MAX HT™ 500: A SECOND GENERATION SODALITE SCALE INHIBITOR

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Abstract

Since its introduction to the Bayer industry in 2004, MAX HT™ Sodalite Scale Inhibitor has been run on a number of plants across the globe under a variety of operating conditions and has demonstrated that it can completely eliminate sodalite scale. However, the first generation product readily adsorbs to solids found in some liquors, so that even at low levels of solids (50-200 ppm) the dosage requirement can be adversely affected. Examples of low levels of solids that can be found in some liquors include sand filter backwash, precipitated oxalate, and ESP dust. MAX HT™ 500 Sodalite Scale Inhibitor was developed to be more tolerant to these low levels of solids, providing the elimination of sodalite scale at dosages similar to that observed with the first generation product in liquors containing no solids. This paper will discuss the plant experience with both products.

1. Introduction

Silica that is present in bauxite ores as silicates, primarily clay minerals, dissolves quickly under typical Bayer alumina digestion conditions. A majority of the silica subsequently precipitates as a sodium aluminosilicate – sodalite or DSP (desilication product). The Bayer liquor remains supersaturated in silica, however, and this supersaturation is greatest after the alumina precipitation step, i.e. in the spent liquor. As the alumina-depleted liquor is reheated, the rate of silica precipitation in the form of sodalite increases markedly with increasing temperature due to faster kinetics. This precipitation occurs as scaling on the inside of the heat exchange tubes and significant loss of heat transfer occurs (Armstrong 2000, McGaughey 2004, Müller-Steinhagen 1994, Whittington 1998, and Yamada 1985). Besides the obvious costs of maintenance and labor required to clean the scaled up heat exchangers, the impact of scale may also be seen in increased energy consumption, increased caustic losses, reduced liquor flows, reduced throughput, reduced evaporation, and even reduction in production.

New reagents were introduced in 2004 which successfully demonstrated the elimination of sodalite scale in evaporator and digester heat exchangers (Spitzer 2005a,b and 2008). Since then, a number of plants have successfully trialed these products (Riffaud 2006 and Oliveira 2008), many using these reagents full time. None of these plants have experienced any negative downstream effects.

The first generation MAX HT Sodalite Scale Inhibitor was designed to adsorb readily to the red mud solids so that it would leave the circuit with the mud rather than build up in the circuit. However, this limits its use to double stream digesters and evaporators. Even in single stream plants, benefits have been found in treating evaporator heaters. In some double stream plants, there are low levels of solids present in the liquor. Under these conditions, the first generation MAX HT does not work effectively; and, therefore, a new product was developed to be more tolerant to these low levels of solids. The development and plant testing of this new product, MAX HT 500 Sodalite Scale Inhibitor, will be discussed in more detail later in this paper.

2. Background

A generic structure for the sodalite scale inhibitors is shown in Figure 1 (Spitzer 2004 and 2008). The important feature of this structure is the incorporation of the silicon containing group Si—O_3. It is proposed that this group interacts with the growing aluminosilicate crystal either by incorporation into the crystal or by adsorption onto the growing crystal surface in such a way that the crystal growth is stopped. The mechanism is depicted schematically in Figure 2. The mechanism is based on the classical mechanism for crystallization and inhibition as explained in detail by Perez (1998). In this mechanism, the overall free energy goes through a maximum at the critical size of the embryos. This means that if the growth is stopped before the embryos reach the critical size, the driving force is for the crystal to go back into solution which is at a lower energy level. This explains why MAX HT is so effective at a low dose, which is well below what would be a stoichiometric dose if the mechanism was simple chelation of silica in solution.

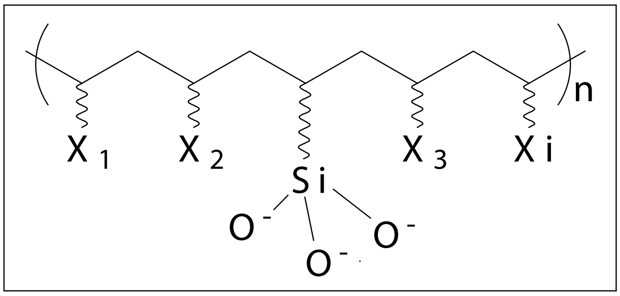

Figure 1. Generic structure for MAX HT Sodalite Scale Inhibitor

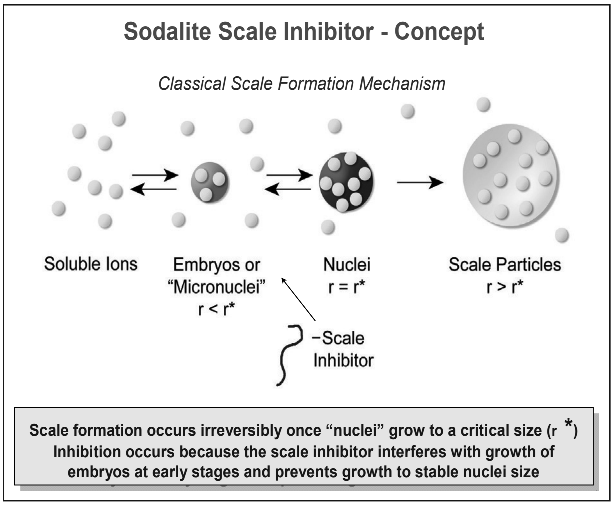

Figure 2. Proposed antiscalant mechanism for MAX HT Sodalite Scale Inhibitor

3. Benefits of MAX HT

MAX HT sodalite scale inhibitor has been used successfully in a number of Bayer process plants (Oliveira 2008, Riffaud 2006, and Spitzer 2005b and 2008). The product is used to eliminate and/or minimize scaling in evaporator and digestion heater tubes at dosages ranging from 20-40 ppm. A typical result on the prevention of the decay in the heat transfer coefficient is shown in Figures 3 and 4. Typically, the on-stream time for a heater is increased from some 8-10 days to 45-60 days for digestion and 20-30 days to >150 days for evaporators. This ability to maintain a high heat transfer over a much longer life cycle between cleanings has resulted in a number of benefits. These benefits are summarized below.

1. Increased evaporation when used in the evaporator heaters. This leads to reduced caustic consumption and improved mud settling in the washer circuit because more water is available for efficient washing of the red mud and gibbsite crystals. Another result from improved evaporation is that the plant can run a higher caustic while maintaining the same level of net wash, which will lead to higher production.
2. Increased production. This is a result of an increased average flow due to being able to maintain the outlet temperature without having to reduce flow to accommodate a lower heat transfer rate.
3. Reduced energy consumption per ton of alumina. Savings in the range of 0.1-0.3 tons of steam per ton of alumina have been observed for the evaporators alone.
4. Less direct steam to the digester when used in the digester heaters. This is a result of being able to maintain the maximum live steam heater outlet temperature which eliminates or reduces the need to add steam by direct injection in the digesters. The results in less extraneous dilution which impacts soda recovery and therefore caustic consumption.
5. Reduced digester and evaporator heaters cleaning and maintenance. This leads to a reduction in cost for the acid, labor, tube changes, etc. There is also less exposure of the workers to the associated hazards.
6. Steadier plant operation. This is a result of being able to maintain flow and have a more stable demand for steam.

The use of MAX HT has resulted in many benefits. However, it is limited to evaporators and double stream plants where the undissolved solids content is quite low (<10mg/L). The next section describes the development of a new product that has demonstrated a tolerance to low levels of solids in the liquor.

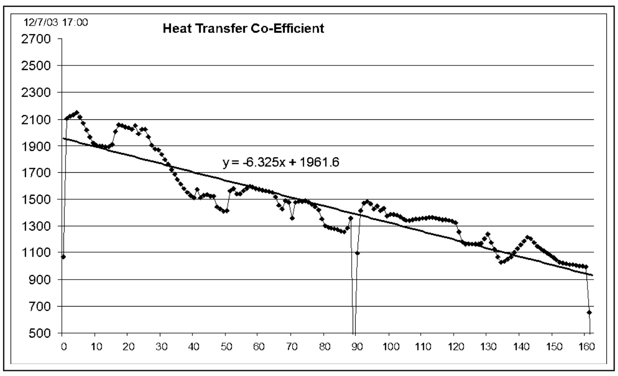

Figure 3. Typical heat transfer decay during ~7 days when no antiscalant was used.

4. Development of MAX HT 500

MAX HT was originally designed to readily adsorb onto solids in order that it is removed from the circuit with the red mud rather than building up in the circuit, which may result in problems down stream.

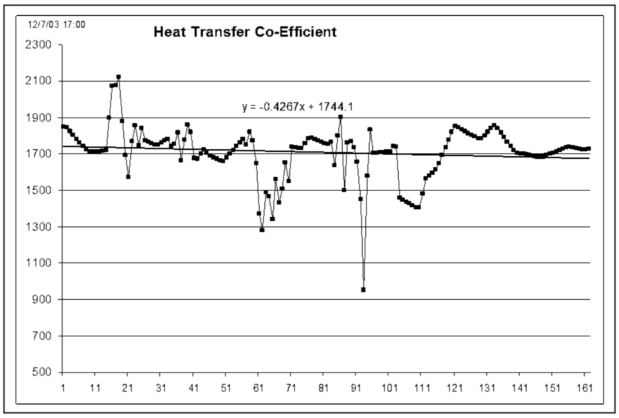

Figure 4. Constant heat transfer coefficient resulting from use of MAX HT.

In most double stream plants MAX HT works quite well at dosages of 20-40 ppm. However, in some plants, especially those that use sand filters, red mud solids may be 50-150mg/L. Other solids that may be found in liquors in double stream plants included precipitated oxalate and ESP dust. These solids have the effect of adsorbing some of the MAX HT and increasing the dosage required to eliminate sodalite scaling. In one such plant with 140-150mg/L red mud solids in the test tank liquor, lab testing gave a dosage of ~70 ppm for complete inhibition of scale formation. Although lab test dosages can not directly predict the required dose in the plant, this lab result certainly indicated that a higher dose would be required in the plant. The solids were examined by SEM/EDX, which showed that these were not simply iron oxides, but iron oxide particles around and on which very fine sodalite particles, many <1 µm diameter, have aggregated (Figures 5 and 6). Lab testing has shown that as little as 10-20mg/L of sodalite can cause a significant increase in the dosage requirement.

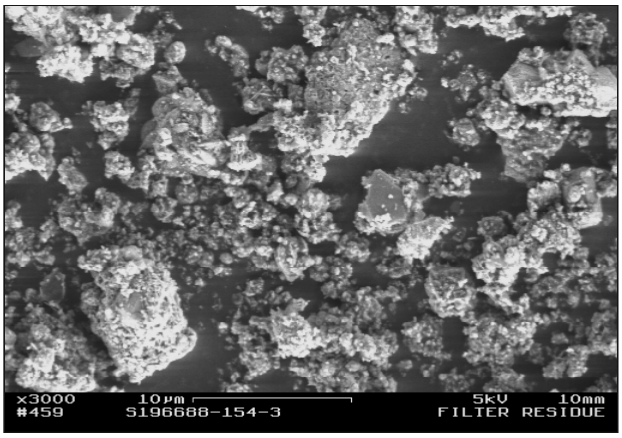

Figure 5. SEM image of test tank liquor solids.

In order to effectively treat the liquors in double stream plants with small amounts of solids (up to 200mg/L), MAX HT 500 was developed to be tolerant to these low levels of solids. It is desirable that the product will be removed from the circuit with the red mud; therefore, MAX HT 500 was designed to be slower to adsorb to the solids and still have the capability to adsorb to the red mud during digestion so that it will still leave the circuit with the red mud.

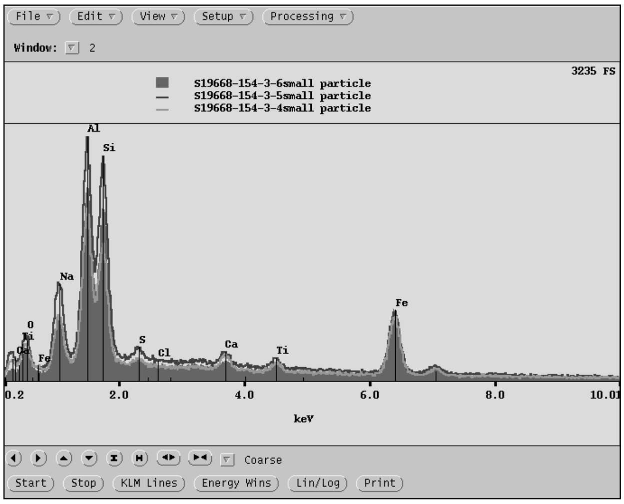

Figure 6. EDX spectrum on smaller particles.

It was necessary to modify the lab test method that we used to efficiently study the performance of various polymer structures in the presence of solids. The original lab test involved the use of synthetic Bayer liquor in a plastic bottle heated over night at 100° C (Spitzer 2005a,b). The modification involved shortening the test period to 4 hours and adding 50mg/L sodalite crystals. The optimum product that resulted from these studies, MAX HT 500, still has the silane group as shown in Figure 1, but the backbone polymer chemistry was modified to give the desired slower adsorption to solids. Sodalite crystals were found to have the most significant effect on the performance of MAX HT, and these solids were chosen for the lab testing to simulate worst case conditions.

Lab testing was conducted at the above plant comparing the new MAX HT 500 to the first generation MAX HT. Figure 7 shows a typical result from this testing indicating that MAX HT 500 is more tolerant to the red mud solids present in the test tank liquor providing complete scale inhibition at a lower dosage than the first generation product.

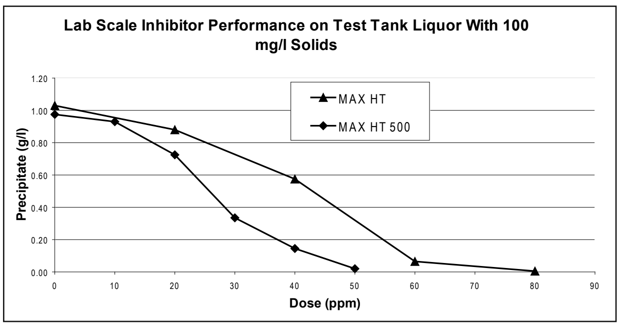

Figure 7. Lab test comparing MAX HT 500 to first generation MAX HT

MAX HT 500 was trialed on this plant, adding the reagent after the test tank to treat the digester heater train. The plant is a high temperature plant with about 100-150mg/L of red mud solids in the test tank liquor. The trial began at a dosage of 50 ppm, which was reduced in stages to a final dose of 25 ppm. The graph of heat transfer coefficient with time for the highest temperature heater shows a fairly steady level, indicating that there is little or no scaling taking place (Figure 8). For comparison, the corresponding heater on the untreated line is shown in Figure 9, indicating a time of about 7 days normally between cleanings. Monitoring of the outlet temperature of the treated live steam heater showed a fairly steady outlet temperature of about 212° C, which is another indicator that MAX HT 500 was performing as designed.

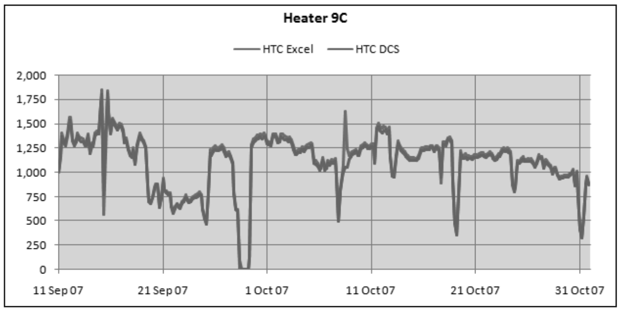

Figure 8. Live steam heater treated with MAX HT 500 (dose 50 ppm at start, reduced in stages to 25 ppm on Day 27).

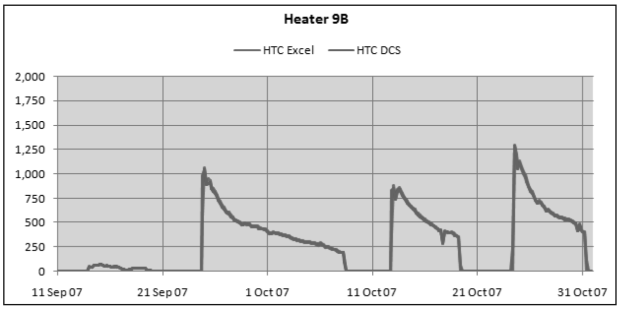

Figure 9. Live steam heater on untreated line during the same period as the MAX HT 500 trial.

These results clearly indicate that MAX HT 500 is effective in liquor streams containing low levels of solids. The performance is similar to that of the first generation MAX HT in liquor streams with no solids present. Therefore, the benefits observed with the first generation MAX HT will be realized with MAX HT 500 in those applications that will require more tolerance to low levels of solids.

5. Effect of Oxalate Solids

Besides the presence of red mud solids in the spent liquor, another solid phase that can be present is solid phase oxalate. This can arise from a liquor that has reached the saturation point for sodium oxalate, particularly after evaporation. In such a liquor that contained 0.2-0.3g/l solid phase oxalate, a lab test of the performance of the first generation MAX HT and MAX HT 500 was conducted (Figure 10). The presence of solid phase oxalate led to a poorer performance for the first generation product, but MAX HT 500 performed well, basically equal to its performance in the absence of such solids.

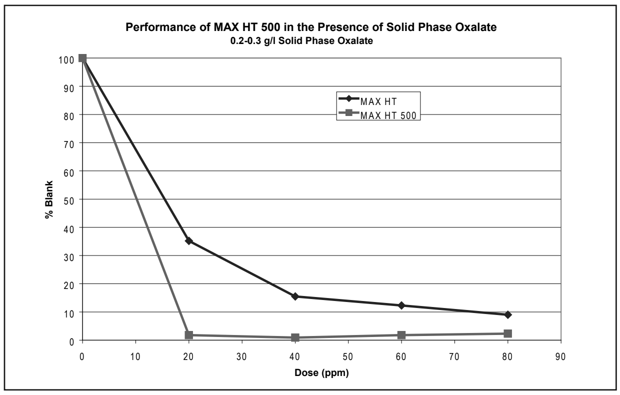

Figure 10. MAX HT performance with solid phase oxalate.

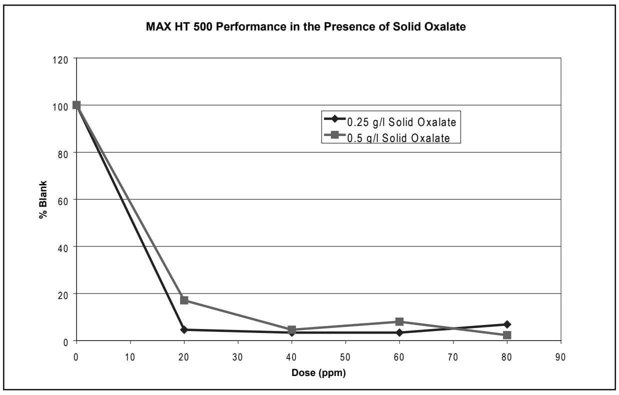

Figure 11. MAX HT 500 performance with added solid phase oxalate.

To further test the effect of solid phase oxalate, another series of lab tests were conducted with MAX HT 500 with added amounts of oxalate (Figure 11). In this experiment, the spent liquor was filtered to remove any undissolved solids and known amounts of solid phase oxalate was added. The solid phase oxalate was obtained from the oxalate precipitation circuit. The results showed that the solid phase oxalate had little negative effect on the performance of the MAX HT 500.

6. Conclusions

1. MAX HT Sodalite Scale Inhibitor is effective in eliminating sodalite scale in evaporators and double stream digester heaters.
2. In the absence of solids, the dosage requirement for MAX HT is low, generally 20-40 ppm.
3. The on-stream time between cleanings for heaters can be increased by a factor of greater than 5 with the use of MAX HT.
4. MAX HT 500 is an effective sodalite scale inhibitor in the presence of low levels of solids.
5. With the use of MAX HT, plants have realized higher average liquor flow, higher average evaporator flow, more stable operation, and higher production.

Acknowledgements

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