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Boiler feed water purification at the Gorge Power Plant, Akron, Ohio

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BOILER FEED WATER PURIFICATION AT THE GORGE POWER PLANT AKRON, OHIO

THESIS SUBMITTED BY B. W. ADAMS TO THE FACULTY OF THE MISSOURI SCHOOL OF MINES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MECHANICAL ENGINEER.

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PROFESSOR OF MECHANICAL ENGINEERING.

The purification of water for use in boilers is not primarily a problem for the engineer. The chemist is alone able to make a complete analysis of the water. From this analysis, he can then recommend the method best suited for the water under consideration.

The present day tendency toward large size boiler units and high overloads has made the question of pure water for these units one of the foremost problems in power plant engineering. The cost of fuel has also had its share in bringing to the attention of executives the necessity of providing every means for increased efficiency in the boiler room. When fuel was cheap, no thought was given to the possibility of saving part of it. In recent years, however, it has been necessary for every user of fuel for power purposes to make every pound produce the greatest possible amount of steam. One of the results of impure water in power boilers is the formation of scale on the heating surfaces of boiler. Another result is the corrosion of the tubes and plates of the boiler. No exact information is available regarding the loss of heat caused by scale in the boiler but it has been estimated that the loss in some cases is as high as thirty to forty percent. Boiler insurance companies say that nearly eighty percent of boiler explosions are directly or indirectly traceable to scale in the boilers. The prevention of scale, therefore, means a saving of fuel as well as decreasing the danger in the operation of boilers.

The conditions of operation at the Gorge Power Plant were such that raw water was used in all the boilers. The boilers were operated at an average of about one-hundred and seventy-five percent rating and considerable scale formed in the tubes of the boilers. It was evident that this caused a large loss in fuel and increased the expense of maintenance. It was necessary to employ a number of men to remove the scale. An investigation was made to determine as nearly as possible the loss caused by the use of impure water. After the investigation, an attempt was made to prevent the formation of scale in the boilers. The complete results of the investigation and the methods adapted for the elimination of scale should be of interest to engineers who have a problem in feed water purification.

Water for use in boilers is not always a matter of choice. If more than one source of supply is available, a complete chemical analysis of the water from each source should be made. The recommendations of the chemist should be followed by the engineer. Water suitable for drinking purposes might be very poor for use in a boiler. The analysis of the water cannot be relied upon to furnish information as to the character of the scale that will be formed in the boiler. Pressure and temperature are factors that control to a certain extent the character of the scale formation. One tube of a boiler, will not have a scale formation uniform in character throughout the length of the tube. This question will be discussed at length under the subject of scale formation in the boilers at the Gorge Plant. The presence of suspended organic matter may change the character of the scale. An analysis of the scale cannot be depended upon for information as the proper method of purification. It is an easy matter to determine the amount of impurities carried into the boiler with the feed water, but it cannot be definitely stated how this amount will be divided between scale and sludge. Caution should be exercised in attempting to pre-determine the character of the scale from the nature of the impurities in the water.

In making an analysis of the water, the chemist should determine whether it contains impurities that will corrode the boiler metal. Some compounds that are apparently harmless in this respect may be changed by the action of heat and water into compounds that will cause corrosion. Free acids are sometimes present in water. These will invariably cause corrosion and should be neutralized in the purifying process.

With a proper feed water it is possible to operate boilers year in and year out without scale or corrosion. The proper softening and purifying of water will usually pay for itself by the decreased maintenance cost due to the absence of scale.

Among the more common impurities in waters are the following:

Calcium carbonate (carbonate of lime) which is but slightly soluble in chemically pure water, but when carbonic acid is present it dissolves in water and forms the bicarbonate of lime which is soluble. Carbonate of lime alone will not form a hard scale, but when present with other substances, it is apt to form a hard scale.

Calcium sulphate is also quite common in all natural water supplies, and is responsible for the hardest boiler scale. Apparently, it also acts as a cementing material causing a hard scale formation with salts which ordinarily would form only sludge.

Calcium chloride is sometimes found in natural waters but is not important as a scale forming impurity. It, however, may be classed among the corroding substances, as after concentration it may be dissociated, liberating hydrochloric acid.

Magnesium carbonate is ordinarily found in water as the bicarbonate. Bicarbonate of magnesia has all the characteristics of calcium bicarbonate.

Magnesium sulphate is common in all natural waters, in which it is extremely soluble. Alone, it will not form scale, but is broken up by the lime salts, from which scale may be formed.

Magnesium chloride is very objectionable since it not only forms scale but causes corrosion by liberating hydrochloric acid.

The sulphates of iron and alumina are present in water supplies contaminated with mine drainage or the waste from galvanizing plants. These substances, when present in a boiler, act like free sulphuric acid, in as much as they are dissociated by heat, the acid being set free and the iron and alumina precipitated as sludge or scale.

Sodium sulphate, sodium carbonate, sodium chloride and sodium nitrate, are neutral, nonscaling and non-corrosive salts. They are not objectional unless present in excessive quantities.

Carbonic acid is present in its free state in all natural waters. Its presence in the boiler promotes pitting and corrosion. It is also the acid which bolds in solution the carbonates of lime and magnesia.

Recently it has been established that oxygen in the water is the cause of pitting and corrosion. Where it has been definitily determined that oxygen was present in the water, apparatus has been installed for the elimination of the air in the water.

The soluble impurities in water are usually divided into those which cause temporary hardness and those which cause permanent hardness. Temporary hardness is due to the carbonates of lime and magnesia. The term temporary hardness is used because these impurities may be removed by boiling. The removal of the temporary hardness of the water by heat is effected by expelling the free and half-bound carbonic acid, by boiling, which breaks up the bicarbonates of lime and magnesia. By continued boiling, all the free and half-bound carbonic acid is driven off, thereby throwing into suspension or depositing the carbonates of lime and magnesia in excess of their solubility in the water. The completeness of the removal of the carbonates by boiling depends on the length of time the water is boiled.

At temperatures below boiling point there is a decrease in the precipitation of the temporary hardness. It is, therefore, impossible to reduce the temporary hardness to the limit of solubility in the time allowed and at the temperature obtained in any of the exhaust steam feed water heaters of either the open or closed types. The length of time the water is subjected to the heating process has an important bearing on the extent of the removal of the temporary hardness. Water may leave the heater perfectly clear with no signs of suspended impurities, but will form scale in the pumps and feed lines. Precipitation by heat is not instantaneous and the time the water remains in the heater is not sufficient for a complete precipitation within the heater. That part of the temporary hardness precipitated in the heater deposits as scale on the pans of the heater necessitating periodic cleaning. This precipitation may continue in the pipe connecting the heater to the pump, in the pump and in the feed lines between the pump and boilers. It may form sufficient scale in the feed lines to lower their capacity and if allowed to continue will eventually close the feed line. Removing the scale from pumps is often necessary. The nature of this scale varies, depending on where it is deposited.

Permanent hardness is due to the sulphates, chlorides and nitrates of lime and magnesia. The removal of permanent hardness from water presents an entirely different problem from that encountered in removing temporary hardness. Calcium sulphate is practically insoluble at temperatures above 300 degrees Fahren Heit, but heat alone, without concentration, will not precipitate all of the calcium sulphate.

Magnesium sulphate is quite soluble at all temperatures, and is not likely to form scale until after concentration. It will, however, react with calcium carbonate and form calcium sulphate and magnesium carbonate, both of which form scale. When concentrated at boiler temperatures, it is apt to react with sodium chloride, precipitating magnesium hydrate and liberating hydrochloric acid. The presence of magnesium sulphate and sodium chloride, after concentration in the boiler, may form scale and cause corrosion.

Calcium and magnesium chloride are similar in that after concentration, they will dissociate liberating hydrochloric acid.

The method used in the purification of boiler feed water depends upon the impurities in the raw water. There is no universal "cure-all" for impure water. The statement, "A boiler is a vessel for the evaporation of water and not a vat for a chemical reaction" is true in most cases. Without doubt, however, the most widely used method of boiler water purification is the introduction of "boiler compounds" into the water. This may be done through the suction of the boiler feed water pump or directly into the boiler.

Boiler compounds may be divided into two classes, those which act chemically and those which act mechanically. Those which act mechanically are far less important than those acting chemically. They consist meainly of the silicate of magnesium or sodium which are supposed to give the surface of the boiler a gelatinous coating which will prevent the adherence of scale-forming matter to the shell and tubes. Kerosene and crude oil are also used. These penetrate the scale and loosen it from the tubes. Graphite is supposed to act in much the same manner. It stands to reason that the amount of these compounds necessay for their effective and continued operation renders their use prohibitive in all but small units.

Those compounds which act chemically are generally composed of sodium hydroxide, soda ash or sodium phosphate in combination with some organic acid such as tannic or acetic. Soda ash (sodium carbonate) forms the basis of nearly all such compounds. Substances sometimes added to the soda ash include oak bark, distillery slops, vinegar, potatoes, corn, slippery elm, manure and molasses. Each of these substances is supposed to take part in the prevention of scale, but their action is doubtful. The starch from the corn and potatoes is used because it delays the chemical action between the soda ash and impurities in the water until the water gets to the boilers. This is to prevent the formation of scale in the feed water lines. Unless some precaution is used, the pipe lines will eventually become obstructed with scale.

The chemistry of boiler compounds is correct but judgment is not often exercised in their use. A compound that is successful in one locality cannot be recommended for universal use. Compounds mixed according to the analysis of the water are more correct in principle and should give more satisfactory results. When the chemical reactions take place within the boiler, a sludge is formed. This must be removed from the boiler through the blow-eff. A great amount of water leaves with the sludge and this means a considerable loss of heat.

To prevent the collection of sludge in the boiler, the water is sometimes treated externally. Sufficient time is then allowed for the chemical reactions to be completed before the water reaches the boiler. A filter is provided so that all suspended matter is removed from the water before it goes to the boiler making it unnecessary to blow down the boiler to remove sludge from it.

Two general methods have been adopted for the external purification of water. They are the continuous and intermittent. With the continuous apparatus, the introduction of the reagents depends upon a proportional feeding device. Adjustments must then be made in the quantity of reagents introduced to meet every variation in the water. This being the case, an error must necessarily occur whenever the quantity or quality of the water changes.

On the other hand, in the intermittent type, measured quantities of water are treated and the exact amount of reagents are added. It is, therefore, possible to treat any water, no matter how it may vary in quantity or quality. The intermittent system requires three tanks. While one tank is being filled with raw water, the chemical reactions and settling are taking place in another and treated water is being drawn from the third tank. This system is higher in first cost, requires more floor space and more attention, but more nearly produces water free from scale forming impurities. *(note)

Hot and cold process softeness is another classification. The hot process is used altogether with the continuous type. In the hot process type the chemical reactions take place in hot water. This results in a more complete reaction for the same length of time and the system is somewhat smaller for the same capacity than the cold process system.

The impurities in the water determines the reagents required for its softening. Lime and soda ash meet the requirements in most cases and are the cheapest reagents known for accomplishing the softening and purification of water. Lime is used for precipitating the temporary hard-

* An exception to this last statement is found in the exchange silicate process which will be described later.

ness, absorbing carbon dioxide and neutralizing acids. Soda ash decomposes the sulphates (permanent hardness) to form insoluble carbonates of lime or magnesia which precipitate, the neutral soda remaining in solution.

A combination of lime and soda is most generally used in water purification. Such a method is used where sulphates of lime and magnesia are in the water together with that of carbonic acid or bicarbonates in sufficient quantity to impair the action of the soda. Sufficient soda is used to break down the sulphates of lime and magnesia and enough lime added to absorb the carbonic acid not taken up in the soda reaction.

Another process of purification which has been developed during the last few years is the exchange silicate system. This process uses a complicated silica compound with a sodium base known under the trade name of "Permutit Zeolite". This system accomplishes the removal of the hardness by percolation of the water through a bed of zeolite material. The hardness is removed from the water by the zeolite exchange principle; the zeolite exchanging its sodium base for the calcium and magnesium bases in the water. A meter is provided to indicate when the softener has passed the quantity of water it was deisgned to soften. The zeolite bed is then automatically regenerated by passing a solution of common salt through the softner. The brine by a reversed exchange reaction gives its sodium base to the zeolite. As it leaves the softener it carries with it in a clear solution the calcium and magnesium extracted from the zeolite. Where the water contains a large amount of temporary hardness, a lime softener may be economically used in connection with the zeolite. The great advantage of the zeolite softener over any other type is that it will deliver water of zero hardness. This cannot be accomplished with any other system.

The discussion of the impurities in water and the different methods of purifying water explain several of the problems encountered in the attempt to eliminate scale at the Gorge Plant. The remainder of these will discuss the methods used, difficulties encountered and results obtained in the plant under consideration.

The Gorge Power Plant is situated in the gorge of the Big Cuyahoga River between Akron and Cuyahoga Falls, Ohio. A dam across the river about a quater of a mile below the power house creates a lake extending above the power house another quater mile. This artificial lake furnishes condensing water and boiler feed water. Jet condensers are used in connection with the turbines. This makes it necessary to use practically raw river water for the boilers.

The boiler room contains twenty-four boilers, sixteen of which are 600 horse power B. and W., four are 500 horse power B. and W. and four are 1000 horse power Badenhausen. Due to the necessity of grate and furnace repair and cleaning, the full capacity of the boiler room was never available. The boilers operated at an average of about 175% rated horse power. The rating was maintained as nearly constant as possibe, the variations in the load being met by "floating" boilers in or out of service as conditions required. The pressure carried was 200 pound per square inch gage which corresponds to a temperature of 388 degrees Fahrenheit. The water for the boilers was heated in open feed water heaters by steam exhausted from the steam driven auxiliaries. The temperature of the feed water varied according to the temperature of the water in the river. In winter the feed water temperature averaged between 180 and 185 degrees Fahrenheit. During the summer it was possible to heat the water to 212 degrees Fahrenheit. This however, was never done on account of bearing trouble which developed in the pumps when the water was too hot. Two hundred to 205 degrees Fahrenheit was the average summer temperature of the water. (It will be noted later that this increase in temperature during the spring months caused considerable trouble and necessitated a change in the system of feeding soda ash.)

The boiler feed water was pumped from the hot well into the feed water heater. The hot well was hot in name only. It received the discharge from the jet condensers and was fifteen to twenty degrees warmer than the water in the river. The ratio of circulating water to condensed steam was about 50 to 1, so the water in the hot well was practically the same as river water.

At the time it was decided to investigate possible savings resulting from a chemical treatment of the water, the formation of scale in the boilers was causing considerable trouble. The loss of boiler tubes was abnormally high, capacity was reduced while tubes were being replaced and two boiler cleaning crews were required to remove the scale from the boilers. Sixty pounds of boiler compound were being used every twenty-four hours, but this was not sufficient for any kind of results. The coumpound cost eight and one-half cents per pound and the cost for complete treatment of the water would have been prohibitive.

The first step in making the investigation was to have a complete analysis of the water made. The result of this analysis was as follows:

Silica				
Oxides of Iron and Aluminum	.479	gr.	per	gallon.
Carbonate of Lime	.210	"	"	"
Sulphate of Lime	2.535	"	"	"
Carbonate of Magnesia	1.645	"	"	"
Sodium & Potassium Sulphates	1.053	"	"	"
Sodium & Potassium Chlorides	1.020	"	"	"
Total Mineral Solids	9.921	"	"	"
Oil and Organic Matter	.350	"	"	"
Free Carbonic Acid Gas	.205	"	"	"
Total Incrustating Solids	7.848	"	"	"
Total Non-Incrustating Colids	2.423	"	"	"

Each of the mineral solids in the water deserve separate consideration as to their probable affect on the formation of scale.

Silica is a scale-forming substance but the amount in the water is small and may be ignored, so far as chemicals for its special treatment are concerned. The same is true of the oxides of iron and alumina.

Carbonate of lime alone will not form a hard scale, but when present with other substances which cement it, it is apt to form a hard scale.

Sulphate of lime is responsible for the hardest boiler scale. This salt acts as a cement, causing a hard scale formation with salts which ordinarily would form only sludge or a soft scale. In combination with the carbonates of lime and Magnesia, the sulphate of lime should ordinarily cause a hard scale.

Carbonate of Magnesia has all the characteristics of Carbonate of Lime.

The Sodium and Potassium salts are neutral, non-scaling and non-corrosive salts and are not objectionable in quantities represented in this water.

Free carbonic acid gas in the boiler promotes pitting and corrosion.

The total temporary hardness represented by the carbonates of lime and magnesia is 4.18 per gallon. The total permanent hardness represented by the silica, oxides of iron and aluminum and sulphate of lime is 3.668 grains per gallon. This would indicate that the proper treatment for this water should be a combination of lime and soda ash; the lime for the temporary hardness and carbonic acid gas, and the soda ash for the permanent hardness.

An investigation was begun in order to determine the probable cost of the installation, operation and maintenance of a purifying system large enough to purify the boiler feed water. The maximum amount of water that had been used is a twenty-four hour period was twelve million pounds and the purifying system had to be of sufficient size to properly condition at least this amount. The peak capacity of the plant had been reached. The load factor for six days a week averages between seventy-seven and eighty-five percent and it was quite improbable that this would be exceeded.

While we were waiting for quotations for the purifying system an investigation was made to determine as nearly as possible the cost of scale formation in the boilers. To make this investigation complete it was necessary to consult the records of tube renewals caused by scale, hours labor for each tube renewal, number of tubes cleaned, number of men in boiler cleaning crew and the average number of man hours for the cleaning crew. The time required for cleaning each tube had to be ascertained in order to determine the cost of power required for the cleaner which was an air-driven Liberty turbine scale cutter, As mentioned before, the physical characteristics of the scale was not uniform in all the tubes.

The boilers were vertically baffled. The scale in the tubes furthest removed from the high temperature of the furnace was softer and required less time for cutting than that in the tubes directly over the furnace. Consequently, it was necessary to determine the average time required for cutting each tube. This was done by taking the time required to cut a vertical row of tubes in each of a number of boilers and the average of all of these taken as the time required ~~required~~ for each tube. This was done without the knowledge of the cleaning crew so that the result would more nearly represent every-day conditions.

The following is a result of the investigation.

Item No. I

Cost of clening Feed water heaters.
Four heaters cleaned four times per year.
Twelve hours required for each cleaning by three
men @ $1.275 per hour, $244.80

Item No. 2

Labor cost for cleaning boilers.
350 days for full boiler cleaning crew
8 men @ $0.40 per hr. $38.40 per day
I man @ $0.525 " " 6.30 " "

Total 44. 70 " "
350 days @ $44.70 per day 15,645.00

Item No. 3.

Power cost for cleaning boilers.
30 minutes per tube, 8.5 hp. for operating tube cleaner, power @ $\frac{3}{4}$ cent per hp. hour. Cost of cleaning 100 tubes $3.19
40,650 tubes per year @ $3.19 per hundred
1296.75

Item No. 4.

Fuel waste from scale on boilers.
assuming 5% loss in fuel from scale 20,560 tons per month, average consumption. 1028 tons per month 12,336 tons per year. Cost of coal delivered to stoker hoppers. $3.81 per ton.
Total for year $47,000.00

Item No. 5.

Coal loss from shut downs for cleaning.
.01 ton loss per boiler horsepower
128x600 = 76,800 boiler hp. 600 hp. B. & W.
32 x 500 = 16,000 boiler hp. 500 hp. B. & W.
32 x 1000 = 32,000 boiler hp. 1000 Badenhansen.
- Total 124,800 boiler hp.
124,800 x .01 = 1248 tons loss
1248 x $3.81 4,754.88

Item No. 6

Cost of replacing new tubes.
$20.00 per tube including labor
416 tubes per year.
416 x $20.00 8,320.00

Item No. 7.

Cost of boiler compound.
60 lb. per day @ $0.085 per lb.
60 x $0.085 = $5.10 per day.
365 x $5.10 = 1,865,50

Item No. 8.

Boilers out of service
Average boiler horsepower out of service 3485
service efficiency 78.4%
$67,400.00 cost of boilers in plant above

actual capacity used, necessary on account
of boilers being down for repairs and
cleaning

$67,000.00 @ 6% interest $4020.00
$67,000.00 @ 8% depreciation $5360.00
Total $9,380.00
Grand Total $88.502.43

Items Mos. 1 & 2 were taken from the power house records of the boiler cleaning crew and need no explanation.

In item No. 3 the power required for operating the tube cleaner was taken from the catalogue of the manufacturer. The tube cleaners had been in use for some time and no doubt required more power. The cost of power at seven and one half mills per horse-power per hour is undoubtedly low. The air compressors were driven by electric motors and considering the efficiency of the motors and comprssors, the cost of power delivered to the tube cleaner was certainly greator than that used. It was considered best, however, to stay on the conservative side in our investigation.

In Item No. 4 a fuel loss of 5% was assumed due to scale in the tubes. According to Prof. Schmidt of the University of Illinois, "Scale varying in thickness up to one-eighth inch causes a heat loss up to ten or twelve percent". The scale in our boiler tubes easily averaged one-sixteenth inch in thickness.

Cost per ton delivered	$3.60
Unloading per ton	0.09
Crushing and distubution	0.10
War tax	0.02
Total	$3.81

Items 5 & 8 cannot be charged altogether to the scale in the tubes. The practice followed in regard to cleaning was that at least the lower six rows of tubes should be cleaned approximately every month, and all the tubes every two months. This schedule was adhered to as nearly as conditions would permit. It was also arranged so that repairs to the boiler was down a for cleaning. Not more than 50% of items five and eight should be charged to scale. Final results will be given with this value and with the two items omitted. The amount of coal lost in cooling the boiler and firing it again is that generally accepted for underfeed stokers.

Item No. 6 was obtained by consulting the record of tube losses and the hours required for replacing a tube.

Item No. 7 needs no further explanation.

Bids were received for a purifying system large enough to purify 12,000,000 pounds of water every twenty-four hours. The system decided upon was the WE-FU-GO, intermittent. This system is sold by the Wm. E. Scaife & Sons Co., of Pittsburg. The price quoted was $130,000.00, installed.

The cost of operating with the water purifying system is given in the following:

Item No. I.

Interest and Depreciation on Investment.

$130,000 @ 5% interest $6,500.00

$130,000 @ 10% depreciation $13,000.

Total $19,500.00

Item No. II.

Cost of Chemicals.

12,000,000 lbs. water per day @ $0.02 per 1000 gallons $10,516.20

Item No. III.

Attendance.

Two men @ $1800.00 each per year. $3,600.

Item No. IV.

Repumping from Water Softening System to Feed Water Heaters.

Head assumed to be 40 ft. with power at seven and one-half mills per horse-power per hour. $664.00

Item No. V.

Boiler Washings.

Two washings per boiler per year, ten hours per washing.

4 men @ $0.40 per hour

I man @ $0.525 per hour.

48 boilers washed @ $21.25 per boiler. $1020.

Item No. VI.

Fuel Loss Due to Boiler Washing.

.01 ton of coal per horsepower loss in cooling and firing up.

32 x 600 equals 19,200 boiler hp. -600 B & W.

8 x 500 equals 4,000 boiler h. p.-500 B & W.
8 x 1000 " 8,000 " " -1000 Badenhausen.
Total 31,200 " "
310 tons of coal @ $3.81 $1181.30

Grand Total---$36,481.30

Withe the exception of Item No. 1 all items under the cost of operating with the water purifying system are based on assumed values. There was no possible way of obtaining exact values. The amount of chemicals used would vary according to the impurities in the water. This was a variable and only an assumed average could be used.

Item No. 1V is based on the only location available for the softening system. Item No. V is based wholly on the assumption that the proper attention could be given the system. Some boiler plants are operated with only one cleaning per year, so our assumption to two washings per year is not unreasonable.

A recapitulation of the cost of operating with and without a purifying system shows the possible saving by installing a softening plant.

With 50% of items Nos. 5 and 8 included in the cost of operating without a suftening system we have:

Operating cost without water softening system	$81,435.00
Operating cost with water softening system	36,419.30
Total saving per year	45,016.70

$$\frac{\text{Saving effected } \$45{,}016.70}{\text{Total investment } \$130{,}000.00} = 34.6\%$$

With items Nos. 5 and 8 entirely omitted form the cost of operating without a softening system we have:

Operating cost without water softening system	$74,376.55
Operating cost with water softening system	36,418.30
Total saving per year	37,958.25

$$\frac{\text{Saving effected } \$37{,}958.25}{\text{Total investment } \$130{,}000.00} = 29.2\%$$

This shows that the water softening system would pay for itself in about three years.

For some unknown reason the management failed to appropriate the funds necessary for a purifying system. The abnormally high cost of material and the business slump which began about this time will probably explain this action.

It was evident, however, that some thing should be done to prevent the formation of scale in the boiler tubes. The boiler compound that was being used was too costly. Soda ash could be obtained for four and one-half cents per pound delivered to the power house. It was decided to use soda ash, using the same system for feeding it into the boilers that was being used for the boiler compound, viz., through the suction of the boiler feed pumps. The amount of soda ash to be used was found by determining the alkalinity of the boiler water. This

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It was evident, however, that some thing should be done to prevent the formation of scale in the boiler tubes. The boiler compound that was being used was too costly. Soda ash could be obtained for four and one-half ceats per pound delivered to the power house. It was decided to use soda ash, using the same system for feeding it into the boilers that was being used for the boiler compound, viz., through the suction of the boiler feed pumps. The amount of soda ash to be used was found by determining the alkalinity of the boiler water. This was done by taking a fifty cubic centimeter sample of filtered boiler water and titrating it with a standard solution of sulphuric acid, using methyl orange as an indicator. The degree of alkalinity was represented by the number of cubic centimeters of acid used to neutralize the solution. A Rice Water Testing Cabinet was purchased for testing the water. This is quite similar to the testing cabinet furnished with water softening systems. For the purpose of obtaining samples of the boiler water, a plug on the side of an angle blow--off valve of each boiler was removed and a quarter inch pipe with pet cock was inserted. The alkalinity of the boiler water varied from five to nine without the use of soda ash.

It should be mentioned here that the alkalinity of a boiler water will vary, depending upon the amount of water the boiler evaporates. All boilers in a battery will not evaporate the same amount of water. It is impossible to have two fires exactly alike or two stokers operating in the same manner. It is also impossible to have the internal condition of all boilers the same, unless feed water of zero hardness is used. There were eighteen to twenty samples of water tested every week for nearly eighteen months. It is, therefore, impossible togive the results of the tests in detail. Several changes in the method of feeding soda ash caused temporary interruptions and time was required to raise the alkalinity of the boiler water to its former value. During these periods, no permanent records were kept.

In order to determine the amount of soda ash necessary to prevent scale, a given amount of soda ash was used until the results could be noted. To begin the treatment one hundred pounds of soda ash were used every twenty-four hours. After one week, the alkalinity of the boiler water had not been increased and the amount of soda ash used per day was increased fifty pounds. After using this amount two weeks the average alkalinity had increased to twelve. Inspection of boilers at this time did not show any decrease in the amount of scale. Twenty-five pounds more were added to the daily treatment. About two weeks after using this amount of soda ash, the water from the boiler feed pumps began to decrease. Finally the pump failed to deliver any water and it was dismantled and overhauled. The openings in the high pressure impeller were almost completely stopped with a hard scale. The whole inside of the pump was covered with a soft chalky scale about a quarter of an inch thick. The pump had not been cleaned for over a year and it was thought the scale was the result of a natural accumulation due to the pump handling hot, untreated water. It was, therefore, cleaned and put in service again. Two hundred and seventy-five pounds of soda ash were still used each day. Just one week after the pump was put in service, it again failed to deliver water. The condition of the pump was identical with that of the preceeding week. It was necessary to prevent a recurrence of this. It was decided to use fifty pound of tri-sodium phosphate every twenty-four hours, in addition to the soda ash. This was recommended by a water purification specialist. The reason for using tri-sodium phosphate was that it would retard the chemical reaction between the soda ash and impurities in the water. Most boiler compounds use starch for this purpose. The pump was again put in operation and the tri-sodium phosphate used. The results were same. The pump operated one week and failed to deliver water. This pump was a Reese "Roturbo" pump. Warthington and Allis--Chalmers pumps handled the same water without scale forming in them. The design of the pump no doubt was partly responsible for the trouble, otherwise, it was a very efficient and dependable pump.

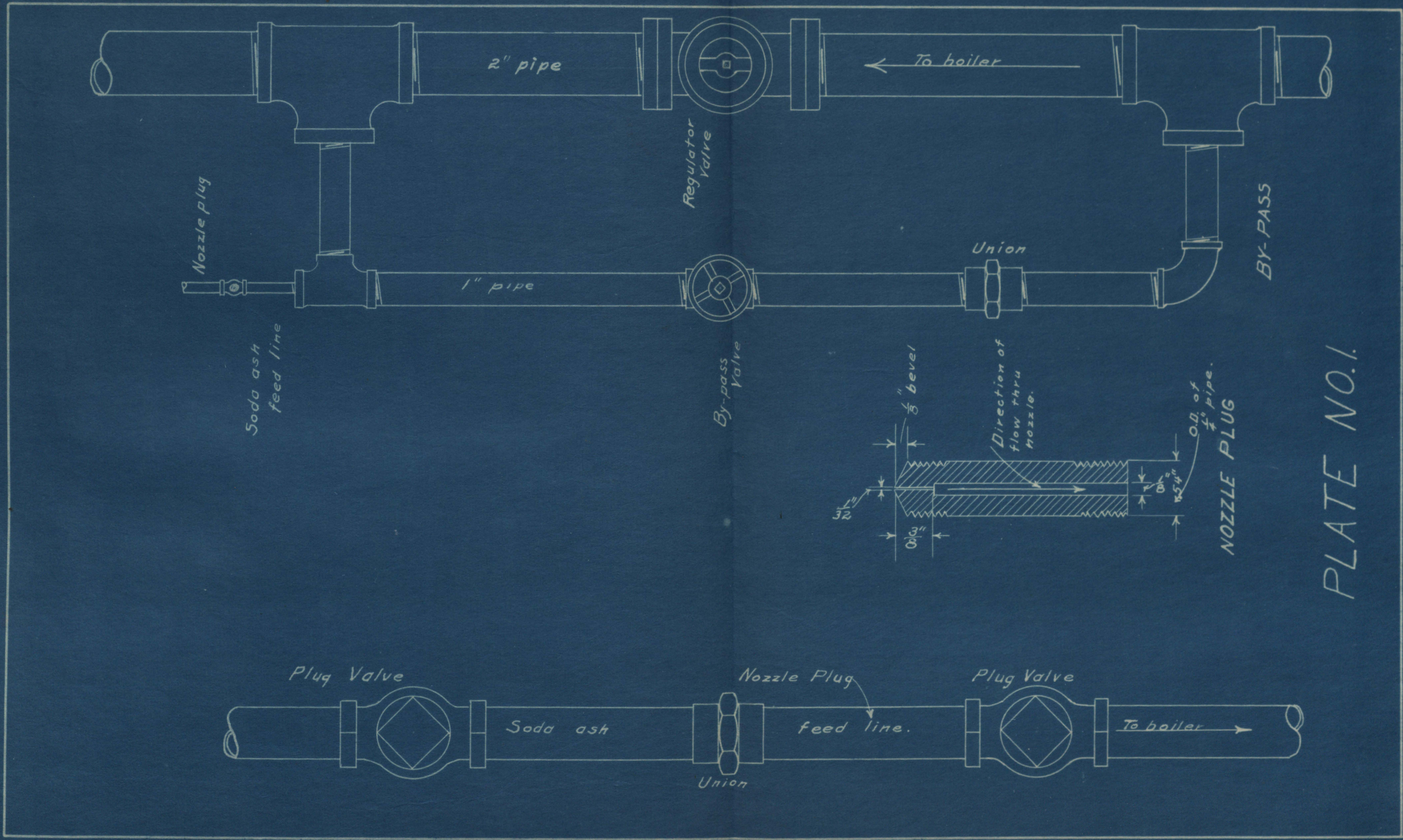
An examination of the pump suction between the pump and soda ash feed was made. A soft scale nearly one-fourth inch in thickness had formed on the inside of the pipe. The reaction between the soda ash and impurtities in the water was evidently taking place in a very short time. The feed water temperature record for a period of four weeks preceeding the last pump trouble were consulted; also the records for the hot well temperature. Both records showed there had been a gradual increase in the water temperature. The average temperature of the feed water had increased fifteen degrees during this time. It was, therefore, concluded that this increase in the feed water temperature was such that the reaction between the soda ash and impurities in the water was taking place in a fraction of a second and that the insoluble particles thus formed were being deposited in the pump and feed water limes. Of course, the reaction was not completed in this time but would continue throughout the feed water lines. This was a dangerous situation and at any time might cause a complete shut-down of the power plant, due to the impossibility of getting water into the boilers. The use of soda ash was, therefore, discontinued until some other plan of feeding it into the boilers could be worked out.

It was decided to feed the soda ash directly into the boilers. The by-pass around the feed water regulating valve was the best place connection to the boiler could be made. Plate No. 1 shows a detail of this connection together with a detail of the fittings necessary and the nozzle plug designed to regulate the amount of soda ash fed to each boiler. As first designed the opening thru the nozzle plug was one-sixty-fourth inch in diameter. It was difficult to keep this open and the opening was enlarged to one-thirty-second inch in diameter. No trouble was experienced in keeping this open.

Plate No. 2 shows the soda ash feed lines in the boiler room. All piping and fittings were extra heavy. A pressure of three hundred pounds per square inch was carried on this line.

Plate No. 3 shows the mixing and feed tanks.

Plate No. 4 shows the motor, pump jack and pump. The speed of the motor could not be changed to suit the various boiler room conditions and the amount of soda ash solution was controlled by changing the stroke of the pump. A one horse power, repulsion-induction motor was used. All fittings were of steel or iron. Brass or bronze are not suitable for fittings on a pipe line carrying any kind of a caustic liquid or gas.


2" pipe
To boiler
Regulator Valve
Nozzle plug
1" pipe
Union
BY-PASS
Soda ash feed line
By-pass Valve
1/8" bevel
Direction of flow thru nozzle.
O.D. of 1/4" pipe.
NOZZLE PLUG
PLATE NO. 1
Plug Valve
Nozzle Plug
Plug Valve
Soda ash feed line.
To boiler
Union

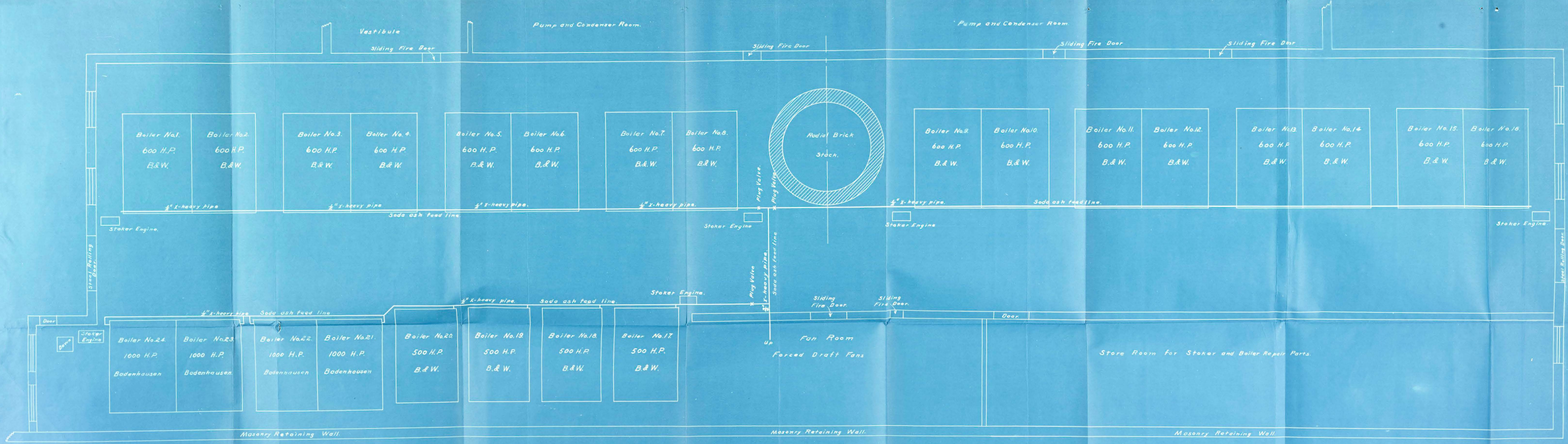
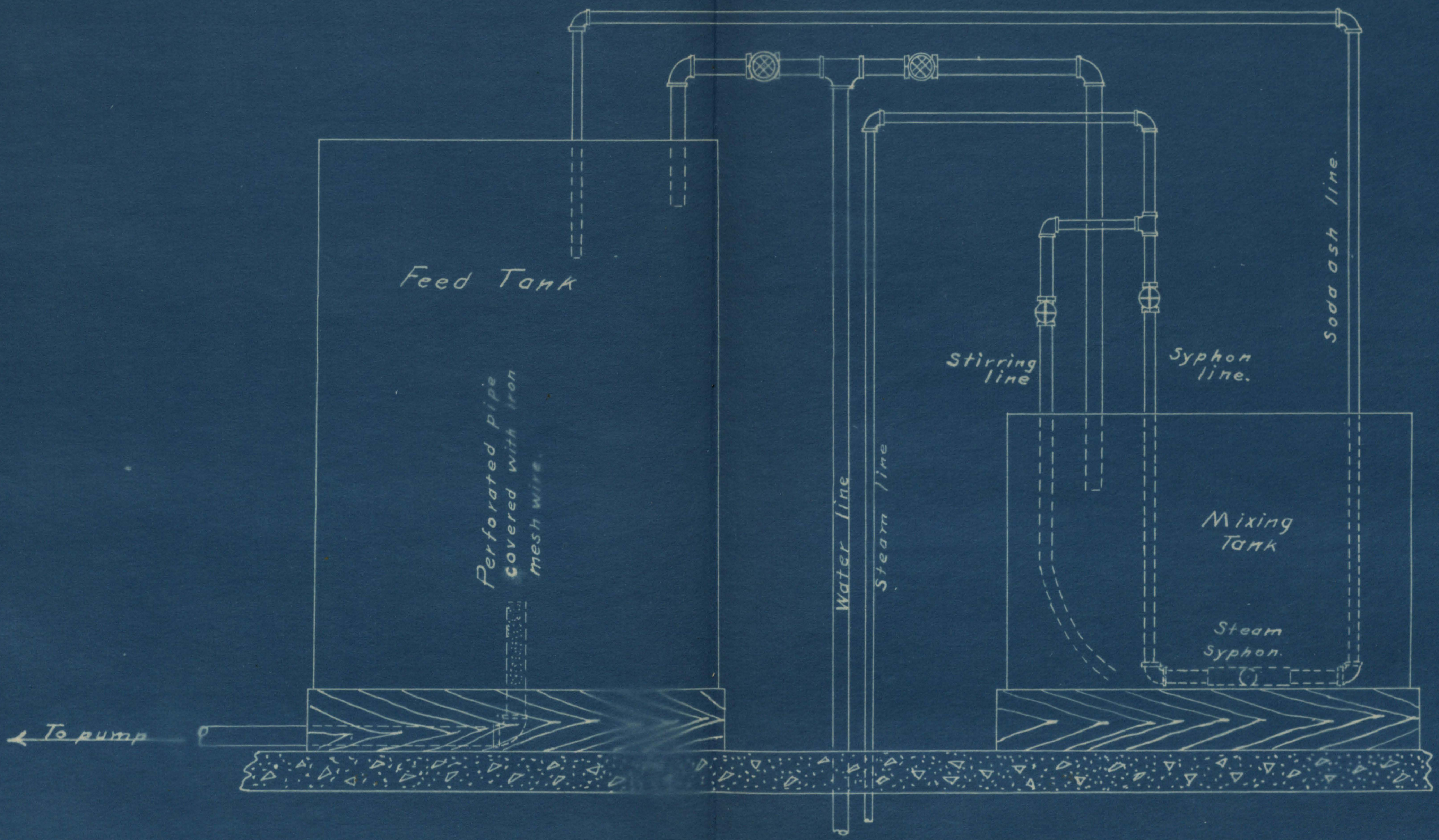


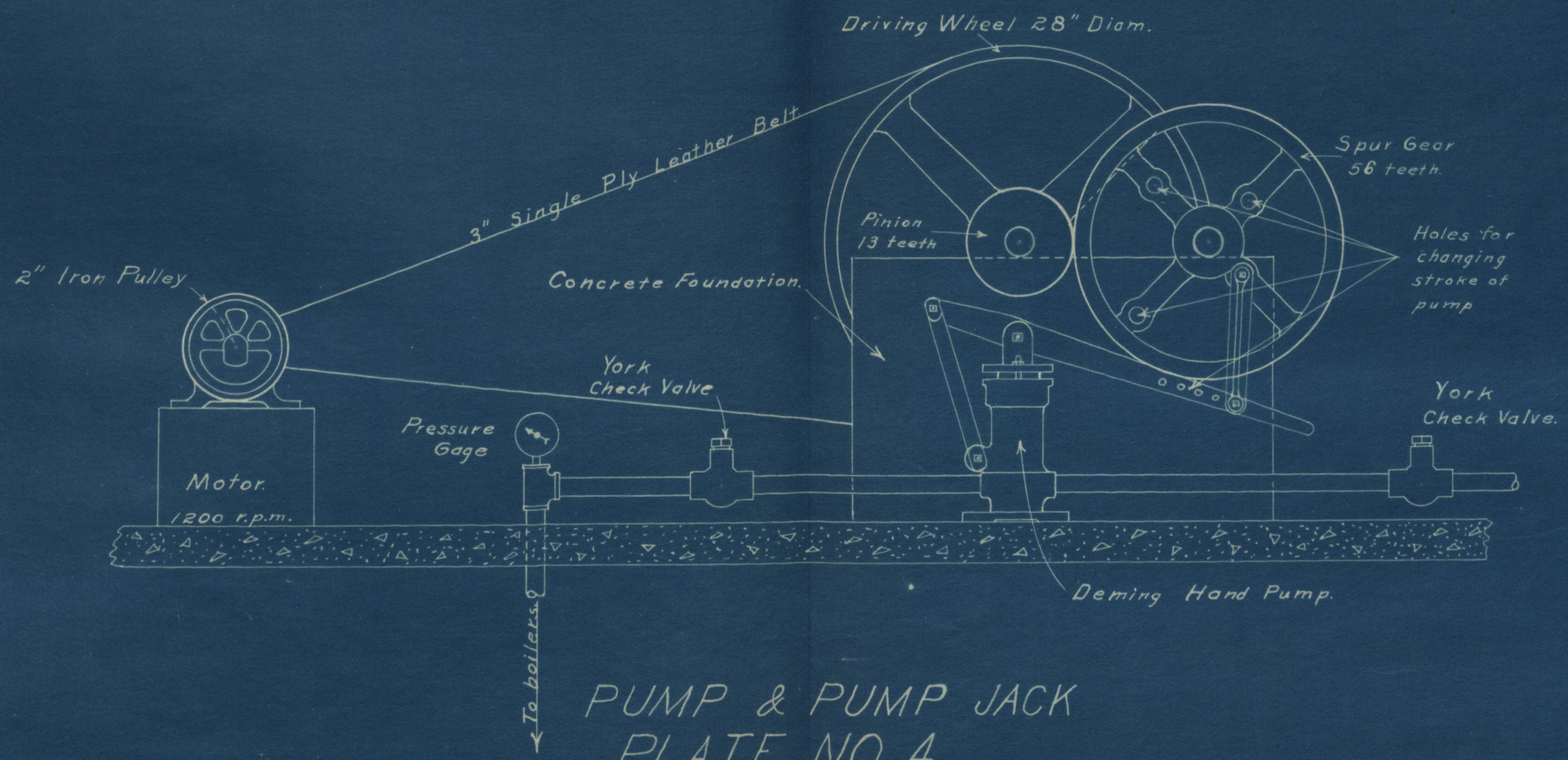
PLATE NO.2.

BOILER ROOM LAY-OUT
GORGE POWER HOUSE
SHOWING SODA ASH FEED LINES
Scale ⅛" = 1 Ft. B.W. Adams



SODA ASH MIXING & FEED TANKS

PLATE NO. 3.



PUMP & PUMP JACK
PLATE NO. 4.

The system was put in operation using one hundred fifty pounds of soda ash every twenty-four hours. The stroke of the pump was so regulated that the soda ash solution was fed thruout a period of about twenty hours. After one week, the soda ash was increased to two hundred pounds per day. No records were kept of the boiler water alkalinity until two hundred and fifty pounds of soda ash were used each day. The tests made were to determine whether or not all of the boilers were receiving approximately the same amount of soda ash. After about four weeks the tests showed all boilers were receiving soda ash and the daily amount was increased to three hundred pounds. After feeding this amount two weeks, the average alkalinity was between sixteen and seventeen. At this time tube losses increased. In one month sixty-four tubes were replaced. An investigation into the cause of this showed that the scale in the tubes was falling off and was preventing the circulation of water thru the tubes. This resulted in blistered and bagged tubes which eventually caused leaky tubes. This condition had not been provided for. It was expected that the soda ash would gradually dissolve the scale and leave the tubes clean. This did happen to a certain extent, but the scale falling from the tubes caused trouble before it was all dissolved. This condition was allowed to run its course and the tubes loss gradually decreased.

The amount of soda ash was increased to three hundred and fifty pounds per day. The average alkalinity increased to twenty and inspection of the boiler tubes showed that a very thin soft scale was being formed. It was not desired to entirely eliminate scale because of the danger of foaming and priming which sometimes results from an excess of soda in conjunction with other impurities. One boiler was operated sixty days without being cleaned. At the end of this time, the scale was practically nothing. The period of operation between cleanings was increased from thirty to sixty days and the boiler cleaning crew was reduced to a foreman and two men. The decrease in labor alone more than paid for the soda ash used and the system as then installed was accepted as the best make-shift for a softening system. The system is still in operation after more than two years. At one time, however, soda ash was not used and a boiler compound was substituted.

Due to the high cost of the compound, it was used only a short time and soda ash is now being used with results that warrant its use until a water softening system can be installed.

The results of the investigation of losses when operating without a softening together with the experience and knowledge gained in the use of soda ash may be summed up as follows:

A water softening system would pay for itself in about three years.

An increase in the temperature of water decreases the time necessary for a reaction to take place between soda ash and impurities in the water.

Soda ash, when fed into the suction of a pump handling hot water will cause scale to form in the pump suction, pump and discharge.

Tri-sodium phosphate will not retard the reaction between soda ash and impurities in the water to an extent that it will prevent scale forming in the pump and water lines.

Soda ash is less expensive than commercial boiler compounds.

An inexpensive system can be designed for feeding soda ash, or any other chemical, into as many as twenty boilers at the same time, each boiler receiving its share of the soda ash.

Soda ash will dissolve old scale in boiler tubes. Also, the scale, under the action of soda ash will fall from the tubes and prevent the circulation of water causing the tubes to bag and leak.

An alkalinity of twenty will allow a thin soft scale to form in the boiler tubes.

Determination of the alkalinity of a boiler water and inspection of the inside of the boiler is a successful method of regulating the amount of soda ash used to soften the water.

An internal treatment of the water will substitute for a softening system when the softening system is not abailable.

Time and patience are necessary to get results. The time required in installing the system used and getting it in operation covered about eighteen months.

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