IMPROVING WOOD KILN BOILER RELIABILITY VIA A NEW WATER TREATMENT CONTROL TECHNOLOGY

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ABSTRACT

The steam boiler is a critical part of the wood drying process. Steam production reliability is critical for product quality and overall production efficiency, and good water treatment is important to maintaining reliable steam production. Normal steam load demand swings in the wood drying process can make responsive boiler water treatment difficult. This challenging production environment inside the mill is made even more so by volatile economic forces outside it; mills are under continuous pressure to accomplish a more expanded and diverse workload with the same or smaller personnel teams. Recently, there have been some new developments to help mill steam operations staff achieve much more consistent, proactive boiler feedwater treatment. The paper reviews the current state of boiler water chemistry control, as well as two new technologies. A case study from a wood products manufacturing facility utilizing these new technologies is presented, along with before and after data comparisons, and ROI assessment.

BACKGROUND

Boise Building Solutions, Manufacturing in Kettle Falls, Washington, is a wood products plant[1]. Like many other wood products plants, they use steam to operate their drying kilns. The steam is used in coils in the kiln and for direct steam injection to regulate the temperature, humidity and overall rate of the drying process. The drying of wood is a critical step to provide a higher value end product. Benefits of a quality drying process include better material usability, increased product strength, reduced shipping costs, and better insulating and finished material properties. Wood also must be dried with even and consistent heating in the kiln to avoid drying defects such as split or warped wood.

Over the last few years, additional forces such as increased competition in the wood products market, and reduced availability of raw material have increased the scrutiny to which any resource allocations are subject[2].

The drying process is an energy intensive step in sawmill operations, and can account for over 80% of the total energy requirement for the plant. As the boiler is the heat source for the drying process, this makes consistent and reliable boiler operation critical for both energy efficiency and a consistent quality end product. The wood products from this mill are used in making high-quality window and doorframes, so product quality and consistency are key success factors for the mill and its customers.

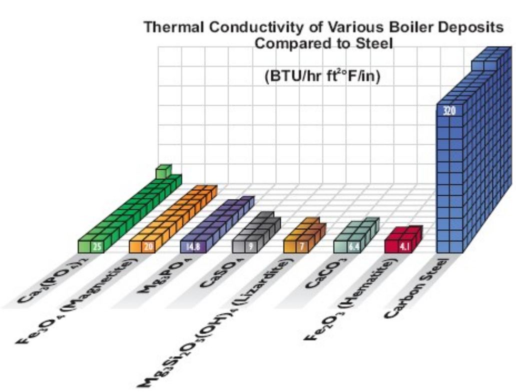

Figure 1 Boiler scale greatly impedes heat transfer and reduces efficiency

The boiler house is an integral part of the mill's operation, and proper boiler feedwater treatment is essential to the successful operation of the boiler. In October of 2006, water treatment services were switched from one supplier to another. The previous treatment program used a flow-based control protocol. There had been some iron deposits in the boiler. Iron deposition is usually indicative of condensate or feedwater corrosion by-products that enter the feedwater, and deposit on high heat transfer surfaces in the boiler. These deposits impair heat transfer, and reduce boiler efficiency, resulting in higher fuel costs, and lower boiler reliability. (Figure 1)[3].

Boise Building Solutions, Manufacturing is always interested in optimized process performance, and reductions in total operating costs. The mill had begun work over two and a half years ago in SPC (Statistical Process Control). When the water treatment supplier described a new development in boiler feedwater chemistry control technology, there was interest from the mill, and an evaluation was agreed to. Criteria for a successful evaluation included:

- Improved chemical control
- Optimized operating costs by reducing water consumption and increasing boiler cycles (reducing blowdown heat losses)
- Reduced chance of iron deposits in the boiler, and associated efficiency losses

SITE SPECIFICS

The mill's boiler is a 150 PSI, Nebraska "A" frame water tube boiler, producing an average of 30,000 pounds of steam per hour.

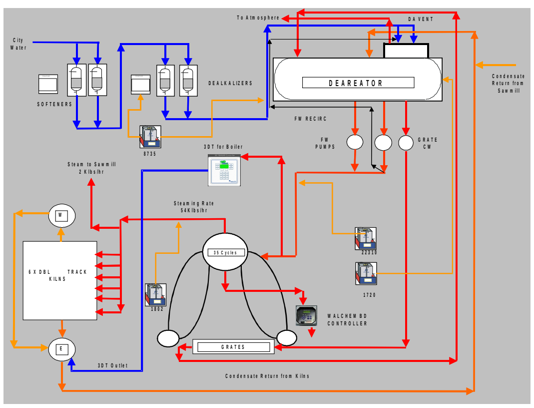

Figure 2 – The boiler system at Boise Building Solutions, Manufacturing is similar to many in the wood products industry

As described earlier, the steam is used for kiln coils and direct humidification steam. Hogged (or hog) fuel is burned as the energy source. Feedwater consists of sodium zeolite softened and dealkalized makeup water, and returned condensate. The feedwater is mechanically deaerated, and chemically treated, using catalyzed sulfite as an oxygen scavenger and a polymer based scale control chemical. A diagram of the system is shown in Figure 2.

Operators test the boiler chemistry daily, and make adjustments based on readings and consultation with Nalco.

APPLICATION TECHNOLOGY

There are many water related challenges encountered when operating a boiler. The more common ones are:

<u>Scale</u> Scale is the result of dissolved minerals, such as calcium and magnesium, exceeding their solubilities and forming deposits.[4] Boiler heat transfer efficiency (See Figure 1) can be negatively impacted by scale. In addition scale can also create serious under deposit corrosion problems. Scaling conditions, when not addressed in a timely fashion, or improperly dealt with, can result in ruptured boiler tubes or other boiler damage. This can cause boiler shutdown and lost or greatly reduced production.

Some of the more common ways to prevent scale from occurring in boilers include ion exchange (softening or demineralization), or reverse osmosis, which remove scale forming minerals from the water. Residual dissolved minerals are prevented from forming scale by the addition of chemical treatment. Table 1[5] shows a brief history of boiler scale control chemistry.

Table 1 – Summary of Boiler Scale Control History[5]

Type of treatment	Developed (est.)	Major advantages	Major disadvantages
Coagulant / Soda Ash*	1900-1950	Reduced potential for scale compared to no treatment, softens scale for easier removal. Reduced scale means longer boiler life and improved heat transfer compared to no treatment.	Still generates scale, which impedes heat transfer, and can increase energy costs. Treatment adds solids to feedwater, thereby increasing blowdown requirements and energy losses. Soda ash can increase condensate corrosion due to CO_2 generation
Phosphate	1930's	Reduced potential for $CaCO_3$ scale. Reduced solids contribution compared to coagulant programs.	Still has potential for phosphate scale
Chelant	Early 1960's	Maintains hardness in a soluble state, reduces solids contribution to boiler feedwater compared to phosphate or coagulant programs.	Potential for corrosion due to overfeed, and potential for $MgSiO_3$ precipitation.
Phosphonates	Late 1970's		Could result in scale if feedwater hardness not well controlled.
Polymer overlay for chelant or phosphate treatment	Late 1970's	Conditioned specific types of suspended solids (eg, Fe_3O_4, Fe_2O_3, $Ca_3(PO_4)_2$ and $MgSiO_3$) to make them less adherent to boiler surfaces.	Same as listed under "Chelant" and "Phosphate".
Polymer only - first generation – polyacrylic acid	Early 1980's	Maintains hardness in a soluble state, reduces solids contribution to boiler feedwater vs phosphate or coagulant programs; reduced corrosion potential vs chelant programs**,** reduces iron deposition rate by dispersant activity**.**	If overfed, these polymers can complex with boiler metal and corrode equipment. High hardness levels can result in polymer precipitation and deposit in the boiler.
Polymer only – latest generation – sulfonated polymer	2001	Maintains hardness in a soluble state. Less corrosive than chelant. Increased thermal and oxygen stability, keeps suspended solids dispersed,, does not precipitate or form precipitates, reduces iron deposition rate**.**	Could be corrosive if overfed.

*(*Although still in some limited use today, modern, more cost effective pretreatment technology has made coagulant programs nearly obsolete)*

Corrosion, the commonly used term to describe the process of returning refined metals[6], such as boiler metal or feedwater piping to its native, oxidized state, is a serious concern in the pre-boiler and boiler system for two reasons. First, it shortens the asset life of the boiler and pre-boiler system. Oxygen corrosion is a common problem that adversely affects the life of the key steam system components as well as dry kiln operation. It is very difficult to operate a dry kiln efficiently if faced with the constant need to replace corroded pipes and fittings.

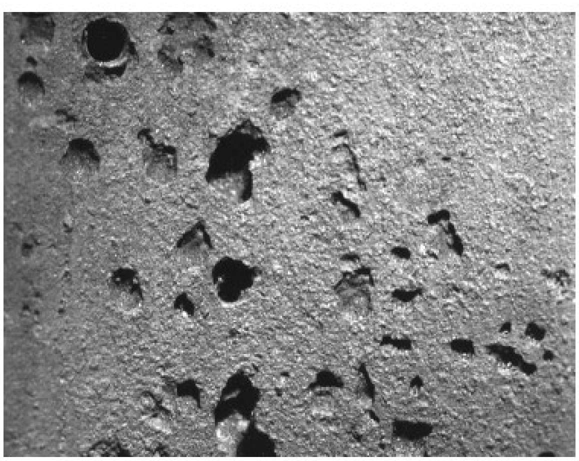

Figure 2 – *Oxygen attack, characterized by its classic pitting appearance*

Pitting attack is a specific and particularly devastating aspect of oxygen corrosion. (Figure 3 (*MVB – from R-923*). This can cause premature metal failure. Second, the corrosion by-products resulting from unchecked oxygen attack can deposit in high heat transfer areas of the boiler as scale (Figure 1).

Iron oxide scale, just as the earlier described calcium and magnesium scales, reduces heat transfer efficiency. In uncontrolled scenarios, blown tubes (or other extensive boiler damage), boiler shutdowns and production losses can result.

Historically, the best practice for preventing oxygen corrosion in boiler and pre-boiler systems has been mechanical deaeration for primary oxygen removal, followed by chemical oxygen scavengers to remove remaining trace quantities.

For decades, the traditional practice employed to control many boiler water scale and oxygen control chemistries has been by sampling the blowdown. One primary reason for this was that the boiler concentrated the treatment chemicals sufficiently to enable them to be measured readily. Although modernization and improvement in test methods have enabled feedwater testing (e.g., cycling up is not required to run many of the tests), many hold onto the old practices of the 1930's through 1970's to test only in the blowdown. The major drawbacks resulting from this approach are related to the lag time between changes in feedwater conditions manifesting themselves in the blowdown.

In a blowdown based control scenario, the operator would sample the blowdown, perform an array of chemical tests, and adjust the feed rate of the scale inhibitor and / or the oxygen scavenger. This constant "add chemical - sample – test – adjust" control loop was the standard. This meant that if a test were missed, an opportunity for adjustment was also missed.

In addition to the challenge of the above testing loop, the physical capacity of the boiler often meant that a detrimental change in feedwater conditions might go completely undetected or not have an impact on the boiler blowdown composition for hours or even days. Feedwater conditions that were potentially adverse to system integrity (e.g., an oxygen excursion, a reduction in feedwater flow rate), if they were detected at all, would only be seen after they had become history, because only the boiler water was being tested. What was missing was a proactive approach to protect the boiler as opposed to a reactive approach that adjusts after the damage has occurred.

Ideally, one would want to measure and control boiler chemistry in the feedwater, because that would enable one to make adjustments to changing conditions in real-time, rather than chasing events or missing them entirely and suffering the outcome.

NEW CONTROL TECHNOLOGY

Nalco's 3D TRASAR™ Technology combines unique detection capabilities to determine and execute correct responses to system variations that delivered many economic and operational advantages. The patented-pending Nalco Corrosion Stress Monitor™ (NCSM)[7,8,9] minimizes pre-boiler corrosion by controlling scavenger feed based on real-time system stresses. In addition, the 3D TRASAR boiler system employs Nalco's patented fluorescence tracing technology to prevent scale formation in the boiler.

The NCSM minimizes preboiler corrosion by measuring and reacting to the net oxidation/reduction potential **of the bulk feedwater** at the actual boiler operating temperatures and pressures. The NCSM detects changes in oxidation/reduction stress, determines the corrective action, and responds in real-time by changing oxygen scavenger or metal passivator feed to protect the system. It is now possible to detect and react to the conditions inside the preboiler system under actual operating temperatures and pressures, allowing this technology package to provide better pre-boiler corrosion protection than has

Feature	Nalco Corrosion Stress Monitor	Scavenger Residual	DO Test	DO Monitor	Corrosion Monitor	RT ORP
Response Time	Very Fast	Slow	Slow	Med	Slow	Slow
Sensitivity	Very High	Med	Med	Med	Poor	Low
Accuracy	High	Med	Med	High	Poor	Low
Precision	High	Med	Med	High	Poor	Low
Dosage Control	High	Poor	Poor	Poor	Poor	Poor
Corrosion Control	High	Poor	Poor	Med	Poor	Poor

Table 2[10] – Methods of monitoring and controlling pre-boiler corrosion stress been available before. Table 2[10] compares the methods historically used to monitor and control oxygen scavenger and pre-boiler corrosion stress.

Boiler scale control is achieved with this next generation of fluorescence instrumentation coupled with the boiler internal treatment programs to protect the boiler from scale and deposits. The 3D TRASAR system detects system variations, then determines and delivers the correct program dosage – again – in the boiler feedwater, in real-time.

EVALUATION, VALIDATION PROCESS AND OUTCOME

The control equipment was installed as shown in Figure 2.

In order to establish baseline performance, and to collect the data upon which a before / after comparison would be made to ensure the criteria for success were met, the equipment was initially operated in a monitoring mode.

Like most wood products plants, and, indeed like a great many other manufacturing plants, the steam load at Boise Building Solutions, Manufacturing varies widely (Figure 4)

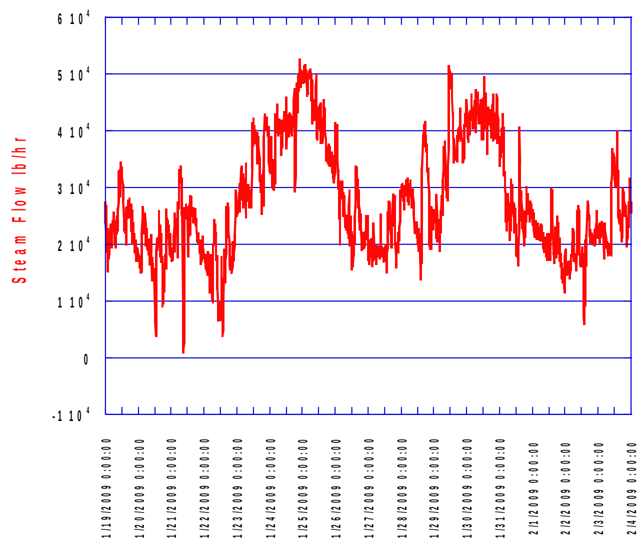

Figure 4 shows the steam load variations
common to wood plants

As a result of the swings in steam load, the boiler feedwater chemistry also varied – Figure 5 shows the extent to which the feedwater scale inhibitor varied.

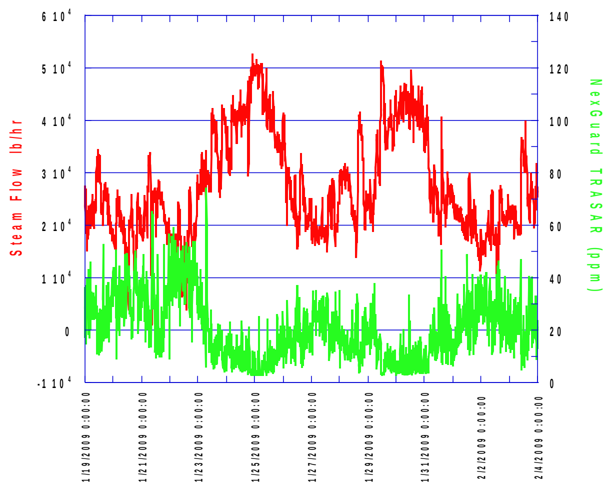

Figure 5 – Steam load and scale inhibitor levels vary greatly during the monitoring phase of the new control technology implementation

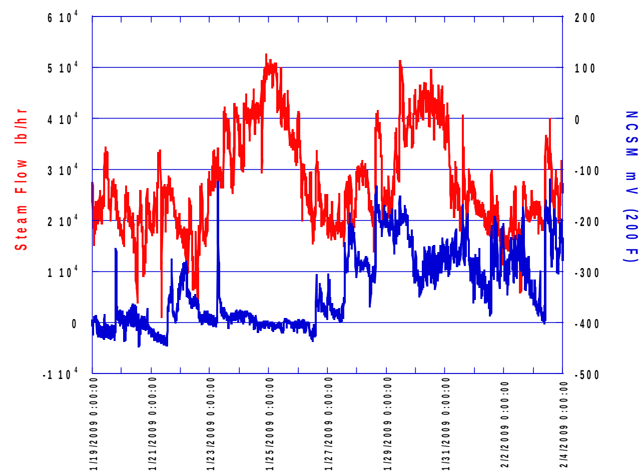

Figure 6 – Boiler feedwater corrosivity also varies widely with steam load swings during the monitoring phase

The continuously changing feedwater – the varying ratio between returned condensate and softened make-up (from production changes), the changes in deaerator pressure and oxygen removal due to increases and decreases in make-up water volumes, all made for a widely varying pre-boiler corrosion stress environment, as shown in Figure 6.

During the monitoring mode, there were some events noted. These events, though site-specific, are good examples of the value provided by these technologies.

Event 1 – Condensate return pump outage On February 12th, during the monitoring phase, one of the condensate pumps experienced a problem and failed, resulting in an interruption of return condensate to the DA. In a normally operating steam plant, it's desirable to return as much condensate to the boiler feedwater as possible, provided the condensate is not contaminated. Good quality condensate is high in purity and heat content. Returning as much good quality condensate as possible reduces fresh water use, fuel consumption, and CO_2 footprint.

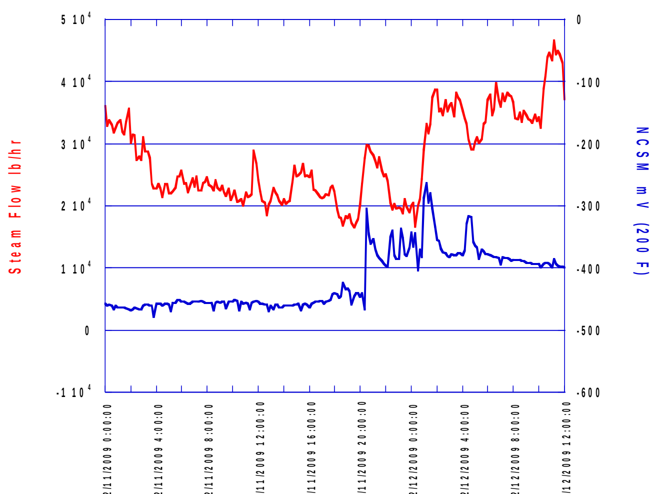

Figure 7 – A condensate return pump outage is recorded as a change in feedwater corrosivity by the NCSM

When the volume of returned condensate suddenly drops, fresh water make-up must be increased in volume to compensate. When that happens, the overall corrosivity of the feedwater changes, usually increasing, as the missing returned condensate is usually less corrosive than the fresh make-up water, having already been chemically treated and dearated before being made into steam.

When the condensate return pump outage occurred, the NCSM readings in the monitoring mode increased, indicating an increase in feedwater corrosivity (Figure 7). If the plant had been in auto-control using the NCSM technology, the corrosion stress event would have been detected and controlled, and the sulfite feed would have been automatically increased to control and minimize the corrosion damage associated with such an event.

Event 2 – Short term boiler outage – during the monitoring phase, on January 23rd, the boiler was briefly (24 minutes) brought off-line to facilitate cleaning the boiler's ID (induced draft) fan (Figure 8)

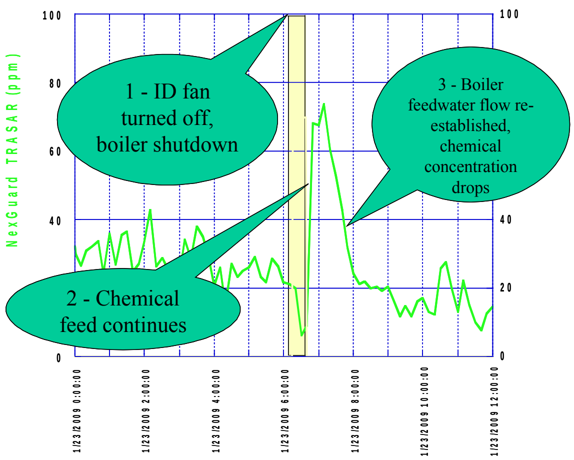

Figure 8 shows how a chemical overfeed can occur in the absence of real-time control capability

During the boiler outage, the feedwater line was inactive, but feed of the boiler scale control chemical continued. When the boiler feedwater line was reactivated, a spike of boiler scale control chemical occurred because the chemistry had been pumping during the outage. If this outage had occurred during the control phase of the evaluation, this spike would not have taken place.

Another event occurred during the feedwater flow stoppage - the NCSM readings climbed (Figure 9). This could occur as a result of many different factors. Had the NCSM been in control mode, it would have automatically adjusted oxygen scavenger feed to compensate.

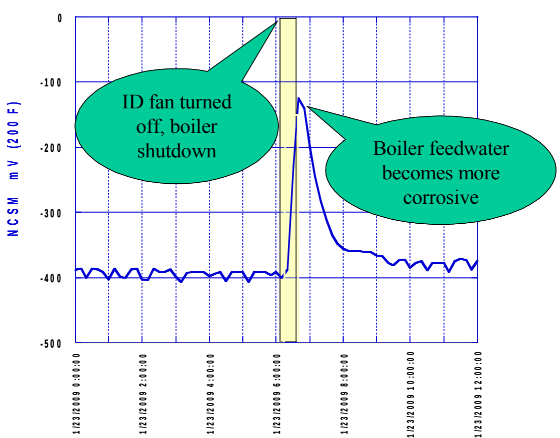

Figure 9 – the feedwater shutdown resulted in a more corrosive pre-boiler environment as shown by the NCSM

After establishing baseline control profiles for both feedwater scale inhibitor and corrosivity, the equipment was switched to on/ off auto control. Outcome is shown in Figure 10. (For the sake of perspective, the steam load variability during the same before / after time frame is shown in Figure 11.)

As one can see, after switching to 3D TRASAR Technology for Boilers controlled feed of scale inhibitor and oxygen scavenger, substantial improvement in feedwater control was achieved. (Note: This control improvement was achieved without complete PID integration linked to the intermittent feedwater pumps. When that step is complete, control improvement will be even greater.)

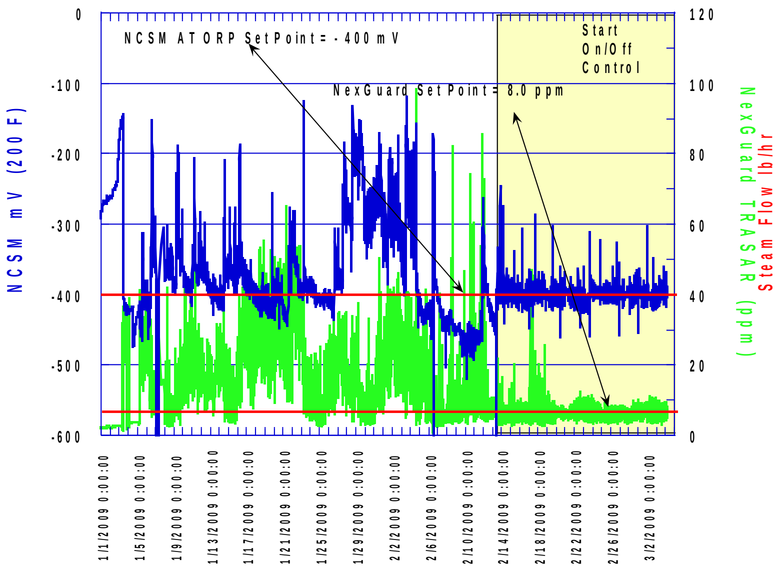

Figure 10 shows the before / after control improvement in scale control and oxygen scavenger chemistry

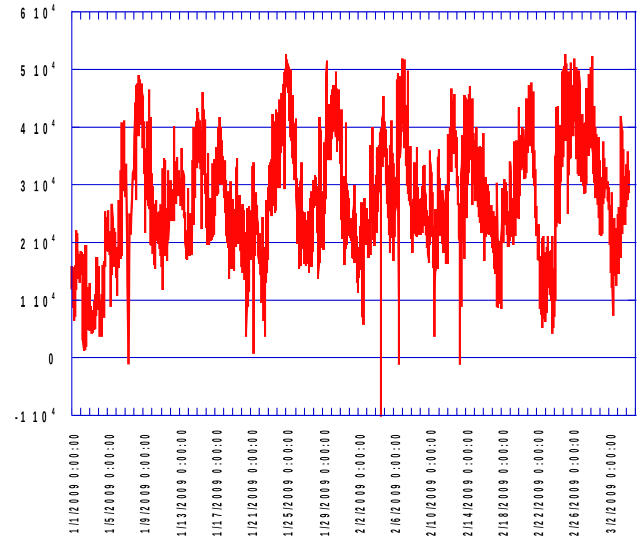

Figure 11 shows the comparatively wide swings in steam load this mill experiences for the same time frame as Figure 10– this is a normal scenario for most manufacturing plants

Statistically, the initial control improvement results are summarized in Table 3

Table 3 – Statistical improvement summary

Feedwater Scale Inhibitor Desired control range: 8 ppm +/- 0.5 ppm				***Pre-boiler Corrosivity*** Desired control range: 400mV +/- 10 mV			
	Before automation 1/9-2/12/09	**After initial automation 2/14 – 3/3/09**	**Comments**		**Before automation 1/9-2/12/09**	**After initial automation 2/14 – 3/3/09**	**Comments**
Average dosage	17.01 ppm	6.7 ppm	Operating above the control range wastes treatment chemicals; operating below the control range increases the risk of scale (wasted fuel), damage to the boiler and production losses	**Average reading**	-366 mV	-401 mV	Values approaching zero (more positive) indicate a more corrosive environment. Excessively negative numbers may mean excessive oxygen scavenger use, leading to higher blowdown levels
Standard deviation	+/- 23 ppm	+ /- 2.4 ppm	An 89.6% reduction in standard deviation	**Standard deviation**	+/- 71mV	+/- 13 mV	An 82% reduction in standard deviation

Specific highlights, in addition to those in Table 3 and visible in Figure 10 are:

- Great improvement in maintaining the pre-boiler environment in a desired reducing condition 44% (before) 87.1% (after) – this indicates that pre-boiler corrosion stress had been taking place, and that it had been going on undetected, unnoticed and thus uncorrected;
- Reduction in scale control chemical overfeed from 73% to less than 15% - and, as the next control protocol steps are undertaken, an even greater tightening of the control range is anticipated, typical of other applications of this technology.

Operations personnel also observed a control improvement in the daily boiler chemistry logs.

SUMMARY

There were numerous benefits from the implementation of these new technologies. They include:

- **Reduced water consumption through optimized boiler cycles of concentration** – between the original work begun when the new water treatment supplier came on-line and this new technology, cycles have increased from 10 to 30 – this reduces blowdown by 69%, and make-up water demand by 6.9%. For a boiler this size, that is a water savings of 2.4 million gallons per year.
- **Reduced wet chemical testing -** It is anticipated that wet chemical testing will be reduced, generating as much as $4-5,000 / year in labor optimization savings.
- **Extended equipment life** – a boiler is not a trivial expenditure – asset preservation reduces depreciation costs
- **Improved energy efficiency from both cycles optimization and cleaner boiler heat transfer surfaces** – as demand for wood increases for other uses, fuel costs will increase – this technology will improve the mill's readiness to deal with increases in fuel costs by optimizing performance.
- **Greatly increased knowledge and control of system behavior** - especially with regard to the pre-boiler corrosion stress environment.
- **Enhanced process visibility** on the waterside of the boiler and its response to mill operational changes.
- **Reduced total operating cost** per board foot of lumber based on the above improvements.

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