Yankee Dryer System: Critical Asset Protection, Monitoring and Control utilizing 3D TRASAR™ Technology by Nalco

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ABSTRACT

Reliable Yankee dryer performance is a key contributor to the smooth operation of every tissue machine. This paper will explore how through the use of 3D TRASAR Technology for Yankee Dryer Systems from Nalco, tissue manufacturers are able to protect this vital mill asset by monitoring/controlling critical parameters within the Yankee dryer condensate system.

When applied, 3D TRASAR Technology for Yankee dryer systems is able to monitor/control the return condensate system to ensure that appropriate chemical treatment programs are applied in response to the dynamic nature of the Yankee dryer steam system. Through examination of the chemical reactions occurring within the return condensate system and customer case histories, this paper reviews the actual performance results achieved through use of this technology including:

- *Minimized corrosion in the Yankee dryer. The Nalco Corrosion Stress Monitor (NCSM) and pH measures the corrosion potential of the condensate in the Yankee dryer system as opposed to the bulk condensate. A supplemental amine feed is proportionally controlled based upon changes in the measured corrosion potential.*
- *Increased machine runnability by minimizing soda straw plugging caused by iron deposition.*
- *24/7 monitoring and alarming of the Yankee dryer operational conditions and condensate system to quickly respond to system upsets and provide diagnostic support.*
- *Analyze the effect of Mechanical, Operational and Chemical (MOC) changes in the steam production and Yankee dryer condensate systems in real time, reducing the production of corrosion by-products.*

INTRODUCTION

In the tissue manufacturing process, the performance of the Yankee dryer has a direct impact on the quality of the finished product. Yankee dryer performance is directly related to the continuous delivery of a high quality steam supply to the dryer and an efficient evacuation system to remove the condensed steam. Both of these elements are critical in maintaining a consistent skin temperature across the dryer surface. These key elements are influenced by the operation of the boiler pretreatment system and control / monitoring of the return condensate chemical treatment program.

When the Yankee dryer performance declines, the tissue machine may experience reduced drying capacity, increased pressure drop at constant steam blowthrough, wet streaks and random coating patchiness. Eventually the crepe quality and uniformity of the sheet will degrade and chatter can occur. When these symptoms become apparent, it is too late, quality and production have already been adversely affected.

To maintain Yankee dryer system performance, the tissue manufacturer must develop a comprehensive plan which addresses three specific areas; steam/condensate chemistry, corrosion / deposit control, and system monitoring.

Steam / Condensate Chemistry – Effect of Alkalinity and Oxygen

The boiler pretreatment system has a direct effect on the amount of carbonic acid and oxygen that can enter the Yankee dryer system and negatively affect its performance. In sodium zeolite softened water systems all of the raw water alkalinity is allowed to enter into the boiler feedwater system. Under boiler water temperature and pressure conditions the alkalinity breaks down and carbon dioxide gas is generated.

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The reaction is shown below.

Breakdown of feedwater alkalinity

$$2\,HCO_3^- \xrightarrow{Heat} CO_3^{=} + H_2O + CO_2$$

Bicarbonate → Carbonate + Carbon Dioxide Gas

$$CO_3^{=} + H_2O \xrightarrow{Heat} 2OH^- + CO_2$$

Carbonate, Hydroxide, Carbon Dioxide Gas

The carbon dioxide gas travels out with the steam and possesses no cause for operational concern until the steam is condensed back into a liquid form. At that point, the condensing water reacts with the CO_2 gas forming carbonic acid which will equilibrate in solution as shown by the reaction below.

$$CO_2 + H_2O \longleftrightarrow H_2CO_3$$

Carbon Dioxide, Water, Carbonic Acid

$$H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

Carbonic Acid, Hydrogen, Bicarbonate

Systems operating with higher boiler feed water alkalinity will generate more carbonic acid in the return condensate system and, if not continuously monitored and adjusted for, will produce periods of depressed condensate pH and a more corrosive environment to the return condensate internals including the Yankee dryer. It should be noted that the remaining bicarbonate alkalinity will recycle with the return condensate back to the boiler where it will once again breakdown to form additional carbon dioxide that will leave with the steam.

One ppm of carbon dioxide in a 140°F condensate stream will drop the pH an entire pH unit, from 6.5 to 5.5. A pH of 5.5 is 10,000 times more aggressive to mild steel than a pH of 7.5 and 1,000,000 times more aggressive than a pH of 8.5. Since corrosion rates increase with temperature, the aggressiveness of a low pH condensate stream cannot be ignored. Figure 1 shows how carbon dioxide can depress the pH of pure water at varying concentrations and temperatures.

Alkalinity levels in the boiler feedwater can be reduced through enhancements to the boiler pre-treatment equipment. In most tissue mills, which operate with low pressure boiler systems, the boiler feedwater make-up system is typically based around sodium zeolite softeners alone. By adding a reverse osmosis train to the pre-treatment strategy, mills have shown a reduction in make-up water alkalinity

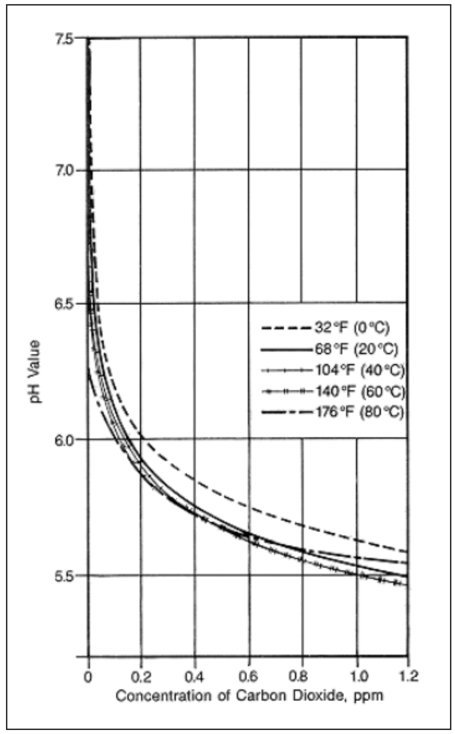

Figure 1 – *pH values of solutions of carbon dioxide in pure water at various concentrations*[1]

by up to 95%. Note: Care must be taken to consider operational changes that will be required to the boiler system during reverse osmosis outages. The sudden increase in alkalinity with no operational changes to the boiler can charge the system with large amounts of carbon dioxide, causing significant pH depression across the Yankee dryer.

For tissue mills which operate at higher boiler pressures demineralizers will be utilized in their pretreatment system. In demineralized make-up systems, the make-up water alkalinity concern has already been addressed as this process reduces alkalinity levels to near zero.

Most tissue mills indirectly monitor/control the effects of carbonic acid present in the condensate system by checking the pH of the main return condensate receiver in the power plant. Through the use of 3D TRASAR technology, we have seen that this practice is insufficient in maintaining consistent system protection of the Yankee dryer system leaving it vulnerable to low pH excursions.

Another element that must be taken into consideration within the pre-treatment and return condensate system is oxygen. Oxygen can enter in the condensate system and the Yankee dryer through ineffective operation of the feedwater deareator or air inleakage from vacuum seals. Oxygen dissolved in 140°F pure condensate is 6 to 10 times more corrosive to iron than its carbon dioxide molar equivalent.

When both carbon dioxide and oxygen are present the resulting corrosion rate is 10 to 40 times greater than the sum of the corrosion rates of the two gases acting separately.

Corrosion/Deposit Control

Yankee dryer performance is directly related to the effective removal of the condensed steam from within the dryer. A common Yankee dryer condensate removal design utilizes “soda straws” to evacuate the condensed steam. If flow through these straws is restricted, the condensate can build up within the dryer causing inefficient operation and poor sheet quality. The most common cause of soda straw flow restriction is plugging of the straw orifice with accumulated iron. The tip of the soda straw is very susceptible to deposit formation due to the large pressure drop experienced in that section of the pipe. This iron deposit can be caused by the formation of active corrosion by-products within the dryer system or by the rapid release of the passive magnetite layer which forms on the drum wall and internals. Both of these events can occur when a corrosive atmosphere is present within the Yankee dryer system.

A corrosive atmosphere will be present whenever there is an imbalance between the level of carbonic acid and oxygen present within the condensate stream and the chemical treatment program utilized to neutralize/scavenge these elements. Because of the dynamic nature of the tissue machine operation (grade changes, breaks, etc.), this balance is continuously shifting making it difficult to maintain a non-corrosive atmosphere at all times.

A critical element effecting Yankee dryer performance and reliability is in the establishment and maintenance of a thin passive layer of iron on the internal drum surfaces referred to as magnetite. Metal passivation is a critical process that occurs and provides protection of the Yankee dryer system. Passivation is the formation of an insoluble nonporous protective oxide on a metal surface. Cast iron and steel will self-passivate in water if no contaminants are present. The reaction is very slow under 212°F. Passivation can be accelerated by the use of chemical treatment (amines), however, under the operating conditions present within the Yankee dryer system, the passivated layer is not very robust and is easily damaged, both mechanically and chemically if the system is not properly controlled. Damage to the magnetite layer will release particulate iron into the bulk condensate stream and, depending on severity, cause a threat of plugging at the tips of the Yankee dryer soda straws. The reactions that drive the passivation process are shown below.

1) $Fe^0 \rightarrow Fe^{+2} + 2e^-$ (oxidation)

2) $Fe^{+2} + 6H_2O \rightarrow [Fe(H_2O)_6]^{+2}$ (hydrated)

3) $[Fe(H_2O)_6]^{+2} \rightarrow Fe(OH)_2 + 2H^+ + 4H_2O$ (hydrolyzed)

4) $Fe^{+2}(OH)_2 + H_2O \rightarrow Fe^{+3}(OH)_3 + 0.5H_2$ (oxidation)

5) $n\ Fe^{+3}(OH)_3 \rightarrow [Fe^{+3}O(OH)]_n + n\ H_2O$ (polycondensation)

6) $2[Fe^{+3}O(OH)]_n + n\ Fe^{+2}(OH)_2 \rightarrow n\ Fe_3O_4 + 2\ n\ H_2O$

Note in step 1) above, two electrons are released as the base metal is ionized. The reaction must be allowed to passivate the base metal, but limited, to prevent excess magnetite formation. In the presence of carbonic acid and/or oxygen, the passivation process becomes a corrosion process. Figure 2 shows how oxygen impacts the corrosion process and how hydrogen is released by the process.

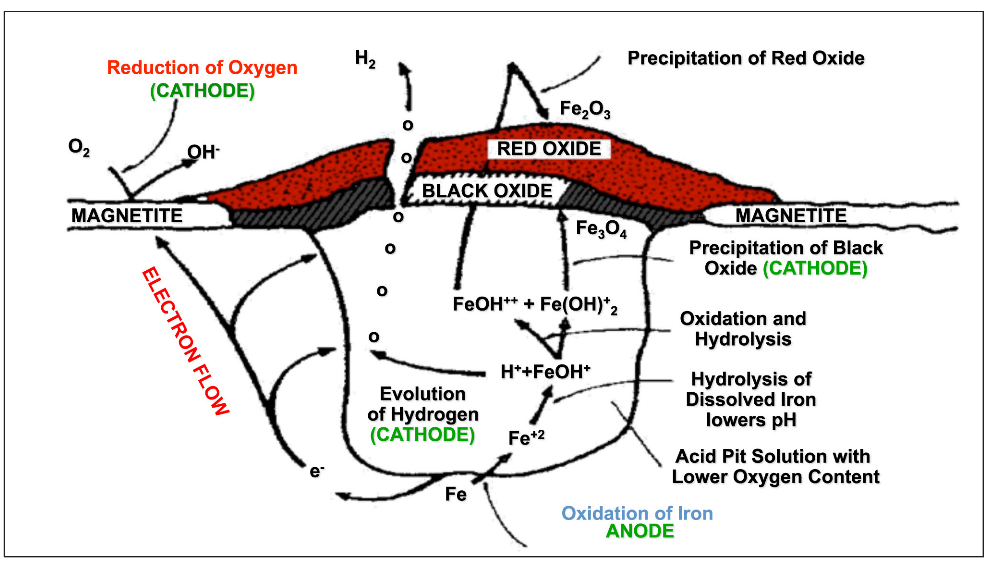

Figure 2 – *Electrochemical oxygen corrosion reaction*[2]

Please note the electron flow from the anode of the corrosion cell to the cathode. Measuring this electron flow is a direct indication of the corrosion rate within the corrosion cell.

MONITORING

Because of the variability in boiler pre-treatment system and tissue machine operation, it is imperative that a monitoring and chemical control program be established that maintains a non-corrosive atmosphere within the Yankee dryer and return condensate system at all times.

Table 1 lists common techniques used to monitor the return condensate systems within the tissue industry today. The table also highlights some of the limitations these monitoring techniques face when trying to assure/confirm proper corrosion control within the Yankee dryer system.

None of the tests listed above provide a direct indication of the atmosphere present within the return condensate in the Yankee dryer. All of these techniques utilize indirect measurements in an attempt to quantify the corrosive nature of the Yankee condensate and to provide assurance that the appropriate chemical treatment program is being applied in response to the changing operational conditions.

3D TRASAR Technology for Yankee Dryer Systems

Realizing how dependent Yankee dryer system performance is on a comprehensive plan that effectively addresses the steam/condensate chemistry, corrosion/deposit control and monitoring, 3D TRASAR technology for Yankee dryer systems from Nalco was developed to continuously monitor and control those critical parameters associated with maintaining dryer performance. The technology incorporates sensors which monitor Yankee dryer condensate system pH, conductivity, presence of boiler water carryover (via inert TRASAR), and water corrosivity in real time. 3D TRASAR technology collects these system measurements along with other Yankee dryer data (steam flow, dryer pressure, etc.) every 6 seconds and utilizes this information to determine the appropriate chemical treatment adjustments necessary to maintain a stable Yankee dryer condensate environment. The level of responsiveness achieved through this technology to the changes in system demand minimizes system upsets and limits the production of corrosion by-products and soda straw deposit formation within the Yankee dryer.

A critical component of the 3D TRASAR technology is the Nalco innovative way of directly monitoring the corrosive nature of the return condensate stream. Instead of relying on indirect measurement techniques, the patented Nalco Corrosion Stress Monitor (NCSM) was developed to measure the oxidation reduction potentials of hot water systems at system temperatures and pressures. When combining the NCSM readings with Fe^{+2}, soluble iron, wet lab testing, an optimal control range is able to be determined for the Yankee dryer operation which minimizes system corrosion potential and the subsequent soda straw plugging concerns that may result. Once this range is determined, the 3D TRASAR technology will continuously monitor and re-adjust the chemical treatment program to maintain system control within the specified range.

The 3D TRASAR technology also offers the ability to monitor remotely on a 24/7 basis generating alarm notifications when the system is operating outside of control limits that are established by the mill. This provides the mill and Nalco the ability to quickly respond to upsets that are outside of normal operating conditions and provide diagnostic support to determine their cause. Alarm conditions are communicated immediately to persons chosen by the customer and Nalco.

Table 1 – *Common methods of return condensate monitoring and their limitations*

Instrument or Test	Limitation
pH	Indirect measurement of only one of the components of corrosion. Does not measure effect of oxygen in the return stream
Dissolved Oxygen	Oxygen will preferentially flash off with the steam through the condensate flash tank and will not remain with the condensate.
Conductivity	Single component measurement to identify boiler water carryover, amine overfeed, and/or raw water contamination.
Particle Monitor	Slow sample time that cannot be used to control amine.
Millipore Testing	Grab sample only. Requires 5 fps sample flow for measurement to be representative. No continuous monitoring of system conditions.

The following case studies highlight the use of 3D TRASAR technology for Yankee dryer systems as part of Nalco's comprehensive plan to improve Yankee dryer performance by addressing the steam/condensate chemistry, corrosion/deposit control and monitoring of this critical mill asset.

Case Study 1

A US mid-western tissue mill had experienced Yankee dryer soda straw plugging concerns in the past. As a result of these concerns, the mill established a satellite condensate treatment application ahead of the Yankee dryer system. After being introduced to 3D TRASAR technology, a decision was made by the mill to evaluate the use of this technology for the Yankee dryer systems to determine if improved treatment program efficiency and effectiveness could be gained through use of this technology.

Prior to the use of 3D TRASAR technology to automate the satellite condensate treatment, the program was adjusted by the operations staff based upon the pH of a grab sample taken off the Yankee flash tank. 3D TRASAR technology was installed utilizing this same sample point so that data could be compared to previous results obtained through manual control. The pH control range that the operators were targeting was 8.8 to 9.2 based on the metallurgies in the Yankee dryer and soluble iron wet tests that showed 0 ppb iron levels when operating within this control range.

Figure 3 below shows the results of the evaluation performed utilizing 3D TRASAR technology for Yankee dryer systems. The first portion of the graph shows when the 3D TRASAR system was in monitoring mode only. This initial evaluation established the operating benchmark for manual control in maintaining the desired pH control range. In manual control, the Yankee dryer system was experiencing regular pH swings from 7.5 to 9.5.

The second half of the graph shows when the 3D TRASAR technolog for Yankee dryer systems was placed in control mode. The 3D TRASAR controller was able to maintain Yankee dryer pH between the desired control limits, 8.8 to 9.2 on a consistent basis. Based upon these results, the mill is proceeding with additional enhancements to the satellite chemical feed system to provide additional tightening of this control band.

Once this 3D TRASAR system control was put into place, an evaluation was performed to determine the resilience of the passive magnetite layer that had now been established on the Yankee dryer internals. This passive layer provides a protective barrier against active corrosion on the metal surface within the Yankee dryer. A test to simulate a low pH excursion was performed to determine the length of time this passive layer would remain intact before releasing iron into the return condensate stream. In addition to collecting the information from the 3D TRASAR system, soluble iron testing was performed throughout the test. Table 2 summarizes the relationship observed between the soluble iron levels, pH and the NCSM.

This data shows that the passivated magnetite iron layer in the Yankee dryer deteriorated in a short period of time and is not robust. It took just over 3 hours for the passivated layer to begin shedding measureable amounts of iron. This soluble iron once released into the bulk condensate stream could deposit at the tip of the Yankee dryer soda straws causing flow restriction.

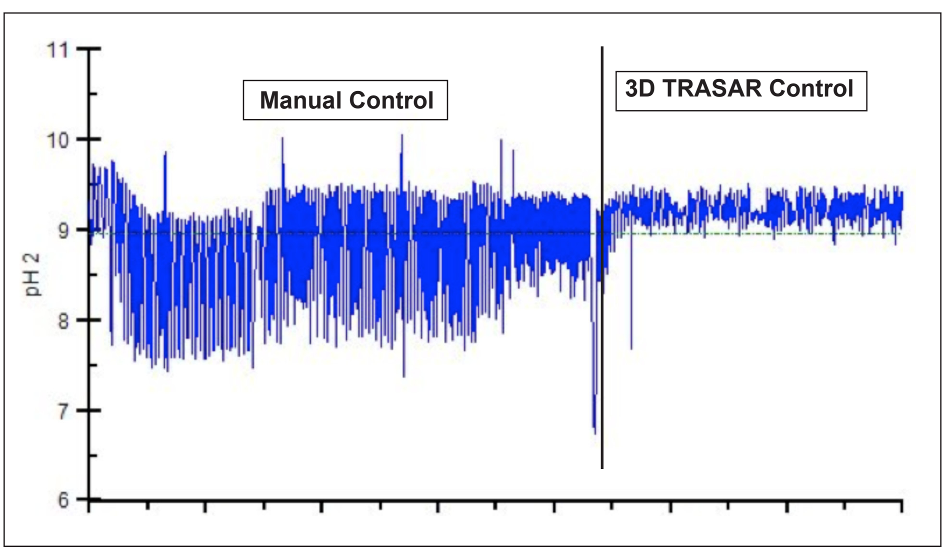

Figure 3 – *Condensate pH control obtained through 3D TRASAR for Yankee dryer systems*

Table 2 – *Effect of low pH excursion on metal passive layer and soluble iron throw*

Time	pH	NCSM reading (mv)	Soluble iron (Fe^{+2})
8:30 am	9.01	-702	0 ppb
Amine off 8:40 am	9.01	-702	0 ppb
9:40 am	6.95	-640	0 ppb
10:45 am	6.64	-625	1 ppb
11:45 am	6.54	-620	1 ppb
1:00 pm	6.2	-590	3 ppb
3:00 pm	6.01	-560	10 ppb
Amine on 3:15 pm			
5:00 pm	9.0	-702	0 ppb
6:30 pm	8.9	-700	0 ppb

Case Study 2

During the first seven months of operation of a greenfield tissue machine, the tissue machine experienced five unscheduled maintenance outages due to poor tissue quality created by concerns with the performance of the Yankee dryer system. Each unscheduled machine outage was preceded initially by a gradual decrease in blowthrough steam velocity within the Yankee and an increase in differential pressure across the system. Just prior to the tissue machine being taken out of service, both of these operational conditions accelerated in their rate of degradation, as seen in Figure 4. The longest period between these outages was 42 days.

In each incident, soda straw plugging caused by iron deposits was determined to be the cause of the poor Yankee dryer performance. After each outage, operational changes were made to try and eliminate soda straw plugging – increased venting off the condensate flash tank, increased pH control range in main return condensate sample, new soda straws installed, installation of multiple sample points around the Yankee dryer, etc. With each operational change made, the time period between unscheduled outages remained unchanged.

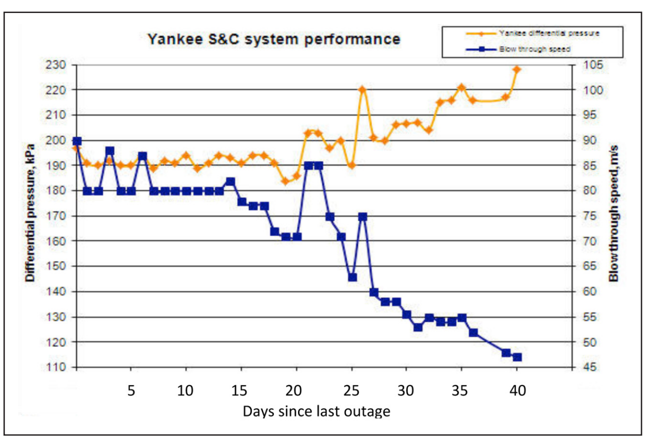

Figure 4 – *Yankee S&C System Performance – Plugged Soda Straws layer and soluble iron throw*

Nalco was asked to evaluate the problem and to offer recommendations for operational changes to minimize the soda straw plugging and eliminate these unscheduled outages. Because of the speed and nature of the deposit formation, it was believed that the plugging occurring in the soda straws was due to excessive corrosion rates present within the Yankee dryer system. Corrosion rates of this magnitude indicated that a combination of elevated carbon dioxide and oxygen levels were likely present in the return condensate system.

A comprehensive plan was developed to improve the mechanical removal of oxygen and carbon dioxide within the steam supply system (increased dearator venting and RO installation) and to improve the level of system monitoring and control in the boiler feedwater and Yankee dryer condensate systems via 3D TRASAR technology.

3D TRASAR Technology for Boilers was installed in the feedwater system to monitor deaerator mechanical performance and to optimize the feed of chemical oxygen scavenger resulting in reduced feedwater system corrosion. Nalco 360 Service was utilized to monitor system performance around the clock in analyzing system alarms through human interaction, not static computer monitoring.

To improve the monitoring/control of the Yankee dryer, the mill incorporated 3D TRASAR technology for Yankee dryer systems in the return condensate line between the Yankee dryer and the condensate flash tank. This system was also tied to Nalco 360 service so that immediate analysis and action could be taken in case of system alarm, Figure 5.

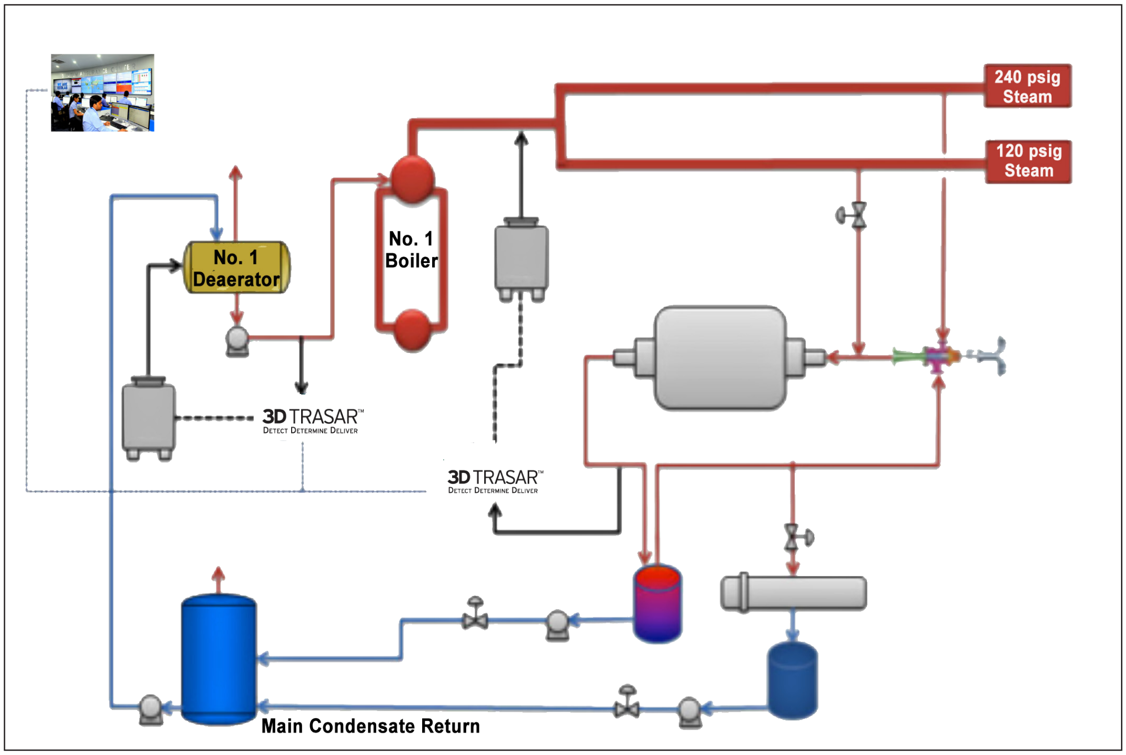

Figure 5 – *Layout of 3D TRASAR Technology application points and Nalco System Assurance Center*

Through the combination of mechanical changes made to reduce oxygen and carbon dioxide levels, and the implementation of 3D TRASAR technology in the boiler feedwater and Yankee dryer systems, condensate corrosion rates have been significantly reduced and soda straw plugging concerns eliminated. This tissue machine is now running consistently on the mill's scheduled six month maintenance outage plan. There has been no sign of soda straw plugging as evidenced by a consistent Yankee dryer differential pressure and blow through velocity between outages (Figure 6) and through internal inspection performed during the six month outage.

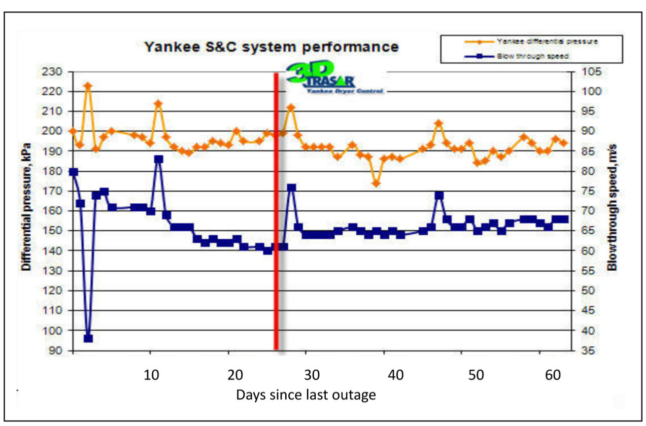

Figure 6 – *Yankee S&C System Performance – Clear Soda Straws*

SUMMARY

Reliable Yankee dryer performance is a key contributor to the smooth operation of every tissue machine. Through application of 3D TRASAR Technology for Yankee Dryer Systems from Nalco, tissue manufacturers are able to maintain the performance of and protect the internal surfaces of this vital mill asset by monitoring/controlling critical parameters within the Yankee dryer condensate system.

REFERENCES

1. P. Hamer, J. Jackson, and E.F. Thurston 'Industrial Water Treatment Practice' Butterworth, 1961
2. I. Cotton 'Oxygen scavengers – the chemistry of sulfite under hydrothermal conditions' National Association of Corrosion Engineers, March 1987

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