Improved Turnaround Practices Saves Millions in Energy and CO_2 Emission Costs for Ammonia Plant

NALCO
An Ecolab Company

CASE STUDY – CHEMICALS

CH-1425

BACKGROUND

Significant attention is routinely given to treatment and control of cooling water systems. Often, however, less focus is provided to these systems once they come down for turnarounds. Unfortunately, system reliability as well as the length of time between turnarounds can be adversely impacted during these outages. Some of the related concerns include:

- Stagnant water corrosion
- Aerobic (slime-forming) bacteria growth
- Anaerobic (corrosive) bacteria growth
- Drying/cracking of piping corrosion products – chip scale
- Iron buildup and deposit formation

A poorly executed turnaround can adversely affect the long-term equipment life as well as premature heat transfer problems. Typically, heat exchangers are inspected and cleaned via hydro-blasting as necessary, but this practice does not affect the headers and transfer piping of the system. This creates the potential formation of chip scale that can break loose and plug exchanger tubes after start-up, resulting in reduced cooling water flow and loss in energy efficiency. Events that contribute to chip scale include changes in water chemistry, temperature, and low flows that are experienced during shut down and start-up. Cooling system performance can be compromised if lay-up procedures do not properly address the potential formation and removal of chip scale.

CUSTOMER IMPACT	eROI℠	ECONOMIC RESULTS
Improved heat transfer of surface condensers reduced steam demand by 15,000 pounds per hour	ENERGY	Annual energy efficiency savings: $892,206
Increased energy efficiency reduced CO_2 gas emissions by 9.7 tons per year	AIR	CO_2 emissions savings: $1.07MM per year Equivalent to the annual emissions from 1,692 cars

eROI is our exponential value: the combined outcomes of improved performance, operational efficiency and sustainable impact delivered through our services and programs.

Figure 1 – *Example of chip scale and plugged tubes*

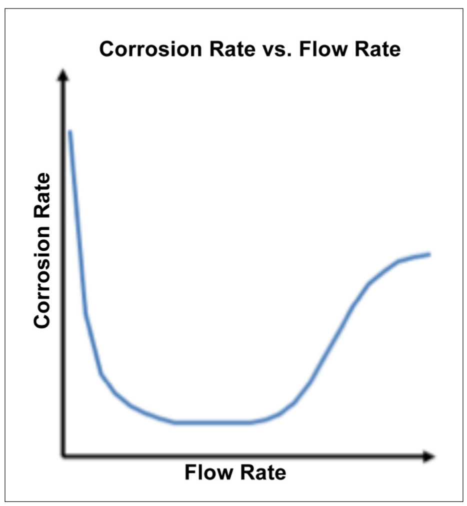
A consistent goal throughout the Ammonia and Fertilizer Industry is for longer production runs between turnarounds, as long as four years. In this study, an older plant often experienced difficulties attaining efficient production operations following outages, which were attributed in large part to chip scale. Nalco worked with the customer to develop and implement best practices for shutting down and starting up their cooling water systems.

SITUATION

The dynamics of the cooling water system changes drastically during an outage. Low flow or stagnant water conditions create an ideal environment for increased corrosion and microbiological fouling. Before discussing turnaround best practices, it's helpful to first explain the corrosion mechanisms at work.

The flow of water across a metal surface has a direct effect on the movement of corrosion inhibitors to the metal surface as well as the removal of corrosion products away from the surface. The flowing water is broken into two parts, a thin diffusion boundary layer at the metal surface and the bulk solution. The diffusion boundary layer's thickness varies inversely with the flow rate.

Optimum flow velocities for mild steel exchangers in cooling service are generally set at 3-6 ft/sec (0.9-1.8 m/sec). As the velocities increases over 6 ft/sec (1.8 m/sec) the effects of erosion/corrosion become more pronounced. High velocity erosion/corrosion has a substantial increase in metal loss because the turbulent water has enough energy to destroy the protective films. When these beneficial films are destroyed the corrosion rate increases substantially.



When flow velocities decrease below 1 ft/sec (0.3 m/sec), corrosion rates become extremely high. This is due to the increased thickness of the diffusion boundary layer and its relationship to mass transfer. Mass transfer defines the transport of corrosion inhibitors to the metal surface and corrosion deposits away from the metal surface. As the boundary layer becomes thicker, the concentration of corrosion inhibitor at the metal surface falls below effective treatment levels. Iron tuberculation also increases because the corrosion deposition cannot be transported away from the metal surface. The graph provides a general illustration of the relationship between water velocity and corrosion.

A critical step in protecting the cooling water system during the turnaround is how the lay-up is planned and executed. The absolute best method of lay-up is to not take the cooling water system out of service. This means keeping the cooling water recirculating with its normal velocity and normal treatment program. If only a small portion of a system will have to come down for a turnaround, only remove cooling water service the minimum amount required for maintenance. By maintaining recirculating cooling water to the rest of the system, the potential for corrosion, microbiological growth, and chip scale formation are minimized.

For most outages, it's not possible to maintain normal water system operations. In order to fully protect a system when the water recirculation is stopped, the system must be treated one of two ways: Wet lay-up or Dry lay-up. Choosing which method is largely based on the primary problem issues associated with that system and maintenance constraints.

Wet Lay-up

If the system suffers from fouling and chip scale issues, especially if experienced after previous outages, a "wet lay-up" procedure should be utilized. It is also a preferred method when there are sections of piping that cannot be fully drained (esp. underground piping) or if a system is greater than 15 years old. For older systems, wet lay-up is preferred over "dry lay-up" since drying and subsequent cracking of piping tuberculation can often lead to chip-scale. When the recirculation water is restarted, chip-scale as well as other deposits will be dislodged and settle out in low flow areas such as the channel head and inside the tubes. This can obstruct or completely block the water flow through the tube, leading to future problems with heat transfer, fouling and corrosion. The normal water treatment program will not provide corrosion inhibition during periods of stagnant water flow. The only way to minimize corrosion during stagnant water situations is to treat the systems with very high inhibitor and biocide concentrations to protect against corrosion and fouling.

Dry Lay-up

This method is designed to prevent corrosion by assuring the system is free of any water, however, due to the need to maintain surfaces throughout the system of transfer piping as dry as possible it is often not feasible for cooling water. This procedure can be used for newer systems (< 15 years old) where the cooling water recirculation lines have not experienced significant corrosion, deposition and fouling. Since these lines are relatively clean, there is less of a chance of post turnaround chip scale that can foul heat exchangers during and after start-up. By performing a dry lay-up procedure, metal surfaces are protected from corrosion by keeping moisture out of the equipment.

Procedures to effectively drain, dry, and purge a cooling water system is site specific. Purging the system with either nitrogen or plant air will help ensure the equipment remains free of moisture. Plant air must be moisture-free. The selection of nitrogen or plant air should be fully evaluated to ensure all proper steps for personnel safety are taken into account.

SOLUTION

Nalco reviewed the turnaround steps below with the plant's operation team to understand current practices, identify potential gaps, and make recommendations that encompassed mechanical, operational, and chemical aspects of a good turnaround procedure.

Shut Down / Wet Lay-up / Start-up

- Equipment inspections
- Cooling tower basin cleaning
- Exchanger repair/replacement plans
- Exchanger cleaning plans
- Exchanger hydrotesting procedures
- Cooling tower repairs
- Recirculation pump or screen repairs
- Individual exchanger repassivation plans
- System return to service plans, timing
- Start-up cooling water recirculation procedures
- Exchanger back flushing and return to service
- System repassivation
- Transition back to base treatment program

A wet lay-up procedure was selected since the plant is over 30 years old and has a history of chip scale issues. Key elements of the program are discussed below.

System Preparation

Before the turnaround and the wet lay-up, the microbiological and Total Dissolved Solids (TDS) levels must be lowered as much as possible. Microbiological levels need to be at a minimum to reduce the demand on the wet lay-up biocide and reduce the source for biological inoculation during the turnaround. Minimal TDS levels reduce the corrosion potential of the water and also allow the system's blowdown to be minimized or blocked prior to shut down. Five days prior to shut down, dosages were increased for the biodispersant and the oxidizing and non-oxidizing biocides to clean up the system.

Wet Lay-up

Twenty-four hours prior to system shutdown, inhibitor and biocide chemistries were increased to maximize lay-up concentrations. The system pH was also set to 8.5 to minimize corrosion and aid the passivation process. All inhibitor and non-oxidizing biocide levels were routinely monitored and adjusted as needed.

System Repassivation and Start Up

Precautions were taken after completing maintenance and mechanical cleaning to effectively flush accumulated debris, iron, and silt from the cooling water system. This minimizes the potential for exchanger fouling and plugging as a result of chip scale and other debris being transported throughout the system piping. All exchangers on the cooling water circuit were back flushed until the water ran completely clear. This is particularly important for those exchangers that sit at the end of the cooling water supply piping that can accumulate trash. Strainers on the inlet side of the exchangers were also inspected and cleaned prior to start up.

The passivation treatment program was initiated as soon as possible after heat exchangers were cleaned to minimize flash corrosion. It is important to repassivate carbon steel heat exchangers and supply piping to minimize flash corrosion and/or deposit formation. All metal surfaces will benefit from pretreatment; however, rust, oils, and organic films must be removed to ensure the protective film formation. Corrosion progresses unchecked under these foreign materials due to the formation of localized corrosion cells or pitting.

As with the wet lay-up procedure, the recirculating water pH was set to 8.5 to minimize corrosion potential of the makeup water and aid the repassivation process during startup. Circulation velocity was maintained at a minimum of 3 ft/sec (0.9 m/sec) through all the heat exchangers during repassivation. Passivating chemistries were applied at concentrations approximately five times normal dosage and maintained for the next two days. Key water system operating parameters were monitored throughout the process to assure optimum conditions.

It is important to note that iron will be picked up into the re-circulating water at startup. It is not uncommon to find iron levels as high as 10 ppm at startup. The iron is removed from the system through blowdown. Systems with iron levels greater than 6 ppm will need to operate at low cycles to quickly remove the iron from the system. Systems with heavy iron contamination will consume more products because of the high blowdown.

RESULTS

The program successfully removed iron chip scale and prevented corrosion during and after the turnaround. Heat transfer was significantly improved as documented by comparing vacuum readings and steam flow data before and after the turnaround. (Table 1)

For this ammonia plant, the cost of 20,000 pounds of steam per hour is $140. The annual value of reduced steam generation of 15,000 pounds/hour is $892,206, as shown in the Table 2.

In addition to energy savings, the plant also reduced its costs for CO_2 emissions. The fixed cost per ton of CO_2 produced is $110. Every 1,000 pounds of steam produces 152 pounds of CO_2. The annual savings from reduced CO_2 emissions is over one-million dollars as shown in the Table 3.

Table 1

	Vacuum			Steam (lbs/hour)		
Condenser	Before	After	Difference	Before	After	Difference
CT102	20	24	4	75,000	70,000	5,000
CT104	12	22	10	75,000	65,000	10,000

Table 2

Steam (lbs/hour)	Steam Cost ($/hour)	Hours/Year	On-line Factor	Steam Savings ($/Year)
15,000	$105	8,760	0.97	$892,206

Table 3

Steam (lbs/hour)	CO_2 (pounds)	CO_2 (tons)	CO_2 Cost ($/ton)	Hours/Year	On-line Factor	CO_2 ($/Year)
15,000	2,280	1.14	$110	8,760	0.97	$1.07 MM

Nalco, an Ecolab Company

North America: ***Headquarters*** – 1601 West Diehl Road • Naperville, Illinois 60563 • USA
Nalco Champion – 7705 Highway 90-A • Sugar Land, Texas 77478 • USA
Europe: Richtistrasse 7 • 8304 Wallisellen • Switzerland
Asia Pacific: 2 International Business Park • #02-20 The Strategy Tower 2 • Singapore 609930
Latin America: Av. das Nações Unidas 17.891 • 6° andar • São Paulo • SP • Brazil • CEP 04795-100

www.nalco.com