Asset Management through Corrosion loss prevention in a Urea Plant

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ABSTRACT

In a large Urea plant in The Middle East a sudden failure was reported right after maintenance and return. A series of investigation and failure analysis showed startling information. A stainless steel component issued from the warehouse was found defective. In a modern Urea plant like that, about 54 different types of stainless steels(1)are used - some of them are patented and whose composition are not revealed. This is a unique plant that utilizes Natural gas as source of required Carbon di oxide. This called for a revamp on all previous failed cases of components - their origin, supplies, composition, warehouse and preservation methods etc. Is it wrong to expect the components to serve till suggested service life, or plan a proactive method to prevent failure – and if so on what basis? Some simple steps were introduced to avoid failures in future. This is a compilation of some case studies evoking active discussion.

INTRODUCTION

Corrosion awareness is widely spoken of these days and in spite of training, education, best engineering and maintenance practices, failures do happen. There are several reasons known or unknown to us which cause the failures to occur. For example:

1. the case of Richmond refinery in California where a great disaster took place because the carbon steel side-cut which conveyed hot diesel contained just a little lower percentage of Si content. If the Si content was higher the pipe line would have lasted longer. It shows the importance of trace elements in carbon steel, which was not realized until then.
2. In the mid eighties, pipes were manufactured with a small percentage of Mn to improve metallurgical properties. But in the recent years it is found to foster the growth of Mn bacteria which eventually cause pipe failures.

We can list many such examples of good or excellent engineering practice which failed in the field-the case of FBE coatings- the case of ERW pipes and so on.

We learn only after mistakes have happened and this presentation is one such eye opener situation.

MATERIAL SELECTION

When plants were deigned fifty or sixty years ago, the best available technology and materials were employed or used. Yet, we must understand that metals are not stronger than environments and over a period of time, deterioration sets in certain locations to a larger extent. In addition to this, the raw material input have over the decades considerably changed for the worse and in spite of best care, trace impurities find their way in.. Plant and equipment and piping system were not designed anticipating such changes and so more aggressive action occurs on already corroded parts and so failures occur at unexpected situation. So we are left with certain element of uncertainties.

Added to this is the problem of material mix up which takes place inadvertently specially in locations where specific alloys are designated and can force unexpected failures. This could happen when we have untrained personnel handling such material.

This is a simple presentation which high lights the importance of extending our training programmes to non engineering staff of any organization who also contribute to corrosion control directly or indirectly

In a modern urea plants more than 54 types of stainless steels are said to be used for various applications such as piping systems, reactors storage vessels and so on.
Ammonia is produced from natural gas and process air.

The process is divided in the following steps:

Step 00: Mercury & H2S Removal.

Step 01: Natural gas compression & desulphurization.

Step 02: Process air compression system.

Step 03: Primary & Secondary Reformers & steam generation system.

Step 04: High & Low temperature Shift conversion.

Step 05: CO2 removal system.

Step 06: Methanation system.

Step 07: Synthesis gas compression and Recycle gas compression.

Step 08: Ammonia synthesis system.

Step 09: Refrigeration system.

Step 10: Ammonia recovery system.

Step 11: Hydrogen recovery system.

Step 80: Process condensate stripping system.

The first, third, fourth and fifth steps are designed to remove impurities such as sulfur, carbon monoxide, carbon dioxide and water from the feed, hydrogen and synthesis gas streams. In the second step, hydrogen is manufactured and nitrogen is introduced into the process. The sixth step produces anhydrous ammonia from synthesis gas. All ammonia plants use this basic process, although process conditions such as temperatures, pressures and flow rates vary from plant to plant.
Three areas of failure

- Sulfur—present in natural gas feedstock, it causes high temperature sulfidation of metals, and it combines with other elements to form aggressive compounds, such as hydrogen sulfide, sulfur dioxide, and carbonyl sulfide.

- Chlorides—may be present, either by entrainment in natural gas, as carryover from boiler feed water, or in cooling waters. They may cause localized attack of some stainless steels.

- Carbon Dioxide—occurs in steam reforming of natural gas. It combines with moisture to form carbonic acid.

- Small quantities of sulfur are present at all times, either as H2S, SO2, or carbonyl sulfide. Traces of chlorides may also be present, either by entrainment in the natural gas or as carryover from boiler feed water used for steam manufacture. Thus, condensates highly corrosive to steel may be formed at the beginning of a carbon bed regeneration cycle. However, serious corrosion is avoided by addition of a small amount of ammonia to the steam to keep the condensate at a neutral or slightly alkaline pH. In the case of plants which have replaced CS by stainless steel, it is not certain if this step is correct.

The most affected components where failure are anticipated are

Pipe sections, Valves, Nozzles, elbows and Flange Joints which need special attention

The main equipments employing a lot of tubing material are primary and secondary reformer employing specific stainless steel alloys for specific equipment and section
Included are the process effluent transfer line from the primary to the secondary reformer; and crossover lines between the secondary reformer and primary waste heat boilers; and the primary waste heat boilers themselves. To prevent refractory erosion by the hot, high velocity gas streams, refractory surfaces are frequently lined with metal shrouds 1/16 to 1/4 inch thick (1.58 to 6.35 mm) of Types 304, 321 or 310. Types 304 and 321 have demonstrated satisfactory oxidation resistance in piping and equipment operating at 1290 to 1650°F (700 to 900°C) (e.g. transfer lines), whereas Type 310 has provided good protection at temperatures between 1650 and 1830°F (900 and 1000°C).

Therefore it is natural that a reasonable quantity of these material be held in stock or warehouse. The problem arises in that

1. long sections of pipe lines cannot be kept in sheltered store which has to hold about 40,000 items.

2. Stainless steel and carbon steel pipes that look alike (even if there be 200 different types with varying micro compositions but differ widely in physical and chemical properties) can create problems in case of mix up.

3. Even in the commonly spoken Duplex steel, an endless number of tailor made alloys are available and their compositions are held as secret patent and difficult to identify

But each equipment is assigned a specific stainless steel – for eg., AISI Types 304, 321, or 316 stainless steels are specified for-stream instrumentation and valve trim.

Catalytic steam reforming of natural gas occurs at elevated temperatures - 1290 to 1830°F (700 to 1000°C) - so materials of construction may be subjected to a number of high-
temperature metal wastage phenomena in addition to simple oxidation. Sulfur entrainment and boiler feed water salts carryover in the natural gas/steam reformer feed can cause sulfidation and molten salt attack respectively of reformer catalyst tubes, outlet manifolds and transfer lines.

Fluctuations in steam/methane ratios subject alloys for a highly destructive cyclic carburization/oxidation phenomenon similar to metal dusting. Trace amounts of impurities such as lead in reformer tube alloys will promote catastrophic oxidation of these alloys.

Types 304, 321 and 310 inside the primary reformer firebox for heat; thermocouple sheaths, thermal/mechanical protection tubes around thermowells; manifold drain and sample nozzles; and flue gas sample tubing.

High-pressure steam, which is generated utilize demineralizing water with ion exchange resins. Water quality of less than 5 parts per billion total impurities is common. To maintain this purity and for good, all-around corrosion resistance in this aggressive medium, Type 304 is frequently specified for demineralized water storage tanks and piping, and trim in valves and pumps. Type 316 finds applications in the ion exchange resin system because of good resistance to cold, dilute caustic and sulfuric acid solutions which are used for regenerating the resin beds.

One of the important thing to notice is that a wide variety of St steel - 304, 316, 321, 410 etc are used specifically for each purpose.(4,5,6)

**CORROSION PATTERNS**

Three main types of failures commonly occur are

1. Crevice corrosion of dresser valves
2. pitting in piping
3. stress corrosion cracking( 2,3)
A sudden failure in one of the piping was reported after a normal turn around period, and when all possible causes for failures were ruled out, a cross examination on the material drawn from ware house was instituted. In one case a material mix up was found as root cause and in another case the piping has been found to be defective subjected to poor warehousing conditions.

Based on this, corrosion consultant was invited to conduct a three day training programme to all ware house personnel on principles of corrosion and need for preserving different material such as Stainless steel and expensive alloys and fiber glass and non metallic material as well. A half day field work of inspection including open yard and sheltered store to teach the right way of preserving, identification tags, avoiding sticker labels and markings and galvanic corrosion. Care of piping using end caps, right way of wrapping and intact- right way of stacking etc.. Best of all, a half day practical session on testing material and to sort out material mix up, simple test methods and equipments was conducted. Some of the pictures below show the defects and the condition of open field storing.
Even components in racks in sheltered stored were not properly capped or covered and found dusty – specially valves, which is frequent failing component. There were many other effective Ware house management techniques included in that training and was a great welcome. Most of the material were expensive – a million dollar worth- and are meant for critical application.

Right and wrong way of stacking angles and structural material. Condensed water caused water marks which promote crevice corrosion and pitting under dust collected. Like most people the ware house personnel believe that stainless steel is stainless and nee no special attention and the superficial marks can be wiped clean. When basic principles of corrosion was explained – it was a matter of great surprise.

Pipes with no end caps and partially wrapped rods and pipes most of them stainless steel. Some of them suffered galvanic action with the rack supports and condensed water with dissolved gases in the aggressive atmosphere. With stainless steel, if once corrosion begins that is the end of the story. So the right way of preservation was imperative,
What is the best way of preserving the expensive stainless steel material?

For identification of a material what is the best way?

Why Marking with marker pens or using sticker labels is forbidden?

What will happen if tags are torn off by wind or by mistake?

These are tips regularly taught in BCC and other courses to engineers. But warehouse personnel have to see the damages and learn.

These are shown in the following figs.

Following the failure of a pipe line, the investigation pointed the origin of failures is due to poor ware housing principles.– whether a material mix up or a defective stainless steel. The next question is – Who is responsible for this?
These are instructions repeatedly taught in most NACE training courses- BUT TO WHOM?. It stops with engineers and not passed on to the personnel who really need such education.

Even valves in racks in side the sheltered sheds were not preserved properly with no end caps or cover from dust. After inspection they should have been covered properly. Are not these often failing components?

Who is responsible for this?. Warehouse personnel or the end user?

Who should make sure the items are left covered after inspection?

CONCLUSION

1. Following this, a three day in house training with half day field training and tour to ware house and open yard was arranged, where all defective way of handling material which are a million dollar worth was explained.

2. Besides joint inspection both by warehouse personnel and engineering staff- both at time of receipt and issue was recommended to avoid mistaken supply and material mix up,. There were cases of failures on both account. Case of a wrong material supply (AISI 304 instead of 316) was also reported which detected only after usage and failure.

3. Also simple test procedures and testing equipment for various material- not only for metals and expensive alloys- but materials like rubber and gasket material which deteriorate over time was explained.

4. In addition to course material they had a small lab. training as well was programmed drawing samples from their own stores.

After this training every one including the warehouse Manager felt elated about the importance of his personnel in asset management- which are a million dollar worth.

5. This is an area where NACE international can focus attention – not only engineers but other non technical staff as well, who need corrosion awareness training and courses specially in Fertilizer plants where we have not given as much attention as on Refineries.
BIBLIOGRAPHY

1. Corrosion resistance of the Austenitic chromium-nickel stainless steels In chemical environments --- inco new York 1963

2. A.Hassan Faraj- Stress Corrosion Cracking of Austenitic Stainless steel in Fertilizer plants - Corrosion 2003 paper 03523

3. Masuo Nakahara -Preventing Stress corrosion cracking of Stainless steel in Chemical plants- - Instt.. NIDI- no. 10066

