ADVANCES IN FLUORESCENCE DETECTION OF SUGAR IN WATER SYSTEMS

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ABSTRACT

Part of the sugar manufacturing process is the concentration of raw sugar or thin juice using multiple effect evaporators. Condensate from the multiple effect evaporators is commonly used as make-up water to a boiler. Occasionally, juice will mechanically carry over into the boiler condensate system, resulting in a "sugar shot". Immediate detection and notification of a "sugar shot" is critical because sugar juices break down forming organic acids in the boiler, which rapidly depress boiler water pH causing corrosion. Sugar process evaporators and sugar pan boilers use cooling water to maintain vacuum for low temperature operation. The cooling section is open to the process, so sugar contamination can occur during upset conditions. Immediate detection and notification of a sugar contamination of cooling water is critical to prevent microbiological fouling in the cooling system. A fluorescence method developed by Nalco is able to detect sugar contamination in an early stage by measuring naturally occurring non-sugars in the juice that have fluorescent properties. Now this technology has been upgraded on the 3D TRASAR platform with the advantages of low cost, low maintenance, ease of use and calibration. Laboratory tests and field evaluations have shown that the new 3D TRASAR for Sugar technology can improve boiler corrosion and deposit control with continuous real-time monitoring and diagnostics. This results in safer operation, improved system reliability, and reduced operating costs. Laboratory and field trial data will be presented in this paper.

INTRODUCTION

The practice of recycling condensate is common in sugar industry. In fact, it is critical in order to effectively manage the water usage and disposal at each facility. Condensate from the multiple effect evaporators is commonly used as make-up water to a boiler.[1] One of the problems that comes with this practice, however, is the possibility that some sugar juice may leak into the condensate, resulting in a "sugar shot". If this is not detected in time and the contaminated water is returned to the boiler, it can cause severe pH depression as sugar breaks down into organic acids. Sugar juice can cause boiler tubes to blister or even rupture in a short period of time. In addition to immediate damage, it can also cause severe corrosion and redeposition of iron products, reducing overall boiler efficiency and increasing the potential for future failures. Severe "sugar shots" may require a plant shut down.

Sugar process evaporators and sugar pan boilers use cooling water to maintain vacuum for low temperature operation. The cooling section is open to the process, so the plant has the potential for sugar leakage into that system. Leaks occur when the pans are overfilled during increased production pares. The system can be corrected, but it requires early warning of the problem. Once leaks have occurred, sugar flows into the cooling water, resulting initially the loss of a potential saleable product, and ultimately, as bacterial growth in the cooling system. Left unchecked, the cooling system can become severely fouled, resulting in gross inefficiencies and, in extreme cases, fill fouling and deterioration. In addition, since cooling water for condensers is

often treated in storage ponds, sugar contamination in cooling water leads to BOD, TOC and odor issues requiring additional waste treatment.

Consequences of sugar contamination are well known, and sugar detection is a need for sugar factories. Early detection can help troubleshoot the problem and prevent recurrence, leading to safer and reliable operations, ability to use high value condensate and reduced operational costs.

Sugar mills have used various methods for the detection of sugar in their water systems, ranging from monitoring feedwater conductivity/pH, running the qualitative alpha Naphthol test, to the use of sodium/potassium analyzers. However, these methods have their limitations. Some methods are unreliable and are not early detection methods. Some methods require difficult and costly maintenance and calibration. And some are too sensitive, indirect or reactive approaches. An industry need for the monitoring of sugar contamination on-line and the detection of real-time "sugar shot" events is apparent.

Nalco's fluorescence-based technology provides a novel approach for continuously monitoring thin juice in a condensate or a condenser water stream. Though sugar itself does not fluoresce, the non-sugars in thin juice do have fluorescence properties.[2] By monitoring the fluorescence of condensate or condenser water on-line, sugar contamination can be detected in real time. Nalco's first generation of fluorescence-based technology for sugar detection was rolled out in 2000, and has been successfully applied for sugar contamination detection in customers' processes.

The first generation of the fluorescence detection technology was based on a fluorometer that need to be customized for each account, therefore laboratory tests on field samples were necessary for the selection of the appropriate filters and lamp. Field samples need to be frozen after collection, stored and shipped in the frozen state. Another limitation of the first generation fluorescence method is that there was no standard calibration solution. Fresh calibration solutions must be prepared on-site prior to calibrating. This method was based on TRASAR 350 equipment which is no longer available or supported, customers are in need of upgrade. To answer customers' request, Nalco research has been directed to develop and evaluate new sugar contamination detection technologies using a new fluorescence platform with the objectives of low cost, low maintenance, and easy to use and calibrate.

3D TRASAR for Sugar is Nalco's new technology for sugar contamination detection. It is custom-designed to monitor, measure and take corrective action on system irregularities. Based upon proven 3D TRASAR fluorescence technology, this program can add more control to the customer's process. 3D TRASAR has the multi-channel fluorescence capability, and more probes, such as conductivity, pH, ORP and corrosion probes, can be incorporated in the equipment upon customers' desire. Using the standard fluorometer and the standard calibration solution, 3D TRASAR for Sugar unit is easy to use and calibrate. The unit detects contaminations associated with the thin juice at concentrations that would be harmful to the boilers, and allows customers to customize alarm levels for their applications. When upsets are detected the unit will take appropriate corrective action. The sophisticated communication tools integrated into 3D TRASAR for Sugar unit keep plant personnel informed on a timely basis. Information can be accessed through the internet, text message, a facility DCS/SCADA system

or via visual and sound alarms. The program can provide a signal to automatically open or shut valves, turn on chemical pumps and take measurements that can be used to predict future occurrences.

Laboratory evaluation and field trials of the new 3D TRASAR for Sugar technology have been conducted for both sugar beets and sugar cane applications. These tests have shown that the new 3D TRASAR for Sugar technology can improve boiler corrosion and deposit control with continuous real-time monitoring and diagnostics, resulting in a safer operation, improved system reliability, and reduced operating costs. The development of this technology and the laboratory and field trial data will be presented in this paper.

3D TRASAR

3D TRASAR is the most advanced water treatment control system on the market today. The design is based on years of field research and a broad base of industry experience and application.[3] The 3D TRASAR on-line fluorometer consists of a "Flow Cell", a LED light source, filters, and detectors. The LED light source shines across the quartz flow cell, and the Detector reads the emitted light. The quantity of light emitted is proportional to the amount of fluorescent components present in the system. This allows for real-time reactions to prevent upset conditions due to process contamination in water systems. The LED light source is extremely bright at the appropriate frequencies to reliably and repeatably measure the fluorescence properties of the flowing water. As a solid-state device, the fluorometer offers trouble free long life.

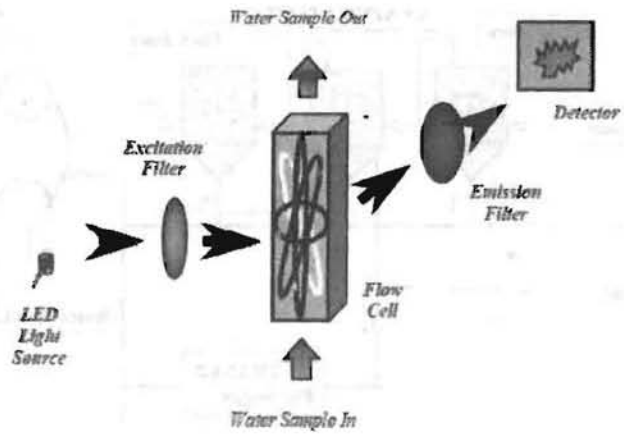

Figure 1 - *3D TRASAR Fluorescence Detection*

The 3D TRASAR controller takes a revolutionary proactive approach to managing the water system. It is equipped with alarm relays, which permit connection to external alarm devices, such as a horn or flashing light. In the event of system upset, an alarm signal can be sent to an optional external alarm source. The unit also has 4-20 mA output signals which can be sent to an external data management system. With the continuous data logger, the magnitude and duration of the upset can be determined. 3D TRASAR controller is able to automatically e-mail stored measurements to a central database that is accessible via the internet. This allows operational data to be viewed and analyzed remotely, from one or more authorized locations using just a

standard web browser. Reports may also be setup and automatically emailed on determined dates or at specified times.

3D TRASAR technology has been applied successfully in cooling tower control and other applications. By adopting this technology to the sugar industry, 3D TRASAR for Sugar can be used in a unique way for the detection of sugar contamination.

DETECTION OF SUGAR CONTAMINATION IN EVAPORATOR CONDENSATE

Sugar contamination is always a threat to any sugar mill that is recycling evaporator condensate to the boiler. Detection of the sugar shot is crucial and a prompt response imperative to minimize the potential for damage.

3D TRASAR for Sugar can detect trace amount of sugar contamination in condensate streams. Figure 2 shows a schematic of a typical boiler evaporator with 3D TRASAR for Sugar applications. The fluorescence is measured as a sidestream of the recirculating water passed through the 3D TRASAR fluorometer. The contamination level in condensate is monitored continuously by one of the 3D TRASAR fluorescence channels. Once the fluorescence intensity reaches the alarm setpoint, an alarm signal will be sent to the external alarm device or to the facilities DCS/SCADA system for notification of thin juice carryover into the evaporator condensate. The 3D TRASAR unit can also provide a signal to automatically open or shut valves.

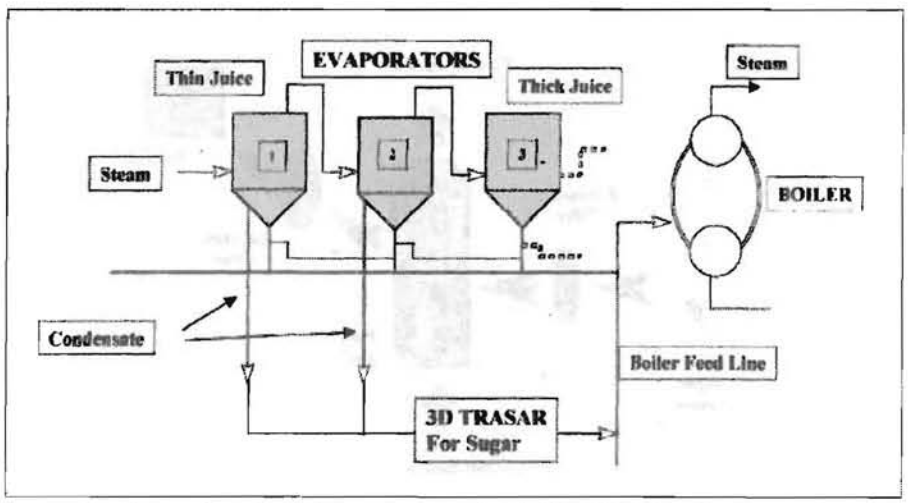

Figure 2 - *Typical Boiler Evaporator with 3D TRASAR for Sugar Applications*

Evaporator Condensate Contamination Detection in Sugar Beet Process - Evaporator condensate usually has background fluorescence, and it was verified that volatile components from the thin juice are the source for the inherent background fluorescence in the steam condensate.[2] Spiking thin juice to condensate increases the fluorescence intensity. Figure 3A shows a graph of fluorescence readings from a 3D TRASAR for Sugar unit for a condensate sample spiked with varying levels of thin juice. Fluorescence intensity enhances with the increase of contamination (thin juice) level. At low concentrations (<1%, v/v), as illustrated in

Figure 3B, the fluorescence intensity is directly proportional to the concentration of thin juice present in the evaporator condensate.

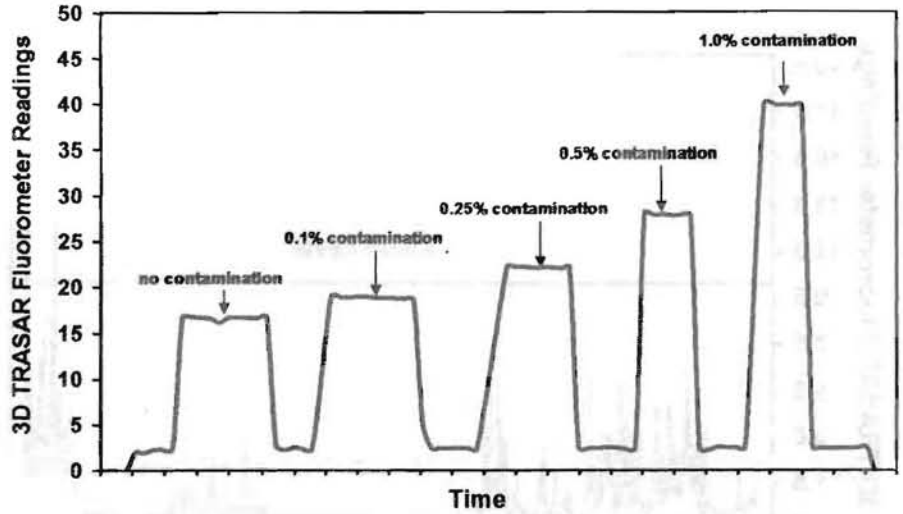

Figure 3A – *3D TRASAR Detection for Thin Juice (Contamination) Spikes in Condensate*

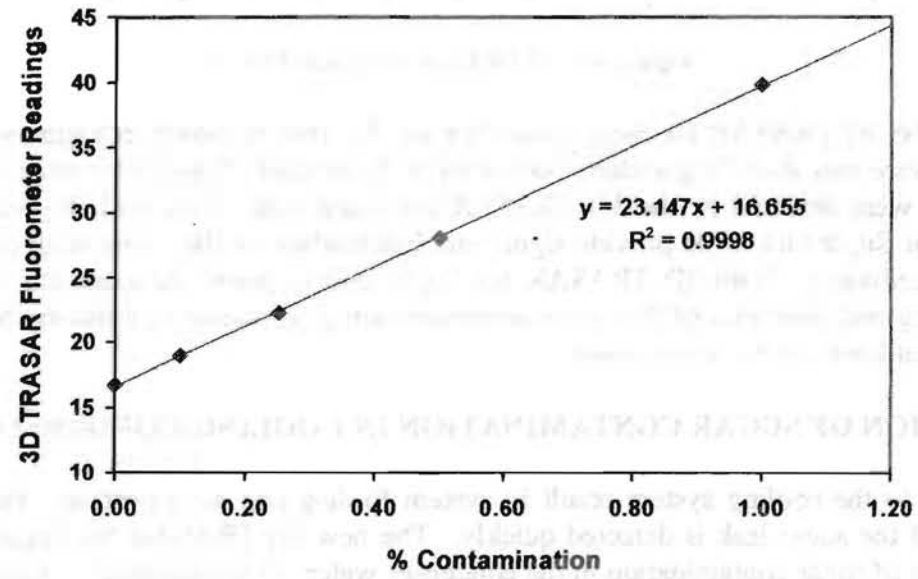

Figure 3B - *3D TRASAR Fluorescence as a Function of Condensate Contamination Level (v/v)*

Evaporator Condensate Contamination Detection in Sugar Cane Process - A trial of the 3D TRASAR for Sugar technology was started in October 2006 in a Louisiana sugar mill. A 3D TRASAR for Sugar unit was installed to provide monitoring of boiler feedwater prior to being pumped to the boiler. Sugar juice spiking tests were performed on-site, and the results indicated that a light trace of sugar was detectable with the 3D TRASAR for Sugar unit, but could not be differentiated from the normal background noise. Medium and heavier traces of contamination were readily seen on the 3D TRASAR for Sugar detector. If the alarm is set at a level that is too

sensitive or to a light trace that is difficult to detect independently, the unit could appear to go into alarm more frequently than desired, giving the impression of false alarms. To minimize the chances of false alarm, the alarm was set at fluorescence reading 10.

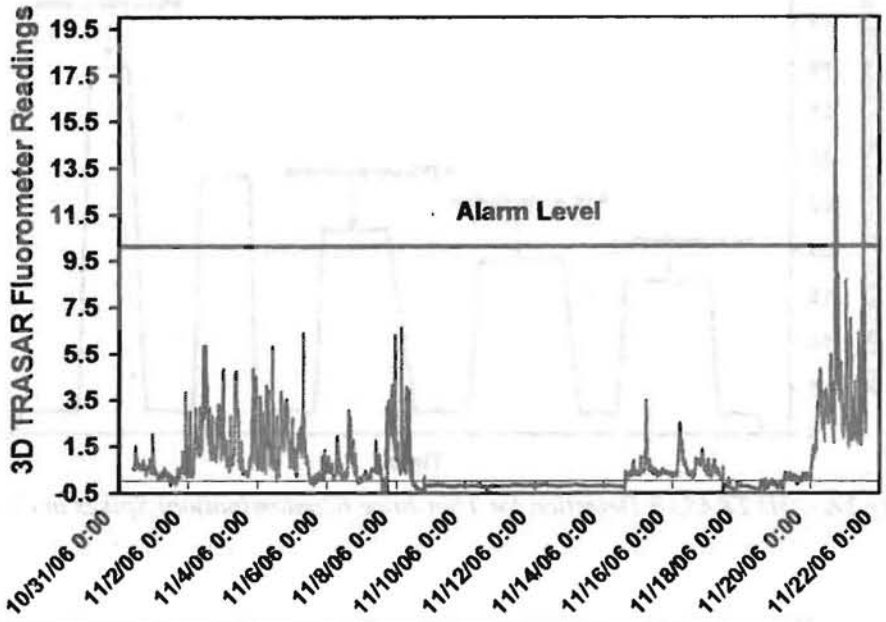

Figure 4 - *3D TRASAR for Sugar Field Data*

Data from the 3D TRASAR for Sugar controller for this trial is shown in Figure 4. During the trial, there were two short "sugar shots" occurred on November 20 and November 21, 2006, and both events were detected by the 3D TRASAR for Sugar unit. This trial showed that the 3D TRASAR for Sugar unit could provide significant information on the monitoring capabilities for the boiler feedwater. With 3D TRASAR for Sugar unit in place, the customer could receive early warning and detection of thin juice contamination in condensate, reducing boiler damage and plant shutdown due to "sugar shots".

DETECTION OF SUGAR CONTAMINATION IN COOLING/CONDENSER WATER

Sugar leaks to the cooling system result in system fouling and deterioration. Fouling can be minimized if the sugar leak is detected quickly. The new 3D TRASAR for Sugar can pick up trace amount of sugar contamination in the condenser water. Once detected, a system alarm will signal any operational changes that need to occur. A typical cooling water system with 3D TRASAR for Sugar applications is illustrated in Figure 5.

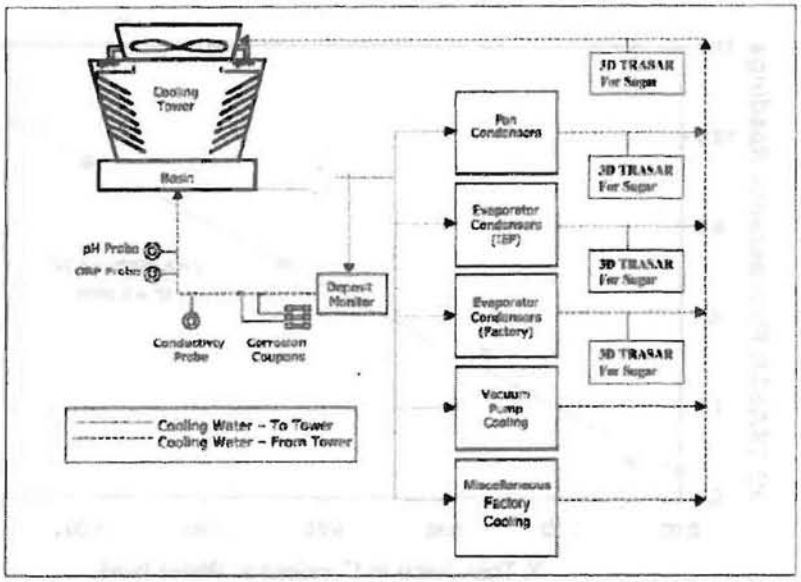

Figure 5 - *Typical Cooling System with 3D TRASAR for Sugar Applications*

Field test was started at a Midwest sugar beet processing plant on August 31, 2006. A 3D TRASAR for Sugar unit was installed to provide continuously monitoring of the quality of condenser water. Condenser water spiked with varying levels of thin juice was injected into the fluorometer to simulate the sugar leaking events. Readings from the 3D TRASAR fluorometer is shown in Figure 6A. Fluorescence intensity increases with the increase of the contamination level. As illustrated in Figure 6B, at low concentrations, fluorescence intensity is a linear function of the amount of thin juice present in the condenser water.

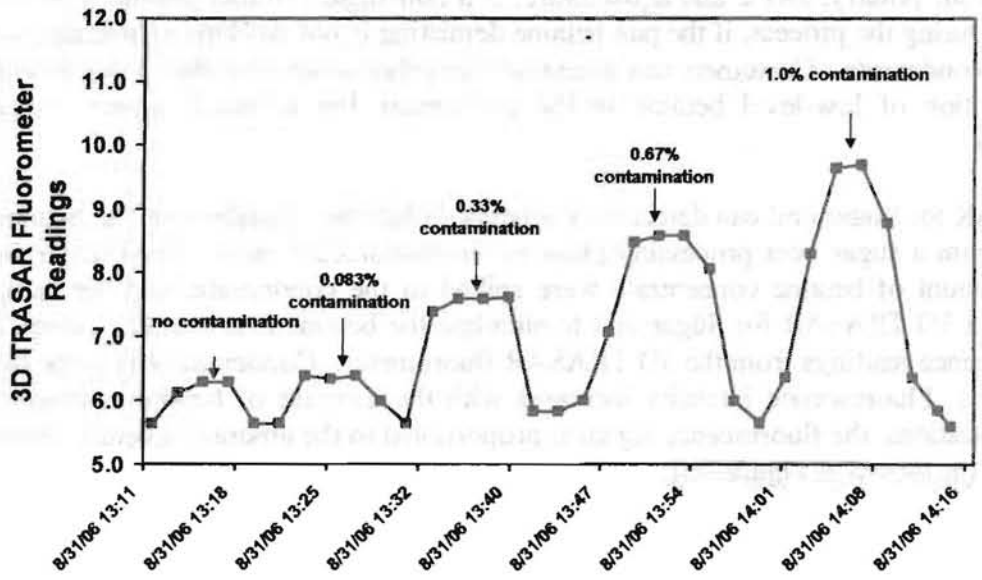

Figure 6A – *3D TRASAR Detection for Thin Juice (Contamination) Spikes in Condenser Water*

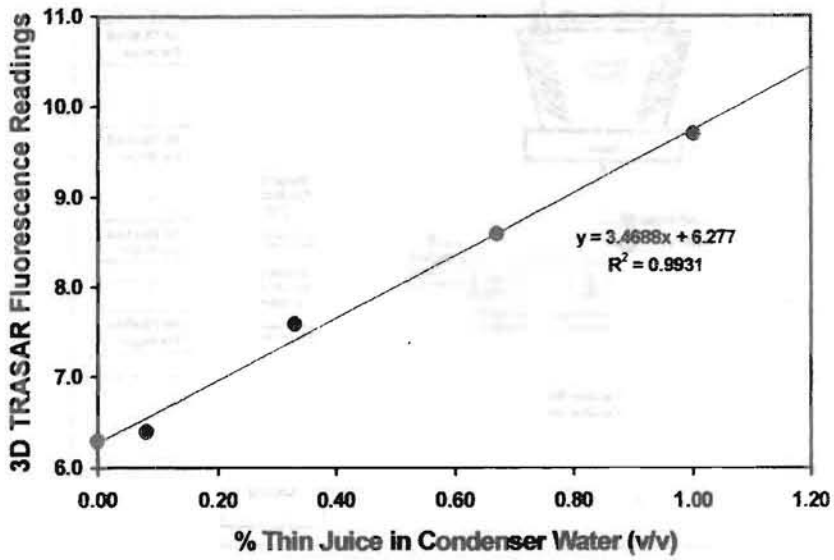

Figure 6B - *3D TRASAR Fluorescence Reading as a Function of Contamination Level*

With the installation of the 3D TRASAR for Sugar unit, the customer could receive early warning and detection of sugar to the cooling tower, minimize sugar lost to the tower and reduce the inefficiencies due to fouling in the cooling system.

DETECTION OF BETAINE IN CONDENSATE

Betaine is the most abundant nitrogenous compound found in molasses. Betaine, an animal feed supplement for poultry, swine and aquaculture, is a non-sugar product produced by some sugar factories. During the process, if the pan betaine demisting is not working efficiently, betaine can leak to the condensate. Customers can potentially loss thousands of dollars a day in lost betaine. Early detection of low-level betaine in the condensate has a direct impact on customer's profitability.

3D TRASAR for Sugar unit can detect trace amount of betaine. Condensate and betaine samples collected from a sugar beet processing plant in Northwest USA were tested in the laboratory. Various amount of betaine concentrate were spiked to the condensate, and the samples were injected to a 3D TRASAR for Sugar unit to simulate the betaine loss events. Figure 7A shows the fluorescence readings from the 3D TRASAR fluorometer. Condensate has some background fluorescence. Fluorescence intensity increases with the increase of betaine concentration. At low concentrations, the fluorescence signal is proportional to the amount of betaine present in the condensate (as shown in Figure 7B).

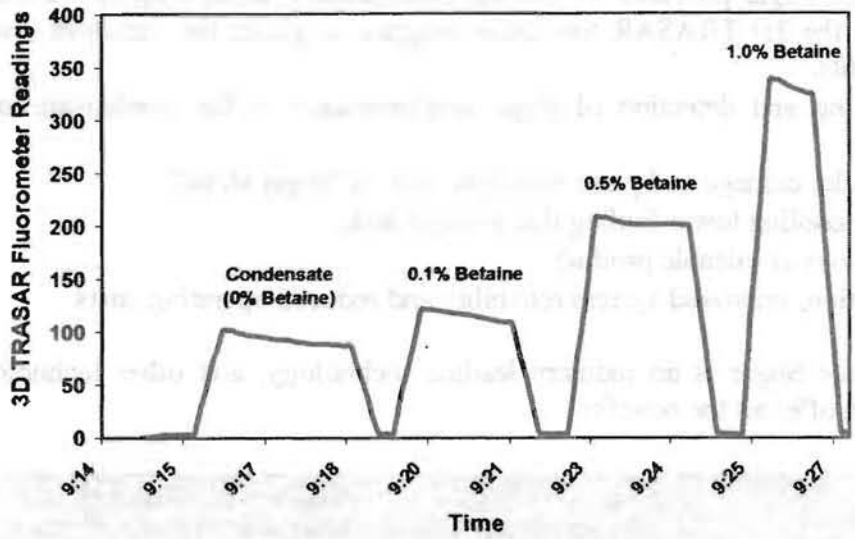

Figure 7A - *3D TRASAR Detection for Betaine Spikes in Condensate*

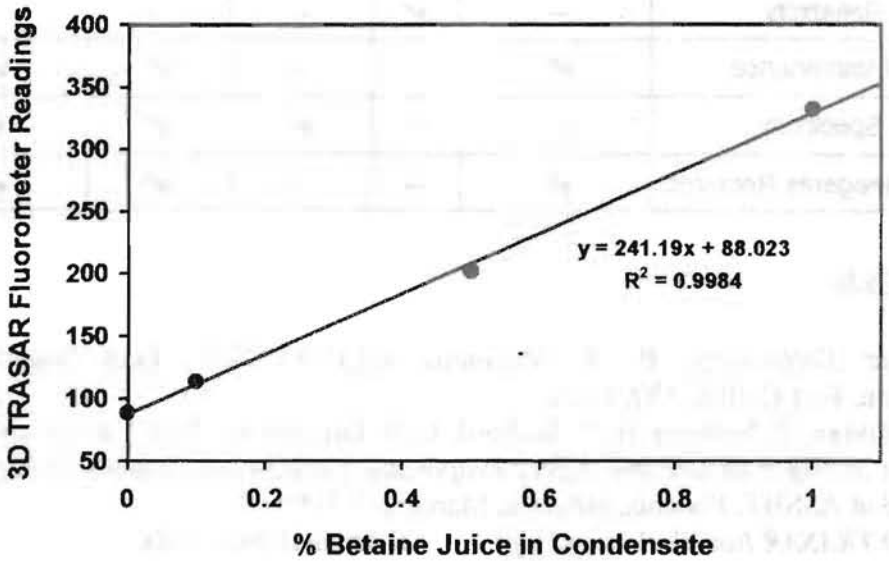

Figure 7B - *Fluorescence Intensity as a Function of Betaine Level in Condensate*

3D TRASAR for Sugar unit can sense low level of betaine, minimizing betaine lost to the condensate, and improving customers' profitability by saving the money that they are potentially losing.

CONCLUSIONS

Laboratory evaluation and field tests successfully demonstrated the effectiveness of monitoring sugar contamination to boiler condensate stream and to cooling system condenser water by using the new 3D TRASAR for Sugar program. The technology can also be applied in other processes, such as betaine loss detection.

3D TRASAR for Sugar provides on-line and continuously monitoring on the customer's water systems. With the 3D TRASAR for Sugar program in place, the customer could receive the following benefits:

- Early warning and detection of sugar contamination to the condensate and the cooling system;
- Reduced boiler damage and plant shut down due to "sugar shots";
- Minimizing cooling tower fouling due to sugar leak;
- Minimized loss of saleable product;
- Safer operation, improved system reliability and reduced operating costs.

3D TRASAR for Sugar is an industry leading technology, and other technologies for sugar detection do not offer all the benefits.

	Conductivity	TOC	Sodium Analyzer	Alpha Naphthol	3D TRASAR
Online Measurement	✔	✔	✔	–	✔
High Reliability	–	✔	–	–	✔
Low Maintenance	✔	–	–	✔	✔
High Specificity	–	–	✔	✔	✔
No Reagents Required	✔	–	–	✔	✔

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2. T. McGillivray, S. Seaborn, B. S. Bedford, D. P. Grueneich, D. O. Larson and C. M. Stuart, *Detection of Sugar in Multiple Effect Evaporator Condensate Systems Using Fluorescence*, Presented at ASSBT, Phoenix, Arizona, March 2-5, 1997.
3. *Nalco 3D TRASAR Installation and Operational Manual*, May 2006.