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Feed Water Treatment at the Illinois State Institutions

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FEED WATER TREATMENT AT THE ILLINOIS STATE INSTITUTIONS

RUSSELL W. LANE*

INTRODUCTION

This paper constitutes a progress report of feed water treatment coordinated with purchase supervision, testing and plant operation at 40 institutional power plants operated by the State of Illinois.

In order that competitive bidding could be accomplished, the State Water Survey was charged with providing specifications and supervising application of treating at these institutions by request of the Purchasing Agent of the Department of Finance. The success of the program resulting from coordinated application and control can best be attested by

(1) complete acceptance by plant engineers
(2) virtual absence of corrosion, scale and resultant tube replacements, and
(3) overall increased efficiency

The success is due to many factors aside from bulk purchase of specific chemicals at competitive prices.

SURVEY

When this program was initiated, the need for a complete survey of each plant was appreciated. Consultation with the different water treating companies revealed that the best method of approach consisted of a survey composed of 13 pages, including complete information on make-up water, boiler plant equipment, operating data, water softening equipment and sketches of pertinent equipment. While considerable time was spent in obtaining this information, this information was necessary for proper design of water treatment for each individual plant and, since that time, has proven invaluable in cases where subsequent calculations were necessary in consideration of installation of external softening equipment, heat exchangers, etc. *(Table **III**)*

DESCRIPTION OF PLANTS AND WATER SUPPLIES

The institutional power plants are located at prisons, hospitals, and colleges. The steam generating equipment of these institutions varies from small 25 hp HRT boilers up to modern water tube boilers of one to four drums and producing up to 60,000 pounds of steam per hour. Steam pressure varies from 3 psig up to 250 psig and 100 F superheat. In seventeen of these institutions, electric power is generated by steam, and in nine of the plants, modern non-condensing steam turbines are employed for this purpose. Heating of the institutions, however, is the primary function of these power plants. The twenty-seven larger institutions each produce 200,000 to 3,000,000 pounds of steam per day during the winter months.

Twenty-one institutions employ surface water supplies and nineteen, well water. Twenty-three institutions use city water supplies. Those institutions using surface

* Illinois State Water Survey, Champaign, Illinois.

water have water supplies of hardness of 70-290 ppm (as $CaCO_3$), alkalinity of 20-200 ppm (as $CaCO_3$) and dissolved solids of 120-350 ppm. Those institutions employing well water have water supplies of hardness of 250-510 ppm (as $CaCO_3$), alkalinity of 220-435 ppm (as $CaCO_3$), and dissolved solids of 320-1420 ppm. Needless to say, the well water supplies provide the greater problem in the boiler feed water treatment.

INTERNAL COMPOUNDS

Although external treatment is provided at twenty-two institutions, all receive internal treatment of one form or another.

The organic blend formula for internal treatment was chosen due to its general applicability to the water treatment needs of the different plants, particularly when used in conjunction with any of several common commercially available chemicals. In this formula, the soda ash serves mainly for providing a soluble non-corrosive product of pH 7.4-8.0 in the chemical vat. The chestnut tannin serves as a sludge conditioning agent, an oxygen absorbent, a scale preventive agent in the feed lines and boiler proper and an organic synergist in foam control[1]. The polyphosphate is helpful in preventing feed line deposits. The anti-foam[2,3] serves as a possible foam preventive agent. During purchase, the supplier is requested to supply reliable evidence indicating the ability of the anti-foam to allow an increase in dissolved solids without production of wet steam in boilers operating at superatmospheric pressures.

The phosphate blend formula[4] was chosen due to its properties of providing proper sludge conditioning and of preventing calcium silicate scale. The domestic blend formulas were chosen for use as complete treatments in the smaller power plants in which the handling of many different chemicals would be inefficient and inconvenient.

TABLE I

COMPOSITION OF BLENDED CHEMICALS

Organic Blend

Soda Ash	5-15%
Chestnut Tannin	67.5-75%
Sodium Polyphosphate	7.5-12.5%
Polyamide or Polyhydric Alcohol type Anti-foam, or equivalent	2.5-7.5%
pH, 1% solution	7.4-8.0

Phosphate' Blend

Disodium Phosphate anhydrous	75-80%
Corn Starch, powdered	20-25%

Domestic Boiler Blends

	Per Cent		
	A	B	C
Soda Ash	25-28	4-6	25-30
Disodium Phosphate	25-28	0	25-30
Sodium Sulfite	30-33	40-45	20-25
Sodium Polyphosphate	2-4	0	4-7
Sodium Nitrate	0	15-20	0
Chestnut Tannin	8-10	35-40	8-12
Corn Starch	0	0	5-10

In addition to these blended chemicals, hydrated lime, soda ash, caustic soda, disodium phosphate anhydrous, trisodium phosphate monohydrate, sodium nitrate, sodium aluminate, sodium sulfite, corn starch, salt and sulfuric acid were purchased.

Complete chemical analysis and inspection of the physical properties (uniformity and solubility) of competitive materials are made on samples submitted with bids for annual purchases. Awards have been made to the supplier providing the best product at the lowest cost.

METHODS OF TREATMENT

The methods of external treatment, when employed in these plants, are hot lime-soda softening and sodium exchange with or without subsequent acid treatment for alkalinity reduction. Internal treatment is being applied in the state power plants as indicated in *Table II.*

TABLE II

INTERNAL TREATMENT METHODS

I Coagulation Type (feed waters of Hardness (as $CaCO_3$) > 60 PPM)

	Boiler Water Composition
Organic blend	90-140 PPM (Theo.) *
Caustic soda or soda ash	200-350 PPMP Alky.
Sodium sulfite	20-40 PPM(asSO_a)

II Coagulation Type (feed water of Calcium (as $CaCO_3$) > 80 per cent of Hardness or, Silica > 5 PPM or oil contamination)

Organic blend	90-140 PPM (Theo.) *
Caustic soda or soda ash and phosphate blend (1:1)	20 0-3 5 0 PPM P Alky.
Sodium sulfite	20-40 PPM (as SO_s)

III Phosphate Residual Type (feed waters of Hardness < 60 PPM and/or Silica > 1/3 Magnesium (as $CaCO_3$))

Organic blend	100-200 PPM (Theo.)*
Disodium phosphate	30-60 PPM PO_4
Caustic soda	200-400 PPM P Alky.
Sodium sulfite	20-40 PPM (as SO_a)

* Theoretical organic blend concent in the boiler water is obtained as follows:
Feed water dosage (ppm) X number of concentrations in boiler water.
Feed water dosage range from 2 to 10 ppm, depending on the following factors:
(1) the type of treatment being applied
(2) the percentage of blowdown
(3) the extent of adsorption of tannin on sludge (precipitated hardness) content.

CHEMICAL APPLICATION, PRACTICE AND DESIGN

Proper application[5] of the chemicals was considered to be a very important part of a successful boiler feed water treatment program. Electrical automatic feeding devices were installed in practically all the larger plants, and have provided savings of as much as 25 per cent in chemicals as compared to previous pot type feeding methods.

These devices have provided relatively uniform treatment with a low chance of human failure.

In general, the following types of feeding systems have been installed:

(1) The automatic intermittent system, employing a pump of 3 gallons per minute capacity.

(2) The continuous low capacity (0-10 gallons per hour) positive displacement feeding system.

The intermittent feeding system may be adjusted to provide semi-continuous or intermittent feed, but does not provide sufficient discharge pressure for application to boilers. The continuous system is advantageous in applications where continuous feed must be applied and where high discharge pressures are required. These methods of application have well fit into the design of the internal chemical feeding system for each plant, which has been found to be an individual problem and dependent on numerous factors, namely:

(1) Analysis of the feed water in preboiler system (Hardness, Calcium, Magnesium, M Alkalinity, pH, Dissolved oxygen and Dissolved solid contents)

(2) Equipment in the preboiler system; feed water heater, vent condenser, continuous blowdown heat exchanger, length of feed water line, etc.

(3) Temperature of feed water

(4) Number of boilers

(5) Type of softening treatment, that is, caustic soda, soda ash, sodium phosphate, etc.

(6) Need for automatic control

(7) Justifiable expense for feeding system

In order to obtain maximum benefit from the feed water treating chemicals and to prevent scale and corrosion in the preboiler system, it is often necessary to apply the organic blend portion of the treatment continuously to the make-up tank, continuous blowdown heat exchanger, vent condenser or feed water heater and sodium sulfite to the storage compartment of the feed water heater or to the suction side of the boiler feed pump. Organic blend treatment at these locations may be particularly necessary in cases of feed waters containing above 30-60 ppm hardness, otherwise serious calcium carbonate scale formation may be expected in the feed lines and the feed water heater. In contrast, softening chemicals such as caustic soda or sodium phosphate are fed intermittently to the suction side of the boiler feed pump in feeding periods of not over 30 seconds duration or directly to the boiler drum by means of a continuous positive displacement feeding system in order to avoid the formation of feed line deposits.

BLOWDOWN

Proper blowdown[6,7] was also known and found to be an important part of a successful feed water treatment program. Proper use and location of continuous blowdown has been advocated. It has been necessary to relocate the blowdown outlet to a level of four inches below the water level in some boilers and in others to change the blowdown outlet to a drum of the boiler where more constant water level is maintained. Over-sized blowdown valves have often been installed, making it necessary for the engineer to operate with a closed valve for considerable periods or to operate with such a small aperture that frequent plugging occurs. These conditions are gradually being corrected. Opening and resetting continuous blowdown valves has been advocated as regular checking practice for each engineer on duty.

TABLE III

	STEAM PLANT DATA		BOILERS
1	Boilers Number		
2	Manufacturer		
3	Date Installed		
4	Type or Design		
5	Water Walls		
6	Steam Pressure		
7	Rated Capacity		
8	Steam Produced By Each Boiler Lbs. Per Hour	Max.	
		Min.	
		Avg.	
9	Water Content		
10	Trough		
	Pipe		
	Scrubber		
11	Draft		
12	Heat Release		
13	Manual Blow-down	Boiler	
		Walls	
		Decon.	
14	Continuous Blowdown		
15	Economizer		
	In and Out °F		
16	Regulator		
17	Steam Purifiers		
18	Superheaters		
	Total ° F		
19	Desuperheaters		
	Water Source		
20	Notes		

CONTROL, TESTING, CLASSES, REPORTS

The importance of good control was also considered a necessity. Arrangements are established for frequent field visits for consultation with the operating personnel. This is continuing to be a very essential and pleasant portion of this program. In order to obtain accurate daily testing results, burette type testing equipment and electrical conductivity testers for blowdown control were installed. Instruction on the use of this equipment was given particular attention. Frequent evening classes were held to discuss boiler water testing, control and methods of treatment. These classes are being continued in order to keep the power plant personnel interested in the subject of boiler water treatment and in the maintenance of good boiler water conditioning.

Water analyses are reported in ppm as a standard procedure. Uniform standard testing solutions were found to be a necessity since as many as three different strengths of silver nitrate and potassium iodide iodate were being used and actually were found on hand in the same plant. As a result of our experience, it would appear that uniform standardization of these testing solutions by the water treating companies would prevent considerable confusion and would provide better results in the water conditioning field. '

TABLE IV

BOILER WATER CONTROL CHART*

................................State Hospital at.., Illinois

Tests	Size Sample	Recommended Ml	Recommended PPM
P Alkalinity (P)	20 ml	5.3-10.4	265-520
Phosphate (PO_4)	1 ml		30-60
Sulfite (SO_3)	50 ml	2.0-4.0	20-40
Dissolved Solids		2800-3800 micromhos (equivalent to 2500-3400 ppm)	

*CONTROL

Organic Blend—7 lbs of organic blend should be fed to each 1,000,000 lbs of steam produced.

P Alkalinity—Acid treatment of the zeolite softened water should be adjusted to maintain the P alkalinity of the boiler water within the prescribed limits.

Maintenance of the P alkalinity content at the 300 ppm level is to be obtained if possible.

If the P alkalinity exceeds 520 ppm, acid feed should be increased.

If the P alkalinity is below 265 ppm, the acid feed should be decreased.

Phosphate—If the PO_4 tests above 60 ppm, the phosphate treatment should be decreased.

If the PO4 tests below 30 ppm, the phosphate treatment should be increased.

Sodium Sulfite—If the SO_3 tests below 20 ppm, sodium sulfite should be increased.

If the SO_3 tests above 40 ppm, the sodium sulfite should be decreased.

Blowdown—If the P alkalinity exceeds 520 ppm or the dissolved solids content exceeds 3800 micromhos, increase blowdown.

If the dissolved solids tests below 2800 micromhos, decrease blowdown.

A minimum of one short manual blowdown per boiler per day is recommended.

Each plant has been provided with a Boiler Water Control Chart[8] *(Table IV)* for ready reference. When located conspicuously at the testing equipment, these charts were found to be of considerable help in obtaining proper testing, proper blowdown and overall control. Samples are collected from the continuous blowdown of the boiler and in many plants, water coolers have been installed to provide cooled samples. In general, the control tests required are the hardness, phenolphthalein alkalinity, phosphate, sulfite, chloride and dissolved solid contents. Specific limits for dissolved solids are prescribed at each plant and have been found to be satisfactory. In general, the maximum dissolved solids is considered to be 3400 ppm. In the case of coagulation type treatment, 1700 ppm is considered the maximum suspended solids limit, while with phosphate residual type treatment, 850 ppm is considered the maximum suspended solids limit.

For the records and constant attention, each plant sends a report of boiler water tests weekly to the Illinois State Water Survey for examination. In addition, a random boiler water sample is requested monthly from each plant and is analyzed for hardness, P alkalinity, M alkalinity, chloride, sulfate, sulfite, silica, oil, phosphate, nitrate, iron, dissolved solids and suspended solid contents. The iron content has been helpful in revealing the condition of the boiler and complete system in respect to corrosion. A subsequent report of the analysis with recommendations is then sent to each plant.

OPERATIONAL PROBLEMS

At the start of this program, numerous operational problems involving power plant equipment were encountered which affected the efficiency of the feed water treatment. While some of these problems have been solved, others require continued attention or equipment changes, which will be obtained in time. The problems encountered are as follows:

1. Operation of feed water heaters

   Inadequate venting of feed water heaters has caused air binding in several plants and has been relieved by relocation of the thermostatic valve, or installation of a throttling valve. In plants having a rather low elevation of feed water heater above the boiler feed pumps, closer attention to control of temperature is being maintained. In general, this type of installation is being replaced with modern deaerating heaters, which operate at temperatures of 225-235 F.

2. Use of mixed or less desirable boiler make-up waters

   In cases where several water supplies were available at an institution, recommendations have been made and changes are proceeding whereby the most favorable water from the standpoint of economic and efficient boiler feed water treatment will be used solely for feed water purposes. Chemical control will be simplified considerably and chemical costs reduced.

3. Lack of coal weighing equipment, steam flow meters and make-up water meters

   All of the larger plants are being outfitted with meters and coal weighing equipment, so that sufficient data can now be obtained to guide the engineer towards economical operation.

4. High percentages of make-up

Attention is being given towards operation with minimum make-up in order to avoid heat losses from increased blowdown, and to prevent increased water consumption, increased chemical consumption and increased corrosiveness of the steam. The practice of adding cooling water at the return condensate vacuum pumps to provide sufficient vacuum in a poorly maintained heating and return system has been discontinued and has reduced make-up requirements considerably in many plants.

5. Oil accumulation

Continual laboratory testing, continual checking of oil removal equipment and oil usage has largely reduced the difficulties due to oil accumulations. One particular plant had serious carry-over difficulties due to oil, but has eliminated these difficulties by following the above procedures, by maintaining accurate dissolved solids control and by employing coagulation type treatment, including phosphate blend.

6. Unsatisfactory out-of-service storage

High iron contents detected in boilers just placed in service have indicated the lack of proper storage methods while the boiler was out of storage. After some experimentation and on consultation with insurance company boiler inspectors, it has been decided to advocate dry storage employing quick lime. Wet storage, employing organic blend, caustic soda and sodium sulfite is advocated only for boilers having superheaters.

7. Corrosion of condensate lines"'[10]

The generally high bicarbonate content of Illinois make-up waters, particularly when zeolite softened, provides a high carbon dioxide content in the steam with resultant acidic type of corrosion and therefore high replacement costs of return lines.

In order to determine the degree of corrosivity of steam condensate, the theoretical carbon dioxide content of the steam has been calculated. This value has not always given an accurate measure of this tendency. Attempts to obtain annual pipe replacement costs have also been unsatisfactory. Therefore, the standard NDHA[11] corrosion testers are used to determine the extent of condensate line corrosion. This method yields values which may be compared with past results obtained by others; consequently, a basic evaluation of the corrosion occurrence is available for consideration of the need for corrective treatment. A short term test of this type has been found to be of particular advantage in plants where changes in water supply, electrical generating equipment, heating system equipment, and steam condensate handling equipment have been made.

In specific plants employing reciprocating engines, the exhaust steam has often been contaminated with sufficient oil to prevent serious condensate corrosion. As these institutions are gradually being converted to turbine equipment, treatment methods for the elimination of corrosion by carbon dioxide are being applied.

This problem requires close cooperation with the Division of Architecture and Engineering in the redesign of such plants and is a regular function of this program.

External treatment methods[12], such as lime-soda softening, lime-zeolite softening, hydrogen-sodium ion exchange and sodium ion exchange followed by direct acid treatment are the methods considered.

As extensive external treatment installations may not be available in many plants due to lack of finances, economic justification, and the size of plant, alternate or supplementary measures for reducing this type of corrosion are necessary. The following methods are being applied: (A number of these methods are consistent with standard accepted practice for eliminating air, or oxygen from the return line system, since oxygen is largely responsible for plugging and pitting occurrences).

a. *Operation with minimum make-up water usage.*

This is accomplished with:

(1) Accurate and economical blowdown rate.
(2) Maintenance of a *tight* return system.
(3) Maximum *return* of condensate.

b. *Operation with an efficient condensate return system.*

Rapid return of hot condensate to vented receivers is necessary and is obtained by:

(1) Employing piping and traps of sufficient size, piping of proper drainage, sufficient pumping capacity and effective venting of holding tanks.
(2) Continual maintenance of traps, lines and pumps.

c. *Internal treatment methods* for steam of lower carbon dioxide.

This is accomplished by:

(1) Use of caustic soda rather than soda ash.
(2) Use of internal type treatment to form calcium carbonate sludge.

d. *Production of oxygen-free steam.*

This is accomplished by:

(1) Maintaining feed water heater at temperatures above 212 F and by application of sodium sulfite treatment.

e. *Close control of existing external treatment systems to provide maximum carbon dioxide removal.*

The importance of this feature was illustrated in one plant where *close acid feed control* was more effective in preventing condensate corrosion than a substantial dosage of neutralizing amine.

f. *Amine type treatments.*

(1) The choice of whether neutralizing or filming amines is to be recommended is based on the relative-economics of the two treatments and the operating features of the individual plant. In general, we think of the application of the neutralizing amines[13] at plants having steam of 5-30 ppm carbon dioxide content and filming amines[14] for steam containing more than 20-30 ppm carbon dioxide.

COST ANALYSIS

Chemical treatment costs per million pounds of steam produced in the State plants range between $1.20 and $8.90. These values are of transient interest only, since they do not include cost of coal, water, amortization and other miscellaneous factors.

When rehabilitation of a power plant is being planned, the State Water Survey has provided the Division of Architecture and Engineering with an evaluation of the economics of as many as fourteen different combinations of treatment and heat savings devices for the production of high quality steam. In addition to quality and economics, other factors have influenced the final choice of treatment.

(1) Complexibility of operation and control.

(2) Safety in handling required chemicals.

(3) Water quality requirements for other functions of institution.

(4) Space requirements.

Choice of the correct water treatment for the individual plant is a complex problem and a complete discussion of this subject is beyond the scope of this paper. A thorough summary on this subject would be a very worthwhile contribution to this Conference.

To date, more or less conventional methods of internal treatment have been applied in treatment of the various feed waters. It is fully recognized that many major improvements are still possible. Many of these require considerable study and often a considerable investment. Lower costs, increased efficiency, and decreased maintenance are the ultimate objectives. For this reason, this program must include additional practical investigations of the factors responsible for known deficiencies.

STEAM QUALITY

At present, a steam quality tester, consisting of a modified Straub degasifier and a recording conductivity meter is being employed in the State plants to determine economical blowdown limits, the effectiveness of competitive antifoam treatments, the effect of boiler design, and the effect of operating procedures on steam quality. This equipment is proving to be helpful in improving the steam quality and is invaluable for instructional purposes to the plant personnel. Preliminary tests have indicated that the carry-over experienced in some of the plants during soot-blowing may be reduced by closer operating control and by proper adjustment and maintenance of feed water regulators.

In conclusion, we believe this program to be an enjoying success. It is with no false modesty that we pay tribute to conscientious assistance and cooperation provided by each of the many plant engineers and their assistants. Particular credit is due to Mr. John M. Sharp, Chief Supervising Engineer for the Department of Public Welfare and to Mr. W. L. Hooker of the Division of Architecture and Engineering in the Department of Public Works and Buildings. The cooperation of the Purchasing Agent's Office has been significantly effective. My personal appreciation and thanks are extended to various water treatment companies and their representatives for their patient assistance and excellent cooperation.

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