This pump may be placed between boiler and heater or between heater and main; the second place is better as the pump will then have cold water to handle.

2. This solution can be used either for condensing or non-condensing operation, the installation being the same for either. A feed pump must be used here and should be placed between economizer and main. This case is bad if the plant is operated non-condensing as then all exhaust steam will be thrown awat at night.

3. This solution consists in the addition of an economizer to solution 1. It will not be necessary to use a feed pump to force water into boiler but it would probably be advisable to do so. Then this solution necessitates two feed pumps.

4. The use of economizers to heat all the boiler feed water would necessitate two feed pumps; one to feed the water returning from the Hill and the other to feed the water from the city mains.

Now the plant is to be non-condensing so that we will use exhaust heaters by all means. For although we have use for our exhaust steam during the day we need only about 15% of this steam for heating feed water, leaving 85% for other uses and this 85% is as much as will be needed. Also the exhaust steam is only needed about five or six months out of each year while a feed water heater is needed at all times. Now having decided to use exhaust heaters it only remains to decide whether economizers will be used in conjunction with them and if so, how. By this decision solutions 2 and 4 are thrown out of consideration, and having decided to use exhaust heaters it only remains to see if solution 3 will be profitable. In doing this let it be assumed that the flue gas temperature is lowered from 550° to 300°, or 200°.

From the booklet of the Green Fuel Economizer Company it is shown that there is approximately 1% saving in fuel for each 20° drop in flue gas temperature. Thus in our assumed case there will be a saving of 10%. Let it be assumed that this drop in flue gas temperature will take the 280 tube economizer suggested by the Green Economizer Co. (See letter). This economizer will cost $3500.00. The amount of coal calculated to be used per year is 1360 tons. (See boiler decision) or $2040.00 worth. Then 10% saving in fuel will be $204.00 But to make the economizer profitable we would have to save 15% of $3500.00 or$525.00 each year. Therefore, eventhough the calculations are based on assumptions, we see that economizers are out of the question.

A solution not mentioned previously is the use of exhaust heaters to heat water from mains and using economizers to heat this water together with the water returning from the Hill to, say 300° . A few moments consideration will show this installation to be unsatisfactory because it necessitates two feed pumps and as the discharges of these pumps will be connected they would, in my opinion, give endless trouble. Of course the above calculations with reference to economizers bars this solution because it will require the same size economizer and the reduction in terperature of flue gases will be the same.

It seems to me that our case is not at all inviting to economizers. It is doubtful if they could be maintained with profit in any plant of 600 H. P., especially where coal costs less than $2.50 per ton. If any device is put in to increase the economy of the plant the increase in economy must be decisive, and the amount of this increase should be proportional to the truble it will cause. For instance if an increase in height of the stack were thought profitable, the owner would not hesitate long in making this increase, for the stack costs nothing to maintain and performs its duties so quietly that no one knows it is around. But not so with a piece of machinery, for where there is motion there is trouble and expense of maintainence, so that if we put a piece of machinery in the plant to increase the economy this increase must be rather sharply defined.

Our feed water heater therefore will be a closed exhaust steam heater, heating only the water taken from the city mains. A feed pump will be placed between the main and the heater. The water from the Hill will return to the boiler thru a trap or to a tank, being pumped from this tank to the boiler. The direct return to the boiler will be better if a suitable trap can be secured.

SELECTION OF STEAM ENGINE UNITS FOR UNIVERSITY POWER PLANT.

In the selection of units for any power plant, whether it be steam, water or gas propelled, we must first of all determine the size of units which best fulfills our needs. Suppose for example we have a mill to run. The power plant will be uniformly loaded at all times.(That is for most cases of mill work) As it is well known that machinery operates most economically when fully loaded, we will select units of just sufficient capacity to drive our mill, without having reserve capacity except in case of probable growth and then not always. Furthermore we will in all probability have no standby units except in some particular cases. Standby units are nice things to have but they increase almost every item in the cost of a plant and the cost of operation, and of course this increased expense varies with the amount of standby power. Most mills have no need of reserve power, since a breakdown merely causes a session of rest for two or three days, and even if working only in day time, have a chance for minor repairs at night--in any event a breakdown is generally of slight importance.

But when we come to a central power plant we have an entirely different proposition from our mill, Most central plants run 24 hours and hence if one unit breaks down we must have another to take its place, as there must be a continuous supply of power, or otherwise few customers will be left to use power. Of course any plant could harbor a breakdown occasionally with a consequent cessation of power, but in cases of public supply the second or third occurrance would bring a rival plant upon the scene. So that in the case of any central plant it behooves us to have

sufficient reserve power for any probable emergency.

Now on coming to the selection of prime movers for our plant we see at once that we must provide for the breakdown of one unit. Of course two units might be out of commission at one time but this would be small recommendation for the engineer or the operator, and is improbable for a plant containing only two to five units, tho is probable in plants with a larger number of units.

In all plants we must have sufficient power to supply the maximum demand, or the peak load, as it is better known. Though the peak load may be for only one half hour out of the 24 it must be supplied. It would seem well if the peak load could be cut down and distributed, but, this is impossible as the plant is made for the load and not the load for the plant. It is also good practice to take the peak load without calling the standby power into use, but in some cases it might be practicable to put the reserve into play, as for instance if the peak load should occur weekly instead of daily. But for our plant it seems best to use the reserve for guarding against breakdown only.

But we must not select out units with reference to peak load only or we may be left behind as power plant designers. As before stated machines work most economically when running fully loaded. Suppose we have two units, one being a reserve, then the units must be of sufficient size to carry the peak load. Next suppose that the average load outside the peak amounted to one eight of the peak with a maximum rise to one fourth the peak, then we see at once that our unit would operate rather poorly most of the time, being only one eight loaded. In this case it would seem best to install two additional units--one a reserve--of one fourth the size of the large unit to take the average load. But in this case the big unit would be used only a small portion of the time which would occasion a poor condition of circumstances. A machine at this day and time must work hard and long to pay for its board and keep and the board and keep of an idle engine amount to a considerable portion of that for the same engine running. So any design is a complicated problem with no fixed solution and in a great many cases with several solutions all of which are equally good.

By the above example we see that we could have nine or ten units--one or two reserve-- of one eight peak load capacity. Thus we could accomodate any load with fully loaded machines, or practically so, by merely putting on enough engines to take the load. This is what is generally done, the number of units varying with the plant capacity and the conditions of loading; always using the smallest number of units to fill the bill satisfactorily For by using the smallest number of units we pay the smallest first cost and upkeep expenses as these expenses per horse power vary inversley as the size units. So we are limited in the selection of units but the limits are by no means close.

Now having digressed upon power plants in generalfwe can get

down to our particular one. As this plant is to be designed with a future enlargement we must keep both future and present plants in view, and should look almost, if not as hard at the future plant as at the present for we do not know when the increased capacity may be needed. But judging from the growth of most power plants it is not entirely invisible.

First we must get the probable present peak load and the probable future peak load. The present peak load is 100 H. P. but this will in all probability be increased to 150 H. P. during the next year and to 250 H. P. during the next four years so that we must consider 200 to 250 H. P. our present load. Now if our 1000 H. P. boiler plant ever becomes a reality we will no doubt have an engine peak of 400 to 600 H. P. or let us say 500 H. P. Next we must look at our present and future load characteristice. This we cannot tell exactly as it is a rather difficult proposition and changes will take place in the future, and the near future, which we must consider our present. But the problem is simplified by the fact that we want the fewest units to fulfill our conditions satisfactorily; also by the fact that the efficiencies of engines do not vary so greatly with various loads as to make the operation with one half or one quarter load out of the question. Indeed this condition of operation frequently obtains and is good practice.

Let us consider a few sizes of units for our plant. Suppose we say 250 H. P. units. Then for the present plant we have two 250 H. P. units, which would give a rather poor economy, the engine being only loaded to a fractional part of its capacity most of the time. But this is not all, we would have to but 500 H. P. of engines. Out of this 500 H. P. of engineswe would probably use only 100 to 175 H. P. which would be bad. But on the other hand let us look at the future plant equipped with 250 H. P. units. We would have three units and the load conditions could be met fairly satisfactorily, one engine taking the load something like half the time. The average load would be 300 to 350 H. P. which gives a much better condition of affairs. 250 H. P. is clearly the upper limit of the size units to be installed.

Let us now consider a low limit. Take 75 H. P. engines; then for the present plant we would have four units. (The units might be slightly overloaded during the peak but this is allowable) With this number of units we could get a very good distribution of power but four units for a 50 H. P. plant are too many as practice and common sense dictate. But when we come to the 500 H. P. Plant the error is still more pronounced. We would have to have eight engines, a number used in plants of ten or twenty times this capacity. Of course the percent of standby power is lower than for a fewer number of units but this is a very doubtful advantage as small units cost more per horse power than larger units. Again the better power distribution is a doubtful advantage as the economy is lower than for larger units. So

without hesitation we can place the 75 H. P. units as an extreme low limit.

We now have our limits for the size engines to be installed. These limits are 75 to 250 H. P., a rather wide range, seemingly. But we must take into consideration the fact that the horse power of any particular engine is not an absolutely fixed thing, and hence makers rate their engines in even numbers, the size of the engine going up in convenient increments. These increments vary, from 5 H. P. for very small engines, to 1000 to 5000 H. P. for very large engines and turbines. So we must consider the sizes of engines available for our plant as 100, 150, 200 and 250 H. P. We may also consider 125 and 175 H. P. units as these can be secured from almost all engine manufacturers. We now have six possible sizes of units and as we do not know definitely the present or future load conditions we will have to select the units on assumed load conditions and by the use of sound judgement. (I hope)

For a better study of the problem let us make a table which will convey the ideas more or less graphically. Let us take 250 H. P. as the present and 500 H. P. as the future peak load, also 150 H. P. and 300 H. P. as the present and future average loads. These are merely assumptions and must not be followed too closely. Never the less these assumptions are probably not so very far removed from the true load conditions. In the following table let plant capacity be the peak load the plant can take without the use of the standby unit. Let the 'percent load' be the percent the average load is of the power of all the machines.

Size Unit	No Units Pres.	No Units Fut.	Plant Capacity Pres.	Plant Capacity Fut.	Percent Load Pres.	Percent Load Fut.
250	2	3	250	500	30%	40%
200	2 or 3	3 or 4	200-400	400-600	37.5%-25%	50%-37.3%
175	2 - 3	4	175-350	525	43%-28.6%	42.8%
150	3	4-5	300	450-600	33.3%	50%-40%
125	3	5	250	500	40%	48%
100	3	6	200	500	50%	50%

By looking at the table it appears that the 100 and 125 H. P. units are the most suitable in the lot. A closer inspection however will convince that this is not the case. The plant would contain too many units for the capacity obtained. In case of the 100 H. P., as a peak load we could take only 200 H. P. and only 250 H. P. with the 125 H. P. units. The latter units however would not make such a bad instalation and would probably give satisfactory results, but the reasons for not selecting this size unit will be made clear later. The 250 H. P. units have been discussed before but let us rename the objections. In the first place the load distribution is bad. Next we must install 500 H. P. to realize 250 H. P. Furthermore we might not want as great a

peak load as 250 H. P. for our plant for several years to come, but of course we will know better when the money is available for the plant. Now for the 200 H. P. units. Suppose at present we install two 200 H. P. Units, then, as in the case of the 250 H. P. engines, we have too much idle power. If we install three units we would only be justified in so doing if our peak should be 350 H. P. or more, and this is in excess of what I believe it will be for the present plant. This size unit is also a misfit in our future plant where we can either take a peak of 400 H. P. with an installation of 600 H. P. or a peak of 600 H. P. with an instellation of 800 H. P. This latter peak is more than I believe will ever be needed, least wise in several years to come, while the former peak is too small in my opinion. Let us now consider the 175 H. P. Engines. A glance at the table will show that this size unit is undesirable. For example we can take a peak of only 175 H. P. with two units and a peak of 350 H. P. with an instalation of 525 H. P. This latter peak is more than necessary for our present plant while for our future plant the only available peak is 525 H. P. with an installation of 700 H. P. 525 H. P. is a greater peak than we will ever need.

We now only have one size unit left, viz. 150 H. P. As all other sizes have been discussed in a negative mood, this is evidently my choice. One great advantage of the 150 H. P. Unit is its flexibility. We can secure almost any power we desire by merely adding an engine. This is also true of the smaller engines but with these we will have too many units. Now not knowing the exact conditions of loading we would prefer to be able to build our plant so as to secure the loading for our engines, and the larger our engines to be able to do this the better. Suppose we put in three 150 H. P. engines, our peak capacity will be 300 H. P. This is a rather high peak for the present plant but this means that the plant will last longer without increase in size than a plant of smaller peak. At any rate we want to build as large a plant as possible for if we happen to secure an appropriation for a plant no one knows when an additional appropriation could be secured for enlargement. On considering our future plant we see that we can take a peak of 450 H. P. with an installation of four engines. Four engines gives the most suitable installation with reference to the rest of the plant, as will be seen later, and after all we must design every part with every other part in view, in other words the plant must be a unit in itself. The decision in favor of 150 H. P. units may be bad and is due more to personal opinion than any concrete reasons. This is where the element experience comes into plat and I have had only a limited amount of this element in power plant design. We could go on giving advantages and disadvantages of each particular size units and could even make calculation on our assumption but the very fact that the calculations are made on assumptions makes them worthless.

Having decided the size of our engine units we can go into the engine details. Here again we have a broad field to select from. But one thing is certainly determined for us. That is we must use a high speed engine. This is not absolutely necessary but if we do not have a high speed engine we must belt our generator or use a very large generator, either of which expedients is

almost unexcusable. Belt connection is to be avoided always and has long since been discarded for connecting engines to generators. The large slow speed generator is costly, as is also the slow speed engine and the cost per horse power of the two combined would be considerably more than for a high speed set, and the increased advantage would be none too marked, The decision for the high speed engines cuts out the consideration of several types of engines. For instance all Corliss engines are outside our ground except possibly the high speed simple Corliss. But more suitable and economical engines can be had than the high speed simple Corliss, and simpler engines too. The very name "high speed Corliss" is almost enough to bare the engine for we think of the Corliss as an inherently slow speed engine.

We might next look at european engines and see if any are adapted to our conditions. The locomobile is clearly out of the question as we want boiler power for heating purposes and anyway the fuel saving is not the only question. The uniflow engine might be possible but it is almost sure to be a heavy, costly machine and probably slow speed. From all accounts the uniflow engines requires a heavy foundation and a rather large floor space, all of which items bring up the unit cost. This unit cost would almost surely be in excess of the cost of American machines to such an extent to eliminate it form consideration. The poppet valve approaches nearer our needs, as we have a chance for a high superheat, (200-250 degrees, as will be shown later), but this engine is open to the objection of other European engines, viz. high first cost and difficulty of getting, although most of these kinds can be gotten from American manufacturers. Anyhow we are Americans in America and ought live accordingly.

We have only two types of engines left to consider; the single valve, simple high speed engine and the single valve, compound high speed engine. It takes only one look to decide between these types of engines, Clearly it would be absurd to use a simple engine here. The simple engine may have a few less number of parts and a slightly lower first cost? This latter statement is doubtful as the manufacturers of engines haveprobably gotten out of the habit of making 150 H. P. simple engines.

As there are several styles of compound engines we had best next choose our style. For driving generators only two styles of compound engines are used and the difference between these is slight. These two styles are the tandem and the duplex. There is little preference between these two as the principle is exactly the same; but the duplex is more compact and occupies less floor space, but a few cents in the price per horse power would offset this advantage. However for the sake of definiteness let us say a 150 H. P. duplex compound engine without steam jacket, the steam jacket causing more trouble and expense than it is worth.

Two important considerations yet remain before we can buy our engines.

1. Shall we operate condensing or not? (a) If we operate condensing will we use the condenser only at night or at all times?

2. Will we superheat out steam? If so to what temperature, 100-250 degrees?

Question 1a is easily answered. If we should decide to use condensers we would buy engines designed for condensers: and if our engines are designed to operate condensing we would want to operate them so at all times. Further if condensers should prove economical they would certainly have to be operated constantly. The other two questions are more difficult but I do not doubt that that installations answering these questions in all possible ways would prove satisfactory. Thus we might have the following combinations.

1. With condensers and superheaters.
2. Without condensers and superheaters/
3. Withour condensers and with superheaters.
4. With condensers and without superheaters.

We must now select one of these four solutions. Take first the condenser question. Our engine is to be a good high speed single valve engine. Now this type of engine does not unvite condensation. The valve motion is unsuitable. It would probably pay to condense of our cooling water would flow thru the condenser by gravity, but this is not so if we have some other disposition for our exhaust steam. In our plant for 4/7 of the time we can use our exhaust steam for heating. Also though we have condenser water in abundance it is not so very well situated and would have to be pumped and the addition of condensers to our engine plant would add enough trouble to offset the increase in economy. So we see that condensing has scarcely an argument in its favor for this class of engine plant and hence we will operate non-condensing. More reasons could be given for this stand, but the ones mentioned above ought to be enough to satisfy one of the undesirability of condensation here.

We now come to superheating. The reasons pro and con, in this case are not so marked as in the decision against condensers. As stated before we have a chance for high superheat here. The reason for this is that we use only about one half our boiler capacity for power. It is evident that we do not want to superheat our heating steam as it will be superheated anyway when the pressure is cut down. Now is an ordinary superheater be installed in every boiler we would get about twice the degree of superheat usually obtained.(We might install independently fired superheaters easily, but could we use this highly superheated steam to advantage? I think not. Our slide valves would operate badly also lubrication trubles, (these are sufficient for saturated steam engines), would be increased. Then again the superheaters might be short lived, but we could probably guard against this. The chief objections to this scheme are engine troubles and the fact that the economy of a compound engine is not increased to such a great extent by superheating, although it is increased some for a moderate superheat. We had better abandon the high superheat as an untried and doubtful project.

The moderate superheat should now be tested out. We can secure moderate superheat with superheaters as ordinarily built in the following ways.

1. We could place a superheater in every other boiler. This would be very well except that when the superheat boilers are out of commission we have no superheat and for this reason our piping might be complicated. These objections are easily overcome however, and this method can be made successful.

2. We could thicken our superheater tubes by incasing them in another tube, or we could put in a sheet of metal tetween the hot gases and the tubes. Either of these methods might prove expedient, and at any rate both would prolong the life of the superheater.

3. In most makes of boilers I believe we could locate the superheater where it would not be subjected to such a high temperature as is ordinarily done, but we could secure the same by virtue of the increased superheating surface.

But before deciding on how we will arrange our superheater we had best decide whether we will use a superheater or not. As said before the superheater does not increase the economy of a compound engine to any great extent, but it does increase it some. Now our boiler plant is limited to a moderate pressure due to the use of steam for heating, and hence the thermodynamic efficiency is low. By the addition of superheaters we could bring this up, although whether the fuel economy would be increased I do not know accurately, but to the best of my knowledge it would . At the present time fuel saving is not of such an importance, but the price of fuel may go up in the next few years to such an extent as to make it so. Anyway our plant, being a permanent one, and belonging to the State University, should be equipped with modern appliances to increase the efficiency, provided these appliances are not too costly or troublesome. The superheater, being a simple device cannot bring the first cost per horse power up to such an extent as to be barred.

Superheaters have been used now for the past several years and without a doubt any first class make would be satisfactory and give very little trouble with careful supervision, with which our plant will be necessarily supplied. So let us superheat our steam to the neighborhood of 100° F. The superheater being part of the boiler and must be selected with reference to the boiler and therefore will be discussed with the boilers.

So now if we decide to use engines as prime movers we have the kind of engine which we wish to buy exactly in mind and the make of engine that we buy will depend on the quality of the engine and the price, and these can be best gotten from the manufacturers themselves. However as we have not yet deceded to use engines we can leave off this detail for a while.

On reference to the letters received it is evident that the above decicion is wrong. Most of the manufacturers recommend a simple engine. The Ridgeway Company suggest a tandem compound indeed, but even then they say a four valve engine is much preferable to a single valve engine. By reference to the performances and prices of the various engines there seems to be no great advantage of any one engine over the others, in fact, the engin es are all close contenders, showing that engines are becoming more and more standardised. But a reference to the letter from the Ames Iron Works and the reprint from the 'Power' sent by them, will show one that their engine is more economical than any other engine in the list under any conditions of operation. Contrary to my opinion gotten from Gebhartt this engine is neither costly bulky or slow speed; in fact it compares with the simple engine in these respects and further more it compares very favorably indeed with the compound engine in economy. The company putting this engine out is no doubt a relaible one and a safe guarantee could no doube be secured with the engine.

When buying a piece of machinery we must of course consider the workmanship used in the building of that machinery. Now the Unaflow engine is new in America so that we ought to pay especial attention to the construction. A careful study of the description of this engine in the catalogue sent me by the manufacturers has convinced me that this engine is a well built American engine, as good as any. The engine is of course simplified by the absence of the exhaust valves and this is something in its favor. Furthermore this engine has found much favor in European practice and is modern in every respect. Being equipped with poppet valves we can use any superheat we desire. But the limited time given for this thesis bars the possibility of making as thorough examination of the various engines as if actually buying one so that the Unaflow engine built by the Ames Iron Works is the most suitable engine for our purpose.

A reference to the letter from the foster superheater people will show the danger of using indirect fired superheaters as I have previously proposed. After thinking the matter over it seems to me that their criticism is just and that we could scarcly make an installation of indirect fired superheaters which would give satifaction except possibly with Heine boilers. These latter boilers when equipped with superheaters have a bypass around the superheater so that the gases pass directly to the stack thus cutting out the superheater. Although I would like to use superheaters, Heine boilers have not been selected and as my desire to use superheaters is not as strong as my desire to use other boilers we had better drop the superheat idea. We could use independently fired superheaters but I do not much like the idea.

CONDENSERS.

Let us first consider condensers for steam turbines if we decide to use turbines. Gebhardt says that with coal costing $1.50 per ton and a power factor of 20% we can afford to maintain a vacuum of 20". This is when the condenser cost is $10.00

per kilowatt. Our condensers however will cost nearer $20.00 than $10.00, so that this vacuum could not be profitably maintained. It is doubtful if any vacuum could be maintained with profit on turbines of this size as the economy is only increased 15% or 20% with a 28" vacuum. If, however, we suppose that coal goes up to $3.00 per ton we could no doubt condense to a 26" vacuum profitably and let us assume this to be the case.

Now our plant at present will be equipped with three turbines, one a standby unit. We can either put in one, two, or three condensers. Then we would have a condenser for each turbine; or a condenser for each of the two turbines which we intent to use regularly with the standby unit connected to one of these condensers, or connected to operate non-condensing; or we could have one co denser connected to all the turbines, this condenser being af suchaa size as to condense the steam from two turbines. Then when our plant is increased to its ultimate size we can put in an additional condenser. I prefer the use of one condenser because we would only want to use the condenser at night when we would have our maximum load and hence would want full condenser capacity so that one condenser would fulfill our needs as well as two.

Now we come to the selection of type of condenser. If surface condensers are used they will cost more, both the first cost and the maintainance cost than either the jet or the siphon condenser. But to offset this increased cost we will save our steam. Now is water costs 15¢ per thousand gallons and if our load is 100 K W for five hours and the uses 40# of steam per k.w. hour with surface condensers we will save

$$\frac{\$(40 \times 100 \times 5 \times .15)}{8.35} = \$0.36 \text{ worth of water each night.}$$

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Now suppose the total expense of condensers is 15% their first cost. Then at 15% $0.36 a day will be the interest on $875.00 which will hardly be the difference in price between a surface condenser and a jet or siphon condenser. But on top of this the surface condenser requires more water per lb. of steam than the jet condenser for the simple reason that there is a metal wall interposed between the steam and cooling water, hence it requires more power for the auxiliaries of the surface condenser than for those of the other types of condenser. Also our cooling water is rather dirty and would , I believe, give trouble in surface condensers but the other condenser will use any liquid. So on the whole it seems to me that the surface condenser would be out of place here.

Now is jet condensers are used we will have to install two cooling water pumps, viz. one to force the water upto the condenser and one to take the water out. This is because we cannot put our condenser low enough so that the vacuum will cause the water to be forced into the condenser. In fact we cannot place our condenser lower than 25 ft. above the water supply and this is beyond the practical limit of suction so that the siphon

siphon condenser seems to fit our case better for we only have to use a pump to pump our cooling water up to the condenser, also we have enough elevation for suitable tail pipes. So let us say one siphon condenser in the present plant and two in the future.

In almost all condenser plants the cooling water is supplied by centrifugal pumps. The centrifugal pump is simple and effective, It is valveless and the motion is rotary, making a much nicer machine than the reciprocating pump, so we had best consider a centrifugal pump. Now we can drive this pump by a turbine or an engine or a motor, all three of these drives are used ant the turbine seems to have preference for large plants. It seems to me that the motor drive will suit us better than an engine or turbine and the cost of each will probaply be about the same. We will not want to use the condenser except when we are generating electricity and hence will never be hindered by lack of current.

Suppose the motor to be 80% efficient. Suppose our main turbine uses 30# water per H. P. hour and that engines or turbines for pump drives use 50# of water per H. P. hour. And suppose the efficiency of the generator is 90%. Then for the motor drive the steam consumption will be

$$\frac{30}{.90 \times .80} = 42\#$$ per H. P. hour as compared to the 50# for the other drives.

CONDENSERS FOR ENGINES.

What has been said with reference to type of condenser in the previous discussion holds equally well here. The surface condenser would be more out of place with engines than with turbines as we cannot use the condensed steam over.

If condensers are used at all they will only be used at night for we have good use of the exhaust steam during the day. During the day we can use the exhaust steam for heating. For heating purposes exhaust steam has a thermal efficiency of 100% but for doing work this efficiency drops to 10% or less--hence the foolishness of condensing during the day. So if condensers are used they will only be used six hours per day except when the weather gets so warm that heating is not needed. We can make correction for this additional time by assuming that our plant operates 365 days per year.

Let us suppose that the cost of a condenser is $1500.00 Let the average load be 150 H. P. which lasts six hours for 365 nights per year. Coal costs $1.50 per ton. Let us assume that the cooling water must be forced against a head of 25 ft. and that it takes 30# of cooling water to condense a pound of steam. Let the cooling water pump have an efficiency of 50% . Then according to the reprint from Power and the letter from the Ames Iron Works the condensing saves about 5# of steam per horse power hour, the engine taking 21# when operating non-condensing

Thus the saving effected by the condenser will be 24% of the steam.

Power required for cooling water pump is

$\frac{150 \times 30 \times 16 \times 25}{33000 \times 60 \times .50} = 1.82.$ But for driving this pump together with the air pump will require probably 5 H. P. These pumps will be steam driven, the exhaust steam being used for feed water heating. We cannot count this heat used in heating feed water in favor of the condenser because if the condenser were not used the whole exhaust steam of the main engine would be abailable for heating feed water. Let us consider that the steam consumption of these auxiliaries is 50#H. P. per horse power hour.

When not condensing the steam consumption of the plant is 150 x 21 = 3150# steam per hour. When condensing the consumption is 150 x 16 + 5 x 50 = 2850# steam per hr. Thus the saving in steam consumption per hour is 3150 - 2850 = 500 #. This saving per year will be 500 x 6 x 365 = 1,095,000# steam at 125# pressure gauge. To make a pound of steam under this condition form feed water, at, say, 200° requires 1025 B. T. U. Let us assume that 9000 B T U out of each pound of coal is transferred to the steam. Then to make 1# of steam requires .114# of coal. Therefore total saving of coal per year due to condenser is $\frac{1095000 \times .114}{2000} = 62.5$ tons. Saving in dollars is $94.00 or we might say $100.00. $100.00 is the interest on $666.00 at 15%. We see at once that the condenser will not be a profitable investment because $666.00 is only about one half the cost of a condenser. More than this we would hardly want to make a saving as small as $100.00 in a plant of this size unless that saving would give practically no trouble which is not true of the condenser.pumps. Our plant is not well situated for condensing. We can scarcely use tail pipes without expensive excavations and if jet condensers were used with a pump for pumping out the condensate another pump would have to be installed to pump the cooling water to the condenser. So on the whole the installation of condensers would be bad engineering.

Our engine units are now decided. We will use Unaflow engines built by the Ames Iron Works. Each of these engines will be capable of driving a 100 K W generator. The engines will operate non-condensing and without superheat and on steam at a pressure of 125#, gauge. Two or three of these engines will be put in at present with room for four.

ENGINES VS. TURBINES.

So far the turbine has not been considered as a possibility for the plant. An examination of the letters from the various engine and turbine builders will convince one that the small turbine is not a serious comptitor of the small engine, even though large turbines have almost driven the large engines out of the field for cintral station work. The large turbine is a

much more nearly perfected machine than the small turbine, while all sizes of high grade engines are on practically the same basis.

Our problem is not a turbine problem. The exhaust steam will be used for heating during the day and for this reason the back pressure will be about 20#. The turbine naturally adopts itself to low back pressure and unless low back pressure can be maintained no turbine is a real competitor of the engine. We can readily see that even if it should prove advantageous to condense at night it would be foolish to condense during the day. For this reason the turbine would operate uneconomically during the day because the turbine is built to operate under one set of conditions and no other.

There is no use of carrying the discussion further because a personal of the before mentioned letters will be convincing enough. the only advantage of the turbine is its lower price--first cost I should say--but to offset this the gest turbine made will use at least twice as much steam as the engine selected. when operating under the same conditions. Another disadvantage of the turbine is its high speed. This would be no harm if alternating current were to be generated: But we want to generate direct current and a direct current generator acts best when operated at about the same speed as the speed of an engine.of the same size. Some of the generators are geared to the turbines and some are direct connected; but the slowest generator speed is 600 R P M to get which gears are used. Modern generators and commutators operate very s tisfactorily at 600 R. P. M., but notice that to get this speed requires the use of gears, while with engines we can get as low speed as is desired by direct connection.

The engine will cost about $600.00 more than the turbine, (That is engine and generator and turbine and generator). Let us suppose that three sets are to be installed; then the engine outfit will require $1800.00 more to buy than the turbine outfit. We can also assume that the turbine will require twice as much steam as the engine, and the latter takes 25# per H. P. Hr. As previously stated it will require 1.4 x 300 = 420 tons of coal to operate the engine one year and since the turbine uses twice as much steam as the engine it will require 420 more tons for turbines than for engines. 420 tons of coal at $1.50 per ton is $630.00, which is the interest on $4200.00 at 15% . Therefore we could afford to pay $1400.00 more for an engine than for a turbine while we only have to pay $600.00

The equipment has all been selected and to give the reader a chance to get everything in mind a summation of this equipment had best be given.

EQUIPMENT FOR THE CENTRAL HEATING AND POWER PLANT.

Boilers-- 250 H. P. vertical header, Babcock & Wilcox water tube boilers, operating on 125# pressure, hand fired. The present plant will have either a battery of two boilers, or a battery of two boilers and a single boiler. The future plant will consist of two batteries of two boilers each.

Stokers--none.

Superheaters--none.

Feedwater heaters--one closed exhaust steam heater capable of heating 1500 gallons per hour.

Feed pumps--one duplex steam driven direct acting pump with a maximum capacity of 1500 gallons per hour.

Ash and coal handling apparatus--none. The coal will be dumped directly from hopper bottom cars into the coal bins.

Engines--160 H. P. Unaflow engines built by the Ames Iron Works. Two or three engines will be installed at present with an ultimate capacity of four engines.

Generators--100 K. W. direct current generators wired for three wire system at 220 volts. Generators direct connected to engines.

Condensers---none.

Seperators--a standard separator will be supplied for each engine.

Piping and fittings--all piping will be standard asbestos covered. All fittings will be extra heavy cast iron.

Traps, etc.,--The plant will contain all such minor auxiliaries, such as traps, where ever they are needed.

PLANT LAYOUT.

As stated before any plant must be designed as a unit; each part must act in conjunction with every other part. Two possible layouts have been prepared. Layout A, which is the first, has been abandoned in favor of layout B. Layout A was designed with the intention of using condensers and is what might be called a rather idealistic design. The building is of reinforced concrete thruought and is somewhat of a novelty. The second building is of brick with the exception of the coal bunkers which are reinforced concrete. The advantages and disadvantages will next be discussed.

LAYOUT A.

As stated before this design was gotten up with the intention of using condensers, but having abandoned the condenser idea this design has likewise been set aside. There are several very marked weaknesses in Layout A and they are enumerated as follows:

1. Costly excavation.
2. Unsuitable engine foundations.
3. Crowded boiler room.
4. Expensive coal handling system.
5. Untried design.

A look at the blue print will show the rather large amount of excavation for the boiler room and its basement. If this excavation should happen to run into rock it would entail a very large expense indeed. Even then the boiler room will be half under ground making a darker room than one all above ground. Again thouble might be experienced in getting the boilers into the boiler room but suitable provision could be made for this. The boilers are shown with chain grate stokers but if these were used the boiler room and hence the whole building would have to be widened 12 ft. which would make the building approach the second building in ground area. But chain grate stokers could not possibly be put in profitably for the Underfeed stokers were right on the line and chain grate stokers cost more than a half more than the Underfeed stokers. The chain grate stoker is the only stoker which I would advise installing, and since it cannot be put in had better be used. Now is no stokers are to be used why have overhead bunkers. They entail the use of expensive concrete construction and coal handling apparatus.

No condensers are to be used but layout A provides for them and by consulting this bluepring it will be seen that the space unoccupied by them is almost unavailable for anything else, but of course it is foolish to make a building which has unusable space for every cubic foot of space represents just so much capital and the interest thereon.

The engines will be mounted on pier-like Boundations 12 ft. high. Furthermore the foundations of every engine is connected to a heavy floor at the top and bottom. Both these floors should be heavy, and the engine room floor especially because it has to support the generators. It is bad practice to connect the engines foundations: they should be entirely independent. The reason for this is apparent. Suppose all the engines were running, and are running in syncronism, that is, the pistons are all traveling in the same direction at every instant. It is easily seen that the combined inertia forces of all these reciprocating masses would require heavy foundations to withstand indeed. Especially when the engines set 12 ft. above the base of the foundations.

This design is novel. There are only two colums, (the stack acts as a column). The building to pay the stack for its service as a column, braces the stack against wind pressure. Whether this arrangement would be safe is doubtful for the stack is subjected to high temperatures as are also the columns, and it is bound to expand. This expansion might endanger the building and such desigh ought to be avoided.

Another fault of Layout A is the concrete construction which does not make a very nice looking building. This difficulty could however easily be avoided by veneering the structure with brick.

LAYOUT B.

Layout B has no such great disadvantages as Layout A: it is a far more common sense and satisfactory design. The whole structure is roomy and convenient and it accords well with modern practice. Besides this the structure will cost less although the stack will cost more.

All the drqwings are to scale. The dimensions were left off for the sake of clearness.

CONCLUSIONS.

I believe that thesis work would be more profitable if a part of a term were devoted to the work entirely and exclusively. The minor details of working problems, attending classes and writing reports is very digressing.and diverting to say the least.

Where coal is $1.50 per ton and first class labor can be secured for $1.50 per day there seems to be no call for either labor saving devices or the auxiliaries in a power plant which are used to increase the economy where conditions are different. Besides the engines and boilers there is apparently no call for other apparatus, such as condensers, economizers, etc., except the exhaust steam heaters, which are economical only for the reason that they are almost costless.

COST OF PLANT.

No estimate could be made which would give satisfaction in any degree but in a general way the present plant will cost in the neighborhood of $50,000.00, complete and ready to run.

LETTERS.

The following letters have been received and some idea of the cost of the various appliances in a power plant may be gotten from them. Also a comparative idea of the performance of various engines and turbines, etc.

154



WILLIAM L. GREENLY.

WILLIAM L. GREENLY, Governor of Michigan for the year 1847, was born at Hamilton, Madison Co., N. Y., Sept. 18, 1813. He graduated at Union College, Schenectady, in 1831, studied law and was admitted to the bar in 1834. In 1836, having removed to Michigan, he settled in Adrian, where he has since resided. The year following his arrival in Michigan he was elected State Senator and served in that capacity until 1839. In 1845 he was elected Lieut. Governor and became acting Governor by the resignation of Gov. Felch, who was elected to the United States Senate.

The war with Mexico was brought to a successful termination during Gov. Greenly's administration. We regret to say that there are only few records extant of the action of Michigan troops in the Mexican war. That many went there and fought well are points conceded; but their names and nativity are hidden away in United States archives and where it is almost impossible to find them.

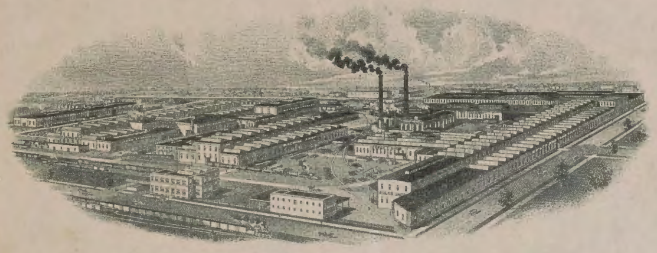
The soldiers of this State deserve much of the credit of the memorable achievements of Co. K, 3d Dragoons, and Cos. A, E, and G of the U. S. Inf. The two former of these companies, recruited in this State, were reduced to one-third their original number.

In May, 1846, the Governor of Michigan was notified by the War Department of the United States to enroll a regiment of volunteers, to be held in readiness for service whenever demanded. At his summons 13 independent volunteer companies, 11 of infantry and two of cavalry, at once fell into line. Of the infantry four companies were from Detroit, bearing the honored names of Montgomery, Lafayette, Scott and Brady upon their banners. Of the remainder Monroe tendered two, Lenawee County three, St. Clair, Berrien and Hillsdale each one, and Wayne County an additional company. Of these alone the veteran Bradys were accepted and ordered into service. In addition to them ten companies, making the First Regiment of Michigan Volunteers, springing from various parts of the State, but embodying to great degree the material of which the first volunteers was formed, were not called for until October following. This regiment was soon in readiness and proceeded by orders from Government to the seat of war

Falls City Whale Co. Ky. Incorporated.

ADDRESS ALL COMMUNICATIONS TO THE CO.

CABLE ADDRESS VOGT.
WESTERN UNION & A.B.C. CODES 5TH EDIT.



OFFICE AND WORKS, 10TH AND ORMSBY.

HENRY VOGT MACHINE CO.
INCORPORATED.

MANUFACTURERS OF
ICE AND REFRIGERATING MACHINES,
WATER TUBE AND OTHER BOILERS.

LOUISVILLE, KY., U.S.A.

Apr. 14, 1915.

Mr. M.B.McMahon,
c/o University of Tennessee,
Knoxville, Tenn.

Dear Sir-

We are in receipt of your letter of the 13th inst. relative to 250 H.P. Boiler. We will get the necessary data together in connection with this inquiry, and send you drawings and preliminary estimate within the course of the next four or five days, which we trust will be satisfactory.

Yours truly,

HENRY VOGT MACHINE CO.

H E Turk

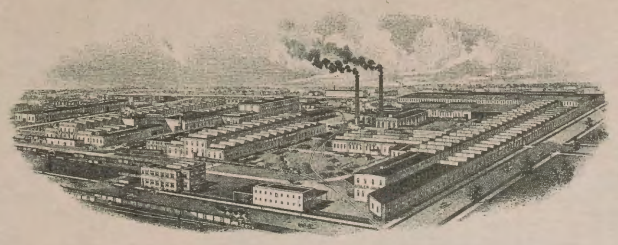
BOILER DEPT.

HE (LK)

ALL CONTRACTS ARE SUBJECT TO APPROVAL AT LOUISVILLE, KY., AND ARE CONTINGENT UPON STRIKES, ACCIDENTS AND OTHER DELAYS BEYOND OUR CONTROL. QUOTATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

ADDRESS ALL COMMUNICATIONS TO THE CO.

CABLE ADDRESS VOGT.
WESTERN UNION & A.B.C. CODES 5TH EDIT.



OFFICE AND WORKS, 10TH AND ORMSBY.

HENRY VOGT MACHINE CO.

INCORPORATED.

MANUFACTURERS OF

ICE AND REFRIGERATING MACHINES,
WATER TUBE AND OTHER BOILERS.
DROP FORGINGS.

LOUISVILLE, KY., U.S.A.

May 25, 1915.

ALL CONTRACTS ARE SUBJECT TO APPROVAL AT LOUISVILLE, KY. AND ARE CONTINGENT UPON STRIKES, ACCIDENTS AND OTHER DELAYS BEYOND OUR CONTROL. QUOTATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

Mr. M.B.McMahon,
c/o University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

Enclosed you will find blue print showing foundation plans for three - 250 H.P. Water Tube Boilers. We have given you a general outline of the building required for these boilers, and you, of course, can make this of whatever size suits you.

We are enclosing print showing elevation of a battery of 250 H.P. Vogt Water Tube Boilers.

The approximate cost of three - 250 H.P. Water Tube Boilers erected, including the brickwork and foundations, as shown on print (exclusive of stokers, pipe connections, breeching and stack) is Eighty Five Hundred ($8500.00) Dollars.

The breeching should not cost, including covering, under ordinary conditions more than One Thousand ($1000.00) Dollars.

As to the stack - we would suggest that you get in touch with the Alphons Custodis Chimney Construction Company, Atlanta, Ga., (Healey Building), as they can give you full data on this subject.

On superheaters we suggest the Power Specialty Company, 111 Broadway, New York, N.Y.

There are a number of first-class stokers made, such

as Westinghouse, Green, Jones, Under-Feed, Murphy, Detroit, etc. The names and addresses of these concerns can easily be located in Engineering papers.

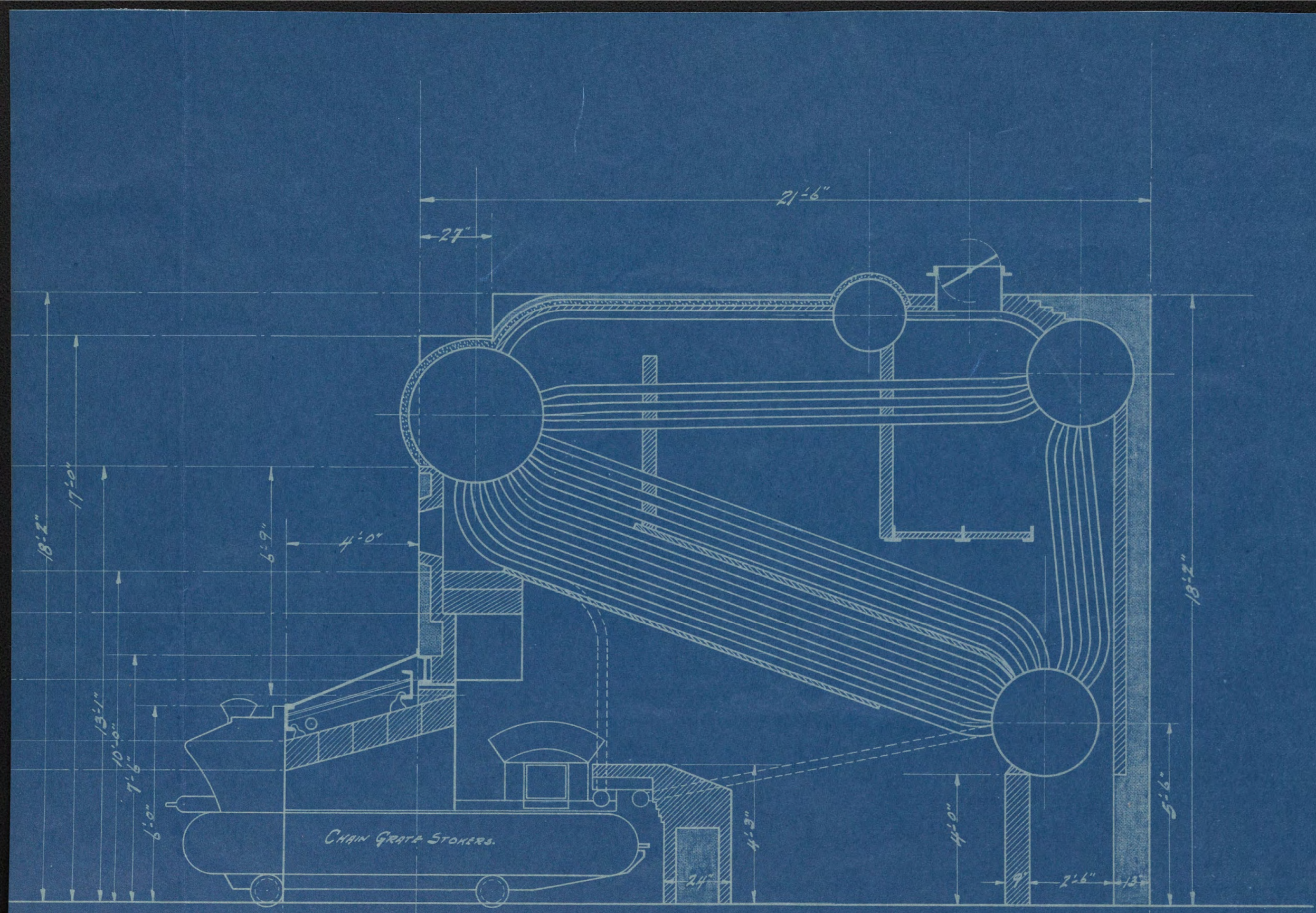
Now if there is any further information we can give you, please do not hesitate a moment to call on us.

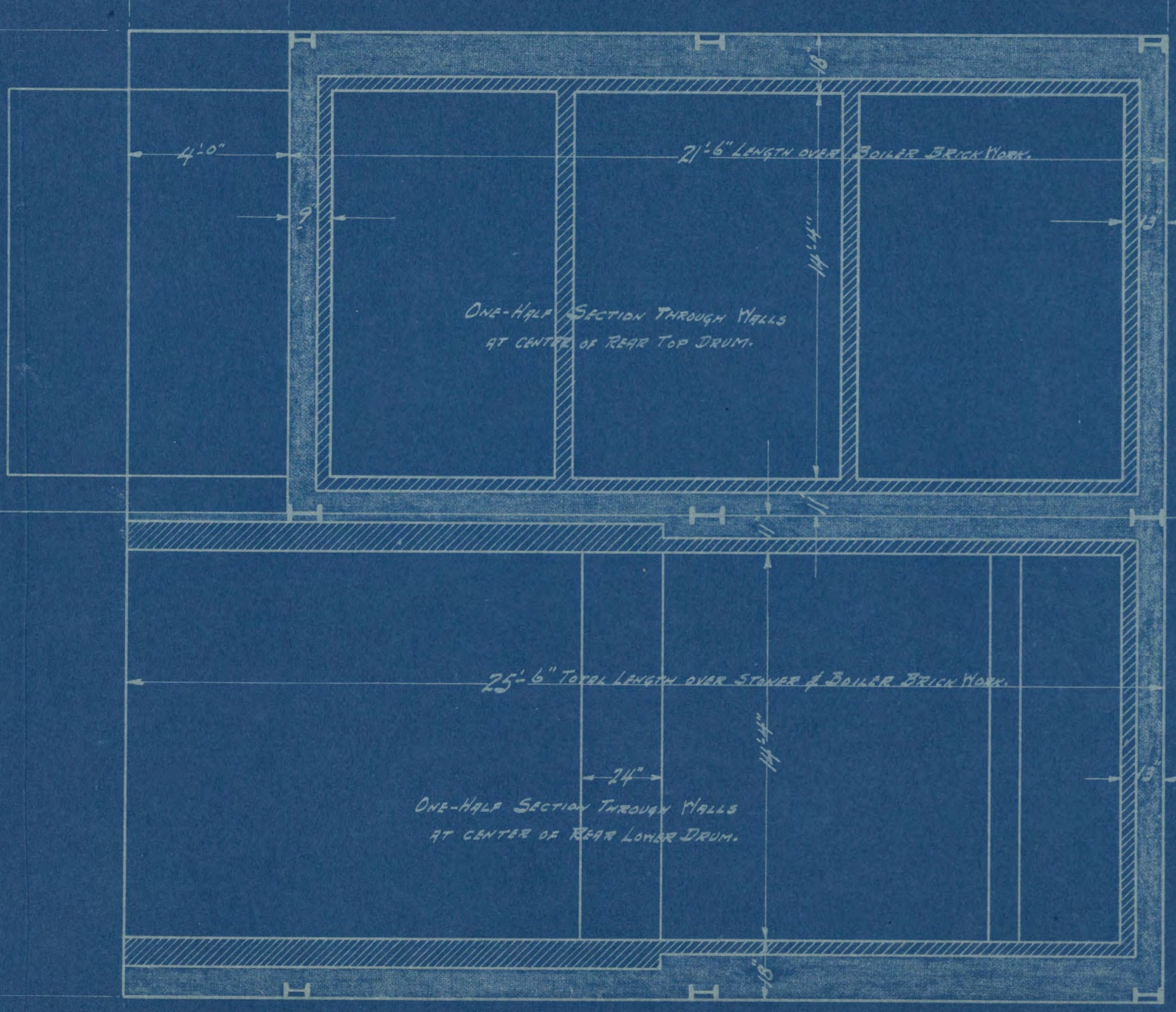
Yours truly,

HENRY VOGT MACHINE CO.

HE (LK) BOILER DEPT.

P.S. We are enclosing blue print showing chain grate stoker as applied to our class "L" boiler.


21'-6"
27"
18'-2"
17'-0"
13'-1"
10'-0"
7'-6"
1'-0"
6'-9"
4'-0"
CHAIN GRATE STOKERS.
24"
4'-3"
4'-0"
9"
2'-6"
13"
5'-6"
18'-2"


4'-0"
9"
21'-6" LENGTH OVER BOILER BRICK WORK.
18"
14'-4"
13"
ONE-HALF SECTION THROUGH WALLS
AT CENTER OF REAR TOP DRUM.
33'-6"
25'-6" TOTAL LENGTH OVER STOKER & BOILER BRICK WORK.
24"
14'-4"
13"
ONE-HALF SECTION THROUGH WALLS
AT CENTER OF REAR LOWER DRUM.
18"

GENERAL OFFICE
ST. LOUIS, MO.

SHOPS
ST. LOUIS, MO. AND PHOENIXVILLE, PA.

HEINE SAFETY BOILER CO.

WATER TUBE BOILERS AND
SUPERHEATERS

ANSWERING YOURS OF BY ST. LOUIS April 24, 1915.

SUBJECT:

Mr. M.B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:--

Replying to your recent favor, we beg to state that our price on one (1) 250 Heine Water Tube Boiler built for 180# working steam pressure (our standard) and a superheater for 100° F. delivered F.O.B. cars Knoxville, Tenn., is Three thousand dollars ($3000.00)

We do not manufacture stokers, but have set our boilers with every type of mechanical furnace. If you will indicate your preference for stoker, we will get prices and plans from manufacturers and arrange our setting to suit the same.

It is difficult to give you the cost of setting without a plan from which to estimate, but we will be glad to do this later.

You speak of three (3) boilers and if you will tell us how you propose setting them, whether singly or two in battery and one singly, we will make you up a location drawing with dimensions.

Under separate cover we are mailing you a B.P. No. LLL-97 that will give you a general idea of setting for two (2) 250 H.P. boilers, also some pamphlets also a copy of our "Helios. We trust you will find these of interest.

Very truly yours,
HEINE SAFETY BOILER COMPANY.

J C Murphy
SALES AGENT.

JCM/JB



MAIN OFFICE
85 LIBERTY STREET, NEW YORK

WORKS
BAYONNE, N.J. BARBERTON, OHIO

THE BABCOCK & WILCOX CO.

BUILDERS OF

BABCOCK & WILCOX - STIRLING - RUST

WATER TUBE STEAM BOILERS

STEAM SUPERHEATERS MECHANICAL STOKERS

BRANCH OFFICES

BOSTON, 35 FEDERAL STREET
PHILADELPHIA, NORTH AMERICAN BLDG.
PITTSBURGH, FARMERS DEPOSIT BANK BLDG.
CLEVELAND, NEW ENGLAND BLDG.
CHICAGO, MARQUETTE BUILDING.
CINCINNATI, O. TRACTION BLDG.
ATLANTA, CANDLER BLDG.
PORTLAND, OREGON, SPALDING BLDG.
TUCSON, ARIZONA, SANTA RITA HOTEL BLDG.
NEW ORLEANS, 533 BARONNE STREET
DENVER, 435 SEVENTEENTH STREET
SALT LAKE CITY, 705-6 KEARNS BLDG.
SAN FRANCISCO, 99 FIRST STREET
LOS ANGELES, I. N. VAN NUYS BLDG.
SEATTLE, MUTUAL LIFE BUILDING
HAVANA, CUBA, CALLE DE AGUIAR 104
HOUSTON, TEXAS, 617 WASHINGTON AVE.
SAN JUAN, PORTO RICO, ROYAL BANK BLDG.

TRACTION BLDG.
CINCINNATI, O. April 30, 1915.

Mr. M. B. McMahon,

University of Tennessee,

Knoxville, Tenn.

Dear Sir:-

Replying to your letter of April 9 to our New York Office and also your letter of the 17th addressed The Stirling Company, Chicago, both of which have been referred to this office for attention as all Knoxville business is handled through this office, and the Babcock & Wilcox and Stirling boilers are both manufactured by the Babcock & Wilcox Company.

We take pleasure in giving you the following approximate prices:-

For one (1) 250 HP wrot steel vertical header Babcock & Wilcox boiler 9 wide 14 high 18 long tubes one 42" drum, built for 200 lbs. safe working pressure, the approximate price would be FOUR THOUSAND FOUR HUNDRED ($4,400.00) DOLLARS.

For one (1) superheater for 100° superheat to be installed within the boiler setting NINE HUNDRED ($900.00) DOLLARS.

For one (1) Babcock & Wilcox chain grate stoker 60" wide by 12' 3" long including 4-1/4" x 5" vertical engine to drive the stoker, the approximate price would be ONE THOUSAND NINE HUNDRED ($1,900.00) DOLLARS.

For one (1) Stirling boiler of approximately 250 HP, built for 160 lbs. safe working pressure, the price would be FOUR THOUSAND ONE HUNDRED ($4,100.00) DOLLARS.

For superheater and chain grate stoker with the Stirling boiler the prices will be about the same as those given above for the Babcock & Wilcox boiler.

The above prices contemplate furnishing all ironwork delivered, erected and bricked in on your foundations at Knoxville, Tennessee.

We enclose, herewith, one print each from our sheets

S.L. 85951-0
P.S.H.D. 5740-0

which show side elevations of the Babcock & Wilcox and Stirling boilers respectively, both being equipped with chain grate stokers. These prints also show a system of coal handling equipment in which you may possibly be interested.

Your letter does not give us sufficient information for us to answer your question regarding the best pressure to carry on the boilers. As we are not familiar with the plans or the conditions under which you will operate, any reply we

might make would be more in the way of guess work than an intelligent opinion. The best boiler pressure, of course, depends on the equipment you install for utilizing the boiler power. We believe, however, that both boilers should be operated at the same pressure so that providing one is out of commission for repairs or cleaning the other can be forced sufficiently to carry both the power and heating load. We might also suggest your consideration of the use of the exhaust from your turbine or engines, as the case may be, for heating purposes as this is a very economical method of heating.

In regard to your last question, we beg to advise that providing the boilers are not being worked beyond their rated capacity either one could readily assume the total load and run up to 200% of rating for a period of two hours. To run at this rating, however, there must be sufficient draft and we would suggest to get this required draft a stack from 175' to 200' in height above damper.

We note from our records that you have a copy of our book "STEAM" and believing you might be interested in some of our other publications we take pleasure in forwarding you, under separate cover, copies of our books "STIRLING", "CHAIN GRATE STOKERS" and "SUPERHEATERS" from which we hope you may get some ideas which will be helpful to you in your thesis work.

Trusting the above gives you the desired information and if we can be of any further service, we beg you will not hesitate to call upon us.

Yours very truly,

THE BABCOCK & WILCOX COMPANY

H. Luehrmann

HL:BI

Enc

Ct NY

MAIN OFFICE AND WORKS
EDGE MOOR, DELAWARE

WILLIAM F. SELLERS,
PRES. AND TREAS.
H. B. BRADFORD,
VICE-PRES.
H. S. GARRETT,
SECRETARY

EDGE MOOR IRON COMPANY

MANUFACTURERS OF

WATER-TUBE BOILERS

ALL AGREEMENTS ARE CONTINGENT UPON STRIKES, ACCIDENTS, DELAYS OF CARRIERS AND OTHER DELAYS UNAVOIDABLE OR BEYOND OUR CONTROL.

QUOTATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

CABLE ADDRESS "EDGEMOOR"
NEW BUSINESS CODE

TELEPHONE
838 WILMINGTON

SUBJECT QUOTATION ON BOILERS FOR UNIVERSITY OF TENNESSEE.

EDGE MOOR, DELAWARE April 20, 1915.

Mr. M. B. McMahon,
c/o University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

We have your letter of April 13th, asking for quotation on 250 horse-power boilers for University of Tennessee, and note that your request is for thesis work. The Edge Moor boiler is built for high pressure service in modern power plants, and would make a very attractive installation in the University Power Station.

We are sending you herewith prints from our drawings No. 3645 and 4115, showing side and front elevation, as well as ground plan, of a boiler installed singly.

We also forward you under other cover copy of our catalogue which may be of assistance to you in your work, and we enclose herewith specification No. 3340, showing how the boilers would be built.

We would quote you a price of FOUR THOUSAND TWO HUNDRED AND FIFTY DOLLARS - $4250.00 on one 250 horse-power Edge Moor Wrought Steel boiler, delivered and erected on foundations provided by the purchaser, at the University Power Plant, Knoxville, Tenn., bricked in and left ready for steam, water, smoke and blow-off connections.

Or we would quote you TWELVE THOUSAND FIVE HUNDRED DOLLARS -$12,500.00 for three (3) 250 horse-power Edge Moor Boilers, two of which would be set in battery, and the third set singly, delivered, erected, and bricked in under the same conditions.

These prices are based on hand-fired installations, and if stokers were used, we would deduct ONE HUNDRED AND FORTY-FIVE DOLLARS -$145.00 per boiler, from the above prices.

Any standard stoker can be applied to the Edge Moor boilers, and in this case we quote on boilers without the lower fronts and grates. We have not used any superheater except the Foster Superheater manufactured by the Power Specialty Co., New York City, since we ceased manufacturing our own superheater.

You will note that the boilers as shown on specification No. 3340, are built for 160 pounds pressure. 125 pounds is such low pressure for a modern plant, we think it advisable to figure on

sufficient to allow for expansion in pressure, and have therefore based our figure on 160 pounds.

Trusting this data will be of interest to you, we remain,

Yours truly,

EDGE MOOR IRON COMPANY.

By _____

SGB C
4-Encs.

Form 209. 2003-15.

EDGE MOOR IRON COMPANY

MAIN OFFICE AND WORKS

EDGE MOOR, DELAWARE

EDGE MOOR WATER TUBE BOILERS

SPECIFICATION NO. 3340.

CIPHER NO. 11-1-12.

SPECIFIED H. P 256.

All material and workmanship to be of the best.
Caulking edge of plates to be bevel planed.
Rivet holes drilled with plates assembled together.
Plates taken apart and all burrs and sharp edges removed.
All necessary plans and drawings furnished.

Headers Made of Open Hearth Flange Steel plates, free from cracks and flaws. Ultimate strength 55,000 to 65,000 lbs. per sq. in. Elastic limit not less than one-half the tensile strength. Elongation not less than 25% measured in a length of 8". Reduction of area at point of fracture not less than 50%. Headers attached to drums by flanges. Tubes expanded into inner plates of headers. Effectually stayed by heavy bolts of special design. Manholes provided with forged steel covers and suitable dogs and bolts in rear headers opposite the drums. A flanged oval handhole, fitted like an ordinary manhole with oval cover and dog, opposite each tube. These covers being on the inside of the header, are tightened in position by the boiler pressure and are independently removable.

Drums Made entirely of Open Hearth Firebox Steel plates. Ultimate strength 52,000 to 62,000 lbs. per sq. in. Elastic limit not less than one-half the tensile strength. Elongation not less than 26% measured in a length of 8". Reduction of area at point of fracture not less than 50%. Outside diameter of drums 35⅛", length 18 feet, longitudinal seams will be lap jointed, double riveted and alternated to avoid a continuous line of rivets. This boiler to have one drums made of plate 3/8" thick.

Tubes 127 American Standard Soft Steel Tubes, 4 inches diameter, 18 feet long.

Steam Outlet Steam outlet five inches diameter, controlling valve furnished by purchaser.

Valves Fittings and Fixtures Boiler to be supplied with the following valves, fittings and fixtures and to have proper openings for same:

2 Size 3" Pop safety valves, set to blow at 125 pounds pressure.
1 Size 2" Feed Water Valves.
1 Size 2" Check Valves.
1 Size 2½" Blow-off Valves.
1 Size 2½ " " Cocks.

One 12 inch Steam Gauge.
Water Column with Water Gauge and three try cocks.
Necessary pipes and fittings for attaching all the above to boiler.

Pressure Working pressure 160 lbs. Hydrostatic Test Pressure 240 lbs.

Fronts Fronts fitted with Tube Header Doors, Fire and Ash Pit Doors and Frames.

Miscellaneous Parts

Hearth Plates. Grate Bar Bearers and Grate Bars. Cleaning Out Doors and Frames, Damper, Buckstays, Tie Rods, etc. Baffle Plates, Tiling and Special Fire Brick as required. Tools per plant:—Handhole and Manhole Wrenches, one Turbine Cleaner, one Soot Blower.

Space Setting Including Brickwork

2 Boilers. Set in Battery.	One Boiler Set Singly.	Dimensions of Grate.
Long 20' 10-1/2"	20' 10-1/2"	Depth 7' 0"
Wide 20' 3"	10' 5-1/2"	Width 10' 9-1/2"
High 17' 3-1/8"	17' 3-1/8"	Square Feet 75.25

(Measured from floor to top of Header). Set 7' 0" above floor.

Heating Surface

Water Heating Surface per boiler 2567. Sq. ft.

Weight

Approximate shipping weight 46500 lbs. each.

Purchaser Provides

Foundations up to floor line.

Adequate openings into boiler room for admission of boilers.

Water for pressure tests.

Non-conducting covering for exposed parts of boiler headers and piping.

Brickwork. Approximate number brick required for ~~XXXXX~~

2 boilers in batt. ~~XXXXX~~ Fire 9200 Red 28500

1 " set singly. Fire 4600 Red 18150

Shipments

Shipment will commence in ____ days from receipt of order.

Payments

Payments to be made in cash as follows:—One half of the contract price ten days after date of bill of lading, one quarter in forty, and one quarter in seventy days after date of bill of lading. These terms to apply to one or more boilers as shipped. Should shipment be deferred by Purchaser, one half contract price will be due and payable within forty days, one quarter within seventy days, and one quarter within one hundred days from date of shipment, as specified in contract.

Possession and Title

Until all work either of erecting, adjusting or testing, shall have been fully completed by seller, and the work accepted by purchaser as completely finished in accordance with contract and specifications, the boiler shall be considered in possession of seller, even though at the works of purchaser. Until final payment of the purchase price, the title of the boiler and the right of removal shall remain in the seller.

Accompanying letter of April 20, 1915.

To M. B. McMahon,
For: University of Tenn. Power Plant.
Knoxsville, Tenn.

EDGE MOOR IRON COMPANY

By [signature]

Ridgway Dynamo & Engine Company

Subject

Ridgway, Pennsylvania, April 21, 1915.

Mr. M. B. McMahon,

University of Tennessee,

Knoxville, Tennessee,

Dear Sir:-

We have your letter of the 12th. inst. and regret that rush of business prevented our taking this matter up more promptly.

We are enclosing foundation plans showing three different units which we would suggest for your purpose, although in the case of the Tandem Compound we found it necessary to send a plan showing an engine direct connected to an alternator instead of to a direct current generator. The only difference this would make, however, in the layout of a plant would be to slightly shorten the shaft length in the case of the direct current machine.

The prices of these three units would be approximately as follows:-

13 & 20 x 16 Tandem Compound, four-valve engines, for condensing operation, 26" vacuum, 225 RPM. with 100 KW. direct connected, direct current generator,
PRICE:- $14,541.00.

14 x 16 Simple, Four-Valve Engines for non-condensing service, 225 RPM. with 100 KW. direct current, direct connected generator,
PRICE:- $10,062.00.

13 x 16 Single-valve, Simple Engines 260 RPM. Non-condensing Service, with 100 KW. direct connected, direct current Generator,
PRICE:- $7,170.00.

These prices are all for three units in each case and are F. O. B. Ridgway, Pennsylvania and include no cost of erection.

Mr. M. B. McMahon,
Knoxville, Tennessee,

The tandem cpmpound units would each require 24 cu. yds. of concrete in the foundation. The simple, four-valve engines would require 19 yds and the simple, single-valve engine would require 18 yards. You will note that the single-valve engine is slightly smaller in the cylinder and is,in fact, on a smaller bed but operated at a higher speed to secure the same power. The four-valve engines do not operate satisfactorily at such a speed.

The weight of one tandem compound unit complete would be 47,000#; one simple four-valve unit complete 35,000# and one single-valve simple unit complete 26,300#.

These prices indlude indicator reducing motions and metallic piston and valve rod packing, indicator piping, combination cylinder relief and drain cocks, lubricators, wrenches etc.

All of these engines are intended for use on 125# of steam and are capable of delivering at 1/4 cut-off in case of the simple engines and .3 cut-off high pressure cylinder in case of the compound, 160 I.H.P., which is ordinarily the amount required for driving 100 KW. generators.

You did not give us the size generators you would require but mention 150 HP. for the engines and we assume from this that you have in mind about 100 KW. for the generators.

We do not ordinarily advise the use of super heated steam. Our engines work very satisfactorily with super-heated steam up to 100 degrees and in some cases at 150 degrees super-heat. This is a matter, which depends mainly upon the boiler practice and cost of fuel in your locality.

We would suggest that for an answer to your question

Mr. M. B. McMahon,
Knoxville, Tennessee,

in regard to super heat and also to determine the question of condensing operation, that you apply the standard test of balancing the annual saving to be made under actual operating conditions against the fixed charges on the additional equipment required, which charges in the case of condensers would include the operating charges, which in turn would include the cost of pumping the condensing water. This latter cost, in case you were using motor driven pumps, which would be entirely feasible, could readily be figured by computing the friction head and static head, allowing for the slip of the pump and efficiency of the motor, figuring your power cost at whatever you assume the cost to be at this plant.

In case you decide on condensing operation you will be quite certain to find that the tandem compound engine would be the most preferable and to decide between the simple, four-valve and the simple, single-valve would require another balance of saving against charges. We do not recommend the use of a tandem compound, single-valve engine, as our four-valve simple engine gives as good economy at no greater cost, and with considerble less complication. We did not quote on cross compound, four-valve as they are considerably more expensive than the tandem compound and have very few compensating advantages.

We give below a tabulation of the steam consumption at different loads for these various engines and also the efficiencies of the generators,-

For the Tandem Compound, Four-Valve Engine unit, Operating on 26" of vacuum.

	Loads			
	50%	75%	100%	125%
Steam Consumption in lbs. per I.H.P. Hr.	16.25	15.45	15.5	15.9

M. B. McMahon,
Knoxville, Tennessee,

Simple, Four-Valve Engine

	Loads			
	50%	75%	100%	125%
Steam Consumption in pounds per I. H. P. Hr.	26.2	23.6	23.8	25.3

Simple, Single-valve Engine.

	Loads			
	50%	75%	100%	125 %
Steam Consumption in pounds per I. H. P. Hr.	31.5	29.5	29.0	29.5

Generater Efficiencies.

	Loads			
	50%	75%	100%	125%
Efficiencies,	90	91	91-1/2	91

In the above tabulations we have assumed that you will not maintain better than 26" vacuum, as this is about the best that is ever actually maintained in service. The figures given are our standard guarantees, which we usually better considerably in our tests but are very satisfactory for estimating purposes, as we can positively do this well in all cases.

We think you will find that with an average sort of annual load factor of say 15%, that if your fuel costs you $2.00 per ton, you will probably do best by using the simple, four-valve engine, non-condensing. If fuel is cheaper than this the single valve will be likely to be found the most economical, but should fuel be $3.00 or your annual load factor considerably higher it is probable that you will find the most economical service to be obtained by the use of the tandem cpmpound engine, operating condensing.

We are sending you under separate cover a complete

Mr. M. B. McMahon,
Knoxville, Tennessee,

set of our bulletins, which describe these various machines in detail and which we trust you will find of interest. We hope that the information given will be satisfactory, and that in the event of this plant being actually built, we may have an opportunity to figure on furnishing the engines and generator,.

In conclusion we wish to remark, that we presume you have given donsideration to the propsition of installing alternating current equipment, which is usually decided upon by Educational Institutions, unless their buildings and campus are very compact.

Thanking you for the opportunity of assisting you in this matter, we are,

Yours very truly,

RIDGWAY DYNAMO & ENGINE COMPANY

Henry B. Jones

Sales Department.

JL.
Bulletins.

NEW YORK, 85 LIBERTY STREET
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ATLANTA, 815 THIRD NATIONAL BANK BLDG.

WORKS, OSWEGO, N. Y.

AMES IRON WORKS

ESTABLISHED 1854 INCORPORATED 1901

MANUFACTURERS OF

ENGINES AND BOILERS

ARTHUR L. MERRIAM, PRESIDENT
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WALTER B. MERRIAM, TREASURER
GEORGE B. HUNT, SECRETARY

OSWEGO Apr.15,1915.

IN REPLY PLEASE REFER TO FILE

ALL AGREEMENTS ARE CONTINGENT UPON STRIKES, ACCIDENTS AND OTHER DELAY BEYOND OUR CONTROL. QUOTATIONS SUBJECT TO CHANGE WITHOUT NOTICE

Mr. W.B.MacMahon,

University of Tennessee,
Knoxville, Tenn.

Dear Sir:

Replying to your favor of the 12th, our recommendation would be that for the plant which you mention installing one of our 14 x 16 Unaflow Engines, operating at 250 RPM, with 125 lbs. pressure, and 26" vacuum, rated at 160-HP, which engine would be of suitable size for direct connection with a 100-KW generator. The price on such an engine would be apprximately $2200.00, f.o.b.Oswego. The generator we estimate would cost about $1400.00, net, f.o.b. the works of the generator builder.

The engine which we would propose to install under such conditions would show a steam consumption of 15½ lbs. per I.H.P. per hour, with saturated steam; and if the steam is superheated 100 degrees, it will show a consumption of 12½ lbs; and if superheated 200 degrees, will show a consumption of 12 lbs, per I.H.P. per hour.

The details of the engine would be as follows: Steampipe 5"; Exhaust pipe 7"; Crank pin 6½ x 5"; Crosshead pin 3½ x 4½; Main bearing 7" x 14"; Outboard bearing 5½ x 11"; Crosshead shoe 7½ x 12; Governor wheel 67½ x 14, weight 4500 lbs; Length engine over all, 13'2"; Width engine overall 9'6"; Weight of engine complete about 20000 lbs.

AMES IRON WORKS, OSWEGO, N. Y.

-We are enclosing under separate cover copy of our bulletin #66, and reprint from "Power" under date of Nov.17,1914, illustrating and describing the engine above referred to; and if there is anything further which you desire information on, we would be very glad to comply with your request.

Yours very truly,

AMES IRON WORKS.

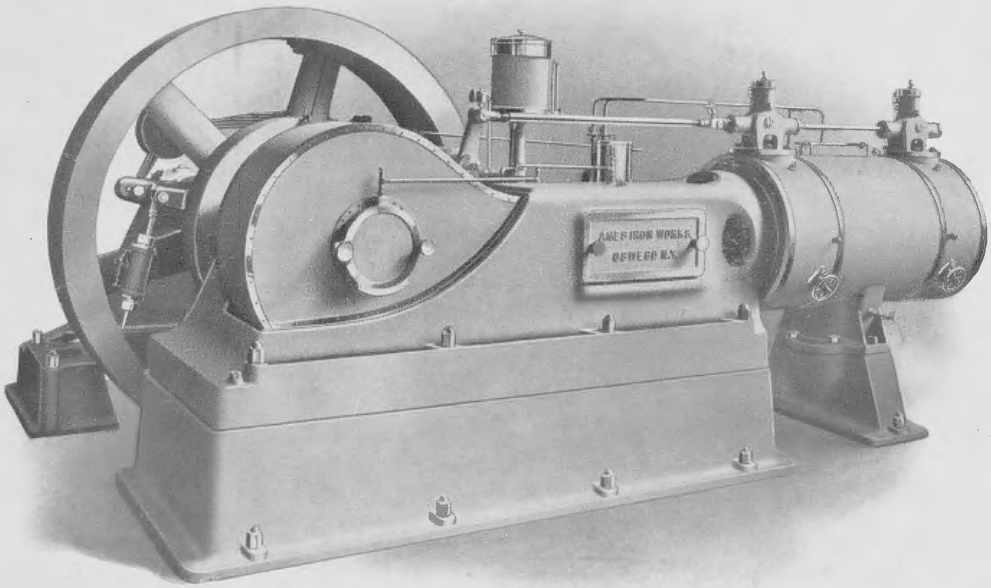
JCG:WRH.

J C Garhill

ENGINEER.

The AMES
Stumpf Una-Flow Engine

BULLETIN No. 66-B



BUILT BY

AMES IRON WORKS

OSWEGO, NEW YORK

OFFICES IN ALL PRINCIPAL CITIES

The UNA-FLOW AMES-STUMPF ENGINE

BUILT UNDER PATENTS OF PROF. JOHANN STUMPF

The Ames-Stumpf Una-Flow Engine

IN recent years several more or less successful attempts have been made to introduce into this country stationary steam engines of types in common use in European countries, and of designs originated and perfected by European engineers. These efforts have been made in several ways, either by the actual acquiring of American patent rights to manufacture, by the rather doubtful method of copying foreign designs, or recently by the importation of the engines themselves.

After several years of careful investigation, of the merits of the different European reciprocating engines, we have adopted for manufacture and sale in this country the Una-Flow Engine, built under the patents of Prof. Johann Stumpf, of Berlin, Germany, and are offering to the steam user an engine which, by reason of its almost universal use abroad, coupled with its peculiar adaptability to American steam engineering practice, will immediately establish itself as the most popular prime mover.

Economy is the watchword all over the world, and this has been developed to such a marked degree in the Stumpf design that the results obtained have been extraordinary.

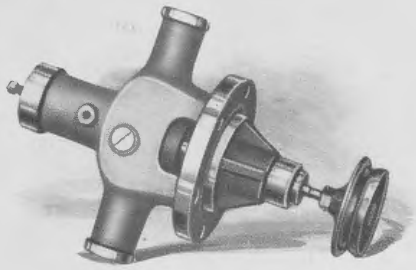
The efficiency of this engine under a wide range of operating conditions and loads, both condensing and non-condensing, is so wonderful that it has worked its way into general use on foreign railways, making the European locomotive a more efficient prime mover than the best American stationary engine.

There have heretofore always been conditions where it was best to use a certain type of engine or turbine, each type having some particular advantage over the other, for the service required, but the Una-Flow Engine, while retaining all the advantages of the various types of engines and turbines, by its elimination of initial condensation, sets a mark in economy of steam consumption unequalled by any other type of prime mover. This feature is very marked at small loads, nearly uniform economy being obtained whether the engine is developing 25 per cent or 125 per cent of its rated capacity, either condensing or non-condensing; a result, never before obtained in steam engineering. This fact, together with its adaptability to either condensing or non-condensing service, with no limitation as to pressure, superheat or operating speeds, as far as the valve-gear is concerned, places the Ames-Stumpf Una-Flow Engine in a class by itself and justifies its consideration in any plant, for any service and under any condition of operation.

Almost every possible mechanical appliance has been developed and perfected looking to high efficiency, but the real cause of the greatest losses (internal cylinder condensation) has been removed in the Stumpf Una-Flow design only.

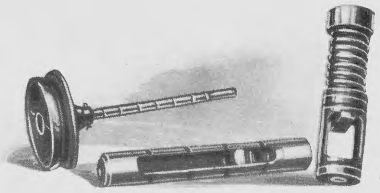
Our experience with this engine, places us in position to make very strong guarantees, which cannot be equalled by any other engine on the American market. To verify these statements, we invite those interested in the actual performance to visit our works and test this engine under any desired condition; and we know the results obtained will remove any doubt from the mind of the most skeptical, and when the highest efficiency is desired we solicit an opportunity to submit specifications and prices.

IN operation, steam is admitted to the cylinder by a double beat poppet-valve of special construction (to insure steam tightness), which is lifted by a roller in the sliding-bar when it comes in contact with the lifting-cam; and the valve is closed by the spring in top of the bonnet with lower end resting on top of a circular crosshead to which the lifting-cam is rigidly bolted. These admission valves being of the double beat poppet type, with upper seat flexible, will always remain tight. The construction of the bonnets and detail of the valve-gear is very simple. The valves are lifted in perfect alignment from their seats, so when the engine is operating at maximum cut-offs the valves and cams are practically noiseless. The valve-stems, operating in long sleeves, make it unnecessary to provide any other packing.

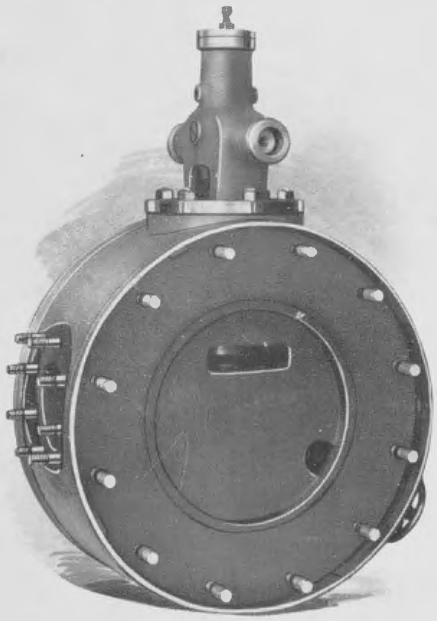


Assembled Bonnet and Valve

There are no exhaust-valves, as the piston is long enough to keep the central ports covered until the exhaust occurs, nearly at the end of the stroke. These central exhaust-ports open directly into a central exhaust-belt encircling the cylinder, from which direct communication is made with the exhaust-pipe or condenser connection. The absence of exhaust-valves, as described above, makes the cylinder end of the engine simplicity itself.



Valve, Roller-Rod and Cam, with Crosshead and Spring



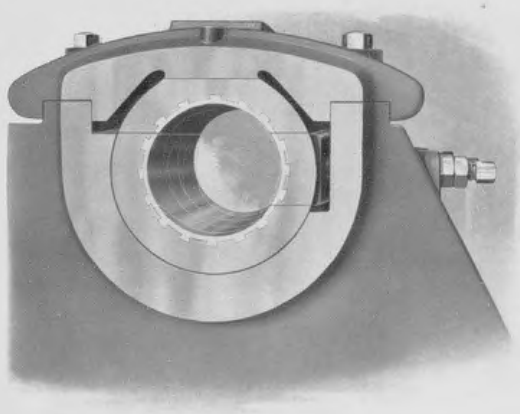
Cylinder-Head and Bonnet

The thermal disadvantage of the alternating flow engine consists mainly in the loss of heat through the cooling of large surfaces of the clearance space by the wet exhaust steam, which flows back with great velocity toward the exhaust-valves, cooling the surfaces and carrying heat to the exhaust. This heat must be replaced by incoming steam, and great internal condensation is the result.

In the Una-Flow cylinder this internal condensation is practically eliminated, as the heads are kept hot by the admission of steam at high pressure and by the heat of compression, while the exhaust-ports are never exposed to the hot steam, so there can be no transfer of heat to be carried to waste.

As an illustration, we might say that the cylinder really consists of two single acting cylinders, set end to end, with a common exhaust; and the economic value of the Ames-Stumpf Una-Flow Engine is to be traced to the uniform direction of the steam where a hot end and a cold end are maintained with a gradual fall of temperature between, the temperature of the walls being at all times higher than that of the steam to which they are exposed.

This Una-Flow principle at the steam end, combined with our regular type of heavy duty side-crank frame, reciprocating parts and governor, provides a construction which is without parallel.



Main Bearing

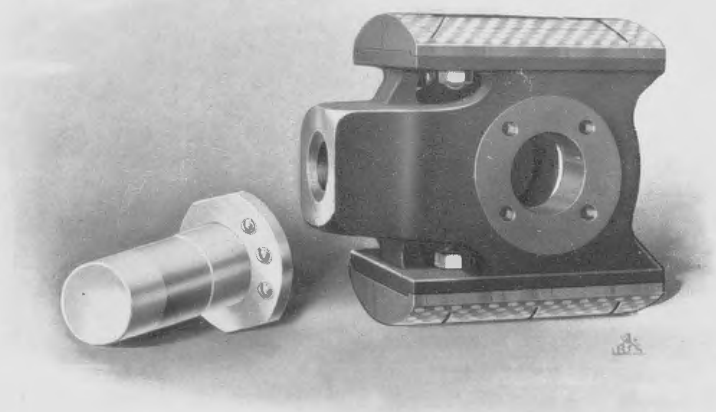
Main Bearing

The main bearing consists of a three-piece box with a heavy lining of genuine babbitt thoroughly peened and bored to gauge. The bearing rests rigidly in the frame and is securely held by means of heavy bolts and lock nuts which pass through the cap and frame housing. This rigid fastening of the bearing in position does not, however, inconvenience the adjustment, as same may be adjusted to the finest degree while the engine is in operation.

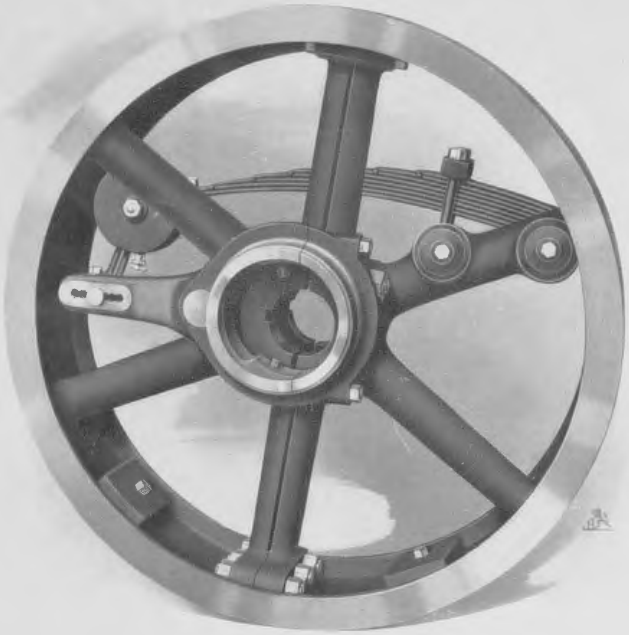
The entire bearing may be removed and replaced within a few minutes; it being only necessary to wedge up under the wheel to take the weight of the shaft off the bottom section of the bearing. *Raising the shaft 1/100 of an inch is sufficient in any case.*

Crosshead and Pin

The crosshead is of box section, made of special mixture of cast iron, having a tensile strength of approximately 28,000 pounds per square inch. The shoes are rigidly bolted in place and the lower one is provided with full babbitt face. The pin is forced in taper seats at both sides of the crosshead and may be removed easily without the use of a sledge. The pin may be given one-quarter turn when worn, thus providing new wearing surface.



Crosshead and Pin



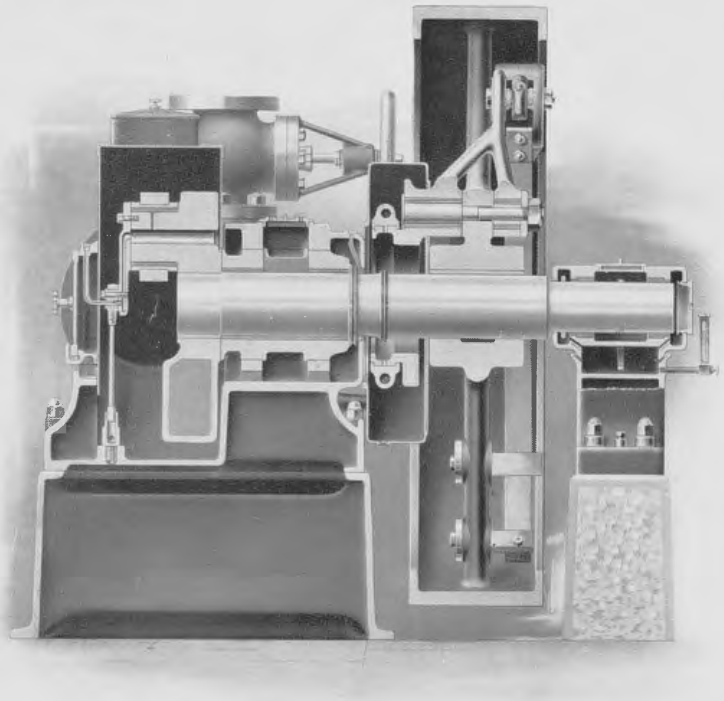
Automatic Governor

Governor

The improved *Robb-Armstrong-Sweet* governor as built by us is a perfect regulating device. It is carried in a heavy fly wheel, is simple and durable in construction, and stable in operation under all conditions of service. The split wheel has planed joints fitted together with a tongue and groove, and secured by heavy bolts in rim and hub. A split eccentric, which is doweled and securely bolted together, is used. Our experience in building the inside connected governor, necessary with the side-crank engine, has shown us that a single bearing lever will not carry the heavy weight of the eccentric and strap without proving troublesome. We use a double bearing lever as shown in the sectional view below, with a heavy pin and double bushings, the inside one revolving. This construction keeps the eccentric in line, prevents eccentric and strap from wearing out of line or running hot and gives a smooth running strap. *These improvements are exclusively our own.*

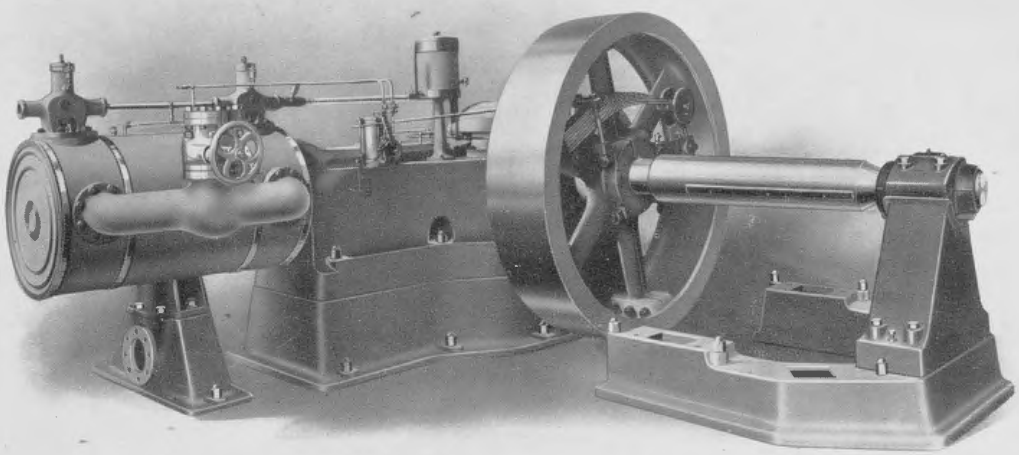
Connecting-Rod

The connecting-rod is of open-hearth forged steel with solid ends and is provided with genuine babbitt-lined boxes and forged steel wedge adjustments.



Vertical Section Through Main Bearing and Governor

Ames-Stumpf Una-Flow Engine



GENERATOR SIDE

Ames Iron Works, Oswego, N. Y.

RADCLIFFE PRESS, OSWEGO, N. Y.

Reprinted from Power, Nov. 17, 1914

The First Stumpf Una-Flow Engine Built in America

SYNOPSIS—The first una-flow engine built in America with the coöperation and approval of Professor Stumpf uses only 12.5 lb. of steam per i.hp.-hr. condensing and 16.8 noncondensing, the minimum consumption being at one-half load in both cases. It is only 15 x 16 in., runs at 250 r.p.m., and is designed to carry 100 kw. at rating.

A number of engines have been built in America upon the una-flow principle, but the first to be built with the consent and approval of Professor Stumpf, under his patents and designed by the engineers of his representative, the Stumpf Una-Flow Engine Co., who know his standards and methods, is that built by the Ames Iron Works of Oswego, N. Y., and illustrated herewith.

TESTS MADE WITH A 15x16-INCH STUMPF UNA-FLOW ENGINE

	Oct. 5, 1914 Noncondensing—Saturated				June 6 1914 Noncondensing—Superheated					Sept. 5, 1914 Condensing—Superheated					
Test No.	I	II	III	IV	I	II	III	IV	V	I	II	III	IV	V	VI
Load	¼	½	¾	full	Friction	¼	½	¾	0.85	Friction	¼	½	¾	Full	1½
Steam pressure, lb. per sq. in.	146	145	145	146	138	140	140	140	137	147	145	145	145	145	140
Speed, r. p. m.	257	256	255	254	262	258	255	253	252	----	----	255	----	----	----
Superheat, deg. F.	----	----	----	----	132	117	130	118	114	50	96	88	93	103	140
Vacuum, in.	----	----	----	----	----	----	----	----	----	26	26	25½	25½	25	24
Load on generator, Amperes	100	200	300	400	----	100	200	300	350	----	100	200	300	400	600
Load on generator, Volts	250	250	250	250	----	250	250	250	250	----	250	250	250	250	250
Indicated horsepower, hp.	55.5	93.4	130.8	171.7	12.9	56.3	92.5	134	152.3	11.5	53	93	131	175.5	257
Steam consumption, lb. i. hp.-hr.	21.0	20.4	20.8	21.3	18.0	17.3	16.8	17.0	17.3	15.0	13.2	12.5	12.5	12.9	15.3

The engine is pleasingly simple in appearance, as will be recognized from Fig. 1; and its internal arrangement and construction are just as simple. Fig. 3 shows a longitudinal and cross-section through the cylinder. Steam enters by the poppet valve in the head, is cut off early in the stroke even at full load, and exhausts through the ports in the middle of the cylinder, when they are opened by the piston passing

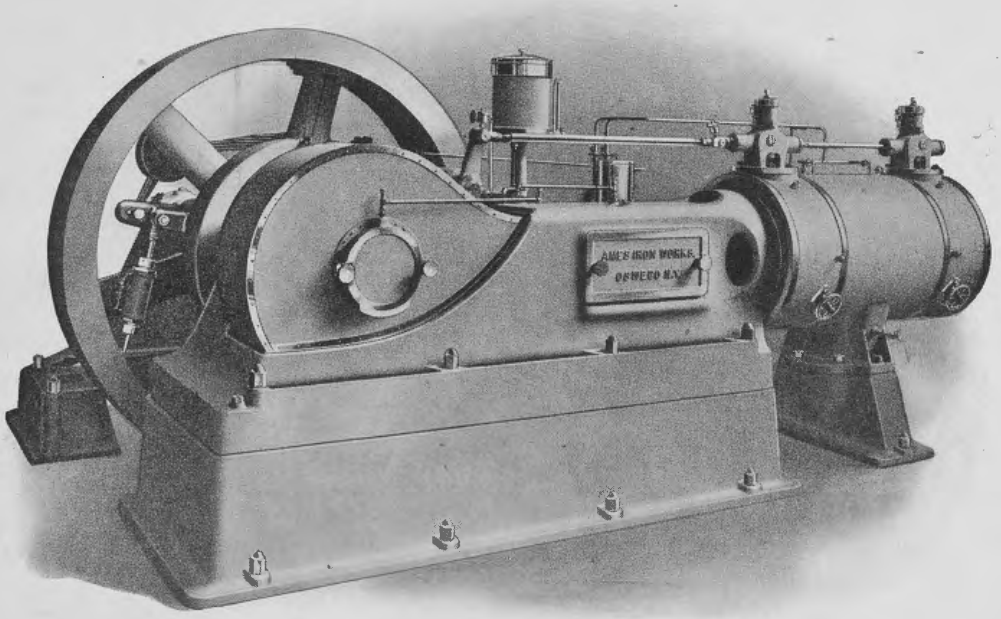


FIG. 1. THE FIRST STUMPF UNA-FLOW ENGINE BUILT IN AMERICA

This engine consists of a 15x16-in. cylinder mounted upon a standard heavy-duty frame. About as many expansions are attainable with the una-flow in a single cylinder without excessive cylinder condensation as over them. The piston is shorter than the stroke only by the width of the exhaust port. If, for instance, the piston were $\frac{9}{10}$ as long as the stroke and the port $\frac{1}{10}$, release would take place when the

stroke was $\frac{9}{10}$ completed and compression would commence when the piston had proceeded $\frac{1}{10}$ of the way on its backward stroke. If, when the piston covers the exhaust port on the backward stroke, the pressure in the cylinder is low, as when the engine is exhausting into a condenser, the compression, even with a moderate clearance, would not be very high. With the exhaust ceasing at $\frac{1}{10}$ of the return stroke there would be $\frac{9}{10}$ of the cylinderful of steam to be compressed into the clearance.

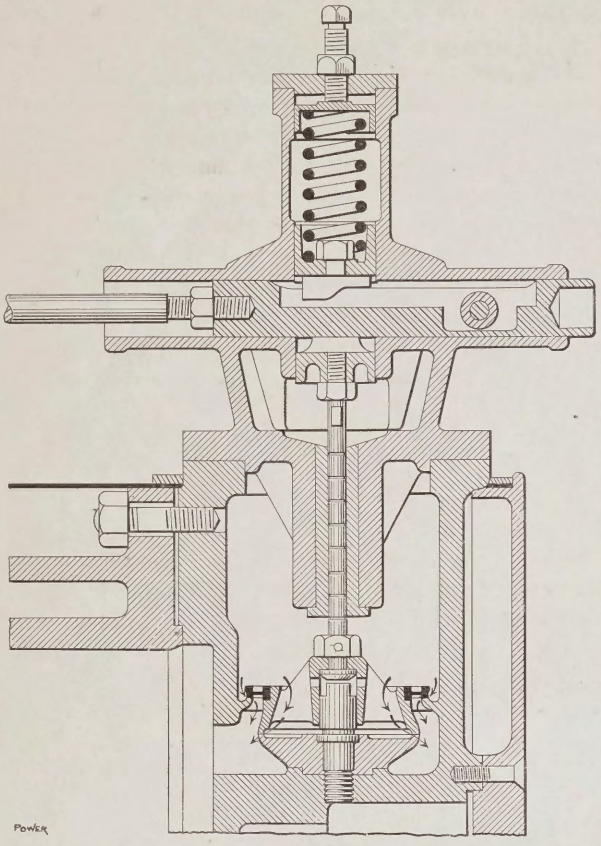


FIG. 2. ADMISSION VALVE AND GEAR

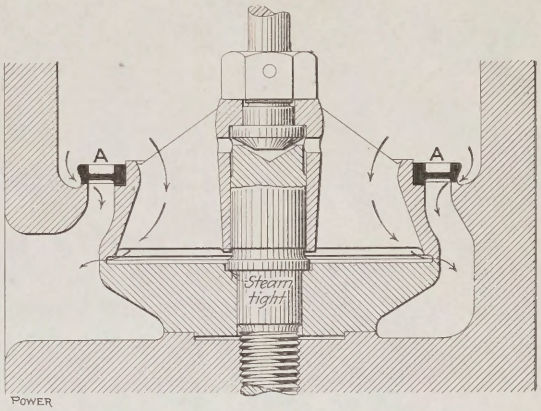


FIG. 4. DOUBLE-BEAT POPPET ADMISSION VALVE

Suppose this to be at the pressure of 2 lb. absolute, about 26 in. of vacuum, and suppose the clearance to be 5 per cent, we have, assuming the pressure to vary inversely as the volume,

$$\frac{2 \times 0.95}{0.05} = 38 \; lb.$$

showing that even with this early closure the compression would run up to only a moderate amount. If, however, the pressure at the instant that compression commenced were that of the atmosphere, say 15 lb. absolute, there would be with the same clearance

$$\frac{15 \times 0.95}{0.05} = 285 \; lb.$$

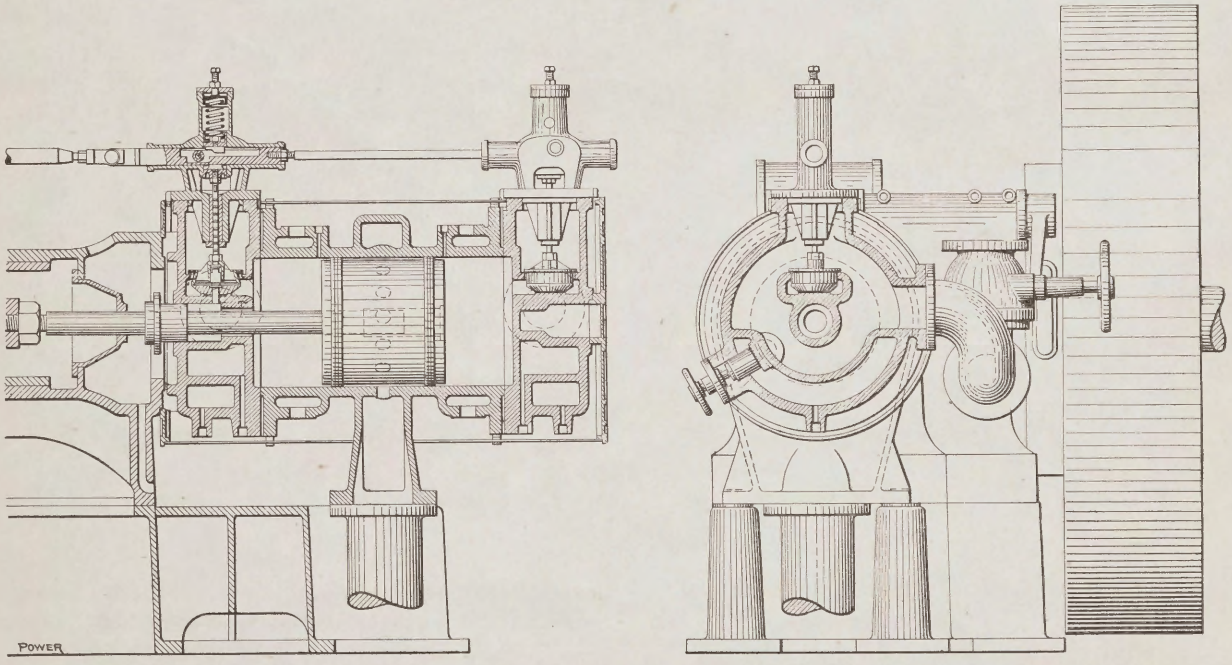


FIG. 3. LONGITUDINAL AND CROSS-SECTION OF CYLINDER

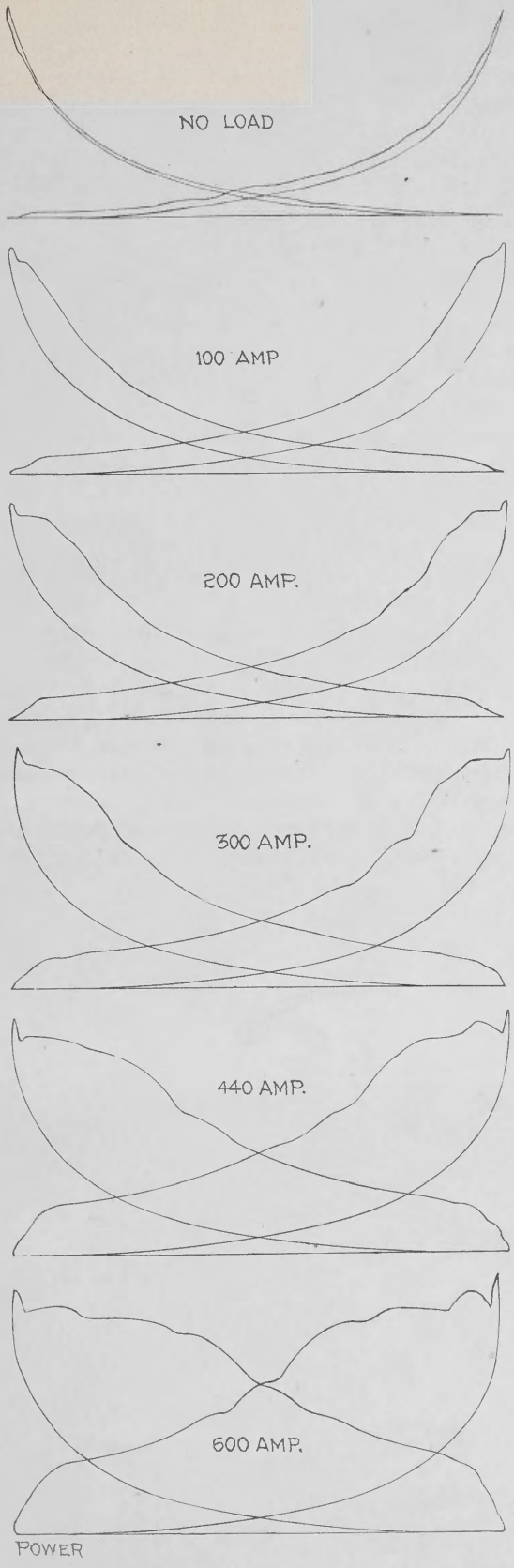


FIG. 5. DIAGRAMS FROM NO LOAD TO 50 PER CENT. OVERLOAD

On account of the absence of the usual exhaust port it is possible to keep the clearance very low, it being only 3.1 per cent in this engine even with its short stroke. For a noncondensing engine it is necessary, however, to have a greater clearance volume when the closure of the exhaust is thus early in the stroke. Professor Stumpf argues that the harmful effect of clearance, due to its volume, is slight compared with that due to its surface, and the engine designed to run noncondensing only has a piston, the head of which is turned out concave. This gives the required increase of clearance volume with the least possible amount of bounding surface. With an engine designed to run condensing a minimum amount of clearance is used, the piston being built in the usual way. In order to meet emergency conditions, as when the condenser drops its vacuum and the engine must run temporarily noncondensing, a

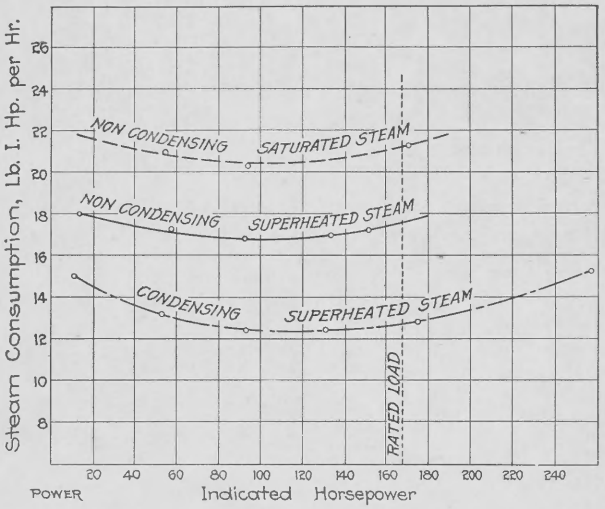


FIG. 6. SHOWING THE FLATNESS OF THE LOAD CURVE

clearance pocket is provided in the head, as shown in the cross-section in Fig. 3, the connection of which with the cylinder is controlled by the valve shown. When, for any reason, the engine has to run noncondensing, this valve is opened, connecting the pocket with the working cylinder and the clearance is increased and the compression kept down, although with a slight impairment of the efficiency on account of the addition to the containing surface. If desired the valve controlling the connection between this pocket and the cylinder may be made to open automatically, precluding the generation of excessive pressure by an accidental loss of vacuum.

The passages surrounding the cylinder between the exhaust belt and the cylinder heads are steam jackets, the motive of the engine being to preserve a hot end or zone for the entering steam; and as the exhaust does not come back through this zone it carries off no heat from it, which explains the economical results obtained by the unidirectional method of flow.

In order to adapt the engine to the use of high degrees of superheat, poppet valves are used, and one of

the remarkable things about the running of the engine is the noiselessness and ease with which these valves are handled at 250 and more revolutions per minute. The operating rod extends across both valves as shown in Figs. 1 and 3 and receives its motion through a rocker arm from the governor eccentric. Where it passes through the valve bonnet, Fig. 2, its section is circular, with a recess in which is carried a roller. This roller, by contact with a suitably designed cam surface, lifts the valve quickly from its seat, and in closing permits it to approach the seat rapidly, but to be brought into actual contact at a diminishing rate which makes no perceptible impact. The cam is kept in contact with the lever, and the balanced valve upon its seat, by the spring shown at the top. The piston immediately below the roller-carrying section is merely a guide. The valve stem depends upon its length, good fit and water grooves for steam tightness, a method long ago used successfully by Professor John Sweet.

The well known difficulty of keeping a double-seated valve tight on both seats at the same time is met by making the upper lip of the valve sufficiently flexible to be pressed onto its seat by the steam pressure. Fig. 4 shows the valve on a larger scale. The cross-hatched portion is of cast metal. The upper lip, shown in solid black, is made by shrinking on a steel ring and then turning it to the section shown, the thin center deflecting enough under pressure to allow the outer ring to seat tightly.

The table on page 1 shows some results obtained with this engine upon the testing floor of the builder's shops at Oswego, N. Y., where they are exceptionally well equipped for such determinations. In Fig. 5 are shown a series of diagrams from friction to 50 per cent overload. Steam consumptions of 12.5 and 17 lb. condensing and noncondensing are remarkable for an engine doing less than 100 hp. and the flatness of the curve of steam consumption plotted against load (Fig. 6) will give the engine a great advantage when used for light or fluctuating loads. These results were corroborated by the editor of Power, who, on Oct. 16, made a test of the engine, assisted by Professors Herman Diederichs and W. M. Swandon of Sibley College, and W. Trinks of the Carnegie Institute of Technology.

With an average load of 100.8 kw. the engine developed 168.46 i.hp., giving an overall efficiency of engine and generator of 80.2 per cent. With steam of 148 lb. gage, 125 deg. superheat and exhausting at atmospheric pressure the steam rate was 17.57 lb., the heat rate 19,022 B.t u. per i. hp.-hr. and the efficiency referred to the Rankine cycle 75.8 per cent. Every precaution was taken to obtain correct results. The weighing apparatus, thermometer, gage and indicator were calibrated, the mean effective pressure corrected for a slight inaccuracy of the indicator spring, and there is no doubt that the engine will carry the load under which it was tested with the steam consumption given.

CABLE ADDRESS "BALLENGINE"
CODES | WESTERN UNION
| LIEBERS

BALL ENGINE COMPANY.

D.N. McBRIER, President
F.B. McBRIER Vice President

A.W. MILNE, Secretary & Treasurer
E.J. ARMSTRONG, Engineer

ERIE, PA. April 20, 1915.

Subject

M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

Referring to your letter of the 12th, in view of the size of units in this plant, which is only about 100 K.W. we would not advise condensing operation, especially in view of the distance and head against which condensing water must be pumped. We believe, by making a few figures, you will find that non-condensing operation would be the more economical.

We would advise simple engines of our non-releasing Corliss type, something about 13 x 18, to operate 225 RPM, for the 100 Kilowatt machine. An engine of this type arranged for direct connection to generator would cost in the neighborhood of $2,000 FOB Erie.

We note that you intend planning for three of these engines at the present time with provision for a fourth. Would it not be better to install one 200 KW machine and one 100 KW machine, to take advantage of the more economical operation of the larger unit.

The 200 K.W. machine would take about an 18 x 20 Engine at 200 R.P.M. and would cost in the neighborhood of $3100, f.o.b. Erie.

The Steam Consumption with either of these units with 125# steam at the throttle with free Exhaust, would be about as follows:

Full Load,	22.6 #/IHP hr.
3/4	22.2
1/2	23.1

Our suggestion to use Simple Engines is partly based on the fact that you will need exhaust steam for heating purposes during a considerable portion of the year. There would no doubt be some economy in using moderate superheat, say, from 75° to 100° F.

We enclose prints K-2885 and K-2931, which show foundation drawings for the engines suggested above. The weight of the smaller machine would be we think about 20,000#. The weight of the larger engine about 32,000#.

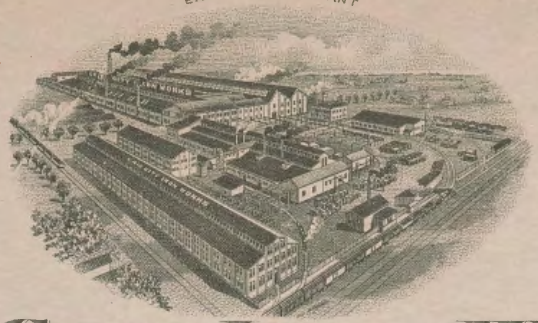
Trusting this information will be of service to you, we remain

Yours very truly,
BALL ENGINE COMPANY,
Per E. A. Hall

EAH N
Encl.

FOUNDED IN 1840.

EAST AVENUE PLANT



PAID IN CAPITAL $2,000,000.

GEO. D. SELDEN, Pres't
E. P. SELDEN, V. Pres't
GEO. T. BLISS, Sec'y
EDW'D C. MOORE, Treas.
THOS. E. DURBAN, Gen'l Mg'r

ALL CONTRACTS ARE SUBJECT TO THE APPROVAL OF THE HOME OFFICE AT ERIE, PENN'A, AND ARE CONTINGENT UPON STRIKES, ACCIDENTS, DELAY IN MILL DELIVERIES AND OTHER OCCURRENCES BEYOND OUR CONTROL. ALL QUOTATIONS ARE MADE FOR PROMPT ACCEPTANCE.

ERIE CITY IRON WORKS

MANUFACTURERS OF

STEAM ENGINES AND BOILERS AND FEED WATER HEATERS

HORIZONTAL AND VERTICAL WATER TUBE BOILERS
LENTZ ENGINES

Erie, Pa., April 17, 1915.

Mr. M. B. McMahon,

University of Tennessee,

Knoxville, Tenn.

Dear Sir:

In reply to your favor of April 12th, we recommend for a 150 h.p.

ALL AGREEMENTS AND STATEMENTS ARE SUBJECT TO CONDITIONS PRINTED ABOVE

engine direct connected to a direct current generator a 17 x 21 Simple Lentz engine, running 200 R.P.M.; price of this engine, f.o.b. Erie, is $4450.00.

The performance when operating condensing with saturated steam will be 18.7 lbs. of steam per h.p. and per hour; when operating non-condensing 22.4.

If superheat is used subtract from above value, 12% for 100 deg. superheat; 17% for 150 deg. superheat and 20% for 200 deg. superheat.

We are mailing you under separate cover foundation plan giving outline of this engine; also Lentz bulletin.

Yours respectfully,

Erie City Iron Works.

Per C. F.

CF:WE

CABLE ADDRESS "GREENE" PROVIDENCE
NEW YORK OFFICE
50 CHURCH ST.
NEW YORK, N.Y.



AGREEMENT SUBJECT TO NON-OCCURRENCE OF STRIKES, ACCIDENTS AND OTHER DELAYS UNAVOIDABLE OR BEYOND OUR CONTROL.
ADDRESS ALL COMMUNICATIONS TO THE COMPANY

PROVIDENCE ENGINEERING WORKS
RICE & SARGENT ENGINES —— GENERAL MACHINERY
521 SOUTH MAIN ST.
PROVIDENCE, R.I. April 15, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

In reply to your letter of April 12th, we are mailing you a copy of each of our engine and pump catalogues, also a dimension print and the first page of specifications for a 12" X 32" Simple, Non-Condensing engine. This engine will develop 150 H.P. at 125 lbs. gauge atmospheric exhaust. We believe this engine to be best adapted for your requirements. Past experience has shown us that the saving effected by running engine condensing under the conditions of water supply that you have stated would be offset by the cost of the extra apparatus and operation of same.

For an engine similar to the one we have shown by the dimension print and sample specification sheet, our price would be approximately Three Thousand Six Hundred Dollars ($3,600.00) f.o.b. Providence.

Hoping that this information will assist you in your thesis work, we are

Very truly yours,

PROVIDENCE ENGINEERING WORKS

HJ

H H Bliss

SPECIFICATION No. SAMPLE.

ACCOMPANYING AND FORMING A PART OF PROPOSAL FOR

RICE & SARGENT CORLISS ENGINE

MADE TO

M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

By PROVIDENCE ENGINEERING WORKS

PROVIDENCE, R. I.

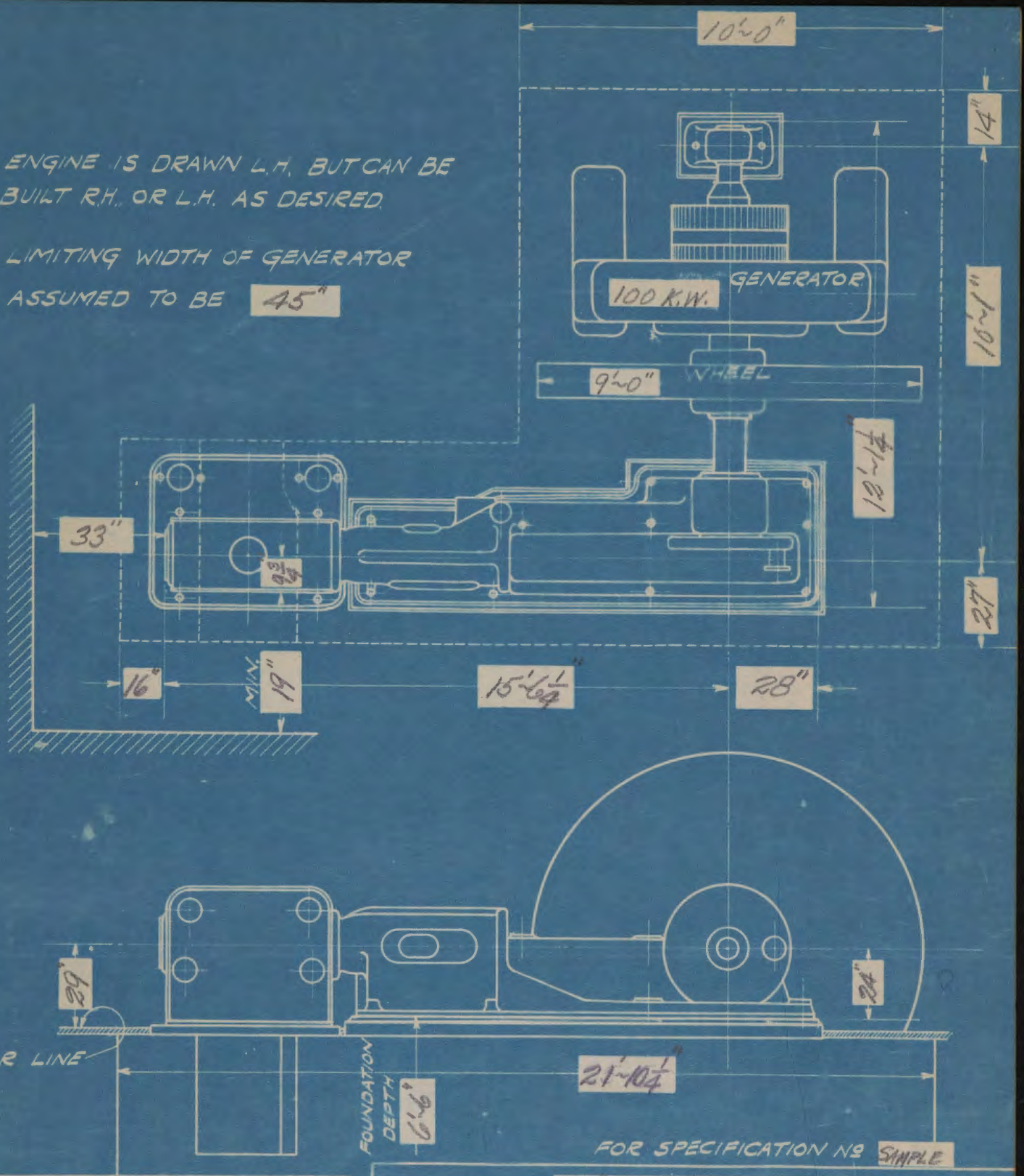
STYLE OF ENGINE

Horizontal Simple Non-Condensing for Direct Connection to 100 K.W. Generator.

THIS SPECIFICATION IS FOR ONE ENGINE ONLY; BUT APPLIES TO EACH OF AS MANY AS MAY BE OFFERED, OF THE GENERAL DIMENSIONS HEREINAFTER DESIGNATED

GENERAL DIMENSIONS

Diameter of cylinder				12	ins.
Length of stroke of piston				32	ins.
Number of revolutions per minute				150	
Diameter of	Balance	Fly Wheel		9	ft.
~~Face of same~~					~~ins.~~
Weight of same				8,000	lbs.
Diameter of middle portion of shaft				10	ins.
Diameter and length of main shaft journal			8 x	16	ins.
Diameter and length of outboard journal			8 x	16	ins.
Diameter and length of crank pin			4 x	4½	ins.
Diameter and length of cross-head pin			3 x	4½	ins.
Length of connecting rod , center to center			8 ft.	0	ins.
Diameter of same at neck				2½	ins.
Area of inlet ports			10.3	% of piston area	
Area of exhaust ports			12.4	% of piston area	
Face of cross-head gibs			9 ins. wide x	11½	ins. long
Thickness of piston				5	ins.
Steam pressure 125 lbs. maintained at throttle.		Exhausting pressure		Atmospheric	
Indicated Horse Power at 22% cut-off 150		: At 60% cut-off		240	
Maximum cut-off				75-100 stroke	
Diameter of steam pipe	4 ins.	Exhaust pipe		5	ins.
Approximate shipping weight of engine				37,100	lbs.



ENGINE IS DRAWN L.H. BUT CAN BE BUILT R.H. OR L.H. AS DESIRED.

LIMITING WIDTH OF GENERATOR ASSUMED TO BE 45"

FOR SPECIFICATION NO SIMPLE

DIMENSIONS ARE FOR REFERENCE ONLY AND ARE NOT TO BE USED FOR CONSTRUCTION.

12"X32" NON-CONDENSING

SIMPLE RICE & SARGENT ENGINE

PROVIDENCE ENGINEERING WORKS

PROVIDENCE R.I.

DIMENSION SHEET "AA"

APRIL 15, 1915

ADDRESS ALL COMMUNICATIONS TO THE COMPANY

H. A. Greiner, Receiver,

BUCKEYE ENGINE COMPANY

CABLE ADDRESS "BUCKEYE"
CODES: WESTERN UNION
LIEBERS BUCKEYE
A.B.C.-FOURTH EDITION

ENGINE BUILDERS

MEMBERS
NATIONAL FOUNDERS ASS'N
NATIONAL METAL TRADES ASS'N
NATIONAL ASS'N OF MANUFACTURERS

SALEM, OHIO

April 16, 1915

Mr. M. B. McMahon,

Univ. of Tenn.

Knoxville, Tenn.

Dear Sir:

Referring to your letter of the 12th inst., a 9 & 19 x 16 cross compound engine operating at 250 R.P.M. will develop 150 H.P. rated load with 60% overload condensing, 26" Vacuum, 125 pounds pressure. The steam consumption will be 18½ pounds condensing at rated load, 23 pounds non-condensing. The economy would be about 7% gain for every 50% superheat up to say 100°. From this point the gain is not so rapid up to 200°.

A machine of this type would weigh 20,000 pounds, Same would be equipped with a main bearing 6½ x 12 - crank pin 3¼ x 3¼" crosshead pin 3 x 3", high pressure piston rod 2-1/16". Low pressure rod 2-3/8. Crosshead shoe area 66" square inches.

We are sending you under separate cover one of our catalogs and trust the data given will be satisfactory.

Yours very truly,

D. J. McConnell

Sales Dep't.

DJMc-H

Cin-38 1m 1-11-11

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICE
SCHENECTADY, N. Y.

NOTICE. Quotation No.

AFTER 15 DAYS THIS QUOTATION IS SUBJECT TO CHANGE WITHOUT NOTICE TO SECURE PRICES GIVEN HEREIN THIS QUOTATION NUMBER MUST BE NOTED ON ORDER.

CINCINNATI OFFICE, PROVIDENT BANK BUILDING.

April 27th, 1915.

Mr. M. B. McMahon,
Student, University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

Your letter of April 12th to our Schenectady factory has been forwarded to this Office for attention.

You do not state your proposed conditions of operation in sufficient detail to enable us to give you very accurate information, but for estimating purposes the following figures may answer your purpose:

ITEM #1:

1- 150 Kw. direct current, 125/250 Volts, 3600 RPM, 3-wire Curtis turbine generator set for condensing operation -
Price, F.O.B. factory - - - - - - - - - - - - - - - $6300.00

The same turbine for non-condensing operation -
Price, F.O.B. factory - - - - - - - - - - - - - - - $5850.00

ITEM #2:

We do not manufacture condensing machinery, but a suitable Surface condenser to condense 4600 lbs. of steam per hour at 28" vacuum, referred to a 30" barometer, assuming standard pumping levels and temperature of inlet water at 70 deg. F., would cost approximately F.O.B. Cars, Cincinnati, Ohio - $2000.00

A suitable Jet condenser to condense the same quantity of steam and under the same conditions, would cost approximately F.O.B. Cars, Cincinnati, Ohio - $1600.00

The steam consumption of the condensing turbine with

125 lbs. (gauge) initial pressure, no superhwat and 28" vacuum would be -

50 Kw. - - - 37.7 lbs. per Kw. hour,
100 Kw. - - - 31.1 lbs. per Kw. hour,
150 Kw. - - - 30.1 lbs. per Kw. hour.

The steam consumption of the non-condensing turbine, when operating with 125 lbs. (gauge) initial pressure, no superheat and atmospheric back pressure, would be:

50 Kw. - - - 64.5 lbs. per Kw. hour,
100 Kw. - - - 53.0 lbs. per Kw. hour,
150 Kw. - - - 52.3 lbs. per Kw. hour.

The approximate dimensions of either the condensing or non-condensing turbine, would be:

Length - - 12 ft.
Width - - 6 ft.
Height - - 5 ft. 5 ins.

Approximate Weights:

Net - - - - 16000 lbs.
Shipping- - 19500 lbs.

The saving due to superheat would be approximately 1% for wach 12½ deg. Fah. superheat for the non-condensing turbine and 1% for each 14 deg. Fah. superheat for the condensing turbine.

As we have no knowledge of the number of circuits to be controlled, nor the amount of current per circuit, we can give no figures regarding the cost of a switchboard, but if you will call upon Mr. J. H. Barksdale, of our Knoxville Office, Bank & Trust Bldg., and let him know your requirements in this connection he will be able to give you an approximate price for the switchboard equipment.

Folio #3-

GENERAL ELECTRIC COMPANY

We enclose our bulletin NO-4887-A describing our small turbine generator sets.

It is understood that the information and prices given above are for preliminary estimating purposes and do not constitute a proposal to supply the apparatus specified.

Yours very truly,

NCR:CY

DISTRICT TURBINE SPECIALIST.

DE LAVAL

TRADE MARK

DE LAVAL STEAM TURBINE COMPANY

EXECUTIVE OFFICES
165 BROADWAY
NEW YORK

WORKS AND SALES OFFICES

CABLE ADDRESS
"TURBINCO, TRENTON"
NEW BUSINESS & A.B.C. CODES

TRENTON, N.J., April 22, 1915.

Mr. M. B. Mc Mahon,
University of Tennessee,
Knoxville, Tennessee.

Dear Sir:-

We have your letter of April 12th at hand, but owing to the rush of other work, we were not able to write you in connection with the proposition you have in mind until this date.

In determining the unit to offer for any given capacity, the question of economy is very important as this will determine in a large measure the type of unit to offer.

We note that you desire a direct connected set and we would say in this connection that the price of a 150 H.P. turbine, direct connected to a 100 K.W. direct current generator would be in the neighborhood of Thirty Five Hundred ($3500.00)Dollars or Four Thousand ($4,000.00) Dollars net, f.c.b. works.

With 125 lbs. steam pressure and atmospheric exhaust the full load steam consumption would be in the neighborhood of 65 lbs. per K.W. hr. and with 125 lbs. steam pressure and 28" vacuum the steam consumption at full load would be in the neighborhood of 39.5 lbs. per K.W. hr.

The economy of the turbine for every 10° superheat is usually decreased by about 1%.

If better economy is desired it is usually advisable to offer a turbine with a single reduction gear so that the turbine may be allowed to operate at its most economical speed and also that the generator may be allowed to operate at a slower speed.

The question as to whether or not a turbine should be operated condensing or non-condensing depends largely on the local conditions, such as the amount of circulating water available for condensing purposes. The cost of coal

DE LAVAL STEAM TURBINE CO.
TRENTON, N. J.

TO Mr. M. B. Mc Mahon SHEET #2 DATE 4/22/15

is also an item which will determine whether or not an economical turbine is desired and also as to whether or not condensing operation should be provided for.

Hoping that the above data will be of use to you, we are

Yours very truly,

DE LAVAL STEAM TURBINE COMPANY,

G. J. Crosley

Asst. Sales Manager.

GBP/W

B. F. STURTEVANT COMPANY

General Office and Works, Hyde Park, Boston, Mass.

OFFICES IN ALL PRINCIPAL CITIES

Sturtevant

(REG. U.S. PAT. OFF.)

MAIL AND TELEGRAPH ADDRESS HYDE PARK, BOSTON, MASS. PASSENGER AND FREIGHT STATION READVILLE, MASS.

SUBJECT: 100 KW Turbo-Generator

IN YOUR REPLY REFER TO HML

HYDE PARK, BOSTON, MASS., April 20, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

In reference to your request of April 14th for data and prices upon a 150 HP turbine for direct connection to a direct current generator, would state that we have prepared a quotation and complete specifications upon a 100 KW D.C. turbo-generator, as this size seems to be the nearest in line with what you have asked for and we trust will prove of assistance to you.

The specifications we are enclosing are made exactly the same as our commercial propositions.

This turbo-generator unit will consist of a 100 KW turbo-type TF generator direct-connected by flexible coupling to a Sturtevant type 5 E size turbine. The entire unit is mounted upon a rigid case iron sub-base as illustrated in photograph which we are enclosing.

Net price of this apparatus to the University of Tennessee will be twenty-seven hundred and nine dollars f.o.b. Readville, Mass.----------$2709.00
Shipping weight of the unit is approximately 10,500 lbs. and the freight rate from Readville to Knoxville eighty-five cents (85¢) per hundred.

We shall be pleased to furnish extra copies of this proposition to you or any of the professors in the University for their files in case they decide later to install such a unit.

We do not manufacture condensers but would refer you to the C. H. Wheeler Mfg. Co., Philadelphia, or the Wheeler Condenser & Engineering Co., Carteret N.J., or Henry R. Worthington, Harrison, N.J.

Yours very truly,

B. F. STURTEVANT COMPANY

By H. M. Latham

Mgr. Power Apparatus Dept. L.S.

LS:FJT

ALL AGREEMENTS ARE CONTINGENT UPON STRIKES, FIRE, ACCIDENTS OR DELAYS BEYOND OUR CONTROL. ALL PRICES ARE SUBJECT TO CHANGE WITHOUT NOTICE, AND ALL CONTRACTS AND ORDERS TAKEN ARE SUBJECT TO THE APPROVAL OF THE EXECUTIVE OFFICE AT HYDE PARK, BOSTON, MASS.

SPECIFICATIONS

OF

Sturtevant

(REG. U. S. PAT. OFF.)

Turbo-Generating Set

FOR

.....

.....

.....

B. F. STURTEVANT COMPANY

Hyde Park, Boston, Mass.

F1003-1M-2-18-15

B. F. STURTEVANT COMPANY

General Data 100 **K.W. Direct Current Turbo-Generator**

For ..... **Date** Apr. 16, 1915.

Turbine			B. F. Sturtevant Generator		
Size and Type		E-5	Frame		
R.P.M.		2200	Type		TF
Steam Pressure (Gauge)	Lbs.	125	No. Poles		8
Exhaust Pressure (Gauge)	Lbs.	---	Voltage, No Load		115
Vacuum	Ins.	---	Voltage, Full Load		125
Superheat	°F	---	Commercial Efficiency	½ Load %	87.5
Number of Nozzles		10		¾ Load %	90.5
Steam Connection Dia.	Ins.	4		Full Load %	91.5
Exhaust Connection Dia.	Ins.	8		1¼ Load %	92
			Temperature Rise	°C	
			Cont. Full Load	Arm.	40
				Field	40
				Com.	45
			1¼ Load 2 Hours	Arm.	60
				Field	60
				Com.	60

Total Weight of Unit (Net) 8975 Lbs.

Total Weight of Unit (Shipping) 10500 Lbs.

Steam consumption per KW hour 65# (Non-Condensing)
" " " " " 59# (Condensing)

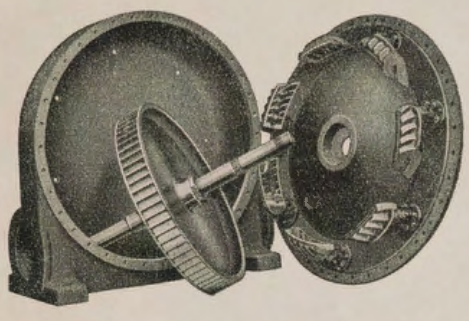
$2709 f.o.b. Readville, Mass.
Freight to Knoxville, Tenn., 85¢ per hundred

B. F. STURTEVANT COMPANY
Hyde Park, Boston, Mass.

General Specifications
Steam Turbines

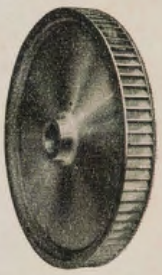
Casing

The casing which is split vertically consists of two castings of close grained iron, each having an integrally cast bearing bracket. As live steam pressure exists only in the steam chamber cored in one half the casing, the casing joints are subjected to low pressure only, and are scraped to tightness without the use of gaskets or packing. The nozzles are rigidly attached to that half of the casing containing the steam chamber and are not disturbed in position when the two halves are taken apart for inspection. The longitudinal alignment and the radial clearance between the rotor and the nozzle may be inspected by means of small holes provided in the exhaust side of the casing.



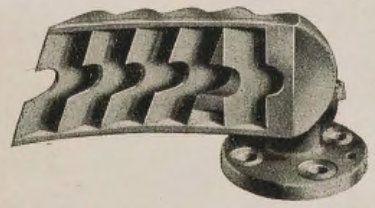
Rotor

The rotor or bucket wheel consists of a forging of open hearth steel, the buckets being milled into the solid metal rim. The rotors are carefully adjusted for both static and dynamic balance, the latter adjustment being made for the speed at which they are designed to operate. All surfaces coming in contact with the steam are carefully finished and polished to minimize steam friction.



Nozzles and Reversing Buckets

The nozzles and reversing buckets are of Tobin bronze, cast together in segments. They are designed to give the best steam economy and are accurately and carefully finished to minimize steam friction. The nozzles are controlled by hand valves on the outside of the casing. By closing one or more of these hand valves when the turbine is operating under light loads, economical operation at such loads may be obtained.



Shaft

The shaft which is nickel steel is turned and ground to size and is fitted with adjustable steel thrust collars to maintain longitudinal alignment.

Bearings

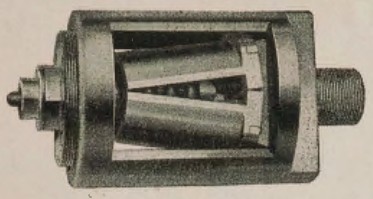
Ring oiling split bearings of the self-aligning type, lined with a special high grade bearing metal are employed.

Packing

The shaft packing is of a special metallic type so arranged as to combine tightness with a certain amount of flexibility. It requires no lubrication or cooling water. The stuffing box may be easily repacked.

Governor and Regulating Valve

The governor which is of powerful design is of the centrifugal type carried directly by the shaft of the turbine and is protected from external injuries by a closed cast iron hood. The governor controls the speed by means of a balanced regulating valve.



Emergency Valve

A separate emergency valve operated by a lever which is automatically tripped by means of a mechanism independent of the main governor whenever the turbine speed exceeds a predetermined maximum is also provided. This valve is in general not required on turbines direct connected to fans or blowers and is not furnished under such conditions unless specified.

Lubrication

The only parts of the turbine requiring lubrication are the main bearings. These are supplied with oil by means of a channelled oiling ring from which the oil is picked off and delivered to the bearing by a specially designed scoop creating a pressure which forces the oil to the bottom of the bearing.

Base

When used in connection with apparatus arranged for direct driving, a cast iron sub-base on which all the apparatus forming the unit may be mounted, will be furnished.

Material and Workmanship

Material and workmanship are first class throughout and all surfaces requiring paint are filled and given one coat of paint before shipment.

Accessories

Each turbine is furnished with a steam gauge and a set of wrenches.

Testing

All turbines are thoroughly tested and adjusted under conditions approximating as nearly as possible the actual working conditions. The steam and exhaust passages are further tested hydrostatically to a pressure of double the working pressure.

B. F. STURTEVANT COMPANY

Hyde Park, Boston, Mass.

GENERAL SPECIFICATIONS — TYPE TF GENERATORS

General Design Type TF Generators embody the results of a number of years' experience in the design and construction of high speed generators, intended for use in connection with turbines.

Magnet Frame The magnet frame is of cast iron with ample cross-section, provided with integrally cast supporting feet.

Pole Pieces and Field Coils The pole pieces are of forged steel, securely bolted to the magnet frame. The pole shoes are of the laminated type especially designed to give the best magnetic characteristics. The field coils are of double cotton covered wire, thoroughly insulated and protected against moisture or mechanical injury. The interpoles are of forged steel with coils of proper proportion to secure perfect commutation under all conditions of load.

Armature The armature is of the iron clad, slotted drum type, built up of soft annealed steel punchings, each insulated by a coat of japan. In the smaller sizes these punchings are assembled directly on the shaft; in the larger sizes, upon a spider. In the latter type adequate spaces are provided for internal ventilation of the armature core. The armature coils are of cotton-taped copper bars held in the slots by fibre wedges, the ends of the coils being securely held in place by binding wires.

Commutator The commutator bars are of hard drawn copper assembled on a solid cast iron sleeve and held in place by shrink rings, this construction preventing distortion of commutator bars due to centrifugal stresses. The mica insulation between commutator bars is cut away at the top to prevent any possible trouble from high mica. The commutator wearing surface is extremely liberal.

Balancing To eliminate all vibration in operation, special balancing rings at both ends of the commutator and at the back end of the armature are provided. By means of these, the balance of the machine is adjusted to a nicety before shipment.

Brush Gear and Brushes The brush gear is designed to be very rigid, thus preventing vibration of the brushes. In the smaller sizes it is supported from the bearing casing, and in the larger sizes from the magnet frame or from an independent yoke supported from the base. The brush holders are securely clamped to the brush stud. The brush holder is so designed that the brush tension may be readily adjusted, the tension spring being so arranged that it is not subject to overheating. The brushes are of the highest grade carbon and graphite with heavy flexible connectors.

Shaft The shaft is of nickel steel, and so designed as to possess a very high critical speed.

Bearings In the self-contained type of machine (to 25 K.W. inclusive) the bearings are of the ring oiling type with special oil deflectors to prevent leakage. In the pedestal type (35 K.W. and above) the lubrication is of the forced feed type, oil pressure being supplied by a gear pump driven from the shaft, oil being delivered to the bearings at a pressure of 25 lbs. per square inch. The bearings are provided with oil deflectors to prevent leakage.

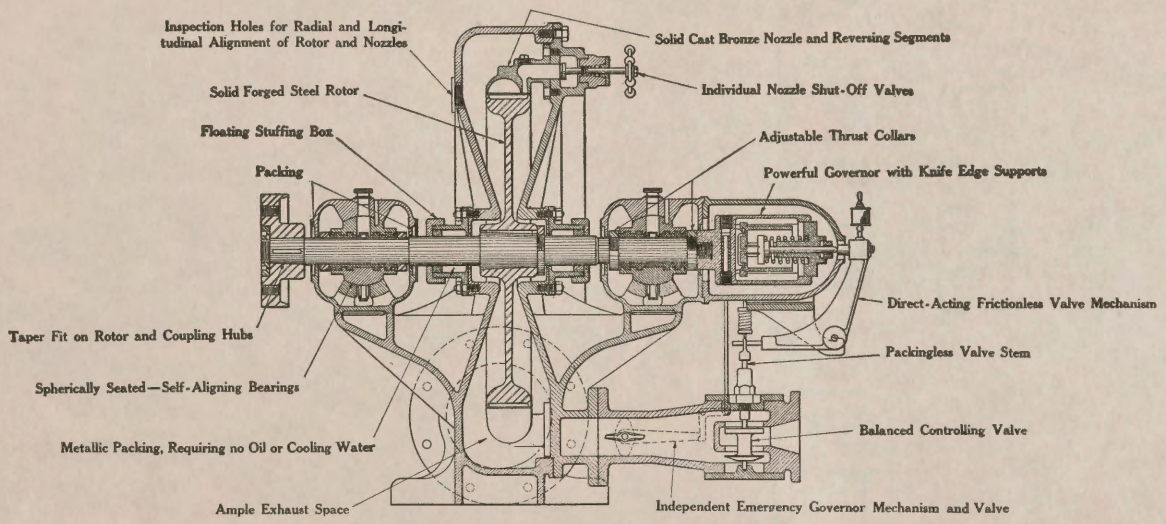
Terminals A terminal board with lugs of ample capacity is located on the side of the magnet frame.

Finish All of these machines are thoroughly filled and painted before shipment. Materials and workmanship are of the highest grade throughout.

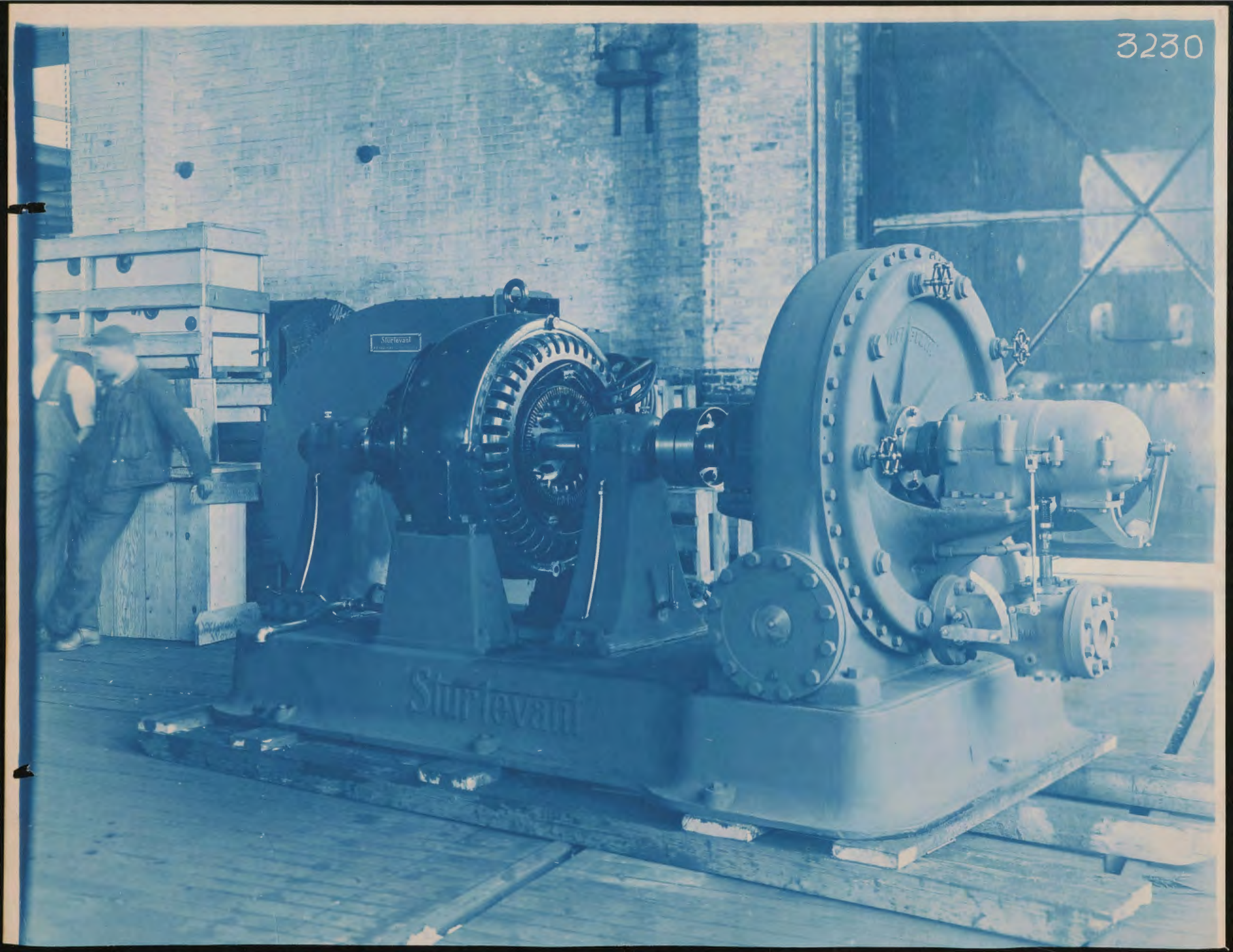
Testing Before shipment all machines are thoroughly tested under conditions as nearly as possible identical with those of actual practice, and final adjustments are made. In addition, the dielectric strengths of the various parts of the machines are tested with 1500 volt alternating current for one minute.

Accessories Each generator is furnished with a field rheostat and an extra set of brushes.

Type 5 Steam Turbine



B. F. Sturtevant Company, Boston, Mass.


3230
Sturtevant
Sturtevant

B. R. HOSHALL THOS. H. ALLEN, ENGINEER G. W. SIMMONS

HOSHALL, SIMMONS & CO.

POWER PLANT, PUMPING, WOOD WORKING
MACHINERY
CONTRACTORS EQUIPMENT

REPRESENTING
CHUSE ENGINE & MFG. CO.
WATERLOO CEMENT MACH'RY CORP.
WALSH & WEIDNER BOILER CO.
INGERSOLL-RAND DRILL CO.
TERRY STEAM TURBINE CO.
CHARTER GAS ENGINE CO.
PLATT IRON WORKS CO.

REPRESENTING
WYSONG & MILES CO.
H. B. SMITH MACHINE CO.
NEWMAN MACHINE CO.
A. B. FARQUHAR CO.
THE WHELAND CO.
SIDNEY TOOL CO.
CHALLONER CO.

TELEPHONE MAIN 4050
90 SOUTH FRONT STREET
MEMPHIS, TENN.

Apr. 20, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

Your letter of Apr.12th addressed to the Terry Steam Turbine Co. at Hartford, Conn. has been referred to us for attention. We will be very glad indeed to give you all the date that you could possibly want along these lines.

In order to make sure that you get the identical data in case we actually had a plant to sell, I have referred this matter again to the factory, asking them for blue prints and other date covering the machine.

I will therefore send you later a complete proposition on this turbo-generator.

In the meanwhile under separate cover I am sending you some literature.

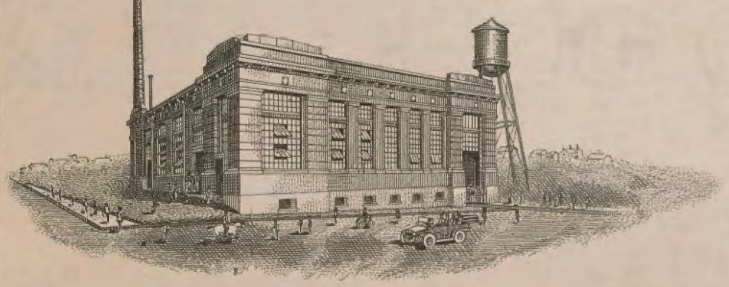
In fact it will give us a great deal of pleasure to co-operate with you to any extent that you may desire, and I hope that you will consider us at your service. Kindly give my personal regards to Prof. Ferris.

Yours very truly,

HOSHALL, SIMMONS & COMPANY

By Thos. H. Allen

THA/RH.

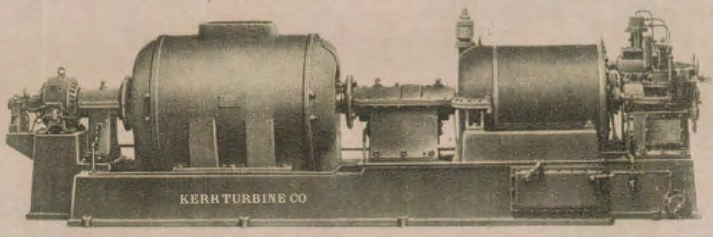


POWER PLANTS EQUIPPED

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CABLE ADDRESS:
"KATYCO, WELLSVILLE"

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SHANGHAI

KERR TURBINE COMPANY

BUILDERS OF THE

'ECONOMY' STEAM TURBINE

TURBINES DIRECT CONNECTED TO
GENERATORS, BLOWERS, PUMPS
AND FOR BELT DRIVE

WELLSVILLE, N.Y. April 15, 1915.

Mr. M. B. McMahon,
c/o U. of T.,
Knoxville, Tenn.

Dear Sir:-

In response to your letter of April 12th beg to state that a 100 KW direct current generator operating at 1200 R.P.M. and driven by a 150 H.P. multi-pressure stage "ECONOMY" turbine through three to one "ECONOMY" herring bone reduction gear so that the turbine speed will be 3600 R.P.M. can be furnished fob factory for about $2700 to $2800 for non-condensing, and for about $2900 to $3000. for condensing operation. With 150 pounds steam initial pressure and atmospheric exhaust, the steam consumption in pounds per KW Hr will be as follows:

1/2 load	3/4 load	4/4 load	5/4 load
58.0 #	51.1 #	47.0 #	49.4

and on a condensing turbine with the same initial pressure and 28" vacuum the steam consumption will be:

1/2 load	3/4 load	4/4 load	5/4 load
30.9 #	28.8 #	27.2 #	28.1 # per KW Hr.

We can also furnish direct connected units, but the high degree of accuracy and perfection of the modern "ECONOMY" herring bone reduction gears makes it possible to offer a better propesition, both as regards price and steam consumption on geared units, it being possible to use not only a more efficient but a smaller turbine of the higher speed so that the total price per unit in this particular instance is actually less than it would be for a direct connected unit.

As regards superheat with non-condensing operations you can subtract 1% for each ten degrees F. of superheat up to 200 degrees total. For condensing turbine this will be approximately 1% for each 14 degrees superheat up to 200.

We are enclosing photo of 300 KW Kerr-Crocker-Wheeler geared turbo

KERR TURBINE COMPANY

April 15, 1915.

Mr. M.B.M. #2.

generator installed at the Columbia Plate Glass Works, Blairsville, Pa.

Yours very truly,

KERR TURBINE COMPANY.
BY A E Seelig.
General Sales Mgr.

AES-GMH

FORM 170

ALLIS-CHALMERS MANUFACTURING COMPANY

MILWAUKEE, WIS.

CABLE ADDRESS
"FOUNDERS"

April 14th, 1915.

Mr. M.B.McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

We wish to acknowledge receipt of your favor of the 12th inst. calling for information on a 150 HP steam turbine to be direct connected to direct current generator, price to include suitable condenser.

In this connection we regret to advise that our company does not build a steam turbine unit in as small a capacity as you call for which would be suitable to operate both condensing and non-condensing. We, however, have a complete line of units developed which will operate non-condensing and would be pleased to send you information on such a unit if you will kindly arrange to forward us more information relative to voltage which you are figuring upon as well as the back pressure which turbine would be required to exhaust against.

We are in a position to give you figures covering a machine which would meet your requirements and would like to have you advise us as to water temperature which would be available for condensing purposes and location of available water supply from turbine power plant.

Most steam turbine builders at the present time use a correction of approximately 1% for every 10° increase in superheat between the limits of 0 and 100° F. superheat, i.e. any steam guarantees which would be made on a dry steam condition would be bettered 1% for every 10° superheat.

Upon receipt of your reply to our letter we will be pleased to give you more information relative to your requirements.

Yours very truly,

AHW TJ

ALLIS-CHALMERS MANUFACTURING C

Per Robert A McKee

Manager Steam Turbine Dept.

FORM 570

ALLIS-CHALMERS MANUFACTURING COMPANY

MILWAUKEE.WIS.

CABLE ADDRESS
"FOUNDERS"

April 22, 1915.

Mr. M. B. McMahon,

University of Tennessee,

Knoxville, Tennessee.

Dear Sir:-

Referring to your letter of April 16th.

The 100 KW, normal, 2400 RPM, 125/250 volt, 3 wire, direct current, non-condensing steam turbine driven generator would cost approximately $3000.00, FOB Milwaukee, and would weigh approximately 14000#.

This unit would be about 5' wide, about 5' high and about 10'6" long. The steam connection would be 3½" and the exhaust connection 9".

For normal load the temperature rise would be 40° for coils and 45° for commutator.

Steam consumptions, based on 125# gauge, dry saturated steam, at turbine throttle, and 16# absolute at turbine exhaust nozzle, would be approximately as follows:-

K.W. LOAD	LBS. PER K.W. HOUR
50	91
75	74
100	66
125	62

The generator would be provided with slip rings for neutral connection and balancer coils. The temperature guarantees, of course, apply to a condition of balanced load. The generator will carry, without undue heating, an unbalanced current in the neutral

equal to 25% of normal full load current, and under these conditions the generator would maintain a voltage on either side of the system which will not vary more than 2% from one-half voltage between line wires.

We attach hereto one print of our sketch ST-11298 which will give you an idea of the appearance of a unit of this kind arranged for two wire operation.

In reply to your question as to setting turbine on solid foundations, would advise that it is preferable to mount apparatus of this kind on separate foundations, however, small units of this size are often set directly on a reinforced concrete floor.

With reference to the condenser, would state that we do not build a condenser as small as would be required, and would refer you to the C. H. Wheeler Manufacturing Company, Marquette Bldg., Chicago, for information covering same.

Although we do not build a condensing unit as small as this, for your information would advise that a condensing unit would cost approximately 15% more than non-condensing unit. Dimensions and weights would be about the same except that the exhaust nozzle for the condensing unit would probably be 12" in diameter. The steam consumptions of a condensing unit with 28" vacuum, referred to a 30" barometer, at turbine exhaust nozzle, would be about one-half the steam consumptions of the non-condensing unit.

If we can be of further service, please advise us.

After you get the condenser information you will have a basis for figuring out your problem as to whether a condensing or

a non-condensing unit will be the more suitable, and in this connection do not overlook the power used to operate condenser, especially at low loads on the turbine unit.

Yours very truly,

ALLIS-CHALMERS MANUFACTURING CO.

Per R. A. McKee

Manager, Steam Turbine Department.

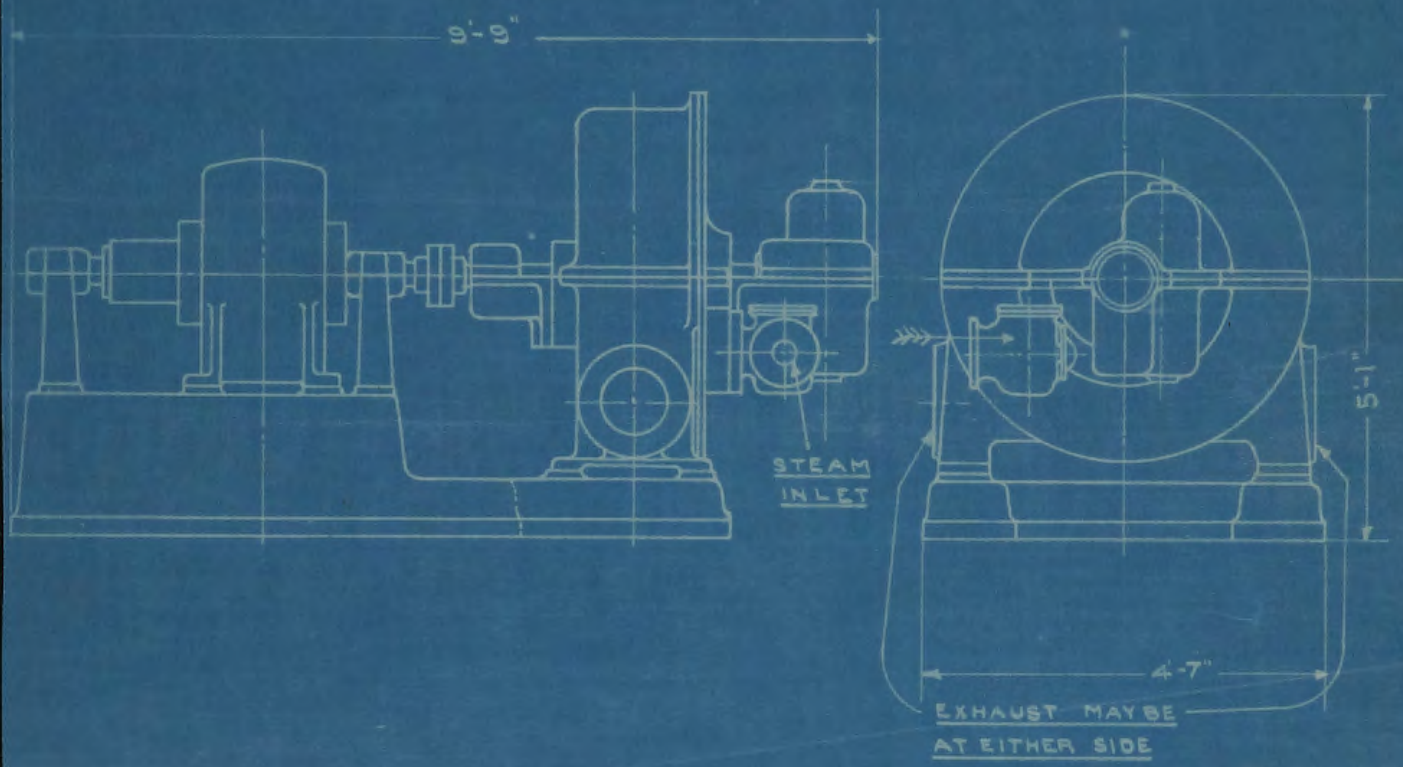
ACF-H

Encl. 1 print of ST-11298.

ALLIS-CHALMERS MF'G. CO.

MILWAUKEE, WIS.

IMPULSE STEAM TURBINE & D.C. GENERATOR.



GENERAL DATA:-

RATED CAPACITY [redacted] [redacted]

REVOLUTIONS PER MINUTE ..... 2400 R.P.M.

DIAMETER OF STEAM INLET ..... 3½ IN. DIA

DIAMETER OF EXHAUST OPENING ..... 9 IN. DIA.

TOTAL ESTIMATED WEIGHT ..... ~~10500~~ 11300 POUNDS.

FOR ESTIMATE ONLY SUBJECT TO CHANGE WITHOUT NOTICE.

[redacted]

SKETCH Nº ST-11298

Robert A. McKay
EA 7-24-18

PLEASE ADDRESS REPLY TO THE COMPANY AND REFER TO INITIALS OF THE UNDERSIGNED.

THE WESTINGHOUSE MACHINE COMPANY

EAST PITTSBURGH, PA., U.S.A.

SALES OFFICES:
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LEE C. BULLINGTON
SALES MANAGER SOUTHERN DISTRICT

ATLANTA, GA, Apr. 19, 1915.

Mr. M. D. McMahon,
University of Tenn.
Knoxville, Tenn.

Dear Sir:

Referring to your letter of inquiry of the 12th inst. addressed to our Works at East Pittsburgh, Pa. which has been referred to us for attention and answer, would advise that the cost of a 150 K. W. 125 volt direct current turbo-generator would be approximately $3600.00, f. o. b. our Works, East Pittsburgh, Pa. The over-all dimensions would be as follows:

Length, 13'- Width 4'-9";- Heighth- 4'-6"

The gross weight of the unit would be 10,250#.

The steam consumption when operating with 125# pressure at the throttle and with exhaust free from back pressure would be 45# per K. W. per hour. This would be with the turbine specifically designed for non-condensing operation. A turbine might be considered specifically designed for condensing operation say with 28" of vacuum, and the economy improved about 15%.

Understand, however, in connection with turbine design, that if a turbine is designed particularly for non-condensing operation, and at any time it is operated condensing, of course the results obtained under the condensing condition will not be as good as if the turbine was specifically designed for condensing work. This is also true if turbine is designed for condensing operation, and at any time, it is operated under non-condensing conditions. A turbine designed for condensing operation would cost approximately 10% more than the above named figure for non-condensing unit.

Regarding the matter of surface condenser, note that your letter does not state any temperature of injection water, and it is impossible to accurately tell you just what size condenser to use, and a dependent cost without this information.

Assuming however, that water at a temperature of 75 degrees is available, and handling say 7000# of steam per hour, and maintaining a vacuum of 28", a 1000 s.q. ft. condenser

of the unit type as illustrated in pamphlet we are sending you, would cost approximately $2600.00 f. o. b. cars, East Pittsburgh. A jet Condenser, to handle approximately the same amount of steam, maintain the same vacuum, with the same temperature of injection water, would cost approximately $1600.00 f. o. b. cars, East Pittsburgh.

Unless water is extremely scarce for condensing purposes, or must be conserved for some reason, a jet condenser would possibly be preferable to that of the surface type, requiring less power, less cost of maintenance, with lower first cost. The vacuum would be the same from either type. The surface condenser would require 1000 g. p. m. of water to be circulated, whereas the jet condenser would require 640 g. p. m. The surface condenser would require 20 H. P. to operate, and the jet condenser 18 H. P.

From the above figures, you can easily determine whether it would be a saving to operate the turbine unit condensing at all, bearing in mind that it would take about 1000# of steam to operate either condenser, if steam driven, or a corresponding amount of power if driven by motors. In other words, you have 10 or 12% of the total power being generated being consumed by auxiliaries.

Under separate cover we are sending you several pamphlets which may be of assistance, and we trust that the entire information given will serve your purposes.

Yours very truly,

L. C. Burlington

LCB/MH SALES MANAGER SOUTHERN DISTRICT.

P. S.

We neglected to advise that the turbine unit would consist of a high speed turbine of the impulse type, direct connected to reduction gear, the turbine operating at 2700 r. p. m. the ratio of the gear being 3 to 1, and the generator being of the slow speed type operating at 900 r. p. m. This is the most up-to-date style of turbine unit now on the market, and you will note that we gain the high efficiency of operating the turbine at its maximum spindle speed, reducing this through the reduction gear, and operating the

generator at its best point of efficiency, and also eliminating commutator troubles, which are encountered in operating direct current generators at high speed.

Yours truly,

C. P. COLEMAN AND G. M.-P. MURPHY, RECEIVERS OF

INTERNATIONAL STEAM PUMP COMPANY

DEANE STEAM PUMP PLANT

HOLYOKE, MASS. April 17,1915.

Mr. M.B.McMahon,
Univ. of Tennessee,
Knoxville, Tenn.

Dear Sir:-

We have your letter of April 13th in reference to information about surface condenser and pumps, and would state that we build no surface condensers at this plant , all such work being done by our Associated Shop, The Henry R. Worthington, Harrison, N.J. We are, therefore, taking the liberty of referring your letter to our Condenser Dept., 115 Broadway, N.Y., and requested them to furnish you the information desired.

Yours truly,
C. PHILIP COLEMAN AND GRAYSON M. P. MURPHY,
RECEIVERS FOR
INTERNATIONAL STEAM PUMP COMPANY,
SUCCESSORS to THE DEANE STEAM PUMP CO.

By Charles L. Newcomb
Manager.

HMC/AES

Stephens-Adamson Mfg. Co.

Conveying, Transmission and Screening Machinery

S-A BELT CONVEYORS

W. W. STEPHENS, PRESIDENT
F. G. ADAMSON, TREASURER
D. B. PIERSEN, VICE PRESIDENT
G. H. STEPHENS, VICE PRESIDENT
F. H. McWETHY, SECRETARY

MAIN OFFICE AND WORKS
Aurora, Ill.,

April 17, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

We acknowledge receipt of your favor of the 15th with sketch showing the general arrangement of the boilers and bunkers for the power plant for the University of Tennessee.

We are forwarding you, under separate cover, section #4 of our #19 catalog and would refer you in particular to the general arrangement of our pivoted bucket conveyor as illustrated on page #374 and 375.

The arrangement as you have outlined it in your sketch is similar to the scheme shown on page #374. Our suggestion would be the installation of a steel track hopper beneath the railroad siding; this hopper feeding onto an apron conveyor which in turn will discharge through a coal crusher onto a pivoted bucket conveyor. This latter conveyor will operate through a tunnel beneath the boilers elevating at one end and passing horizontally over the coal bunkers. At the end of the bunkers nearest to the railroad siding we would suggest you install an ash hopper which can be arranged with spout to discharge into cars on the same track.

By running the conveyor beneath the boilers it can be used for handling both the coal and ashes.

This type of conveyor can be furnished in a lot of different sizes having capacities of from twenty to eighty tons per hour of coal, and if made in lengths up to 300' horizontal and with a vertical lift up to 80 or 90 feet.

While an arrangement cheaper than that outlined above could be installed, the pivoted bucket system is the type of equipment usually installed in the modern coal handling plants and we recommend it above any other under conditions where both coal and ashes are to be handled.

We are issuing a special catalog covering pivoted bucket installations and as soon as this is received from the press we will be glad to forward you a copy.

Yours very truly,

STEPHENS-ADAMSON MFG. CO.,

FHM:FG.

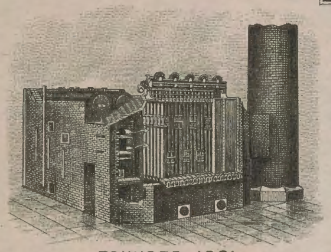
Secretary.

CABLE "ECONOMIZER" NEW YORK, CODES: A.B.C. 5TH EDITION, WESTERN UNION, ENGINEERING TELEGRAPH.

THE GREEN FUEL ECONOMIZER CO.

BUILDERS OF GREEN'S FUEL ECONOMIZER,
AND MECHANICAL DRAFT APPARATUS

GENERAL SALES OFFICE
90 WEST STREET,
NEW YORK. 4213



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WAKEFIELD, ENG.

APRIL
16TH
1915

Mr. M.B. McMahon,
c/o University of Tenn.
Knoxville, Tenn.

E-325-327 & 327.

Dear Sir:--

Referring to yours of the 13th inst., regarding proposed installation of economizers in connection with new power plant to be installed at the University of Tenn., we would offer the following suggestions:--

Weare enclosing a yellow sketch showing two arrangements, labeled - for identification- sketches "A" and "B". Sketch "A" shows stack as you recommend on your proposed arrangement; i.e., with two boilers on either side and we have shown an economizer on each side of the stack of sufficient size to take care of the gases from two boilers. For this information we would recommend using two economizers, each 192 tubes, arranged in sections 6 tubes to the section, each tube 9' long. Each machine to contain a total of 2448 sq.ft. of heating surface. There would be two machines, with a total number of tubes for the entire plant of 384.

In view of the fact that only three boilers are to be installed at the present time, it might be well

MR. McMahon.

to make the arrangement as shown on sketch "B" with the stack located at one end of the boiler house and one econoe mizer for the entire installation. For this proposed layout with three boilers in service, we would recommend an economizer of 280 tubes, 10 tubes to the section, each tube 9' long; making a total of 3570 sq.ft. of heating surface. When the fourth boiler is installed, there would then be occasion to install 120 additional tubes, making a total machine of 400 tubes, 10 tubes to the section, each tube 9' long.

We are also enclosing dimension sketches showing the principle dimensions of the several economizers which we have recommended, in order that they may be of value to you in making the general layout of the plant. The econemizers quoted upon would cost as follows:--

192 tubes	$2455.	each machine
280 "	$3425.	" "
400 "	$4825.	" "

The above prices are given f.o.b. Beacon,N.Y. with freight allowed to Knoxville,Tenn. and include the sectional covers for enclosing the front side of the economizer, the necessary engine or motor for driving the scraper mechanism, with the required counter-shafting.

The reason we have been unable to figure the erection definitely is that we do not know the details of the layout sufficiently to enable us to give you a price of this work. We could furnish the services of a competent

MR+McMahon

mechanic to superintend the erection of the equipment for the sum of Six ($6.00)Dollars per day and his expenses; all common labor to be supplied by the Purchaser. The Purchaser would have to supply all foundations and masonry work and all the necessary piping.

In regard to the stack, we believe this is of sufficient size - if the boilers are operating at approximate rating. The economizer can be set in concrete foundations, if the concrete is well laid.

The economizer up-keep charges are very slight, indeed; 6% on the investment being ample to cover depreciation and repairs.

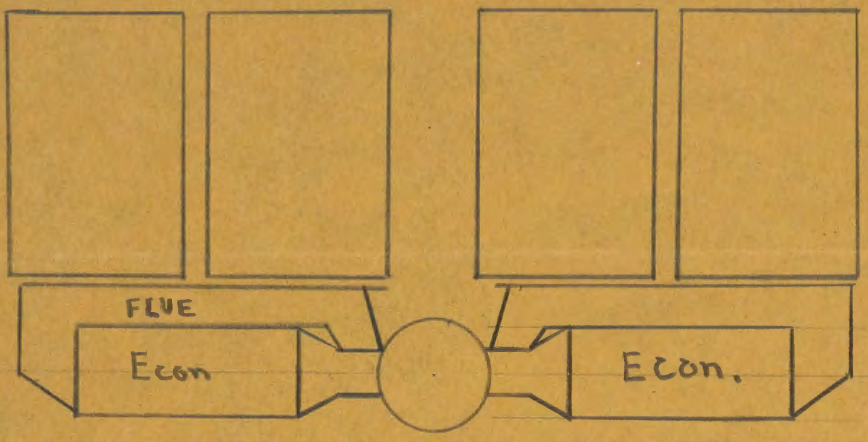
We are sending you our economizer catalogue #142 which we trust will prove of interest.

Trusting the information given above will meet with your requirements, we are,

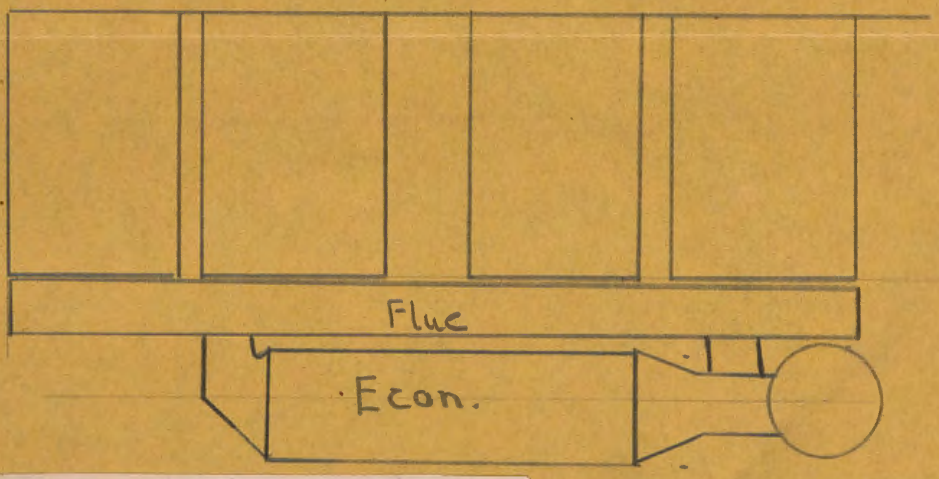
Yours truly,
THE GREEN FUEL ECONOMIZER COMPANY

HRG-N
ENC'L

H R Green



Sketch #A



#B

Green Fuel Economizer Company, New York

For enclosure to:

M B McMahon

Kenneth Senn

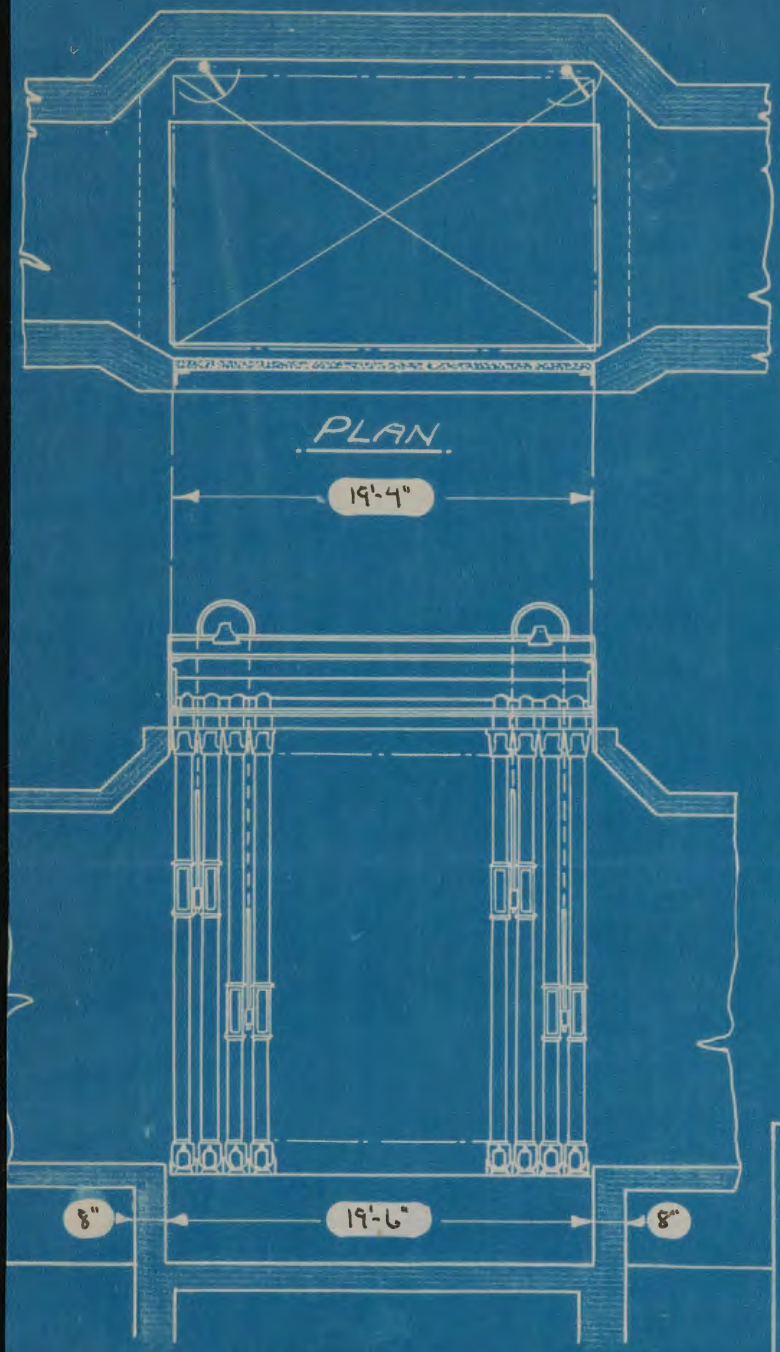
Date

rsity of Tennessee

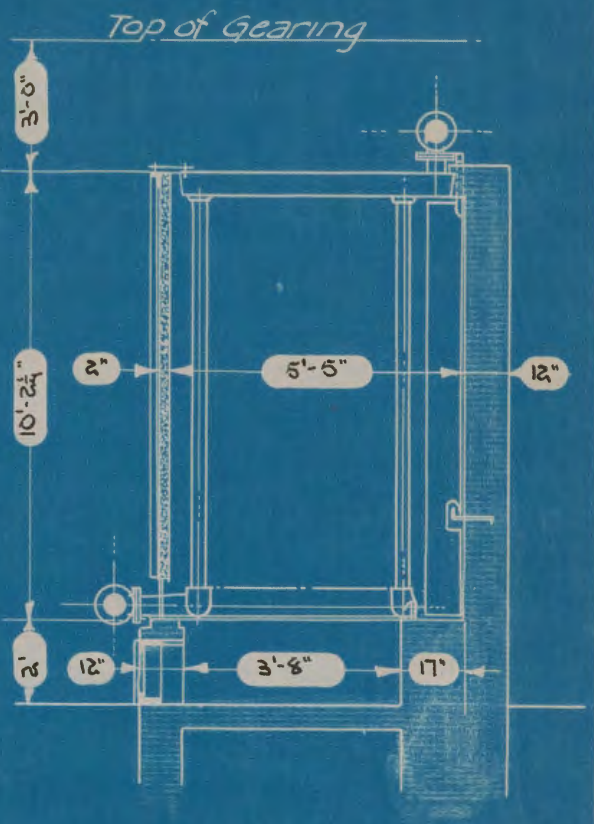
Proposed Sketches

The Green Fuel Economizer Co

New York



ELEVATION



CROSS SECTION.

APPROXIMATE DIMENSIONS OF STANDARD GREEN ECONOMIZER consisting of

192 Tubes. 32 Sections.

6 Tubes per Section.

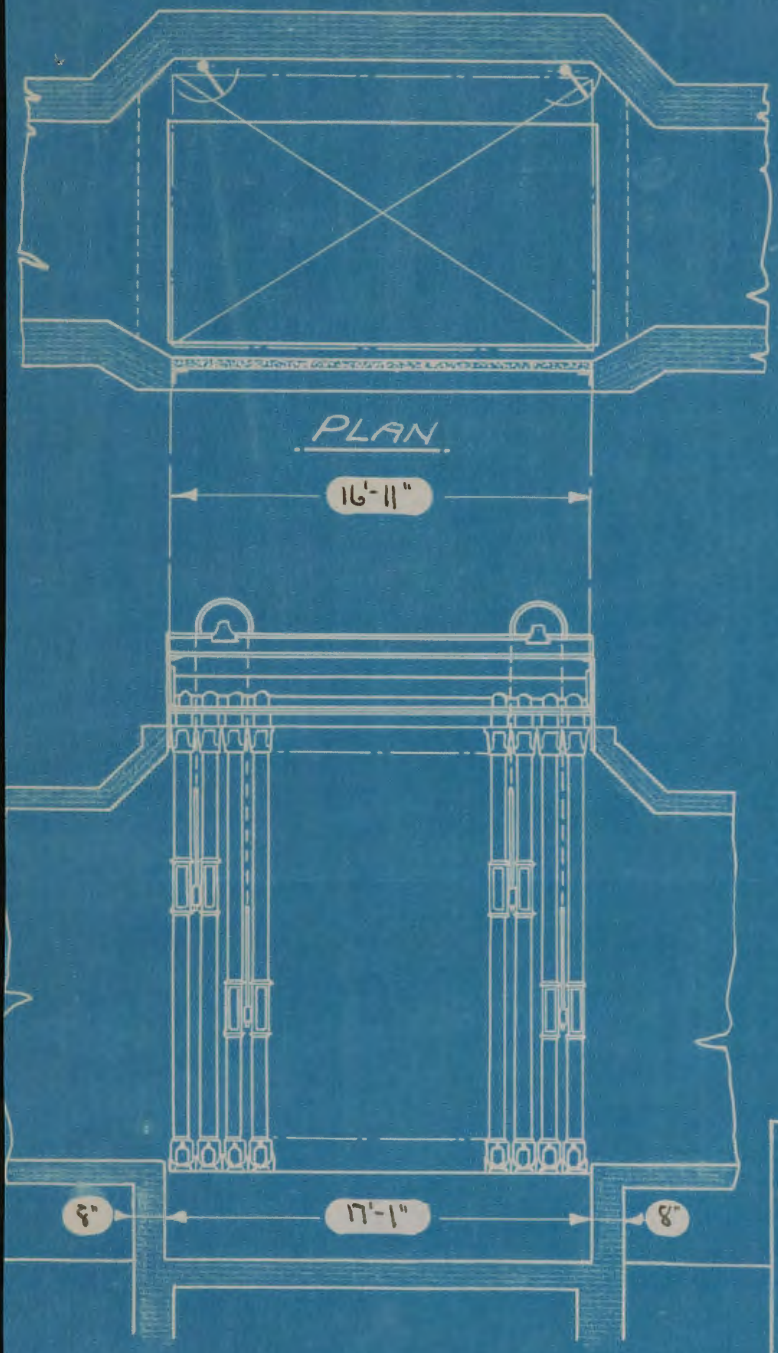
Each tube 9'-0" in length.

Total Heating Surface

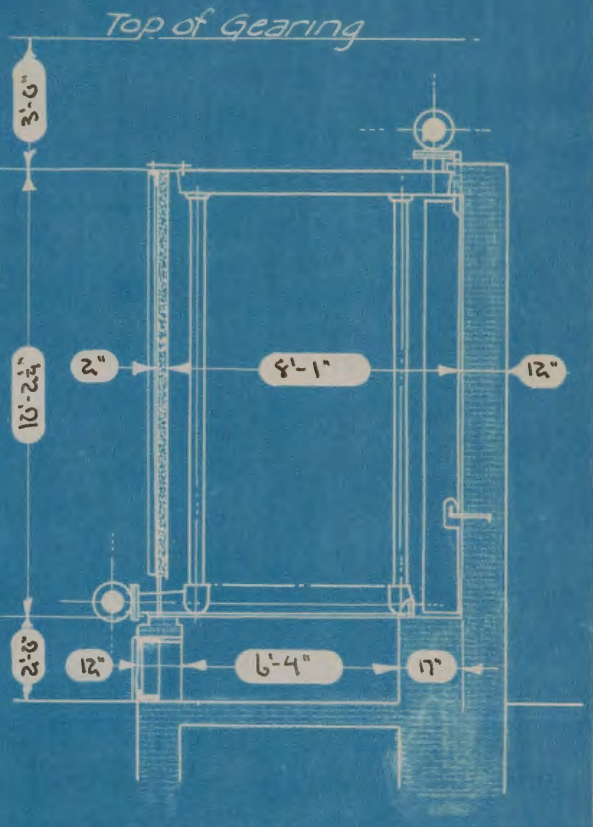
2448 square feet.

THE GREEN FUEL ECONOMIZER CO.
BEACON, N.Y.

Dr. by C.W. Tr. by. W.M. Ex. by	CONT. No.
Scale.	
Date. April 3, 1915.	DWG. No.



ELEVATION



CROSS SECTION.

APPROXIMATE DIMENSIONS OF STANDARD GREEN ECONOMIZER consisting of

280 Tubes. 28 Sections.

10 Tubes per Section.

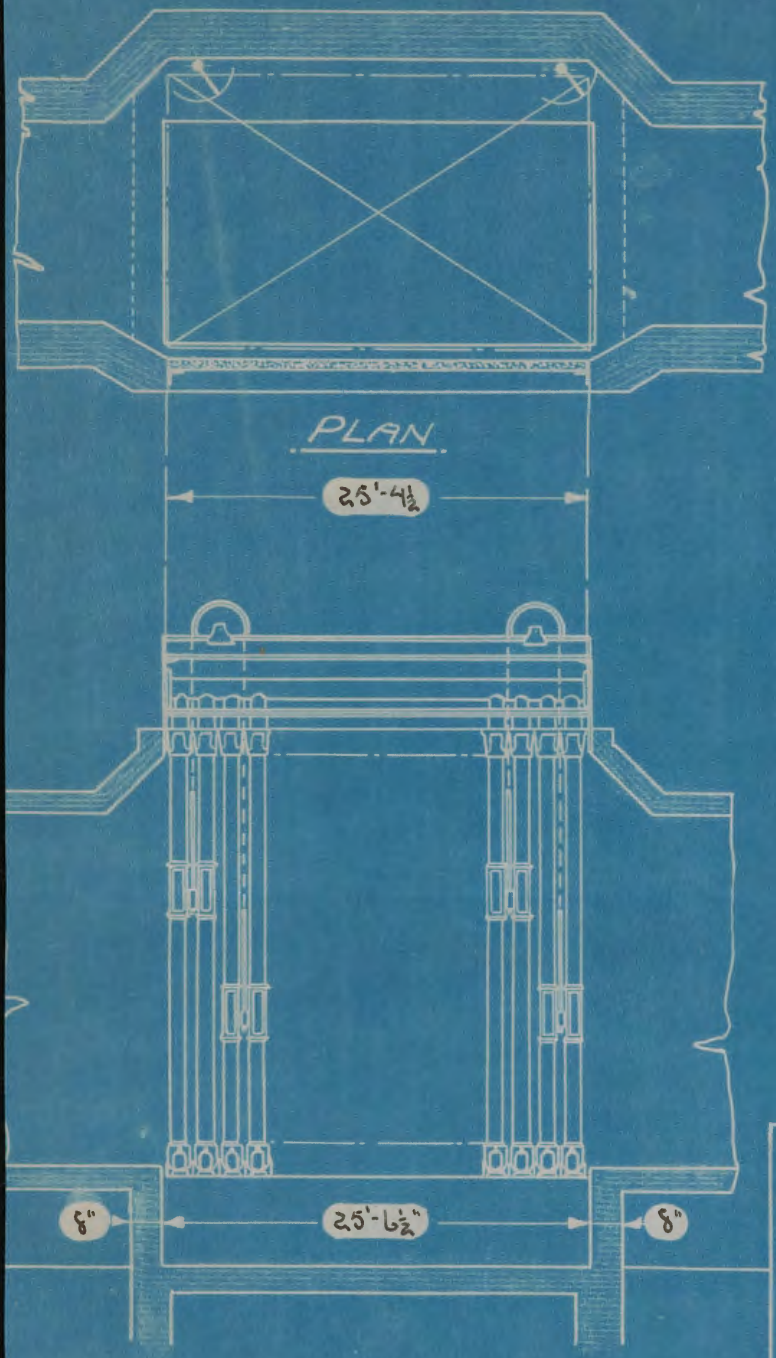
Each tube 9'-0" in length.

Total Heating Surface

3570 Square feet.

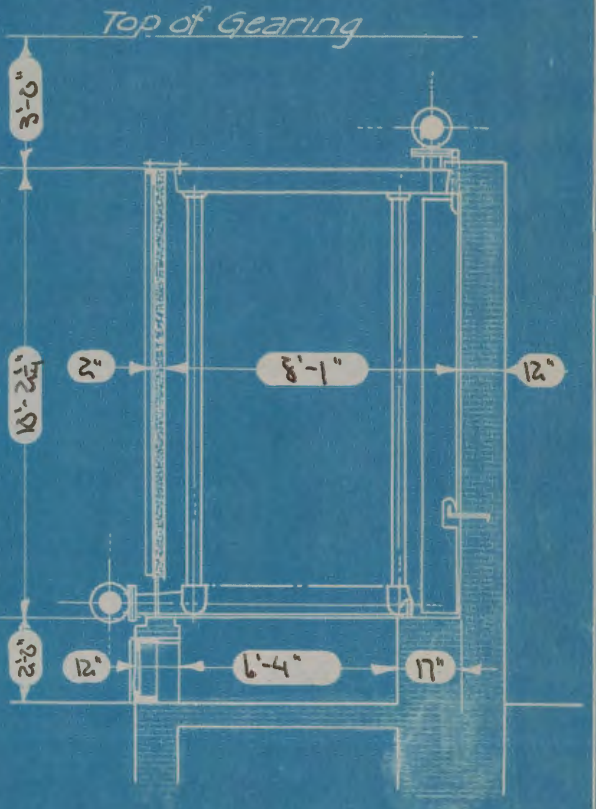
THE GREEN FUEL ECONOMIZER CO.
BEACON, N.Y.

Dr. by C.W.	Tr. by. W.M.	Ex. by	CONT. No.
Scale.			
Date. April 3, 1915.			DWG. No.



PLAN

ELEVATION



CROSS SECTION.

APPROXIMATE DIMENSIONS OF STANDARD GREEN ECONOMIZER consisting of

400 Tubes. 40 Sections.

10 Tubes per Section.

Each tube 9'-0" in length.

Total Heating Surface

5100 square feet.

THE GREEN FUEL ECONOMIZER CO.
BEACON, N.Y.

Dr. by C.W. Tr. by. W.M. Ex. by	CONT. No.
Scale.	
Date. April 5, 1915.	DWG. No.

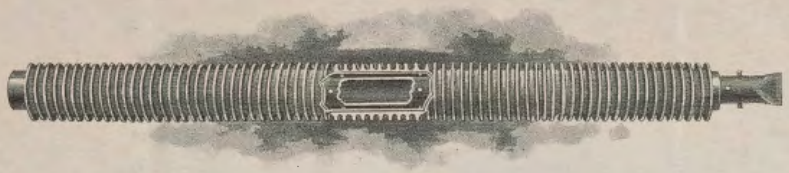
POWER
Power Specialty Company
111 Broadway,
New York.

FOSTER SUPERHEATERS

SUPERHEATED STEAM SPECIALTIES

BRANCH OFFICES:
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BIRMINGHAM, BROWN-MARX BUILDING.

CABLE ADDRESS "REWOP" NEW YORK.



WELL W. FOSTER, PRESIDENT.
ERNEST H. FOSTER, VICE PRESIDENT.
LOUIS B. NUTTING, SECRETARY.
HERBERT M. BALDWIN, TREASURER.
JOHN PRIMROSE, CHIEF ENGINEER.

RBN-S.

HARRIS TRUST BUILDING, CHICAGO, ILL.
April 19, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tennessee.

Dear Sir:-

Yours of the 13th inst. addressed to our New York office has been referred to us for attention, as Knoxville is in territory under charge of this office.

We will be very glad to give you any assistance we can along the line you indicate and presume you have in studying the matter considered possible installation of a Direct Fired Superheater in place of superheaters within the boiler settings, if you are convinced that there will be no economy in superheating all the steam generated by the boilers.

It is not good practice to install superheater within the boiler unless all the steam generated by the boiler passes through the superheater, for reasons which will be apparent to you upon further consideration. Among other objections would be that the superheater would be endangered as it would be impossible to be sure at all times that steam of sufficient quality was passing through it, as there might be times when all the steam from the boiler would pass through the saturated steam connection owing to possible interruption of demand for steam through the superheaters.

You do not indicate what degree of superheat you have in mind. Superheaters can be installed within the boiler settings to add as high as 200° of superheat to the steam generated by the boiler. As you probably know, the ordinary practice is to superheat steam for either reciprocating engines or turbines about 125 or 150°, depending of course upon the length and size of piping boilers to prime movers.

Price for Foster Superheaters delivered and erected in four 250 H.P. Babcock Boilers, complete and designed to add from 125 to 150° superheat to all the steam generated would be approximately THIRTY-FIVE HUNDRED DOLLARS.....$3500.00, this including connections boiler to superheater, thermometer and insurance policy for one year, and to and including flanged superheater outlet outside boiler setting ready for connection

Mr. M. B. McMahon,
University of Tennessee. 4/19/15.

#2.

to steam header.

While we do not guarantee as to life and maintenance further than the ordinary manufacturer's guarantee against repairs necessary during first year of operation which appear to be due to inherent defects or faulty workmanship, we can assure you from our experience in installations aggregating several million horse power that maintenance of Foster Superheaters is so low as to be practically ignored. We have had installations in continuous service for ten and twelve years without any repair whatever. One customer recently advised us that he had not spent $40.00 on 40 Foster Superheaters in service some eight years in forty 500 H.P. boilers.

Although you may have one of our catalogues, we are taking this opportunity to send you copy under separate cover, including therewith our bulletins Nos. 7 and 8.

Very truly yours,
POWER SPECIALTY COMPANY,

R. B. Whiting

Chicago Sales Manager.

N.Y.

AMERICAN ENGINEERING COMPANY

MACHINISTS AND FOUNDERS

ADDRESS ALL COMMUNICATIONS
TO THE COMPANY AND REFER TO

PHILADELPHIA April 21st, 1915.

"S.QUO."

Subject: "TAYLOR" STOKER

Mr. M. B. McMahon,
The University of Tennessee,
Knoxville, Tenn.

Dear Sir:-

Replying to your letter of the 15th instant, we beg to hand you under separate cover one print each of our drawings #S-14942 and S-14943, showing the application of three 3-retort TAYLOR Stokers to 250 HP B & W boilers. We are also sending you one copy of our catalog and "Facts", which will give you considerable information as to installations which we have made and results obtained from operation at these plants.

As we do not know the conditions existing in the plant to which you refer in your letter, we can, of course, give only an approximate estimate as to the cost of the installation. We would say, however, that we could furnish three stokers with fan equipment, drive and regulation for approximately $7,500.00. If only one stoker were bought with the necessary auxiliaries, the price would be in the neighborhood of $3,500.00. These prices would not cover air ducts, foundations or brickwork, simply the apparatus delivered and erected on foundations furnished by the Purchaser.

If we can be of any further service to you in this connection, kindly advise.

Yours very truly,

AMERICAN ENGINEERING COMPANY
STOKER DEPARTMENT

L M Harris

lmh/jm
prints S-14942 and S-14943
catalog and Facts all under s.c.

The Under-Feed Stoker Company of America

Eighteenth Floor Harris Trust Building

Chicago

April Seventeenth,
Nineteen Hundred Fifteen

CABLE ADDRESS:
"JONESTOKE CHICAGO"
CODES: WESTERN UNION,
MARCONI, BUSINESS,
LEIBERS.

E-67192 C-98623

Mr. M. B. McMahon,

c/o University of Tennessee,

Knoxville, Tennessee.

Dear Sir:-

We thank you very much for your kind favor of the 15th inst.

As regards a price for a stoker equipment for three 250 H.P. boilers, would say that it would be, approximately, $4209.00. This includes stokers, dead plates, engine and blower, air piping, blast gate, belting, freight and cartage, automatic feed attachment and regulating valve.

To complete the installation it will be necessary for you to furnish steam piping, boiler fronts, excavation, brick work, foundations for engine and blower, common labor and steam fitting.

In every installation these items are always furnished by the purchaser owing to the fact that it can be done more cheaply by the purchaser than it can be done by us.

As regards the brick work, you know that it does not take any morebrick work to brick up one of our stokers than it does to brick up the boiler for hand firing.

As regards steam piping, you will have to make con-

DIRECTORS:
LLOYD HARRIS
JAMES L. ROSS
A.W. HOLMESTED
DAVID FASKEN
WILLISTON A. KEEN
FREDERICK W. GARVIN
FRED A. DALEY

OFFICERS:
FRED A. DALEY — PREST. & TREAS.
DAVID FASKEN — VICE PREST.
JAMES L. ROSS — SECY.
FRANK M. SMITH — ASST. MGR.
W. J. KENNEY — CHF. ENGR.

nections in your headers for other work and connections can be included at the same time for the stoker engine and automatics.

Foundations for engine and blower can be put in at the same time the foundations are put in for the boilers.

All of this work can be done more cheaply by the party who sets the boiler and does the steam piping than to make two separate bids on same.

The price we have quoted you above includes the services of an erecting engineer to supervise and assist in the erection of the stoker, and to instruct those that will have charge in the proper operation of same.

Regarding the amount of power it takes to run the stoker will state that the engine which drives the blower is an 18 H.P. engine and the amount of power it take to run the stoker all depends on the load that you are carrying. This we cannot give you, unless you absolutely know the amount of coal you intend to burn in your furnace.

As regards the results to be obtained we will make the following warranties:

Economy. The Contractor warrants that by the proper use of the stoker equipment it (the stoker equipment) will effect a saving of not less than ten percent in fuel bills over the results that are regularly obtained in the ordinary running of the plant by hand firing on common grates, the fulfillment of this warranty to be based upon the cost of evaporating a given number of pounds of water by hand and stoker firing as provided by paragraph 8 of this agreement.

Capacity. The Contractor warrants that it can increase the capacity of the boiler to be equipped at least twenty-five percent beyond rated capacity, the hourly evaporation of 34½ lbs. water from and at a feed water temperature

of 212 degrees F. into steam at atmospheric pressure constituting one horsepower, the rated horsepower of the boiler being based upon 10 square feet of effective heating surface for water tube boilers, 12 square feet for return tubular boilers, and 7½ square feet for internally fired boilers, per horsepower.

Smoke Abatement. The Contractor warrants to practically abate the nuisance of smoke issuing from the tops of the smoke stacks or chimneys serving the boilers herein specified unless the boilers be forced greatly beyond rated capacity, or when fires are being started or cleaned.

We also wish to advise you that the first time our Atlanta representative is in Knoxville we will have him call upon you.

Sincerely trusting that the above information meets with your approval and if there is anything further you desire you will call upon us, we beg to remain,

Yours very truly,

THE UNDER-FEED STOKER CO. of AMERICA

Per Fred O'Donnell

FOD-D

KINCAID STOKER COMPANY

507 EAST PEARL STREET

CINCINNATI, OHIO

STATIONARY,
LOCOMOTIVE AND
MARINE STOKERS

April 14, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:

Answering yours of the 13th, we enclose herewith one of our bulletins, which will, we think, give you a full idea of the operation of the Kincaid Stoker.

Regarding power required, tests made on old types of this stoker, by Prof. Goss, at Purdue, in heavy locomotive service, showed less than 1% of steam generated to be required to operate the stoker. The newer designs take less steam than the old one, but we haven't any scientific tests to know just what they are using now.

As to price for 250 H.P. boiler, before quoting we ought to have the following information:

Type of boilers - manufacturer's name & address, if possible.
Length and Width of grates.
Thickness of front walls.
Style of fronts -- Full flush or half arch.
If full flush, distance from dead plate, or bottom of fire door, to bottom of clean-out door, located above the fire door.
If half arch, distance from dead plate or bottom of fire door to lowest point of breeching or overhanging part.

Price on new installation runs somewhat less than on application of stoker to old boilers, for the reason that the boiler front, as supplied with the stoker and the brick work around the door, when put in new, are entitled to a corresponding credit from the price of that boiler as supplied with a regular front. Old installations require the front casting to be replaced, and the brick work around the door to be changed. Prices also include erection and instruction of firemen. Naturally, the traveling expense cost is the same for one stoker or more installed at the same time. This makes the price per unit less by the proportional amount for multiple installations.

In this connection, would advise you to send to the Bureau of Mines, Washington, D.C., for the technical paper #80 entitled "Hand Firing Soft Coal Under Power Plant Boilers. This is a very valuable document. It gives not only directions to the fireman, but discusses exactly the theory of combustion on which the development of the Kincaid Stoker is founded. It also contains good material in the way of information as to causes and remedies of clinker, the most common causes being thick fire and stirring the fire. The Kincaid Stoker is the only stoker that does not disturb the fire. Every other stoker moves the hot fuel bed and this immediately causes the clinker to "puddle" into large masses, even when the clinker is not absolutely fused to plastic or running state.

Furthermore, this bulletin shows clearly the different chemical conditions in various fuel beds, and from determinations of fusion points of ash or oxidizing and reducing flame conditions shows that ash is fusible at lower temperatures under reducing condition than under the oxidizing, therefore, the thinner the fire, the less is the reducing zone. The oxidizing zone remains practically constant.

The over-feed, or scattering system of firing is the only one that gives an absolute control over the depth of the fire bed, all over the grate. Chain-grate stokers have a progressively diminishing depth. Inclined grate stokers have the same defect, and under-feed stokers have an excessively heavy fuel bed where the green coal is fed, and an excessively light fuel bed out at the edges. We think the over-feed principle to be the only proper principle for combustion, and the only one under which the proportions between CO and CO^2 can be maintained, so that the CO is completely combined before getting into the flues.

This bulletin, we think, a very valuable contribution to the body of combustion knowledge.

Yours truly,

KINCAID STOKER CO.

E Faber Buel

EFD/BK

KINCAID STOKER COMPANY

507 EAST PEARL STREET

CINCINNATI, OHIO

STATIONARY,
LOCOMOTIVE AND
MARINE STOKERS

April 16, 1915.

Mr. M. B. McMahon,
University of Tennessee,
Knoxville, Tenn.

Dear Sir:

On an equipment of three boilers installed at one time, the price of Kincaid Stokers erected at Knoxville will be approximately $2,900. This price, as stated before, will include the cost of the fire brick block arch and front wall at the door, and freight on same, the setting to be done by the bricklayer who sets up the boilers new. It would also include the cost, delivered, of the front casting around the door carrying the lugs to hold the stoker. On a B. & W. setting, this is just a section of the front, the setting of this front also to be done when the boiler is erected by the bricklayer.

The price also includes the services of our supervising erector and the cost of the common labor necessary to help him in the erection. For an installation of three boilers at the same time, he would need not to exceed three men for a week.

Yours truly,

KINCAID STOKER CO.

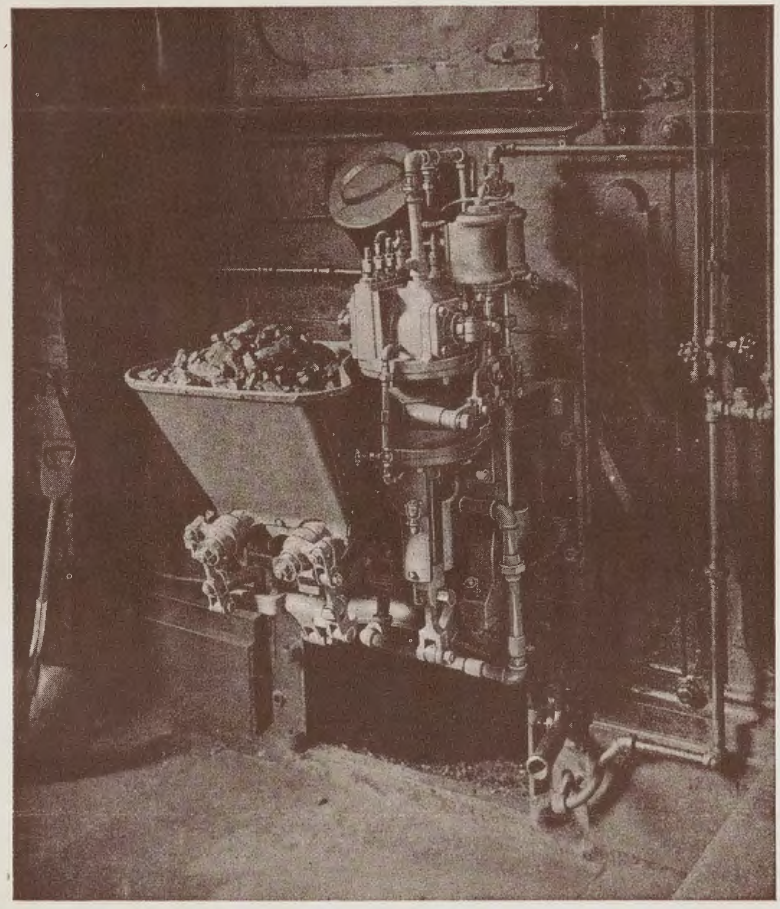
E F DuBrul

EFD/BK

"Fire Light and Often"

THE KINCAID STOKER

Stationary Type



KINCAID STOKER CO.

Stationary, Locomotive and Marine Stokers

507 EAST PEARL STREET CINCINNATI, OHIO

THE KINCAID STOKER

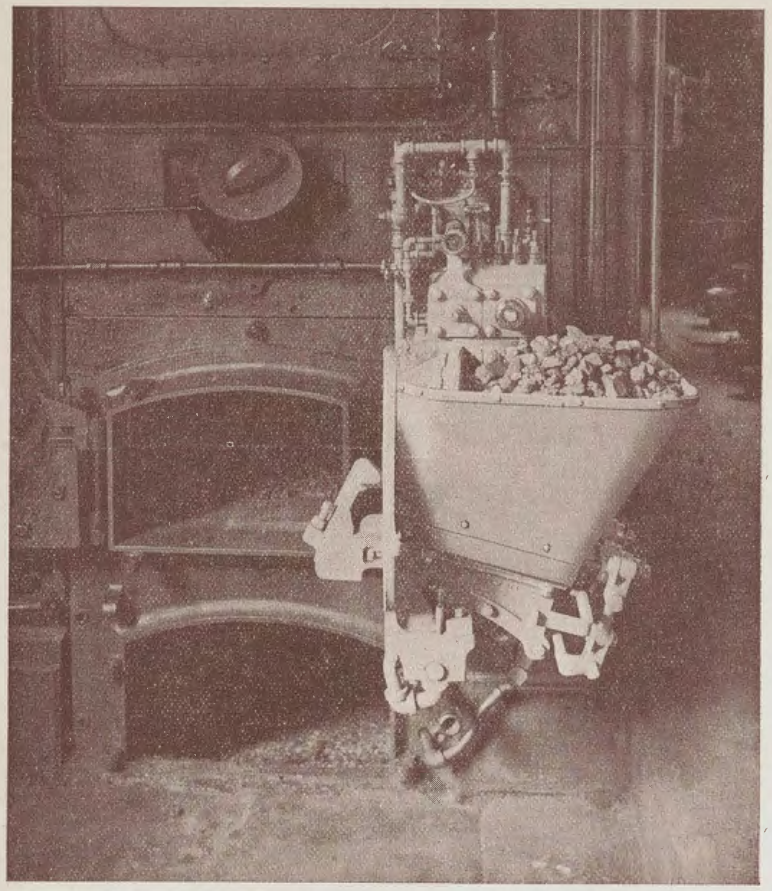


FIGURE 2 ENTIRE STOKER SWINGING FREE FROM FIRE DOOR.

FIRES
- Any kind of coal.
- Any size of coal.
- Any furnace.

SAVES
- Coal.
- Grates.
- Repairs on boilers.
- Work of fireman.

INCREASES
- Profits of owner.
- Amount of steam.
- Steaming qualities of boiler.

ELIMINATES
- Smoke.
- Large clinkers.
- "Hooking" the fire.
- "Puddling" the fire.
- Expense of training new firemen.

PREVENTS
- Waste of heated gases
- Chilling of boiler, caused by inrushes of cold air.

LENGTHENS
- Life of boiler.
- Life of fireman.

MAINTAINS
- Maximum boiler pressure.

ALLOWS
- Forcing of boiler.
- Free access to fire box at any time, for any purpose.

ADVANTAGES

EFFICIENCY

The KINCAID STOKER being of the true overfeed or "Scatter" type, throwing the coal on top of a fire bed, has no moving grates to propel the coal. Moving grates inevitably "puddle" the fire and form large clinkers, which of course interfere with combustion and are very difficult to remove.

The KINCAID STOKER automatically takes care of variations of load. As the pressure goes down, more coal is fed, and as the pressure goes up, less coal is fired.

Peak loads are automatically cared for by heavier firing.

A furnace equipped with the KINCAID STOKER does not coke the coal. It burns it. Small charges of green coal being spread over a hot fire bed, there is no coking effect. The combustible matter is quickly and thoroughly burnt without smoke.

The fire carried with the KINCAID STOKER is very light and the system of firing makes the fire, with the exception of gas or powdered coal, the most sensitive and responsive fire known to the art.

The fire not being "puddled" no clinker is formed, when good coal is used and even when very bad coal is used, the non-combustible matter in the coal is not "puddled" into large clinkers, but is simply left in small pieces, and the clinker is therefore porous and does not interfere with the passage of the air through the fire. In consequence, the poorest grades of coal can be economically and efficiently burned with this stoker.

The moving parts being small and light, very little steam is required to operate this stoker.

ADAPTABILITY

The KINCAID STOKER requires no more head room within the fire box than is needed with hand-firing. Neither does it require any more space outside the fire box than is taken up by one man when hand-firing.

The total space required to swing the stoker around is only 30 x 60 inches, the space occupied by the stoker in operating position being only 30 x 35 inches.

To install the KINCAID STOKER it is not necessary to construct underground ashpits, although such ashpits, or any other mechanical means of removing ashes, can be used to advantage with this stoker. The installation of a KINCAID STOKER requires but a very short time, there being no changes required to the boiler, grates or settings, except at the fire door. This stoker will fire any grate that can be hand-fired.

EASE OF OPERATION

The KINCAID STOKER does not require an experienced firemen to successfully operate it. Inexperienced men have been broken in on this stoker in the course of an hour and have maintained maximum steam pressure more easily than expert hand-firemen were able to do in the same service. Under such circumstances, since the work is much less exhausting than hand-firing, the firemen hold their positions longer, and the continual annoyance of changing firemen is eliminated, as well as the expense and loss involved in educating new men to firing. As this stoker spreads the coal over all portions of the grate evenly and equally, there is no difference in the draft through different portions of the grate, and the fireman does not have to be continually regulating his drafts. As the fire never needs "hooking" or "slicing" the fireman is not exposed to radiant heat from an open furnace door. Where mechanical means for handling coal are not provided, the KINCAID STOKER does not require the fireman to lift the coal very high to fill the hopper.

The construction of the valves of the Stoker engine is such that they **never** need re-setting and will run for years without repairs, having very large wearing surfaces and very slight movement, as well as being perfectly balanced.

DURABILITY

The engine of the KINCAID STOKER is a slow-working, vertical, reciprocating engine, and in stationary practice is rarely required to run over 30 strokes a minute. For most stationary service the average speed is from 15 to 20 strokes per minute, therefore the engine wear is very small. All the moving parts being very light and the work done by them being light, there is but very little wear on these parts. All parts on which there is any strain are made of steel. There are no worm wheels which are so prone to be cut, due to forgetfullness of the fireman to lubricate. The mechanical work on this stoker is of the very best. Every stud or shaft that moves is provided with bronze bearings, which can be easily and cheaply replaced. Design, material and workmanship all make for durability. Being durable, the KINCAID STOKER has an extremely **low cost of maintenance.**

SIMPLICITY

The KINCAID STOKER is of simple construction throughout. Any engineer can very quickly grasp every detail of construction and operation. There being nothing in the fire box, and everything but the distributing plate being outside the fire door, every part is accessible. Except the engine valve and piston all parts are visible. The installation of this Stoker does not mean a reconstruction of a boiler setting. It has no high-priced twyer blocks to burn out and to be replaced. It has no high-priced special grates to burn out. It has no high-priced special boiler settings, or combustion arches to burn out. It has no large and expensive forced-draft equipment to be installed and maintained and which requires considerable power to operate, to say nothing of care and attention.

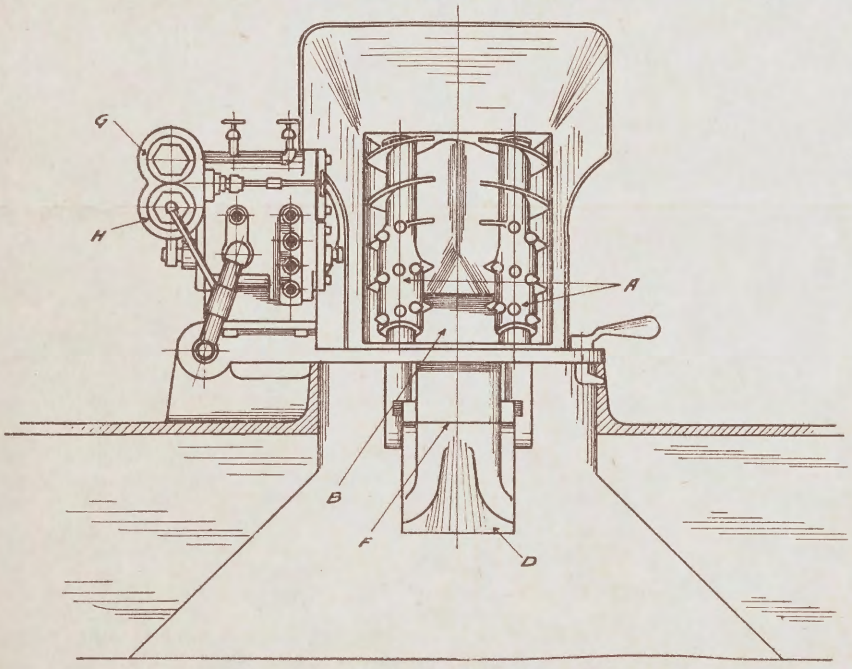


FIGURE 3

The KINCAID STOKER merely fires the coal into the furnace through a closed door, and spreads it evenly over the fire. This is beyond the physical capability of any fireman, no matter how expert, to do by hand. The KINCAID STOKER is not an automatic furnace. It is a truly automatic, mechanical fireman.

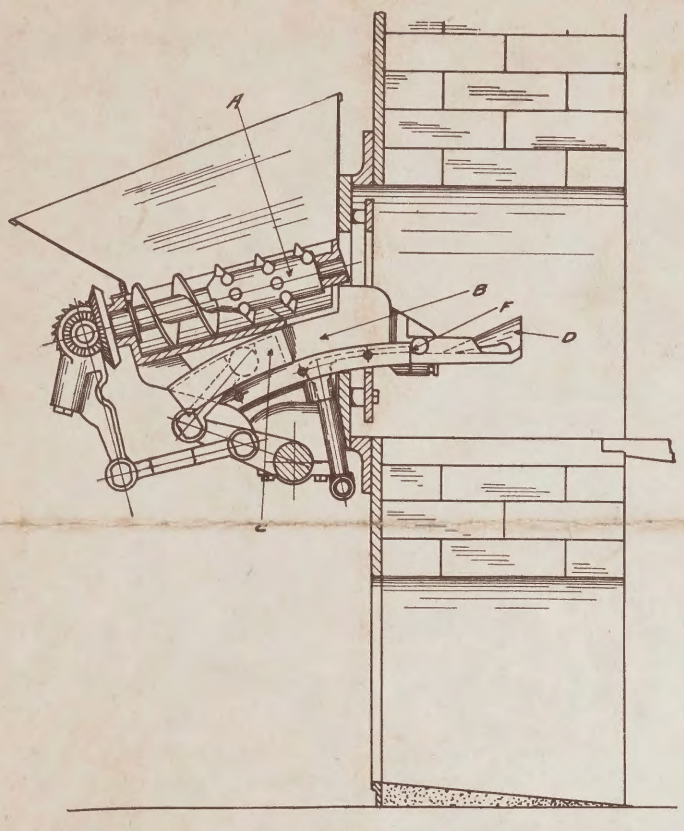


FIGURE 4

DESCRIPTION

The KINCAID STOKER is mounted on a central furnace door, which in turn is mounted on a frame, by means of an extra-heavy hinge bolt made of cold-rolled steel. This hinge bolt passes through heavy hinge lugs on the door and corresponding lugs on the frame. This frame replaces the lower half of the boiler front. The installation of the stoker can be quickly done, as no change is made in the grates, baffling or setting. In cases where the jambs of the door are straight, they should be flared, or the brick around the door can be quickly replaced by a flared block front.

Mounted upon this door the stoker may be swung entirely away from the fire opening (*see Fig. 2*) and free access had to the fire box for any purpose, in the same manner as with the ordinary fire door. In the bottom of the hopper, which can be filled either by hand or any mechanical means, are two worms that carry the coal forward and place uniform charges in front of a reciprocating plunger C in the space B (*Figs. 3 and 4*), this space appearing directly beneath the worms during the receding or backward stroke of the plunger. On the forward ends of these worms are crusher rolls A, to crack any lumps that are larger than three inches. This permits the use of any size of coal, as well as mixed sizes.

Each separate charge of coal is delivered by this plunger into the fire box over a distributing plate D, which as shown in the cut, may be folded back and thereby offer no obstruction when the door is open. While the stoker is working, this plate is in a horizontal position (*Figs. 3 and 4*). At the time that the coal is passing over this plate, the steam from the stoker engine is exhausted through a nozzle F, between the coal and the plate, the coal thereby riding out upon the steam blast and taking momentum from both the steam and the plunger. The plunger reciprocates in a cycle of four different strokes of variable velocity. The heavy or fast stroke delivers its charge of coal over the entire quarter of the grate nearest the bridge wall, the second over the adjacent quarter; the third over the next and the fourth or lightest stroke over the quarter nearest the door. When the cycle is completed, another cycle is automatically started.

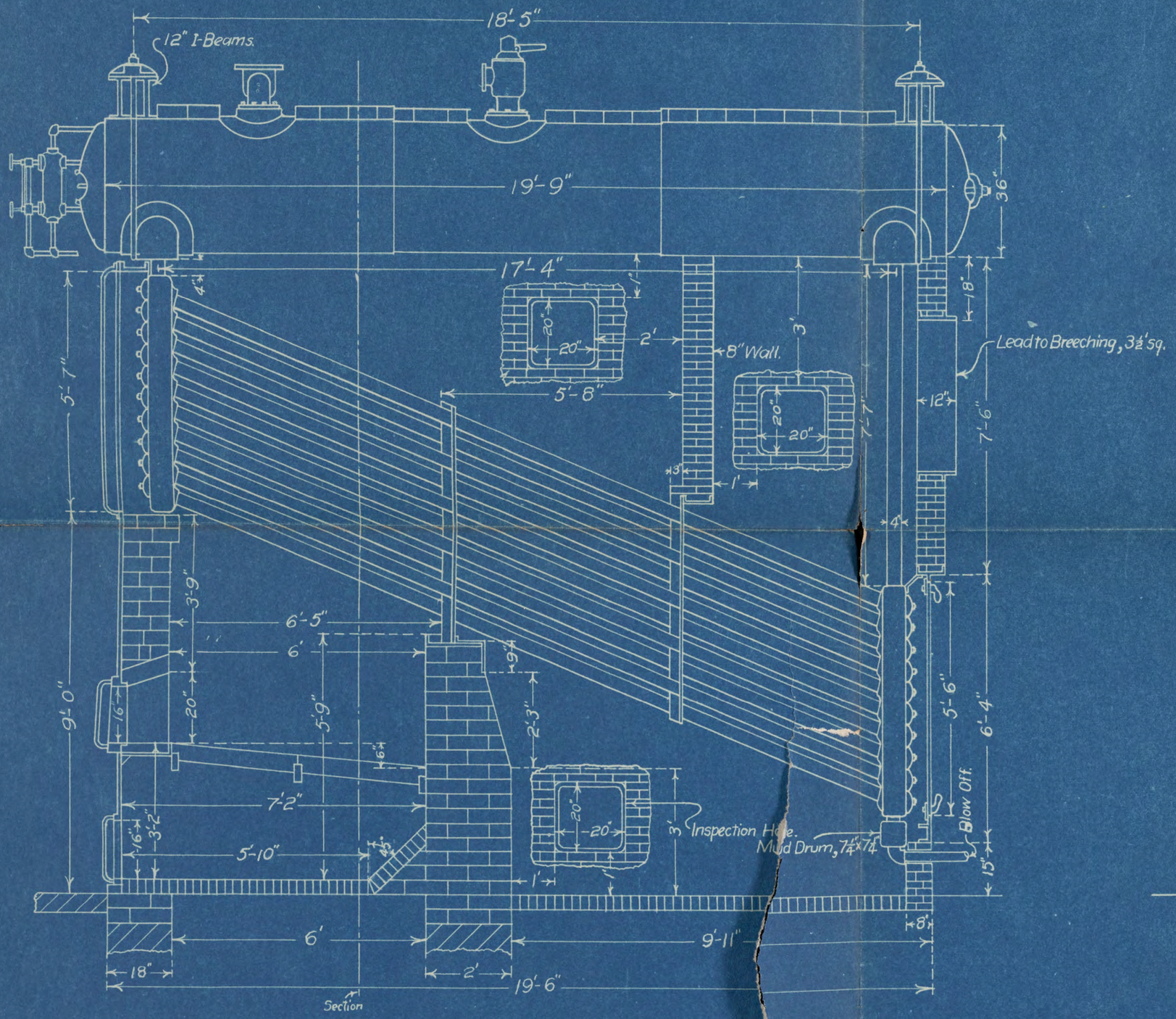
The exhaust is variable in intensity to correspond with the variable strokes of the plunger. By the contour of the plate, which is made to suit the shape and proportion of the furnace, the steam is directed to all portions of that section of the fire box, corresponding to the stroke which is being made, carrying the coal with it. In this manner the coal is spread over the entire grate, building up a very porous and spongy fire, through which air passes easily and evenly. The coal being spread evenly and in small quantities, the volatile gases are distilled in the same manner and there is a perfect combination of these gases and air. The high temperature of the fire box ignites the gases and the small particles of carbon, and they burn before they have a chance to escape in the form of smoke. This results in perfect and thorough combustion, which is the only economical way to have a smokeless stack.

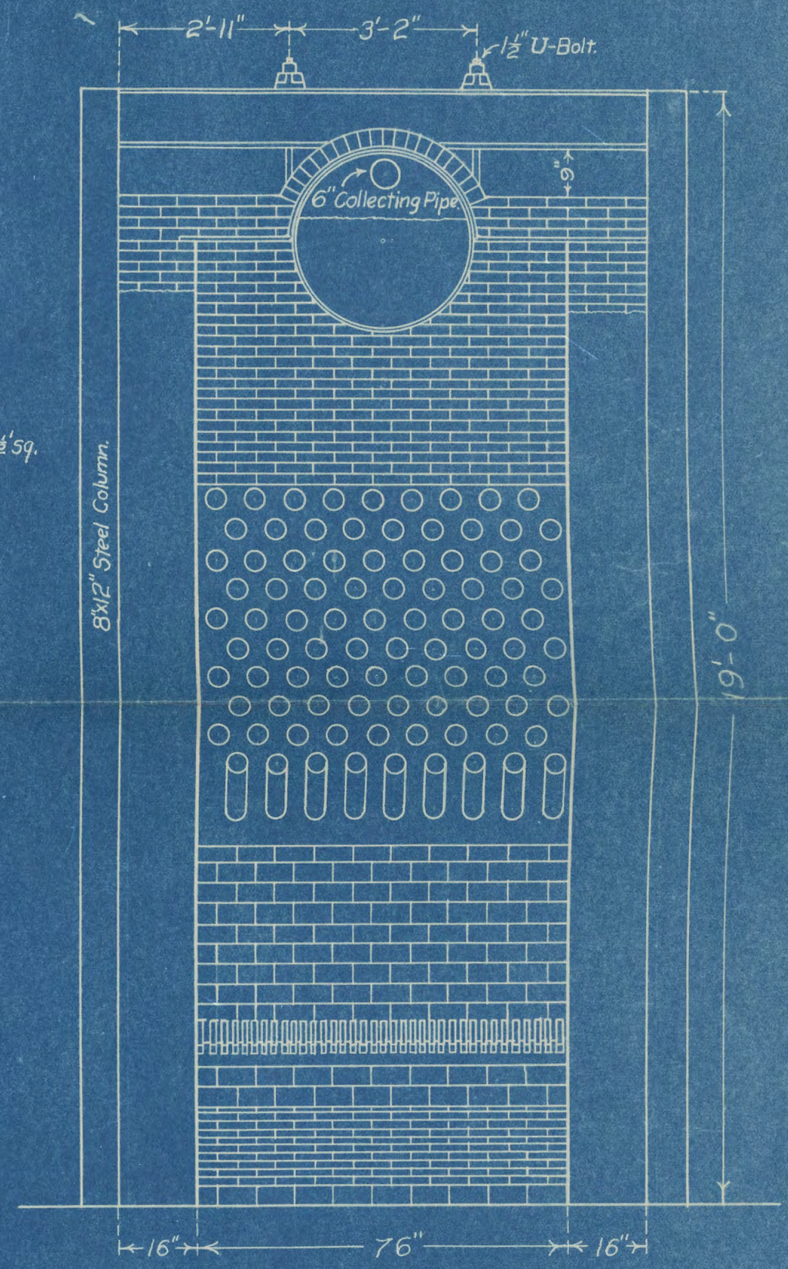
The velocity of the different strokes is controlled by individual throttling valves encased in the valve head of the stoking engine. When these valves are set for a given fire box they need no further adjustment. Fluctuations in the demand on the boiler are accomodated by varying the number of charges of coal, anywhere from 10 to 75 charges per minute. This variation is accomplished by regulating the number of strokes of the engine within a given length of time independently of the velocity of the piston, which remains constant in the cycle before referred to. This regulation is obtained by a small steam-operated piston, within the cylinder G, which having no valves of its own, takes a full head of steam from the main cylinder. The steam piston's speed is controlled by a resistance piston operating within the cylinder or dashpot H; the two pistons being yoked together. Water in the cylinder H, is forced from one end of the piston to the other, and vice versa through a by-pass situated alongside the cylinder.

In this by-pass is a valve, permitting the water to flow slower or faster, thereby controlling the speed of the piston, and in turn the speed of the steam piston. This valve may be operated either by hand or automatically by a variation of boiler pressure as may be desired. The small amount of water which may escape from the cylinder H, through stuffing box leakage is automatically replenished by drawing condensation from the main steam line through a check valve into the cylinder.

200 H.P. Babcock and Wilcox Water Tube Boiler and Setting for University Power Plant.

Drawn & Checked by McMahon.
Scale - 1" = 2'.





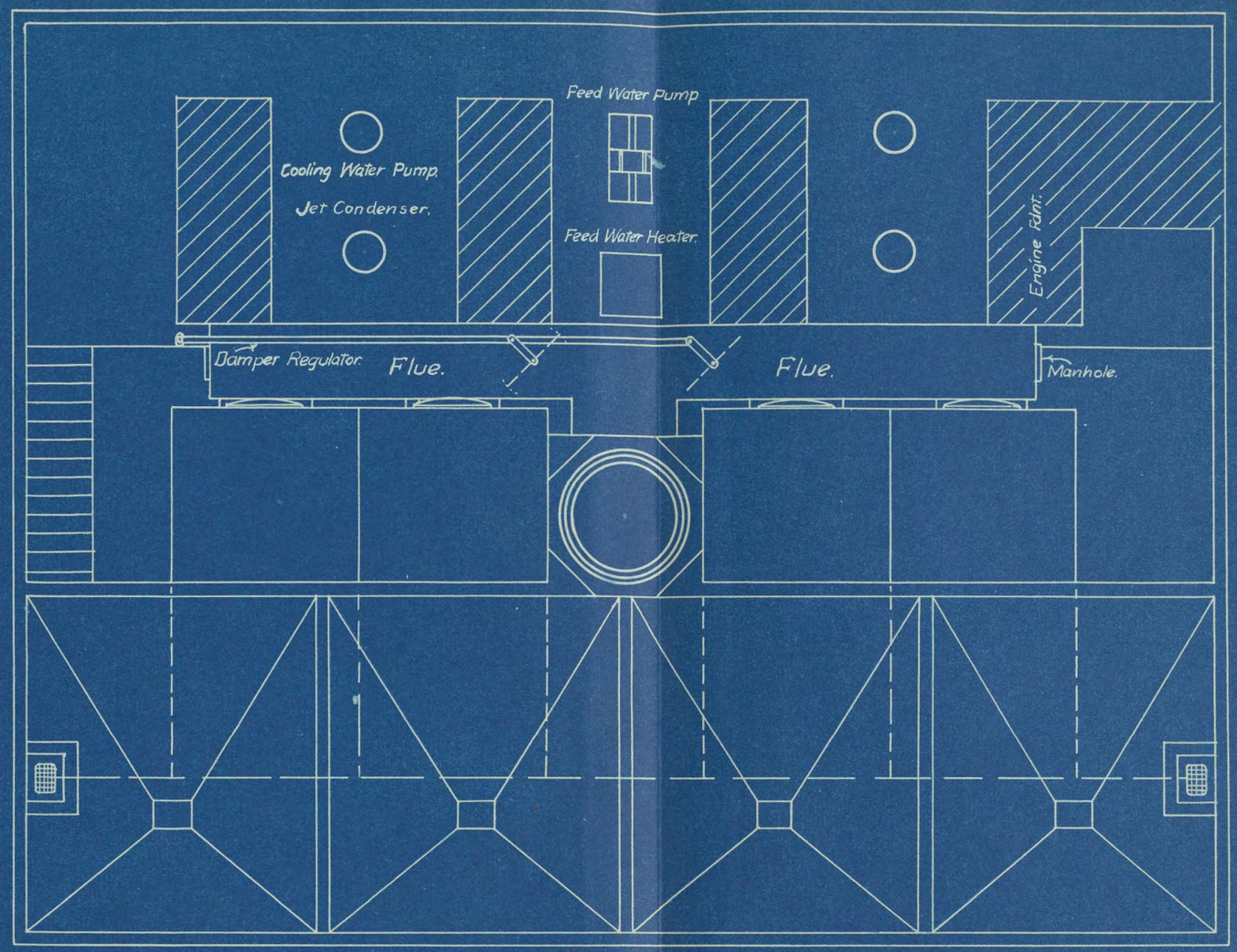
Boiler Data.

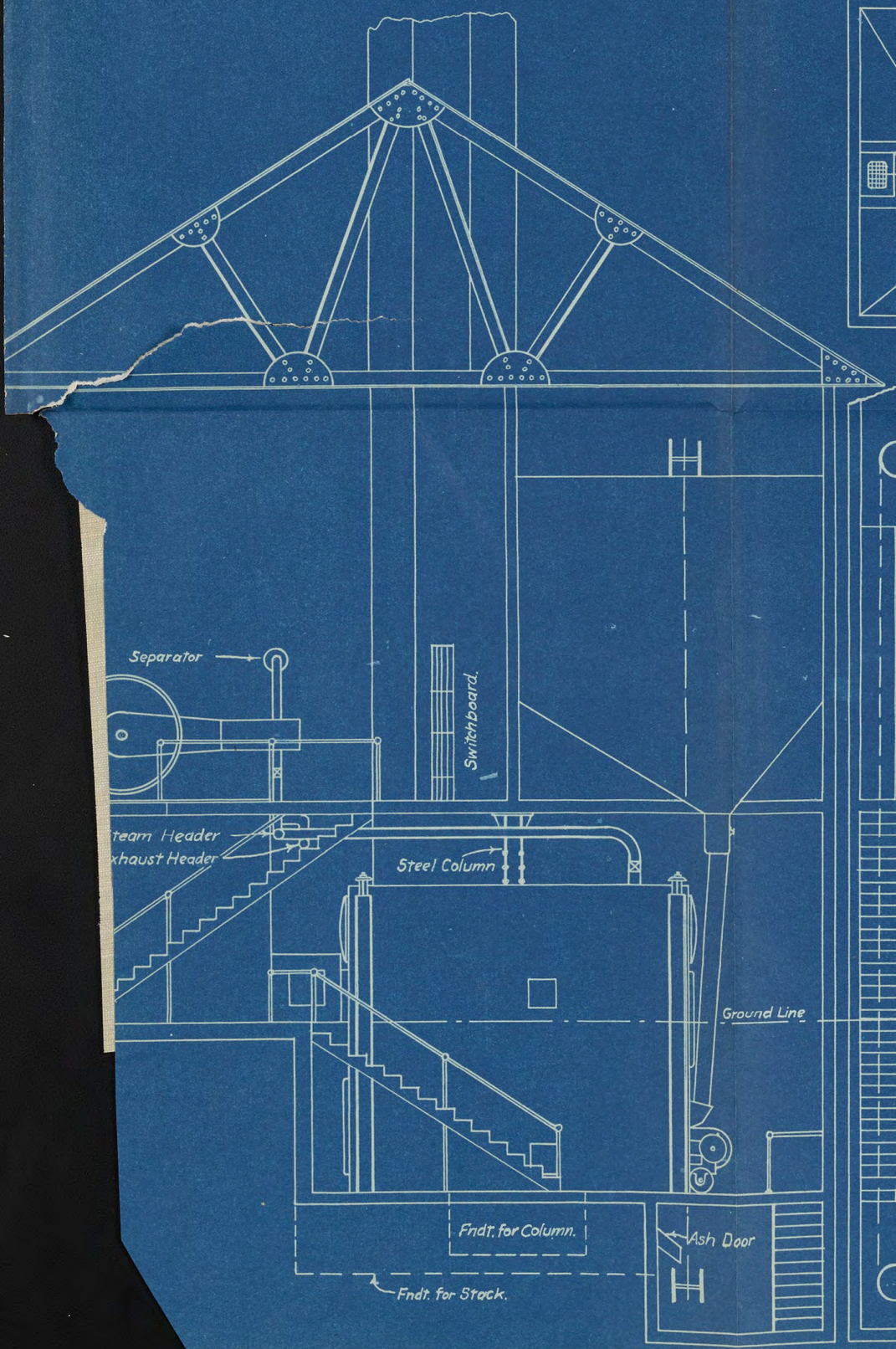
90, 4" Tubes, 18' Long, Sloping 22½°.
Heating Surface (Tubes Only) = 1700 sq. ft.
Grate - 76" wide x 72" long = 38 sq. ft.
Thickness - Drum plate = ¼" - Tubes = .148".
Headers - Cast Iron, Vertical.

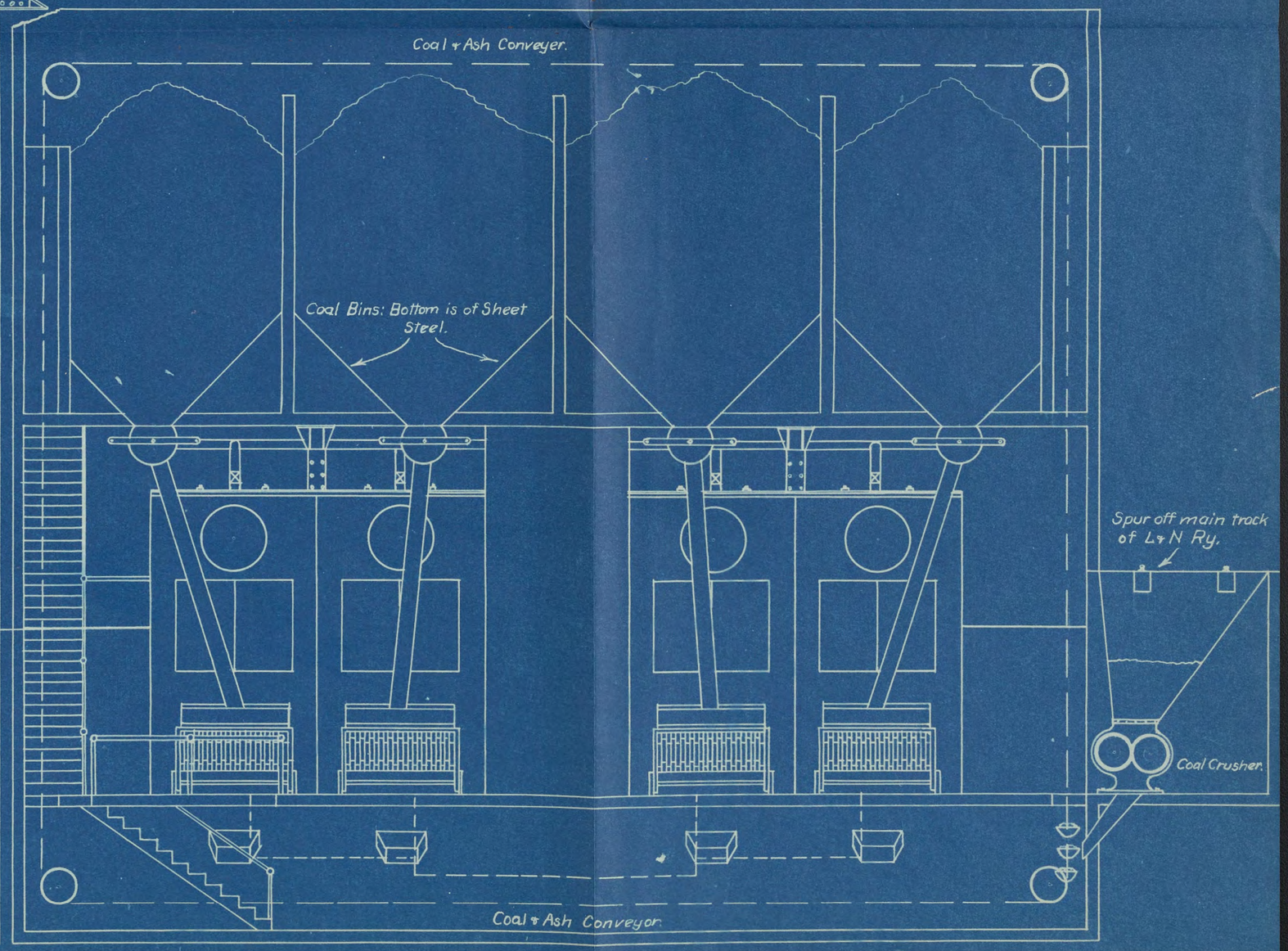
Central Heating & Power Plant for Univ. of Tenn.

General Layout A.

Scale – 3/16" = 1 ft.

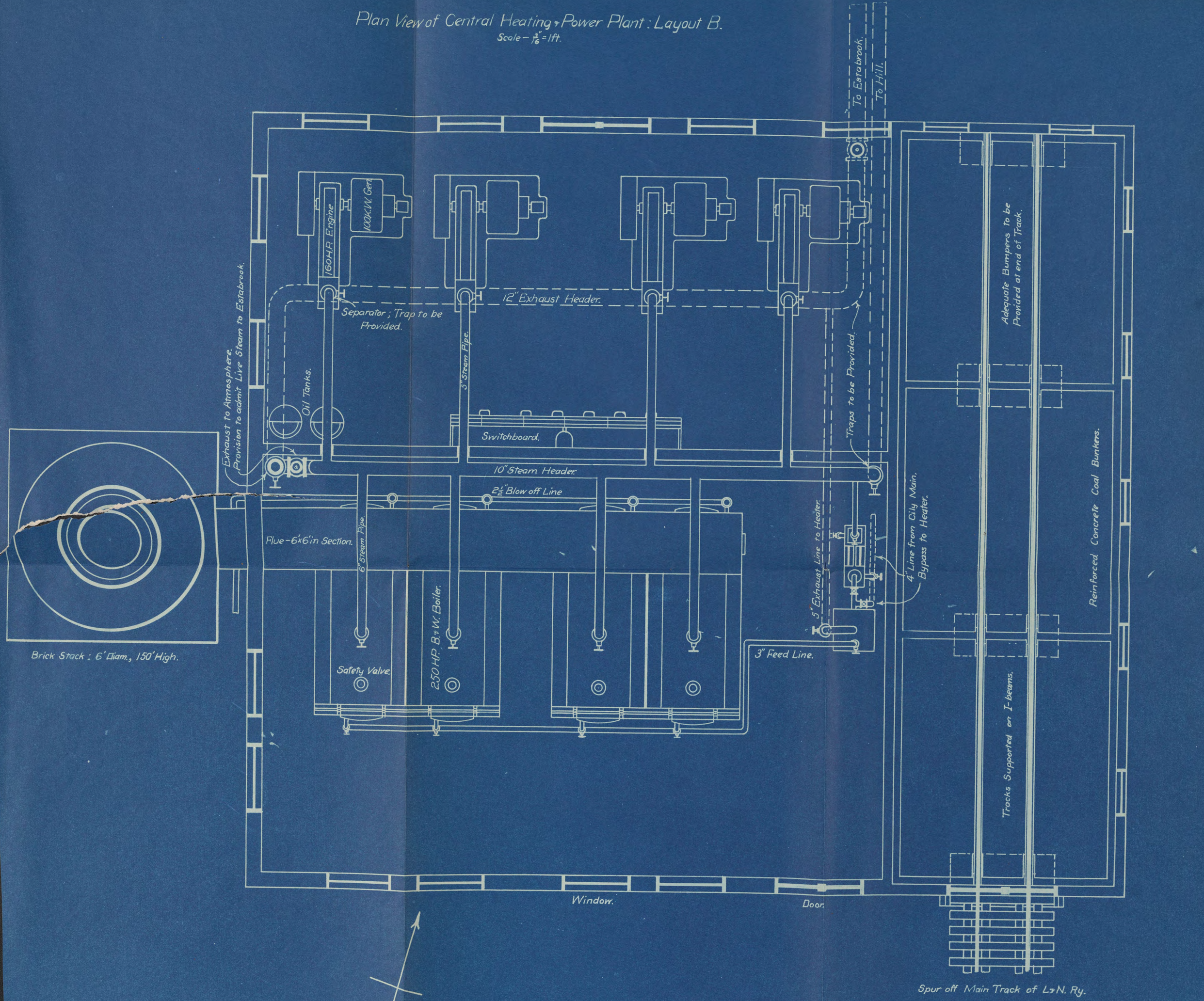






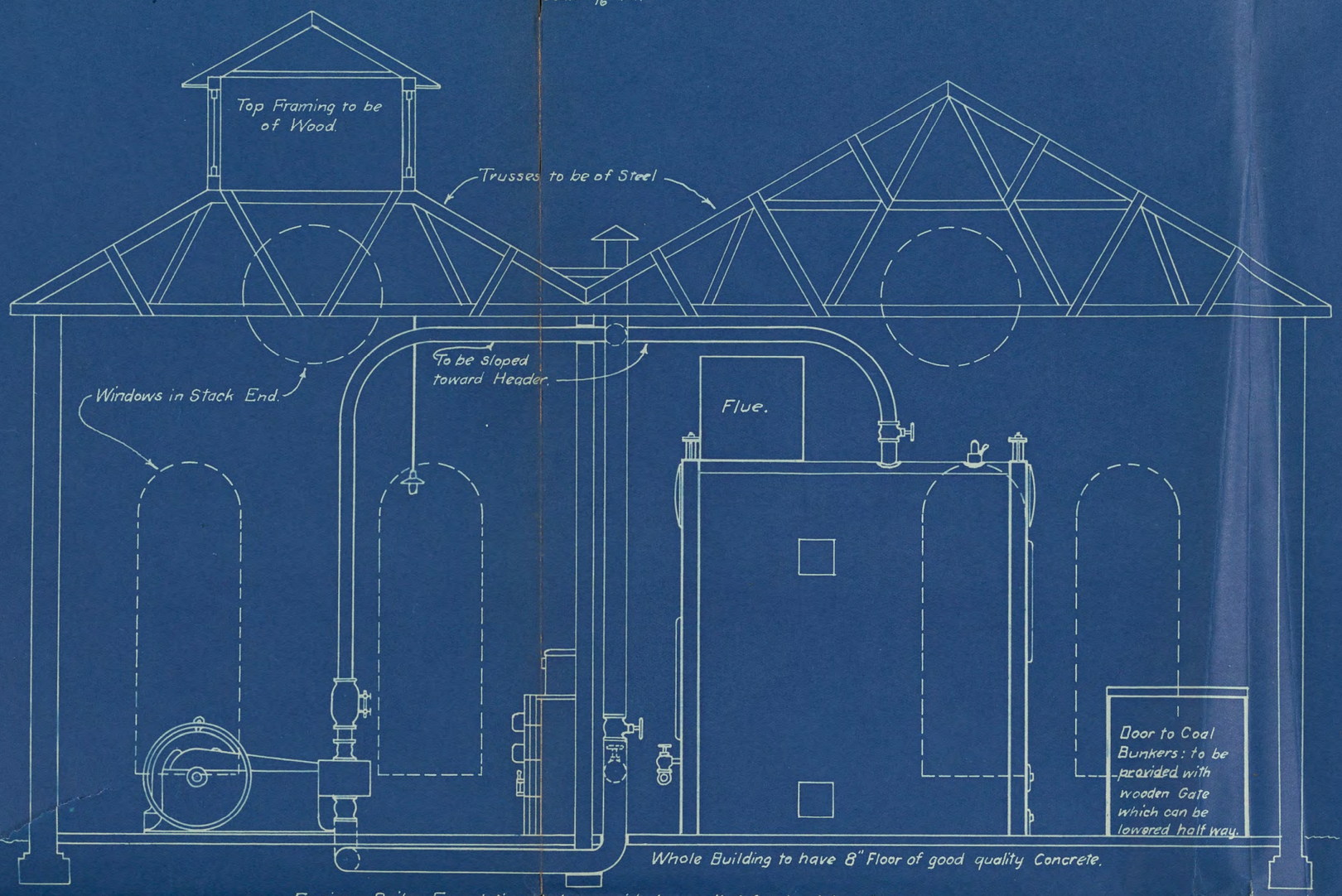
Plan View of Central Heating & Power Plant: Layout B.

Scale – 3/16" = 1ft.



Stack End Elevation of Central Heating + Power Plant.

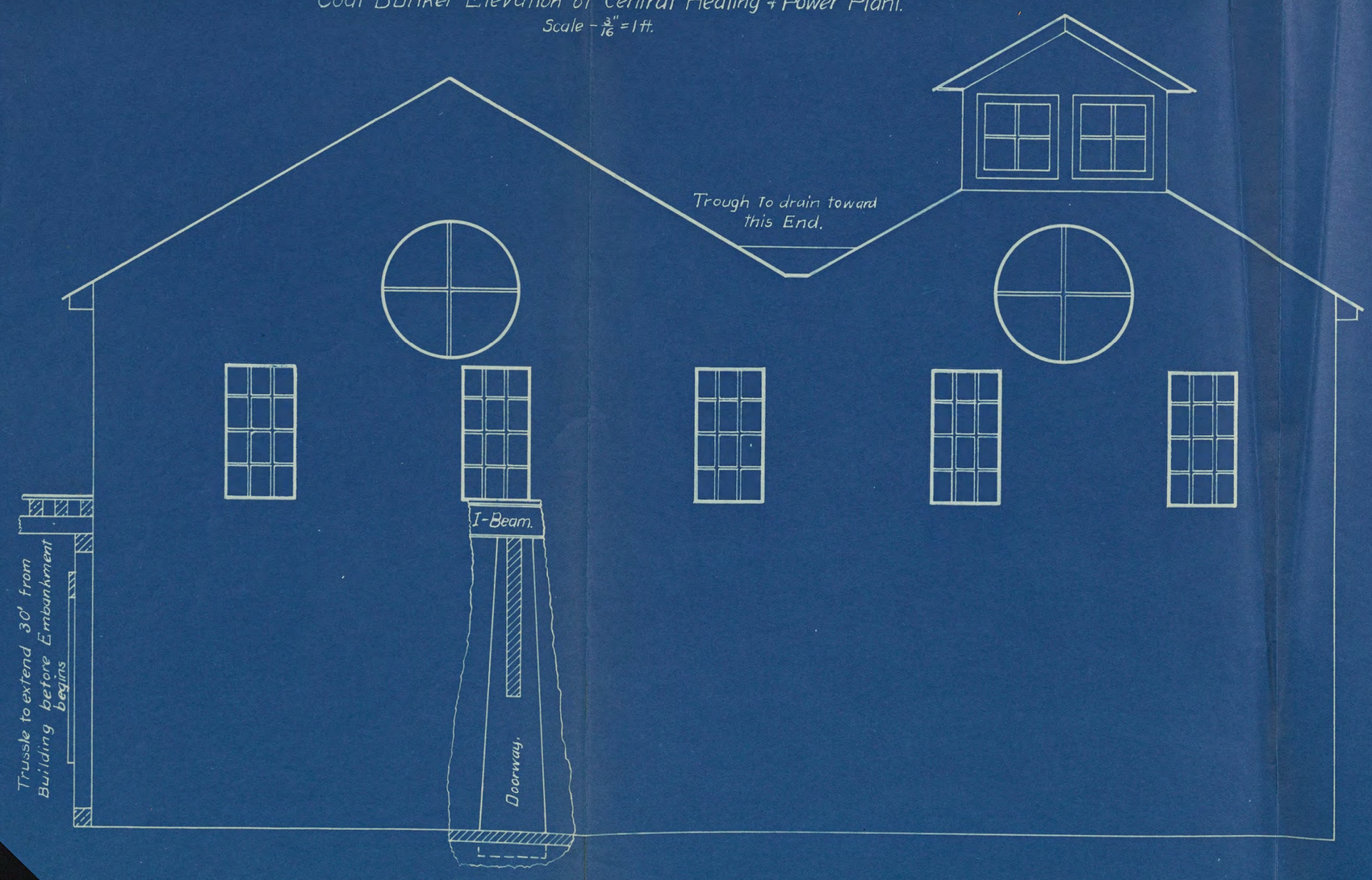
Scale - $\frac{3}{16}$" = 1 ft.



Engine + Boiler Foundations to be provided as called for by Manufacturers.

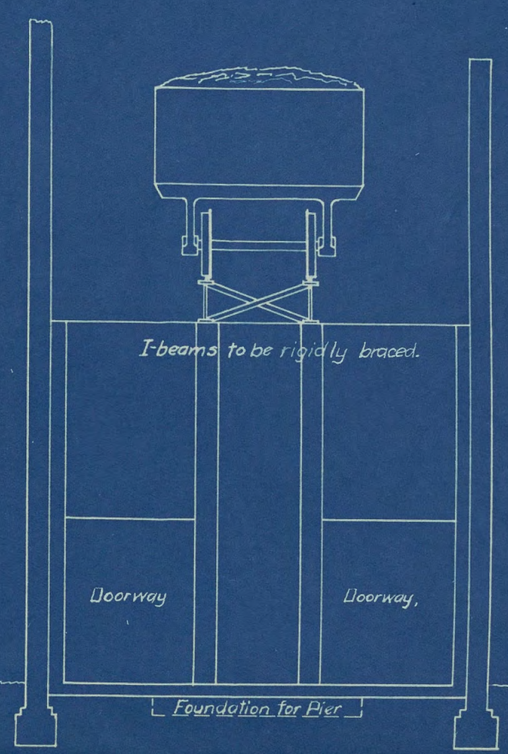
Coal Bunker Elevation of Central Heating + Power Plant.

Scale - $\frac{3}{16}$" = 1 ft.



Cross Section of Coal Bunker.

Scale - $\frac{3}{16}$" = 1 ft.



Notes on Design.

Walls of Building to be of same kind of Brick as are in Estabrook Hall.

Stack is of Brick and should be of some standard Design and preferably to be constructed under Contract by some reliable Company.

All Doorways + Doors to be 8' high unless otherwise specified.

All pipe Fittings to be extra heavy Cast Iron.

Rear Windows will have their Bottoms 5' above Floor.

Front Entrance to be of imposing Design and wide enough to admit an Engine.

Coal Bunkers to be designed to carry 20' of water. I-beam shall carry 40000# placed at its centre.