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CASE STUDY

REMOVAL OF IRON CARBONATE DEPOSITS FROM HEAT EXCHANGERS USED INAMMONIA PRODUCTION USING TECH SONIC CLEANING

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INTRODUCTION

The use of ultrasonic technology for cleaning refinery and chemical plant components has been undertaken since 2003. The use of large-scale ultrasonic systems for cleaning heat exchangers was developed in 2009 to extend the benefits of Tech Sonic ultrasonic cleaning to the energy-critical heat exchange elements of the refining and chemical production.

Herein we describe a project conducted in 2011 in which badly fouled heat exchangers were cleaned at the world's largest nitrogen facility, which produces ammonia, granular urea, urea ammonium nitrate and diesel exhaust fluid.

The Tech Sonic cleaning process was used, which involves a proprietary combination of ultrasonic cleaning systems, chemistry, and process.

In the planning phase we learned that there are 20 very challenging (from a fouling/performance perspective) heat exchanger in their amine processing unit. They pull one unit of 4 exchangers offline each year for cleaning and inspection.

Using EDS, XRD and chemical analysis of the tube side fouling, the main constituents are noted in **Table 1 and Figure 1.**

TABLE 1. DEPOSIT COMPOSITION

COMPONENT	Wt%
FeCO3	96
CaMg(CO3)2	3
Alumino Silicates	<1

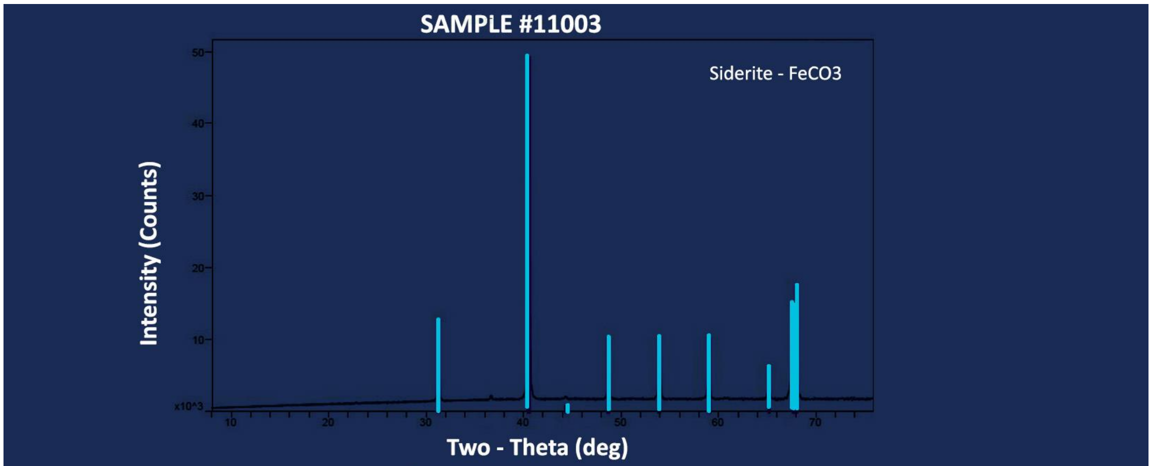


Figure 1. XRD pattern of the deposit

The main fouling component $FeCO_3$ (siderite) had presented a challenge to maintenance over the past 25 years. Turn-around crews employed everything from the latest high-pressure water cleaning rotating tips at 40, 000 PSI, to the harshest of chemical, including hydrochloric baths to try and completely remove the siderite from the tubes.

Our client reported that each method provided less than optimum cleaning results with large expenses incurred as a result of the destruction of rotating hydroblasting tips, chemical stress fracturing of tubes, significant water use, and an overall time to clean in excess of a month for the 4-exchanger train of 106C Exchangers.

By 2006 the client had decided to cap the amount of time they would allow for this process train to be out of operation. Thirty (30) days became the allowable amount of time, thus giving cleaning crews 7 day per unit for cleaning with the remaining 2 days for any mechanical work and reinstallation. During these outages, many of the units were returning far less than 100% clean.

In 2008 the client conducted a study to examine the factors resulting in premature failure of some of the equipment in selected pre-heat trains of 105C, 106C and 109C exchangers.

Both IRIS and Eddy current inspection methods used to measure tube wall erosion and integrity revealed that prolonged exposure to the abrasive, high-pressure water cleaning methods had contributed to early failure of the equipment. Exchangers which could be traced to the use of HCL pre-treatment and cleaning proved to be the candidates for early retirement due to wall corrosion as discovered by Eddy Current testing.

With brand new, replacement exchangers in place for some trains the challenge would be to maintain the level of production now attained without suffering from the incomplete cleaning and premature failure observed previously.

A new, less destructive cleaning method was necessary, and the method needed to provide superior cleaning results in less time than any previously employed technique.

The client agreed to consider a cleaning proposal based on Tech Sonic's proven ultrasonic cleaning method.

METHOD

Tech Sonic's proprietary combination of ultrasonic cleaning systems, aqueous cleaning fluids and process is capable of removing both hydrocarbon and selective inorganic contaminants from the surface of a work piece in a rapid, safe, and environmentally friendly alternative to traditional cleaning methods.

The client's historical experience and process data revealed heavy deposits of $FeCO_3$ within the ID of the tubes in at least 3 of the 4 heat exchangers in a particular unit. There wasn't anything noted about the level of difficulty in cleaning the shell side of these bundles.

It was determined that to effectively remove the siderite from the interior diameter of the tubes, a new chemistry would be optimized for this project. Based on further analysis and solubility testing, the selection of a proprietary organic acid (Sonic Clean AC®) was chosen because of its strength, reasonably good reaction rate and its compatibility with the ultrasonic equipment.

To determine the reaction rates in the organic acid concentrate, a large deposition sample was placed in 100ml of 8% acid. A 0.5ml sample was taken at intervals of time and was then analyzed by ICP.

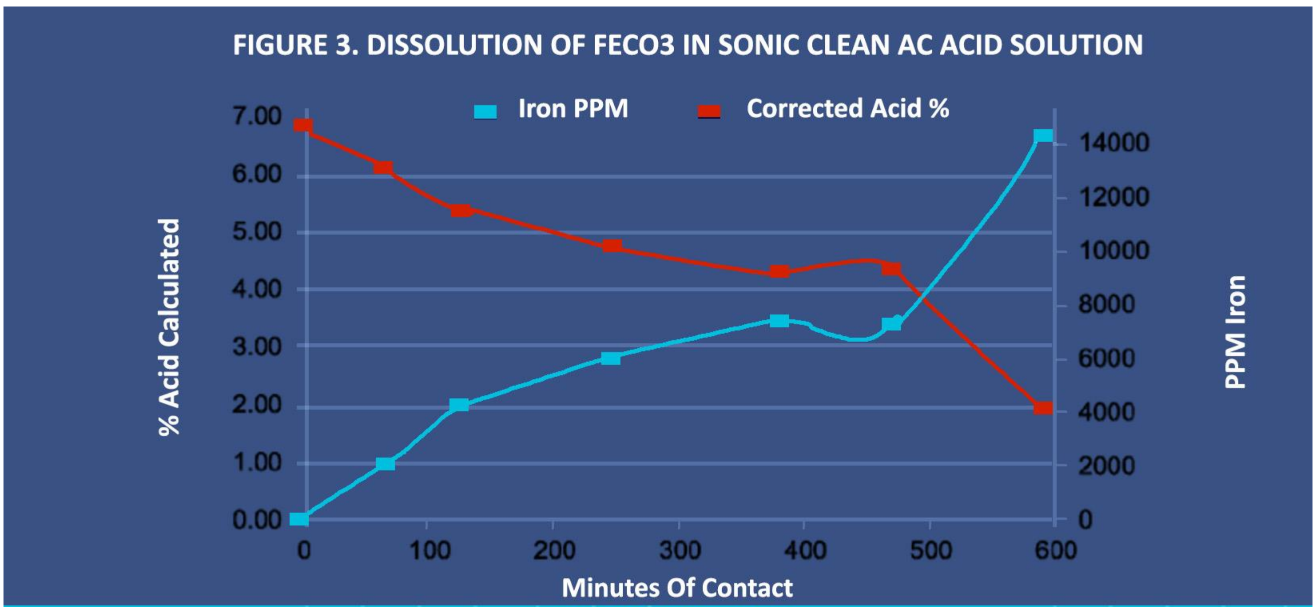
Figure 2 shows an example of the severe fouling observed on the tube-side of the exchangers.

FIGURE 2. A SAMPLE OF THE FECO3 FOULING REMOVED FROM THE TUBE SIDE OF THE HEAT EXCHANGER

Figure 3. shows little or no reaction initially as the solution is heating up, but a rapid dissolution of the solids is seen once a range from 40 and 60°C is reached, after a contact time of 500 minutes. Heat is generated as a by-product of the ultrasonic cavitation in the fluid and the reaction rate increases drastically as the solution temperature nears 60°C at which temperature the cavitation conditions are optimized.

The cavitation produced by the ultrasonic waves provides both mechanical action at the dissolving surface as well as a kinetic advantage by accelerating the reaction by the disruption of the diffusion layer.

This acceleration of the reaction rate offered by the ultrasonic process is a key component toward reducing the overall cleaning time for these heat exchangers.



To take maximum advantage of the enhanced dissolution rates provided by the ultrasonic bath, a process was designed to ensure that would monitor and optimize conditions during cleaning.

The exchangers were to be removed on an hourly basis in order to rinse off any loosened material, and the cleaning chemistry monitored for acid strength and a saturation of iron or a corrosive build-up of chlorides When the acid was spent (below 4% a chemistry change out was performed.

RESULTS

Four exchangers were cleaned for this project. The first exchanger came very clean after a total of 10 hours in the ultrasonic bath and 6 hours of rinse time. The experience gained with this first unit allowed us to alter the cleaning protocol for the subsequent three exchangers, dropping the total ultrasonic bath time from 10 to 8 hours per exchanger. In all, the four exchangers were cleaned in 5 days.

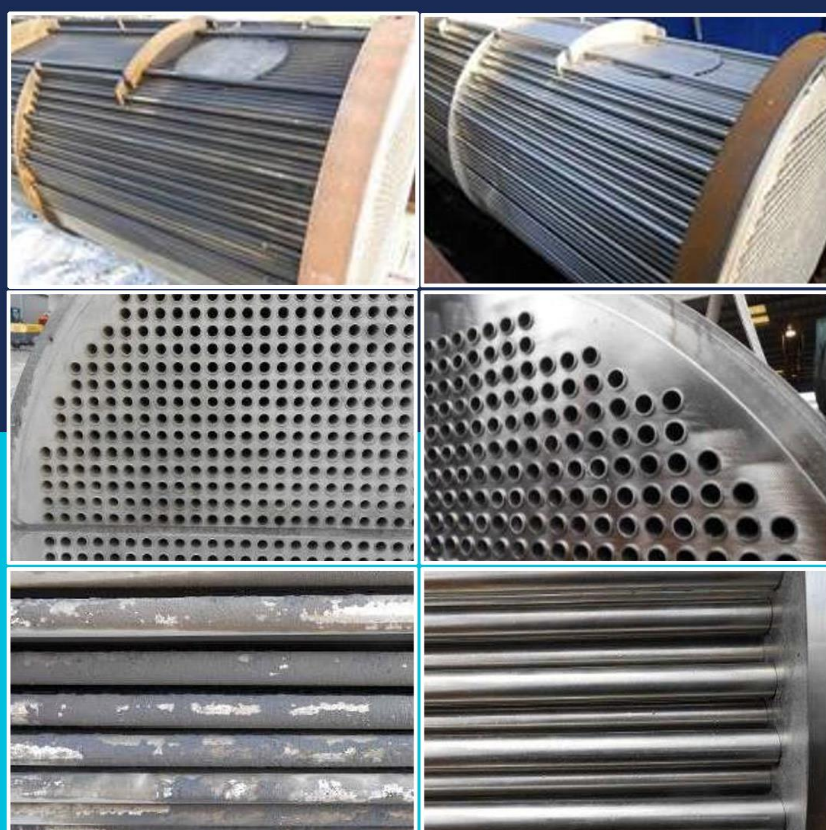
Visual inspections of the units by the client's inspection group deemed the units to be in like new condition. Upon receiving the units back to the plant, the processing group also concluded that the cleaning had returned the units to like-new levels based on initial measurements.

Historically, this client allowed 30 days to clean these same four units. The difficulty experienced with traditional cleaning methods alone, often meant that at least 2 or more exchangers were going back into operation in a partly fouled state.

Using the ultrasonic chemical cleaning method allowed the client to have these units back into operation in 9 days, 21 days sooner than previously experienced. **Figure 4 shows some before and after pictures of one of the exchangers cleaned in this project**.

The tube side fouling is not visible in the photos, however each tube was severely fouled with material similar to that shown in Figure 2.

FIGURE 4. BEFORE AND AFTER PHOTOS OF ONE OF THE EXCHANGERS CLEANED



The shell side of the exchangers were not initially noted by the client to be of a particular concern, it was noted that after cleaning these bundles looked like new on the outside of the tubes as well as on the inside. Heat transfer performance data provided by the client also proved that the units were restored to 100% of design performance.

Of even greater benefit was the increased flow-thru-rate afforded by the cleaning, versus previous cleaning attempts. The ammonia production from this Hx train was measured one month after the cleaning interval.

The client measured an average increase of 23% more production volume of ammonia over the same period the previous year. (Client provided result in February 2011)

OBSERVATIONS

1. The technique is significantly safer than high pressure water blasting alone. The reduction of hydroblasting by >75% is a significant risk reduction and the Tech Sonic ultrasonic cleaning system presented no significant hazards to the operators

2. Significantly faster per unit turnaround was observed: less than 24 hours per unit is possible, in contrast to conventional high pressure washing, which can take more than a week per unit.

3. Far less wastewater is generated. Compared to the hydroblasting alone approach, the new method consumed >75% less water, generating <25% of the wastewater normally associated with the standard Hydroblasting method.

4. Chemistry was spent far quicker than expected. Additional chemistry was required to complete the project. More frequent rinsing might help reduce the amount of chemistry required by removing material outside the cleaning bath.

5. Better determination for the amount of expected fouling in these Exchangers, will allow for better estimating the amount of chemistry required.

6. As the composition of the scale on the shell side differed from the siderite in in the tubes, cleaning of the shell side was complete in half the time of the tube side.

7. The cleaning process did not have to dissolve all of the tube contamination into solution to be effective. By shrinking and loosening the adherence of the fouling from the inner walls, the intermittent high-pressure lancing easily removed large cylindrical chunks of siderite.

8. Titrations of the acid were sometimes inaccurate due to interference by high concentrations of iron. Improved job monitoring of the chemistry is needed to ensure optimal cleaning conditions.

CONCLUSIONS

The project was a success and exceeded the client's two objectives which were to:

a) reduce the overall downtime time for this critical processing unit, and
b) provide better cleaning to improve the overall unit performance.

The Sonic Clean AC Chemistry worked well on all samples of the present fouling. The reactions occurred stoichiometrically and did not have apparent limitations due to saturation.

The combination of Tech Sonic Cleaning Systems, Sonic Clean AC Chemistry and an optimized process proved to be an effective cleaning method for the severe $FeCO_3$ fouling which has historically caused maintenance and production problems.

The client was able to gain 21 days of production time due to the much faster cleaning method. The client also reported a 23% improvement in production rate due to the restoration of the exchangers to like-new condition, as compared to previously experienced results with hydroblasting alone as the cleaning approach.

This client has expanded the use of this technology in several separate projects to date and continues to introduce the method to its other plants throughout the US and Canada.

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