الإتحاد العربي للأسمدة
هيئة عربية دولية Arab Int'l. Organization
Arab Fertilizers Association
Since: 1975

Arab Fertilizers Industry:

Successful Case Studies

2011

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Since 1975

Environmental Projects in Albayroni

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Achieving NOx emissions, satisfying the Royal Commission permissible limits in old operating Reformer Furnaces and Package Boilers without jeopardizing designed production is a major challenge to the process industry.

Albayroni / SABIC targeted to bring down NOx emissions to less than or equal to 60 ng/J in its Reformer and package boilers, which are operating since 1995 in 2-Ethyl Hexanol (2-EH) Plant and since 1983 in fertilizer complex respectively.

Albayroni conducted a feasibility study evaluating all possible means to control NOx emissions. The study detailed all the practicing methodologies for reducing NOx emissions from the Reformer as well as Package boilers and recommended technically most suitable solution.

The paper highlights all the NOx reduction methods evaluated and the advantages of choosing State of the art and Proprietary 'Large Scale Vortex' (LSV) ultra low NOx burners for reformer and low NOx Dynaswirl burners for package boilers over other methods.

INTRODUCTION

Albayroni produces both Fertilizers and petrochemicals products with required utilities produced and supplied internally. The Fertilizer plants which consists of Ammonia & Urea started in Year 1983 and Petrochemical plants consisting of 2-Ethyl Hexanol (2-EH) & Di-Octyl Phthalate (DOP) started in Y 1996 and both these plants are well supported by in-house Utility plants, also started in Year 1983 & expansion in Y 1995. At the time of inception of these units, NOx control measures were yet to initiate in the Kingdom of Saudi Arabia.

Once NOx controls became a reality in Al-Jubail, Albayroni with its commitment towards environment, had taken up controlling such discharges to environment meeting the Royal Commission standards. Two sources of NOx emissions were identified, one at Reformer in Syngas area of 2-EH plant and the other at Boiler of Utility Plant.

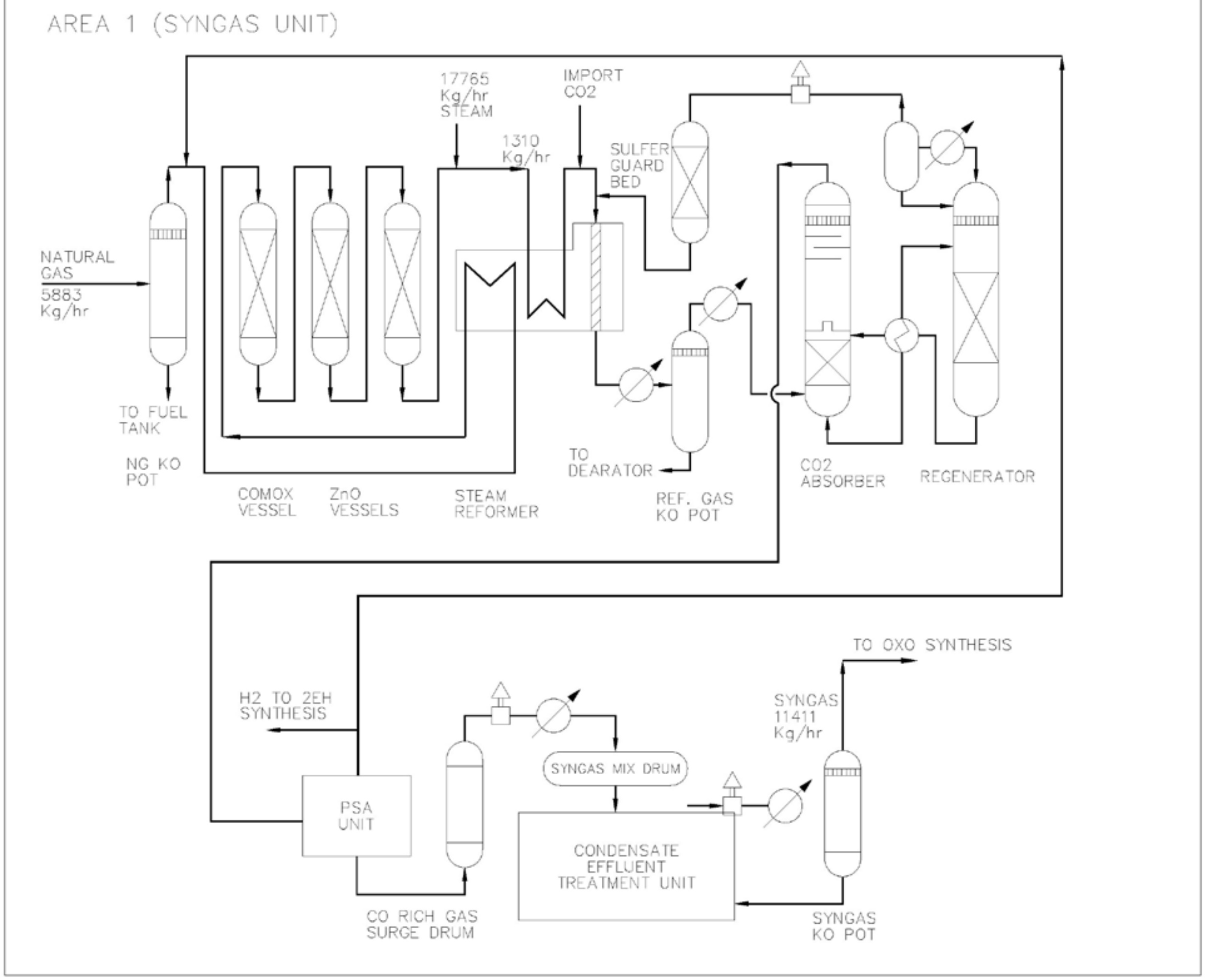
Identifying and evaluating the most suitable options to reduce the NOx levels from these sources to within royal commission standards while maintaining the respective plants design capacities were of top priorities.

SYNGAS AREA OVERVIEW

2-EH plant consists of three processing areas in series viz. Syngas Generation, Oxo Synthesis and 2-EH synthesis. Syngas is one of the main feeds for manufacturing the Aldehyde in OXO synthesis area, which is further used for synthesizing 2-EH. Syngas generation area having a reformer is the only source of producing thermal NOx at 97 ng/J and discharging to atmosphere through its stack.

The objective of syngas generation area is to produce Synthesis gas at 746 kmol/hr from feed Natural Gas with H2/CO ratio of 1.02. In this area, the feed Natural Gas Sulphur removal takes place in Desulphurization section which consists of Hydrodesulfuriser and Zinc Oxide absorbers operating at 380 oC. The synthesis gas unit utilizes a single high temperature reforming stage employing a natural gas steam reforming catalyst in a tubular down fired furnace. The reformed gas, Hydrogen, Carbon monoxide and Carbon dioxide thus produced contains more Hydrogen in relation to carbon monoxide than is needed for the production of 2EH via the low pressure OXO process. The carbon dioxide is then removed from by an amino solvent in a Carbon dioxide removal section and recycled back to reformer to increase proportion of Carbon monoxide in the reformed gas thus reducing the excess hydrogen in the synthesis gas. This gas further introduced to a pressure swing adsorption (PSA) unit filled with molecular sieves where pure hydrogen is removed from the reformed gas to give a waste gas which when blended with a PSA bypass gas gives a synthesis gas with H2/CO ratio of 1.02.

The schematic diagram of the Syngas generation area is displayed in figure 1.


AREA 1 (SYNGAS UNIT)
NATURAL GAS 5863 Kg/hr
17765 Kg/hr STEAM
1310 Kg/hr
IMPORT CO2
SULFER GUARD BED
TO FUEL TANK
NG KO POT
COMOX VESSEL
ZnO VESSELS
STEAM REFORMER
TO DEARATOR
REF. GAS KO POT
CO2 ABSORBER
REGENERATOR
TO OXO SYNTHESIS
H2 TO 2EH SYNTHESIS
SYNGAS 11411 Kg/hr
SYNGAS MIX DRUM
PSA UNIT
CONDENSATE EFFLUENT TREATMENT UNIT
CO RICH GAS SURGE DRUM
SYNGAS KO POT
Figure 1

2-EH REFORMER

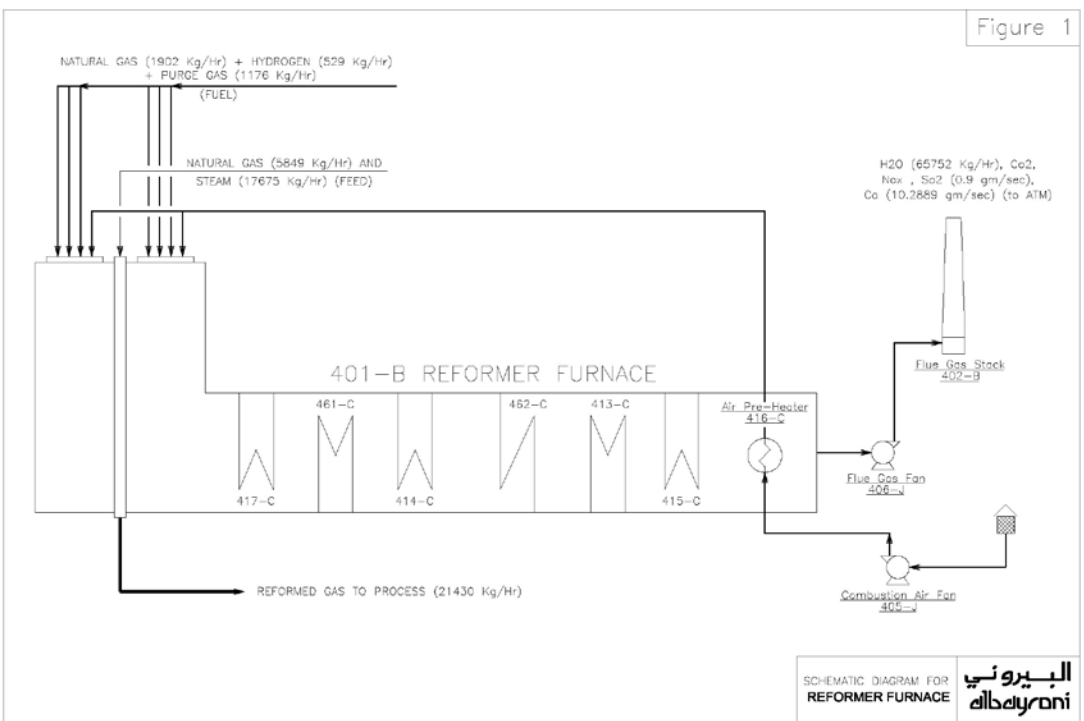
The treated Natural Gas along with process steam is reformed in the gas fired reformer to produce carbon oxides and hydrogen. The reformer consists of primarily radiant section and convection section.

The radiant section has 88 reformer tubes for processing the gas-steam mixture and 35 down fired burners for supplying the heat required for the reforming reaction.

The convection section includes, starting from hot flue gas side, a natural circulation Radiant Shield Boiler (417-C), HT Steam Super-heater (461-C), Mixed Feed Heater (414-C), LT Steam Super-heater (462-C), Desulfurised feed pre-heater (413-C), Flue Gas Boiler (415-C).

The flue gases through Flue Gas Fan (406-J) finally pass to the Combustion Air Pre-heater (416-C) before routed to the Stack (402-B) at a flow of 76231 kg/hr and 146 ^oC temperature. The Reformer section of Syngas area is schematically shown in figure 2

Figure 2

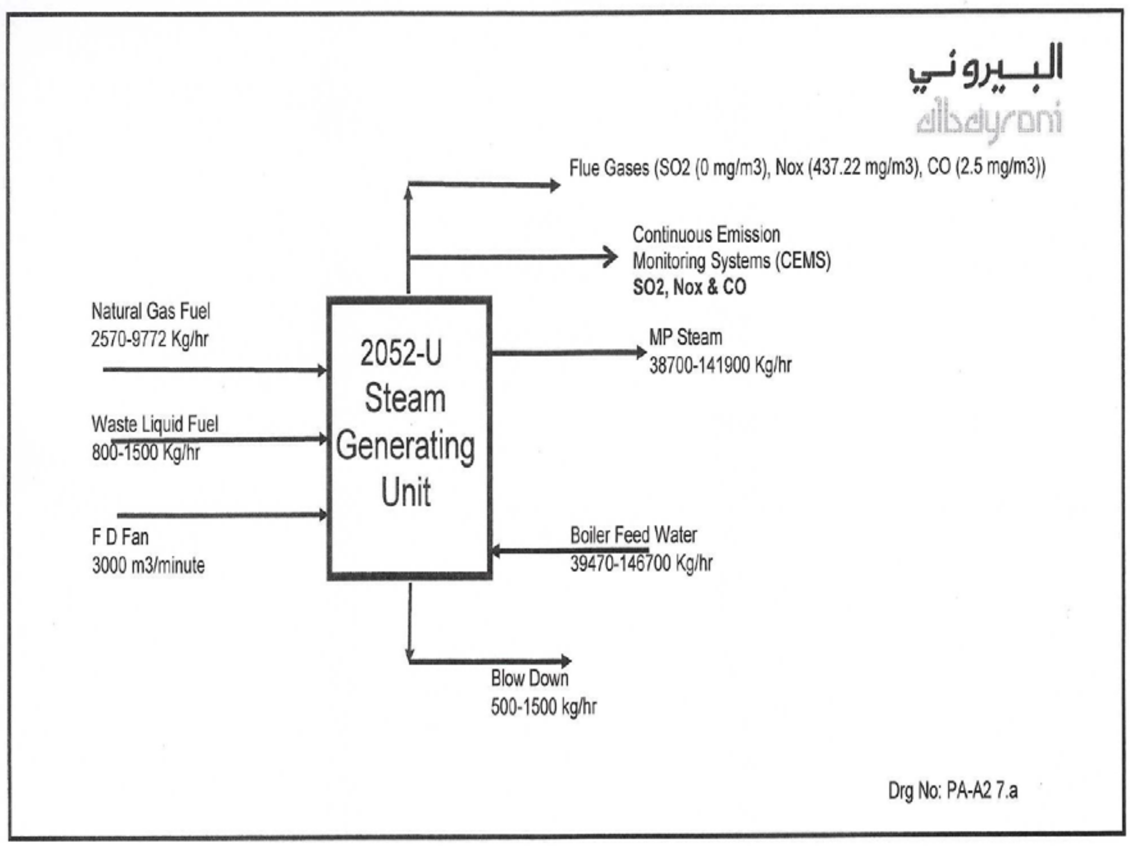


UTILITY BOILER

Albayroni has three package boilers supplied by M/S Mitsubishi two of which fired by Natural gas and the other both by Natural gas and waste liquid fuels. All the three boilers consists of burners, radiant section, convection section, forced draft fan and a stack without an economizer.

Boiler feed water (BFW) is continuously feed to steam drum through tubes where it got heated up because of natural gas firing in the boiler furnace which is operating under slight negative pressure. The boiler consists of radiant section and convection section while required combustion air shall be supplied by combustion air fan and generated flue gases are sent to a stack. The Boiler 2052-U section is schematically shown in figure 3

Figure 3



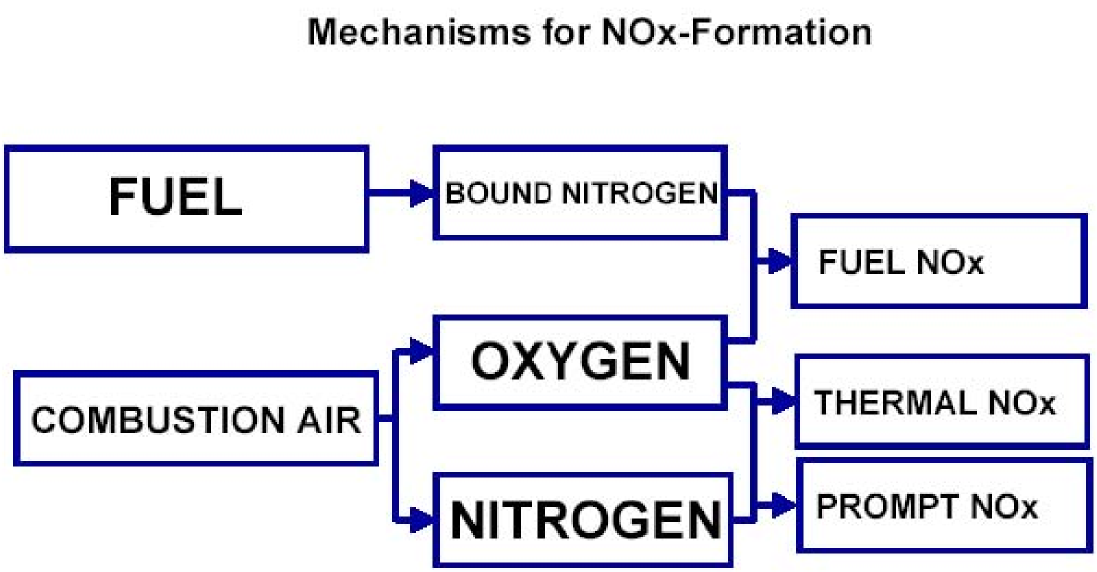
PROCESS EVALUATION OF NOx EMMISSION REDUCTION METHODS

2-EH Reformer NOx Reduction

As part of Albayroni environmental objective a study had been conducted in order to establish the most cost effective method for reducing NOx emission levels from 97 ng/J to 50 ng/J with NOx as NO_2, based on high heating value (<52% of the current NOx emission level)while maintaining the design Syngas production of 746 kmol/hr. Both Primary reduction methods as well as Secondary reduction methods are evaluated.

Mechanisms for NOx Formation

Nitrogen oxides (NOx) is a collective name for NO and NO_2. These oxides are a byproduct of combustion and chemical processes. Most NOx sources in the process industry are high temperature combustion systems.



Factors Affecting NOx Formation

Key physical parameters that influence the NOx formation include fuel gas quality, air-to-fuel ratio, combustion air temperature, firebox temperature, and burner design.

Excess Combustion Air	In general, depending on the burner type, an increase in excess combustion air increases NOx
Fuel Quality	A higher amount of heavy HCBN and or hydrogen increases the flame temperature and increases NOx

Combustion Air Preheat Temperature □	Raises flame temperature which raises NOx
Firebox Temperature	Higher firebox temperature, lower efficiency and higher flame temperature results in higher NOx

NOx Control Technology

There are two main approaches to reduce NOx emission
Primary NOx reduction methods aim to minimize the formation of NOx at the source, which is the combustion process in the radiant section (the firebox) of the furnace. Secondary NOx reduction methods reduce already formed NOx via flue gas treatment.

NOx control methods	
Primary NOx reduction methods	Secondary NOx reduction methods
▪ Ultra Low NOx Burners ▪ Low Excess Air Combustion ▪ Fuel Dilution ▪ Flue Gas Recirculation (external)	▪ Selective Non Catalytic Reduction (SNCR) ▪ Selective Catalytic Reduction (SCR)

A proper understanding of the combustion kinetics and fluid-dynamics in the firebox chamber is required in order to arrive at a furnace design which combines stable and efficient combustion and meets environmental NOx and CO emission constraints.

Primary NOx Reduction Methods:

Ultra Low NOx Burners

Ultra low NOx burners apply staged air, staged fuel or flue gas recirculation techniques to lower NOx formation. Different burner suppliers use these techniques or combinations of these techniques to lower the NOx formation.

Low Excess Air Combustion

Application of automatic excess air control was exist already in the process industry which shall improve the reformer firing control system. Low excess air operation increases the furnace efficiency, while lowering the NOx formation.

Fuel Dilution

Fuel dilution (e.g. steam injection) has been used on only a few process heaters. Typical NOx reduction is in the range 10-20 percent. This reduction efficiency is less than the required reduction efficiency of about 50 percent. Another drawback of this technology is the increased energy costs associated with transporting and reheating the diluent. Because of the above, the fuel dilution technique cannot achieve the required NOx reduction efficiency for this study.

Flue Gas Recirculation (external)

External flue gas recirculation has also been used on only a few process heaters. The portion of flue gas that is recirculated is typically 10-15%. This has effect of diluting the combustion air with inert gases and reduces the NOx formation with about 10-20 percent. This reduction efficiency is less than the required reduction efficiency of about 50 percent. Other drawbacks of this technology are:

- Cost of fan, duct work, controls etc.
- Increased energy costs (associated with transporting and reheating the recirculated flue gas)
- Burner stability concerns, reduced reliability
- Not proven for steam reformer applications.

Because of the above, this option is not further evaluated.

Secondary NOx Reduction Methods:

Selective Non Catalytic Reduction (SNCR)

SNCR uses either ammonia (Exxon Thermal De-NOx) or urea (NOx OUTTM) as the reducing agent for NOx. If urea is the reduction agent, it decomposes to ammonia, which reacts with the NOx. In the absence of catalyst, the NOx reducing reactions that occur with ammonia or urea require relative long residence times at high temperatures. The application of SNCR is therefore limited to process heaters that provide this combination of conditions. The ammonia slip will be greater than that found with SCR. As a result, substantial formation of ammonium bisulphate may occur when sulphur-bearing fuels are uses as in the case of this study. This ammonium bisulphate may collect in air preheater and on the cooler tubes in the convection section. Because of the relative low NOx reduction in the range 30 – 50 percent that is generally experienced, the high ammonia slip and risk of ammonium bisulphate formation, this option is not further evaluated.

Selective Catalytic Reduction (SCR)

SCR uses ammonia as the reducing agent for NOx. The difference with SNCR is that a catalyst is used that allows the reaction to proceed at lower temperatures and that a greater NOx reduction can be achieved. There are three basic types of SCR technology:

- Low-temperature catalyst (150 – 280°C)
- Medium-temperature catalyst (280 – 400°C)
- High-temperature catalyst (400 – 550°C)

SCR Catalyst Deactivation Mechanisms:

Under ideal conditions the SCR catalyst would be able to reduce NOx for an unlimited period of time. However, there are many factors that cause the SCR catalyst to prematurely and/or permanently deactivate. The loss of catalyst activity over time is generally divided into two categories; chemical deactivation and physical deactivation. Chemical deactivation is called poisoning, and is caused by the strong chemisorption of reactants, products or impurities on sites otherwise available for catalysis. Equally important is physical deactivation, which occurs when the pores of the catalyst become blocked, effectively preventing the NOx from contacting the catalyst. Both of these general types of deactivation have the effect of reducing the De-NOx capability of the catalyst. The individual mechanisms of deactivation are summarized below.

Sulphur:

SO_3 formed during combustion and by catalytic reaction combines with ammonia to create ammonium bisulfate, which is a small sticky particle that causes major fouling problems in the air heater and on the catalyst surface. These formations are a function of SO_3 and NH_3 concentrations and occur as the flue gas temperature is lowered. Increased vanadium in the catalyst improves De-NOx activity, but also increases the oxidation of SO_2 to SO_3, increasing the SO_3 concentration of the flue gas. The SO_2 oxidation is a strong function of temperature and even low-vanadium and no-vanadium catalyst formulations will oxidize some of the SO_2 to SO_3. Common SO_2 oxidation rates range from 0.5% to as high as 3% or more on low sulfur fuels. The impact of sulphur can be minimized by increasing catalyst volumes to provide spare surface area for deposition, and by periodic operation at higher temperatures to de-sublime the deposited ammonium bisulfate.

Thermal Sintering:

Thermal catalyst deactivation, known as sintering, can be attributed to changes in the physical structure of the catalyst itself. Thermal sintering causes the loss of catalyst active sites due to metallic crystallite growth, reducing the available surface area for the De-NOx reaction. In addition, the titanium catalyst substrate can lose surface area due to a change in its crystalline structure. Both of these phenomenons occur at high temperatures. Thermal stability is maximized by incorporation of tungsten in the catalyst formulation, with different formulations having different maximum operating temperatures. As a result, sintering is negligible at normal SCR operating temperatures.

Deposition of Alkaline Metals:

Alkaline metals - particularly sodium and potassium - may directly react with active sites and render them inert. Sodium (Na) and potassium (K) are of prime concern especially in their water-soluble forms, which are mobile and penetrate into the catalyst pores. Since the NOx reduction reaction takes place primarily near the outer surfaces of the catalyst, the degree of deactivation depends on the concentration of alkaline metals on fly ash surfaces which may contact the active catalyst sites.

Location of the SCR unit

The location of the SCR unit in the flue gas train is very important. There is some flexibility in the operating temperatures, but in general the performance of an SCR unit is very much dependent on its location within the appropriate temperature “window”.
For this study two locations are evaluated:

- Inlet flue gas ID fan (208 - 221 °C)
- Duct between convection exit and APH inlet (373 - 393 °C)

Low-temperature SCR can reduce investment costs because it can be located at the end of the stack gas train, which is a low-temperature area. This minimizes the need to install complex ducting from high-temperature areas and then return the flue gas to the stack gas train.

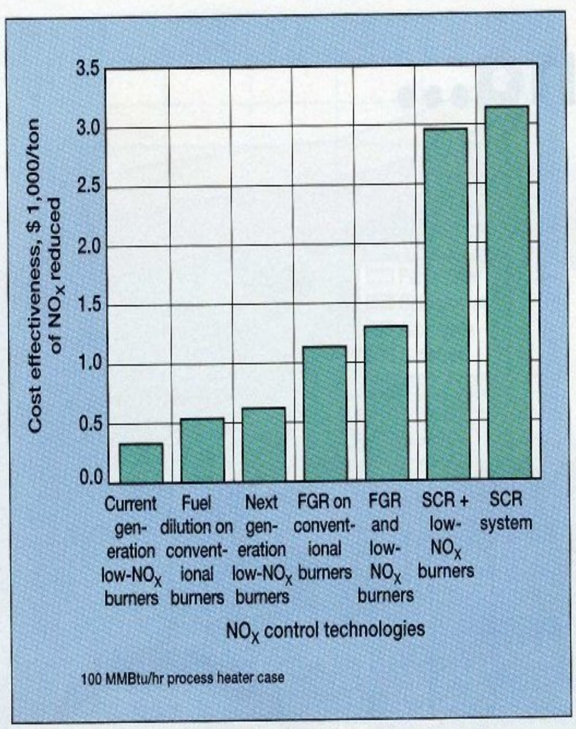
Medium temperature catalyst can withstand high sulphur in the flue gas. However, the main disadvantage is that the proper temperature does not exist in the flue gas train. The temperature of the flue gas in the duct between the convection exit and APH inlet of 373°C and 393°C is above the optimum temperature range for Medium temperature SCR catalyst.

Required Process Modifications for SCR De-NOx system

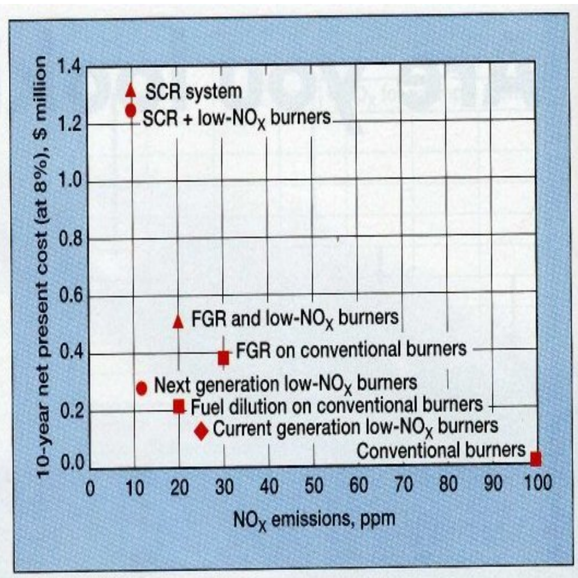
Because of the additional pressure loss of the SCR De-NOx catalyst and the pressure losses of the ducting the flue gas ID fan shall be replaced with a larger fan.

The following additional equipment is required for an SCR De-NOx system:

- SCR Reactor (near flue gas fan)
- Flue gas duct from combustion air preheater to Reactor
- Flue gas duct from Reactor to flue gas ID fan
- Ammonia injection grid
- Ammonia gas supply system from B.L. (NH_3 consumption about 7 kg/h)
- Ammonia flow control
- Dilution media fan (air)
- Replacement of the Flue gas ID fan to compensate for the extra pressure loss
- NOx analyzer at the outlet of the flue gas ID fan



NOx control equipment cost-effectiveness in $/t of NOx reduction.



Cost and performance comparison of NOx reduction equipment (100 MMBtu/hr).

Final Options Left to Reduce the NOx Emissions:

Option A – Installation of Ultra low NOx LSV burners

Large Scale Vortex (LSV) burners can meet the NOx emission requirements. To meet the operations flexibility requirement of possibility of liquid fuel firing (I-BAL), a number of additional measures need to be taken. These are in brief, facilities to vaporize the liquid fuel, preheat the gas fuel and to assure minimum temperature holding of the vaporized fuel to the burners.
As the margins between process design parameters and revamp case conditions for the convection section are very narrow under the current conditions, it should be considered to replace also the flue gas fan to ensure a higher flue gas flow, while firing less hydrogen fuel.

Option B – Installation of an SCR De-NOx system

An SCR De-NOx system can meet the NOx emission requirements. However, the initial investment for such modification is much higher compared to the Ultra low NOx LSV burner's option. The installation of a De-NOx unit will increase the flue gas pressure drop, which cannot be handled by the existing ID fan so that the ID fan shall be replaced. Further, also an ammonia injection grid, ammonia dosing and control and modification of the ducting are required.

Based on following criteria the option A was selected and implemented at 2-EH plant in Albayroni

- No variable costs
- No equipments required except replacing existing burners.
- No catalysts required
- No change in process
- Easy operation & maintenance

Ultra Low NOx LSV Burner

Different burner suppliers like Air Products / John Zink, Lanemark, Zeeco, Hamworthy and Callidus were enquired and finally Air Products / John Zink was selected based on its references for ultra low NOx reformer burners for similar service. Plant past data suggests that furnaces with ultra low NOx burners tend to have a higher flue gas temperature at the radiant cross over by about 20 ^{o}C and this effect was taken into account for furnace performance evaluation with these type of burners.

The LSV burner is based on proprietary know-how from Air Products and Chemicals Inc. The burner is manufactured and commercialized by John Zink Company under a license form Air Products and Chemicals Inc.

References:

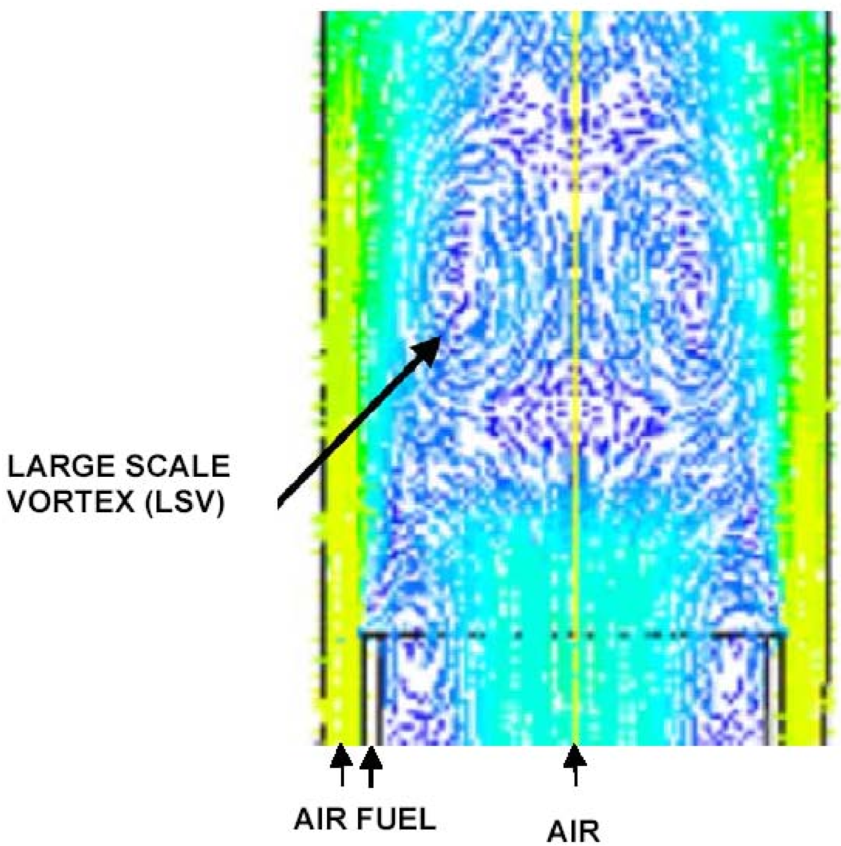
The LSV burner has been successfully applied in two Techip designed steam-reformers currently operated by Air Products. One is the 110 MM SCFD hydrogen plant in Westlake, Louisiana, USA. The LSV burner has also been selected by a European refinery and Technip for an 80 MM SCFD hydrogen steam-reformer project in Northern Europe that is recently started-up.

LSV Burner Principles

To reduce the NOx emission in the stack effluent, the LSV burner and the furnace designers are creating special flow and temperature patterns of fuel, air and combustibles to create local conditions that are unfavorable for NOx formation or which favor the reduction of already formed NOx.

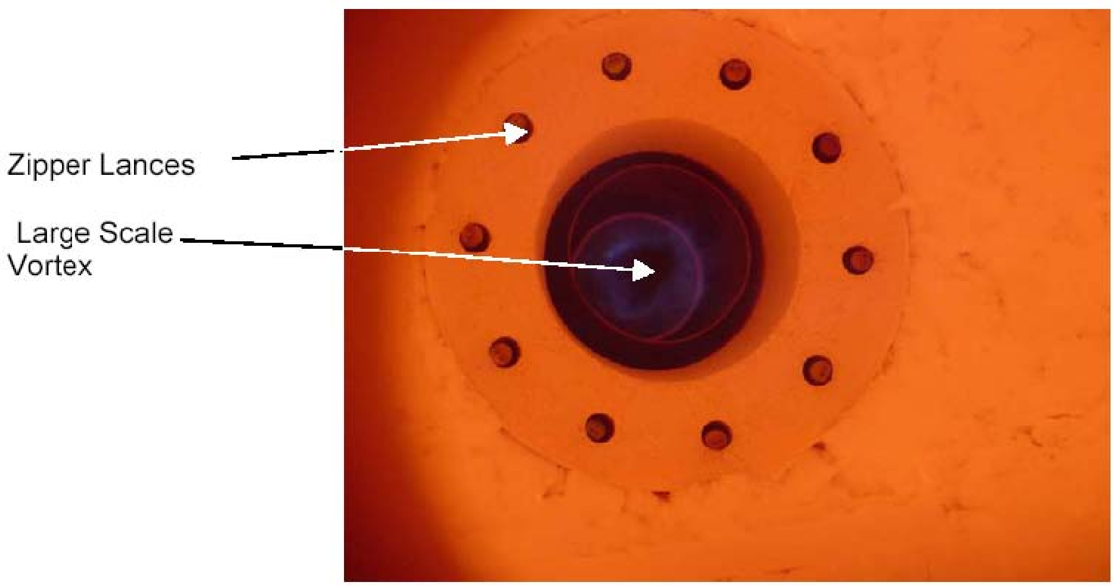
At the same time, the flame needs to be stable not only at design conditions but also over a large turndown ratio. Flame rollover that may cause flame-impingement on the radiant coil should be avoided at all times. The stability of the flame is determined by the burner design and by the firebox geometry and heat-flux patterns. Unfortunately, the conditions favoring low NOx are generally contradictory to the conditions of creating stable flames.

In the LSV burner design, the flame stability is reached by creating a large-scale vortex in the center of the flame. This flame-stabilizing vortex is created by mixing part of the air with a small portion of the fuel at dissimilar velocities. The LSV burner, contrary to other ultra low NOx burners, does not contain metallic or ceramic flame stabilizers, which are known as a source of Prompt NOx.



The LSV stabilizer has a very large turndown ratio providing superior flame stability performance with a variety of fuels and compositions. Typically, the LSV burner has a turndown ratio of 1 to 10 or more keeping the flame stable. The remainder of the combustion air is staged concentrically around the vortex. Specially designed Zipper lances to create optimum mixing stage the largest portion of the fuel. The technology applied in the Zipper TM lances is inspired from the Stealth Aircraft technology where similar mixing principles are applied to keep jet engine exhaust temperatures down to avoid upper atmosphere IR detection.

When fuel lances are exposed to hot radiation, overheating causes coking over time and extensive fouling problems may occur. Due to their efficient mixing capability, the Zipper lances do not require extension into the combustion space and overheating and fouling is avoided.

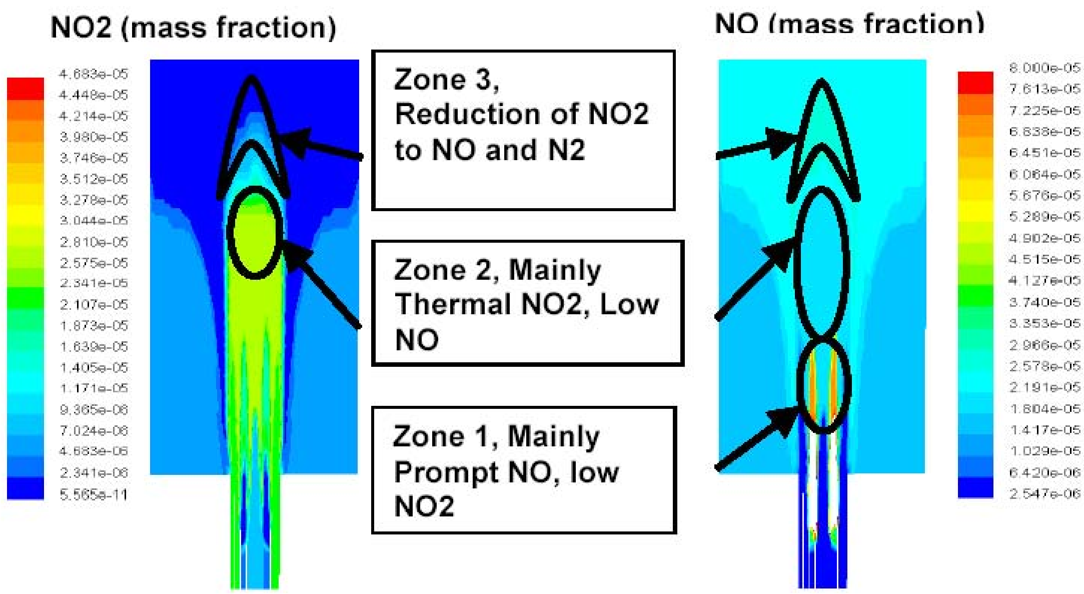


LSV Burner in Service

During burner lighting and the initial furnace heating the LSV burners are switched into a so-called start-up mode. In the start-up mode the fuel is routed to the Large Scale Vortex and to a start-up gun in the centerline of the burner. During start-up mode the flame is visible. During normal operation when the furnace temperature is above 750 °C the burners are switched to Low NOx mode. In the Low NOx mode the fuel is routed to the Large Scale Vortex and to the zipper lances. During Low NOx mode operation, the flame is spatial and the NOx emissions are very low.

CFD-NOx simulation (by TECHNIP) of the LSV burner

Technip has applied its proprietary CFD-NOx simulator to investigate the performance of the LSV burner in a radiant firebox environment such as hydrogen steam methane reformers.
Besides the earlier mentioned laboratory burner simulation, further validations of the CFD-NOx simulator were done using the LSV burner performance data in the Westlake steam-reformer and data of the LSV burner performance for the European Steam-reformer project in the test-furnace. The CFD-NOx simulator successfully predicts the temperature distribution in the firebox as well as flame shape and the profile of the heat flux to the radiant coil. Further the NOx prediction compares very well with the measured plant data. Concerning application of the LSV burner for Technip designed furnaces; each project encompasses a demonstration test of a burner, in a John Zink test-furnace to be witnessed by the customer. During this phase, burner design parameters such as those to obtain desired flame-length and heat-release pattern are finally chosen.
In a CFD-NOx simulation of the LSV burner, three distinct zones can be recognized.



In Zone1, where the first small portion of the total fuel comes into contact with the central air stream, local unburned hydrocarbons cause formation of Prompt NO and the NO concentrations are relatively high. However due to the rapid mixing in the Large Scale Vortex, the absolute volume of such high NO concentrations is very small and consequently the absolute amount of NO remains very low. In Zone 2, where remaining volumes of air and fuel are fed in a staged manner, the NO formed in Zone 1 by means of the Prompt NOx mechanism, as well as molecular N2, are both oxidized to NO2 via the Thermal NOx route. When combustibles are entering Zone 3, combustion in the LSV burner is virtually completed. Concentrations of unburned hydrocarbons are extremely low, and air remaining is only the stoichiometric excess air fed to the burner. Conditions in Zone 3 are favorable for the reduction of NO2 to NO and N2. The NOx left in the flue gas leaving Zone3, determines the final achieved NOx levels. Those are very low and consist mainly of NO with very low amounts of NO2.

Utility Boiler NOx Reduction

In the case of meeting an upcoming NOx regulation in Utility Boilers, two of the vendors M/S Mitsubishi and M/S John Zink considered for technical evaluation based on their wide range of combustion experience. While in the course of technical evaluation M/S John Zink low NOx burners of type Todd Dynaswirl were selected for implementation at Albayroni Utility Boilers mainly based on no additional operating costs are demanded with these new type of burners.

Dynaswirl Low NOx Burners

The Dynaswirl-LN burner was developed to provide the maximum degree of flexibility in achieving high burner turndown, low NOx emissions and improved flame shaping capability. The basis of the design is to develop a stratified flame structure with specific sections of the flame operating fuel rich and other sections operating fuel lean. The burner design thus provides for the internal staging of the flame to achieve reductions of NOx emissions while maintaining a stable flame.

Burner Description

The basis of this burner design is the Dynaswirl-LN burner. The venturi air sleeve for the standard Dynaswirl burner provides for the primary and secondary air flow to the burner. To increase the flexibility of combustion staging and flame shaping capabilities, the Dynaswirl-LN is equipped with a tertiary air recirculating quarl. This is installed at the outer periphery of the burner throat. The tertiary air is mixed in the furnace with the bulk furnace gas to achieve complete fuel burnout and low NOx performance. This provides for the complete burnout of the fuel in the post combustion zone where NOx formation is inhibited by lower combustion temperature and reduced O2 concentration.

PERFORMANCE RESULTS

2-EH REFORMER

NOx measurements were performed by an independent laboratory GBN, Global Business Network, invited and witnessed by Al Bayroni and approved by the Royal Commission.

Source	Average NOx Emission (ng/J) Before Modification	Current NOx Emission (ng/J) After Modification	RCER 2004 Limit (ng/J)
2-EH Reformer (401-B)	97	< 36.0	60.2

UTILITY BOLIERS

S.No	Source	Average NOx Emission (ng/J) Before Modification	Current NOx Emission (ng/J) After Modification	RCER 2004 Limit (ng/J)
1	Boiler 2008U	82.9	22.8	60.2
2	Boiler 2008UA	87.4	20.8	60.2
3	Boiler 2052U	115	26.7	94.7

CONCLUSIONS

1. When evaluating any NOx reduction project it is vital to first determine which control technologies will be able to meet the emissions required.
2. While realizing the value of identifying the optimum solution for each case, evaluating the performance and cost of every available technology can be a daunting task.
3. Only next generation low NOx burners or SCR systems able to meet some of the newest regulations that require NOx emissions less than 10 ppm.
4. Current generation of low NOx burners, fuel dilution on conventional burners and next generation low NOx burners provide the most cost effective NOx control
5. FGR systems which require a fan for flue gas recirculation make up the next tier of cost effectiveness.
6. SCR systems and combination involving a SCR are the least cost effective. However, SCRs are able to achieve a lower NOx emission levels than most of the other options.
7. Installing current generation low NOx burners in combination with SCR system both decreases the overall NOx produced and costs which can be attractive option for the most cost effective way to meet the tightest NOx regulations.
8. Finally the technologies that require only a burner change out or duct work seem to have an economic advantage over those options requiring recirculation fans or complicated SCR systems.
9. When faced with meeting an upcoming NOx regulation, operating companies should enlist an equipment supplier or engineering company with a wide range of combustion experience to aid in selecting the best technology for each application.

10. Albayroni selected M/S Technip for the 2-EH Reformer NOX regulations and M/S John Zink for the Utility Boiler NOx regulations.

Author's Biography

- **C.V.S. Prasad** studied MS in Chemical Engineering at the Regional Engineering College, Warangal, India. Since 1985 for the span of over 24 years he possesses diverse and challenging experience internationally with various manufacturing industries in the fields of operations, projects & process. On a career path had experience with reputed international organizations like SABIC & PETRONAS From 1995-2000 he worked in Albayroni, SABIC and since Y 2005 he is associated with Process section of Reliability & Plant Support department in Albayroni, SABIC.

- **Meshal Al-Muwallad** is a Process Engineer holds a BS degree in Applied Chemical Engineering from King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. After graduation he joined SNC LAVALIN Company. During his work of two years he get the experience in the fields of projects, design calculations, and simulation. Since April 2008 he joined Albayroni, Sabic with Process section of Reliability Plant Support department.

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Arab Fertilizers Association
Since 1975

Urea Dust & Ammonia Emission Control from Prilling Tower

Mr. Rafea Al-Mohaws - Albayroni
Mr. Hassan Al-Khulaif - Albayroni
Mr. Basheer Al-Awami - SABIC

Urea Dust & Ammonia Emission Control from Prilling Tower

***

Presented by:

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Mr. Hassan Al-Khulaif - Albayroni

Mr. Basheer Al-Awami - SABIC

Table of Contents

1.0 Abstract

SABIC has committed itself to adopt the state of the art technology to be a pioneer in environmental sustainability. AlBayroni, one of SABIC Affiliates, owns Urea Plant which was commissioned in 1983. The plant is having a natural draught Prilling Tower with continuous emission of Urea Dust Particles and Ammonia to the atmosphere which was the latest technology at that time.

As a strategic proactive approach AlBayroni has reduced the urea dust, ammonia emission and waste water discharge from Urea plant by implementing a prill tower dust recovery systems. The paper shares the experience of AlBayroni in achieving reduction in Urea dust and Ammonia emission exceeding international requirements/standards. The best available technology was adopted. The system mainly consists of acid wash scrubbers, and a crystallization unit to recover the absorbed materials. PROZAP Co. from Poland did the engineering work and supplied the proprietary equipment while GEA Messo Co. from Germany supplied the crystallization unit.

In addition, this paper addresses the lessons learned during the execution of the project and judged to be of great value to plants who want to implement similar environmental projects.

2.0 Introduction

Al-Jubail Fertilizer Co (Al-Bayroni) is a 50/ 50 joint venture between Saudi Basic Industries Corporation (SABIC) and the Taiwan Fertilizer Company (T.F.C). Al Bayroni was established on December 4th, 1979 to manufacture fertilizers. Commercial production of ammonia and urea fertilizer began in early 1983.

The process licenser of Ammonia plant is KBR and it has a capacity of 1270 MTPD.
In addition, the process licenser of urea plant is Stamicarbon with 1950 MTPD capacity.

In 1995 Al-Bayroni diversified into the manufacture of petrochemicals and started manufacturing of 2-EH (2-ethyl hexanol) in 1995 with a capacity of 470 MTPD and DOP (Di-Octyl Phthalate) in 1997 having 150 MTPD.

3.0 Sustainability, the SABIC way...

DUST CONTROL - AN EXAMPLE OF SUSTAINABILITY:

SABIC, always looking at ways of saving the environment, by optimizing their basic processes, raw material utilization, saving water etc. One such illustrative example is the dust control project taken up by its affiliates Al BAYRONI, IBN AL BAYTAR and SAFCO.

This project was started in 2007 whereby Urea (In Dust Form) and Ammonia emissions released from Urea Plants will be controlled and reduced. The developed technology involved designing of an effective scrubber, using acid and water to scrub off the urea dust and escaping ammonia. The collected solution was further crystallized to make useful saleable product like ammonium sulphate. The implementation was successfully completed at Al-Bayroni and in 2 out of 4 plants in SAFCO.

As a socially responsible company, SABIC always looks at the growth, with sustainability. SABIC takes utmost care in all its processes, to safe guard the environment. With focus on continuous improvement through research, the processes are often revisited and improved to cater to the changing needs and stringent global requirements.

4.0 Urea Plant Process Description

Urea is produced in Albayroni site according to Stamicarbon CO_2 stripping process with design capacity of 1600 MTPD.

CO_2 enters the bottom of the stripper and heated in counter current with urea solution coming from reactor.

Ammonia reacts with stripped gas CO_2 from H.P. stripper in the HP carbamate condenser.

Carbamate is formed with large amount of heat generation. This is cooled by generating steam in the shell side of the carbamate condenser.

In Urea reactor, the slow endothermic reaction involving carbamate conversion to urea product is taking place.

(1) $2NH_3 + CO_2 \rightarrow NH_2COONH_4$

(Ammonium carbamate)

(2) $NH_2COONH_4 \rightarrow NH_2CONH_2 + H_2O$

Ammonium Carbamate → Urea + water.

The reaction mixture, leaving the reactor via an overflow line, is discharged to the stripper, where the mixture is distributed over a large quantity of tubes, by means of liquid dividers between the gas tubes and the tubes sheet. CO_2 gas introduced in counter current flow through the tubes, causes the partial NH3 pressure to decrease, as a result of which carbamate starts to decompose. HP steam is admitted around the tubes to provide the required heat.

The liquid from the stripper is discharged to the recirculation section. Reactor off-gas is entering the bottom of the HP scrubber to be condensed.
The urea carbamate solution leaving the bottom part of the stripper is sent to the low pressure section for further carbamate decomposition and urea concentration of about 72 %.

The urea solution is concentrated to about 99.7% wt by evaporating the water in two stages evaporators under vacuum. The concentrated urea melt is pumped to the prilling bucket, on the top of the prilling tower.

The solidified prills are transferred to the Bulk storage or loading station via Fluid bed Cooler. By original design, the prilling tower was a natural draft prilling tower and the plant did not have a dust recovery system.See the Block body diagram, Figure 1 below

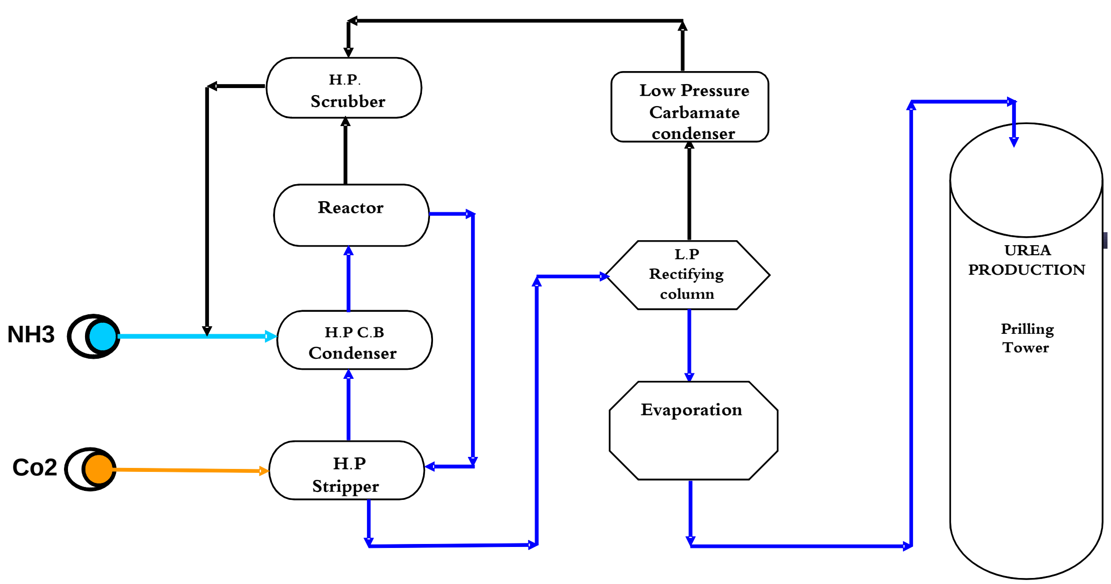

Figure 1

The height of the Prilling tower is about 80 meters and the exhaust was let to the atmosphere without any dust-recovery system. See below Figure 2

Figure 2

Later it was decided to bring down the urea dust and ammonia gas emission from prilling tower to international standards, so urea dust and ammonia gas recovery project was commissioned and put on service since June 2009. Please see below illustration of the project, Figure 3.

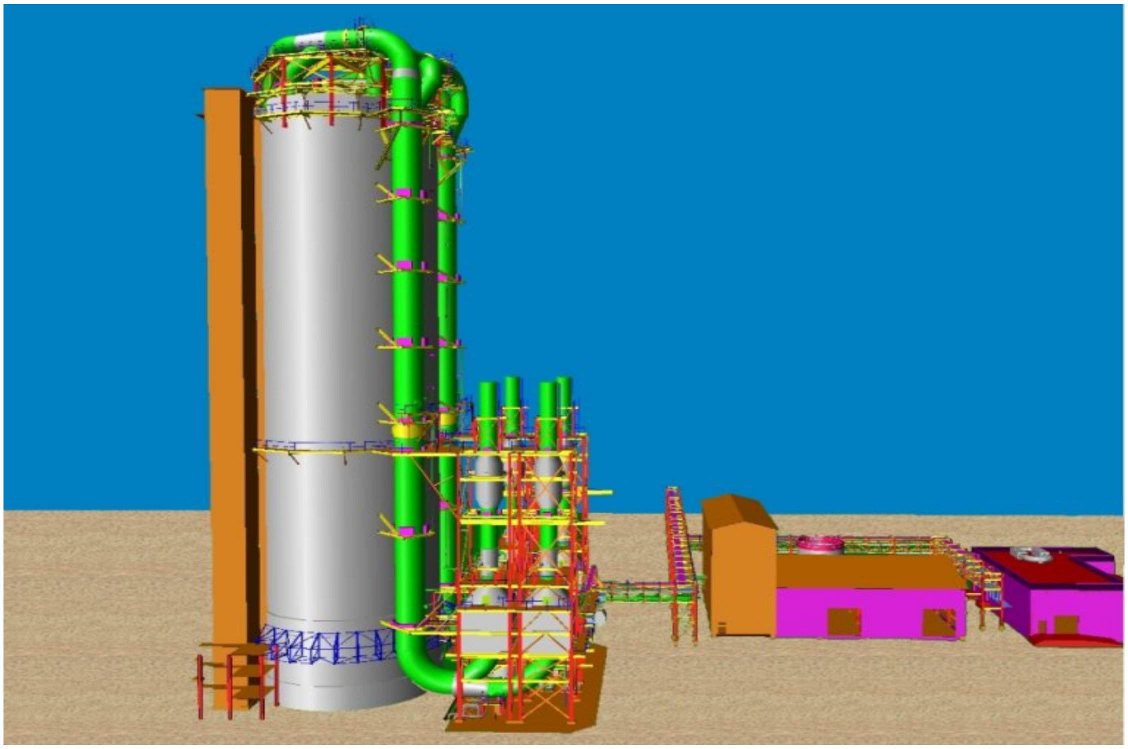

Figure 3

After establishment of this project, prilling tower emissions are safer than the local environmental requirements and the company was given an environmental award.

5.0 Prill Tower Emission Control Project

This paper mainly deals with the urea dust & ammonia gas recovery project which consists of air cleaning unit and Crystallization unit

5.1 Air Cleaning unit:

Flow diagram, Figure 4: as illustrated below

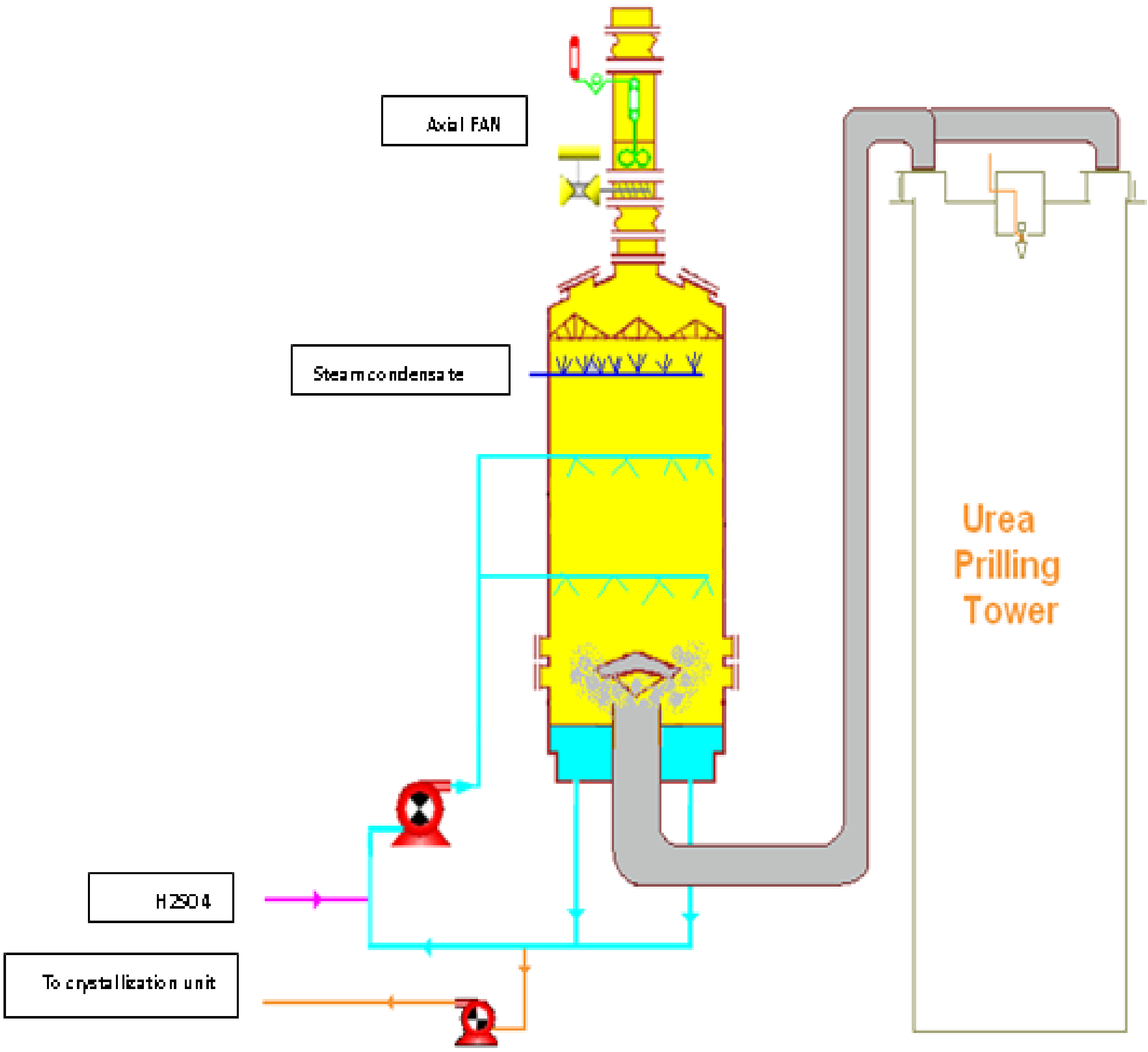

Figure 4

5.1.1 Process Description

The UNIT's service includes cleaning of dust-laden exit air stream leaving Prill Tower of Urea Plant. Capacity of the UNIT is variable and corresponds to the flow-rate of the air stream ascending the prilling tower to cool urea prills.

The scrubbers i.e. the major items of equipment of the air cleaning unit have been arranged on the steel construction fixed on the ground. Exit air stream leaving the existing prilling tower is transferred through 3 m dia. gas ducts down to the scrubbers. The other equipment such as filters, tanks, pumps have been arranged on the ground level also or on the steel construction.

Neither liquid nor solid waste material is discharged from the Exit Air of Cleaning Unit. Some liquid and solid wastes may be formed occasionally during cleaning of filters and other equipment during maintenance work or in emergency conditions.

The air cleaning process involves 2 stages or unit operations, namely:

- **A.** Humidification of the urea dust-laden air stream with water mist up to full saturation with extremely fine water droplets or mist, whereby even extremely fine dust particles, sized 0.3 to 2.0 microns dissolve, thus to form urea solution mist;
- **B.** Neutralization of ammonia carried by the exit air stream, with sulphuric acid added to the humidifying liquid, whereby ammonia sulphate solution is formed;

The above exit air treatment process involves the use of special spraying nozzles capable of producing mist of finely atomized water droplets and demisting pads of high specific surface.

The scrubbers are designed not only to remove urea dust from the exit air stream but also to remove gaseous ammonia carried with the air stream, by reacting it with sulphuric acid, to form ammonia sulphate.

$$\mathbf{2NH_3 + H_2SO_4 \text{ -------------->} \ (NH_4)_2SO_4}$$

Sulphuric acid demand corresponds to stoichiometric usage of the acid reacted with the gaseous ammonia. The injected acid becomes well mixed with the circulating solution in the Mixer. Through passing the system of pumps and filters it becomes thoroughly mixed with the recycle stream. A product (Urea Ammonium Sulphate solution) from Cleaning Unit is tapped off the loop and passed on to the Crystallization Unit.

In acid-free operating mode (i.e. without sulphuric acid injection) product stream tapped from the UNIT is an aqueous urea solution up to 20+25% wt; it shall be sent directly to Urea Plant.

5.2 Crystallization Unit:

5.2.1 Flow diagram

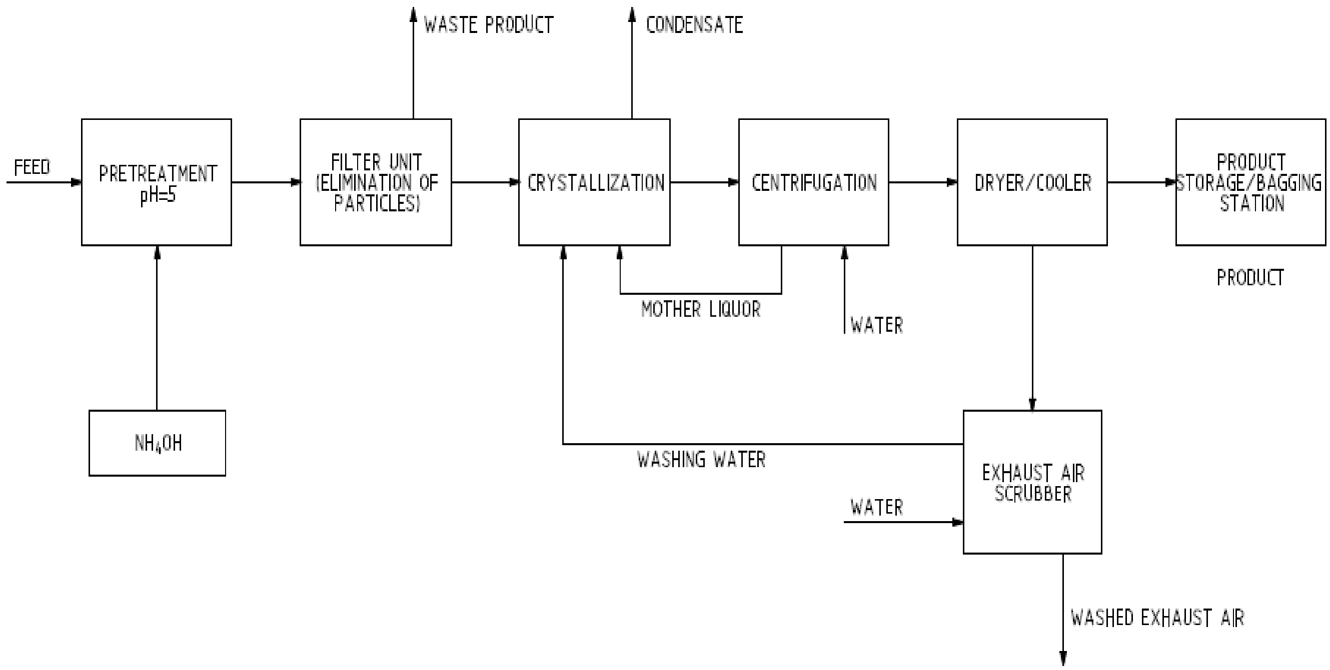

Figure 5

5.2.2 Process Description

To obtain a pure product the feed solution from cleaning unit is firstly treated and filtered.

The feed solution containing undissolved particles is fed flow controlled into a reaction vessel, where ammonium hydroxide (NH_4OH) is added by means of an additional dosing station to adjust the pH-value to around 5. The mixed solution is then guided into a filter where all solids are separated from the solution.

The solution pump delivers the feed solution into the crystallizer system.

The evaporator / crystallizer is constructed as forced recirculation crystallizer. The recirculation pump ensures directed recirculation in this crystallizer, whereby the recirculation rate is matched to the operating conditions of the heat exchange process. The suspension flows through the heat exchanger whereby re-circulating suspension takes up heat, which is put in by condensation of heating steam.

After leaving the heat exchanger, the heated solution is taken to the evaporator. The heat of evaporation required for the boiling process is withdrawn from the solution, which cools down until the equilibrium is reached again.

The cooling of the solution as well as the withdrawal of the solvent water produces a controlled supersaturation of the solution, which is the driving force for the crystallization process. This is immediately started and the de-supersaturation takes place by crystal growth on the suspended crystals.

The crystal slurry is pumped to a centrifuge where the mother liquor is separated from the crystals. From the centrifuge the crystals are fed via a screw conveyor into a dryer cooler unit, where the product is dried up to a final product.

UAS product, commercially known as super ammonium sulphate (SAS) specification is as below:

Parameter	Unit	Specification
Total Nitrogen as N	Wt %	21.00 (Minimum)
Sulfur as S	Wt%	16.70 (Minimum)
Moisture	Wt%	0.5 (Maximum)
Color	-	Yellowish
pH	-	4.5 – 5.5

6.0 Challenges Faced.

6.1 Huge duct and scaffolding erection.

Figure 6

The prilling tower height is about 80 meters and huge SS ducts are to be brought down to reach the scrubber at the ground**.** Extra care was taken to identify the competent scaffolding contractor and the scaffolding was inspected by a third party at every 10 meters. High wind speed was a real obstacle and the job had to be stopped often for safety. To save down time of urea plant only the top portion was erected during the turnaround and the major part was connected when the plant was running. The entire erection, usage and removal were done without a single Loss Time due to Injury.

6.2 Abnormal Sand problems.

Severe sand storms forced some sand dust into the prilling tower and they were caught by the filters in air cleaning unit. We had to clean often and the problem is severe only during dusty wind time. The area around the air intake is also maintained free from dust to avoid this filter choking problem.

6.3 44 side doors to facilitate natural draft operation

It was a tough challenge to modify the top of Prill Tower to make a platform around the Prill Tower to facilitate operators for opening 44 side-doors to revert back to Natural Draft Prilling in case of any technical problem in the system. This is a unique design in the world.

6.4 Modification of the roof plate at Prill Tower top

The top of the Prilling Tower is at 80 m height and to cut away the 2 mm thick SS plate to make six openings and then weld the 2.2 m diameter ducts was challenging in the extreme windy and dusty conditions during June 2008. Also, modifications were done to accommodate the 3 m diameter ducts on two sides of the tower to bring the dust to the scrubber.

Figure 7

6.5 Successfully commissioned cleaning and crystallization without any lost day injury.

7.0 Achievement Results

7.1 Emission Control

The performance test results (PTR) conducted after the commission of the project showed tremendous change in the dust and Ammonia emissions. PTR dates are tabulated below. All the guaranteed figures have been met.

7.2 Performance Data:

Item	Unit	Before	After	Guarantee
Urea Dust	**mg/Nm3**	**206**	**30**	**50**
NH3 Emission	**mg/Nm3**	**210**	**36**	**45**

7.3 New Product

Urea – Ammonium sulphate solution has been crystallized and introduced as a new fertilizer product to the market under commercial name of super ammonium sulfate (SAS).

7.4 Quality Improvement

The new forced draft prilling has helped in removing most of urea dust and reduce the final product temperature. This has helped in reducing the caking tendency of urea prills.

7.5 SABIC Sustainability

By completing this project in Albayroni, no more environmental issues are pending in this affiliate. This project has helped Albayroni to score the 3rd position in Royal Commission Environmental award in year 2009. Also, this project gave SABIC the opportunity to participate in the IFA Green Leaf Award 2010.

7.6 Water Conservation

In the project design, DM water or potable water was planned to be used as makeup water for the cleaning unit scrubbers. However, Albayroni is producing waste water from urea plant which is discharged to Royal commission for further treatment. Now, this waste water has been utilized as the makeup water for the scrubbers. 20 M3/H of potable water has been saved.

8.0 Conclusion

SABIC is on constant search to adopt state of the art technology to be the pioneer to protect Safety, Health and Environment .Urea and Ammonia emissions from the Prill tower or urea granulators can be brought down below international limits by acid-water scrubbing system effectively. Al-Bayroni and Safco plants experience in this project can be of high value lesson learned to plants who want to implement similar environmental projects.

Figure 8

SUCCESSFUL COMMISSIONING OF UGAA PROJECT

Ibrahim M. Al-Qahtani
SF-2 Operations Manager
Saudi Arabian Fertilizer Company (SAFCO)

SUCCESSFUL COMMISSIONING OF UGAA PROJECT

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Abstract:

SAFCO/IBB complex having 4 Urea plants. From the granulator stack along with exit air ammonia is emitted in the range of about 200 PPM.

As a proactive approach for environment protection and sustainable development, SAFCO decided to implement Urea Granulator Ammonia Abatement (UGAA) project for all four (4) Urea Granulators (although Ammonia emissions from urea granulators are within Royal Commission Specified Limit).

In Urea Granulator Ammonia Abatement (UGAA) project, additional acid scrubbers were installed using concentrated sulfuric acid as scrubbing medium to reduce Ammonia emissions from urea granulators.

Ammonia Scrubbers are installed in Urea plants to scrub the exit ammonia by sulphuric acid. The resulting 10% ammonium sulphate solution is further concentrated to Ammonium sulphate granules as product from UGAA plant.

This is the Best Available Technique (BAT) as per European Fertilizer Manufacturing Association (EFMA).

The paper will describe the old arrangement of Urea granulator system, installation of acid scrubbing system, impact of Ammonia emission and Operating experience of Ammonia Sulphate Crystallization Unit.

Introduction:

SAFCO (Saudi Arabian Fertilizer Company), one of the forerunners of downstream petrochemical manufacturing in Saudi Arabia, went on stream in 1969 as the first fertilizer producing company in the kingdom. SAFCO became of the fertilizer and chemical industry.

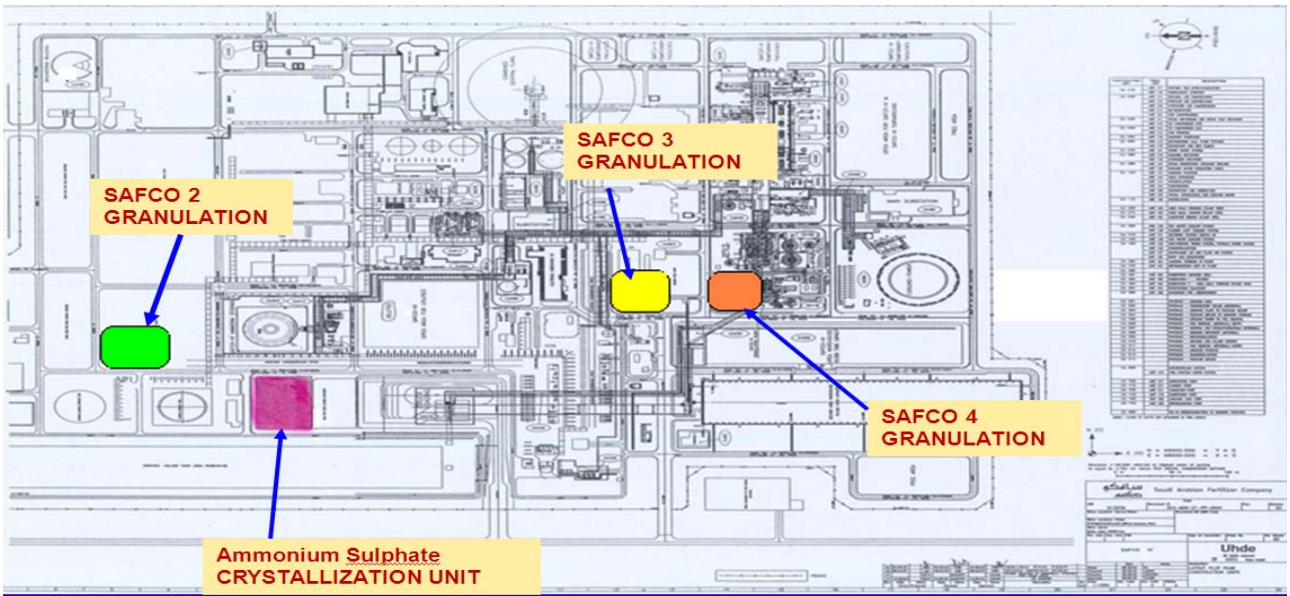
In 1993, SAFCO started up its second ammonia and granular urea complex, located in al-Jubail Industrial City. This was followed by a third plant which began production in January 2000.

Today, SABIC is a world leading petrochemical company in terms of sales and product diversity. Headquartered in Riyadh, SABIC is the Middle East's largest non-oil industrial company and has successfully expanded into Europe, with integrated world-scale production facilities based in Geleen (The Netherlands), Teesside (United Kingdom), and Gelsenkirchen (Germany) and a total yearly production of almost 9 million tons of petrochemicals.

Through their affiliates SAFCO, the world's single largest producer and exporter of Granular Urea, SABIC continues to advance; leading the ammonia industry boldly as demonstrated by the commissioning and successful operations of SAFCO-IV. - commissioned in 1996.

UGAA Project Layout & Details

- Basic Engineering Design by UHDE India.
- Acid Scrubbers designed by Waterleau, Belgium.
- Ammonium sulphate crystallization technology by GEA Messo, Germany.
- Project Execution by SABIC Engineering & Project Management (EPM) & SAFCO Project Team.
- Engineering, Procurement & Construction (EPC) – SIMON India Limited.
- Project implementation was started in year 2007.



The project involved;

- Installation of additional scrubbing system and blowers.
- Extensive duct modification to align with the existing system.
- Provision of pipelines for utilities such as water, steam, instrument air, nitrogen for common facilities.
- Provision of storage tanks for acid, ammonium sulphate solution.
- Construction of Ammonium Sulphate Crystallization Unit.
- Provision of silo and truck loading facility for transferring ammonium sulphate.

UGAA Process Description & Approach

Ammonia Scrubbers are installed in Urea plants to scrub the exit ammonia by sulphuric acid. The resulting 10% ammonium sulphate aolution is further concentrated to Ammonium sulphate granules as product from UGAA plant.

Figure # 1. NEW ACID SCRUBBING SYSTEM IN UREA PLANT

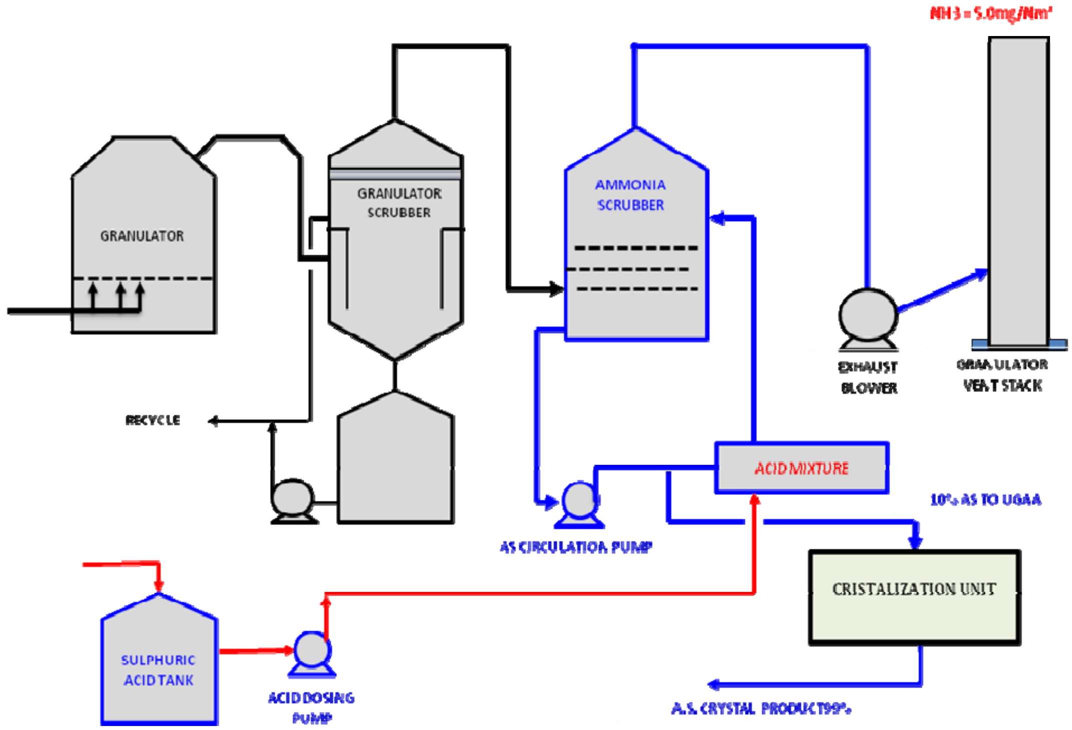
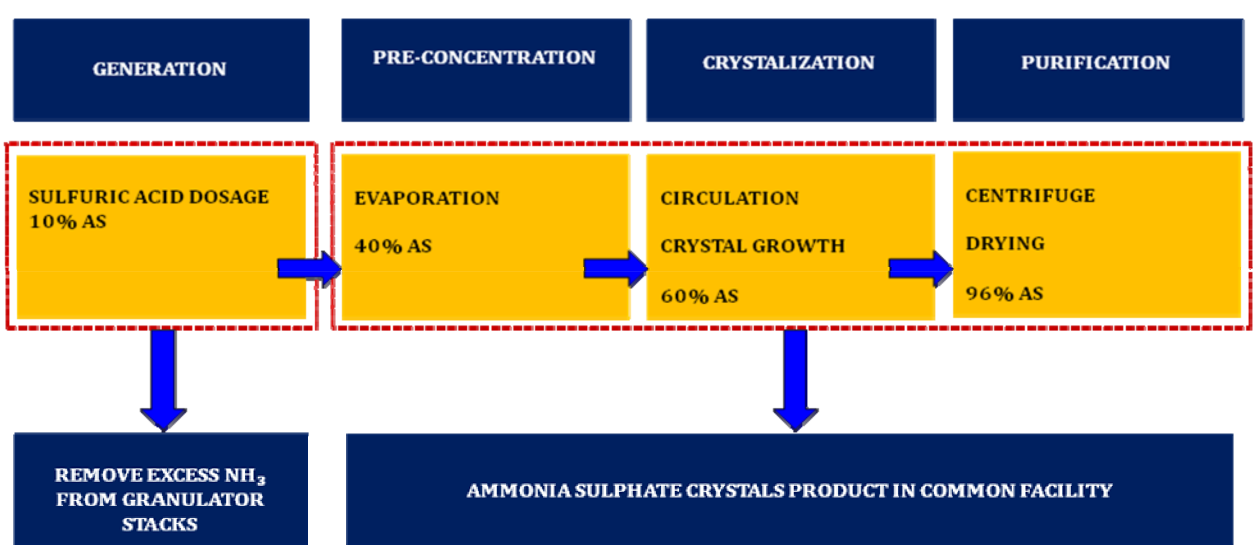


Figure #2. AMMONIUM SULPHATE CRYSTALLIZATION UNIT APPROACH



UGAA MILESTONE

CONTRACT AWARDING DATE:		14th June 2008
MECHANICAL COMPLETION & COMMISSIONING:		
	COMPLETION	COMMISSIONING
SAFCO II	16th January 2010	22nd February 2011
SAFCO III	11th February 2010	27th October 2010
SAFCO IV	September 2011	October 2011
IBB	May 2011	June 2011
CRYSTAL PRODUCTION:		24th November 2010

Project Results

Plants	Significance	AMMONIA		Result
		Mg/Nm^3	TPY	
SAFCO-2	Before UGAA	68.1	312.2	Ammonia emission to atmosphere from SAFCO 2 Urea Granulator Stack reduced by 92 %.
	After UGAA	4.95	22.5	
SAFCO-3	Before UGAA	100.9	410.2	Ammonia emission to atmosphere from SAFCO 3 Urea Granulator Stack reduced by 84 %.
	After UGAA	16.5	66.2	

Although SAFCO were complying with RC limits, UGAA project was installed as a proactive approach for environment protection.

FINAL WORDS

- Drastic Ammonia Emission Reduction to Atmosphere by 85 %.
- The technology involved is proven smooth and reliable.
- Commissioning of UGAA facility is another important milestone in SAFCO history.
- Addition of UGAA unit will augment our responsibility and care toward environment.

الإتحاد العربي للأسمدة
Arab Int'l. Organization هيئة عربية دولية
Arab Fertilizers Association
Since 1975

PIC efforts in Energy Optimization

Salem Alazmi, Operations manager
Lutfy Nayfeh, Senior specialist
Ahmad Abbas, Shift controller

Petrochemical Industries Company (PIC)
Kuwait

PIC efforts in Energy Optimization

Salem Alazmi, Operations manager
Lutfy Nayfeh, Senior specialist
Ahmad Abbas, Shift controller

Petrochemical Industries Company (PIC)

Abstract:

The prices of the natural gas increased sharply in the last five years which affected the Ammonia & Urea production costs as the NG is the main raw material in producing Ammonia. NG is used as process gas & fuel for the primary reformer & steam boilers. PIC formed an energy optimization committee to improve the energy consumption in the fertilizer plants. External energy audit was conducted by consultant on PIC fertilizer plants. 53 opportunities for energy saving were highlighted as a result of the audit. The committee studied the feasibility of these opportunities & implemented 25 feasible schemes. The implemented schemes were monitored for one year to ensure that the achievements are sustained & to evaluate the actual saving. The energy optimization committee established a program includes the following:-

- Setting yearly objectives.
- Establishing internal energy audit program.
- Conducting brainstorming sessions to initiate new opportunities.
- Following up & implementing the new opportunities.
- Monitoring the actual saving of the implemented opportunities.
- Conducting awareness sessions.
- Monitoring, analyzing & controlling the consumption figures. (Zero steam leaks,…).
- Raising opportunities as 6 sigma projects.

The total annual saving was 3.8 MMUSD. The total energy consumption was reduced by 10% in one of the Ammonia plants during the last three years. Utilizing the natural gas condensate of natural gas compressors as fuel gas to the boilers instead of flaring it is an example for one of the implemented energy opportunity.

1. PIC Background:

Petrochemical Industries Company (PIC) is a subsidiary of Kuwait Petroleum Corporation (KPC) owned by the government of Kuwait. Petrochemical Industries Company was founded in 1963. The company pioneered production of Ammonia and Urea in the Middle East.

Since the 1960s an industry for the production of ammonia and nitrogenous fertilizers has been existed in Kuwait, which constantly adopts the latest developments in process technology. Petrochemical Industries Company (PIC) plants were expanded in mid of 1980's & revamped in 2002.

The Company has two ammonia plants with a total capacity of 620,000 MTPA and three urea plants with a total capacity of 1,040,000 MTPA.

PIC is certified for ISO9001:2000 since July, 2001 & ISO14001 since February, 2004.

PIC is looking to be a global leader in petrochemical industries & it has several join venture companies worldwide.

2. Energy Optimization Introduction:

Ammonia manufacturing relies extensively on natural gas as feedstock and fuel, energy costs account for a large percentage of manufacturing costs. Natural gas prices have been increased sharply during the last 6 years as shown in figure 1, the prices are tripled. Improving the energy consumption reduces the production cost and reduces the effluent to atmosphere.

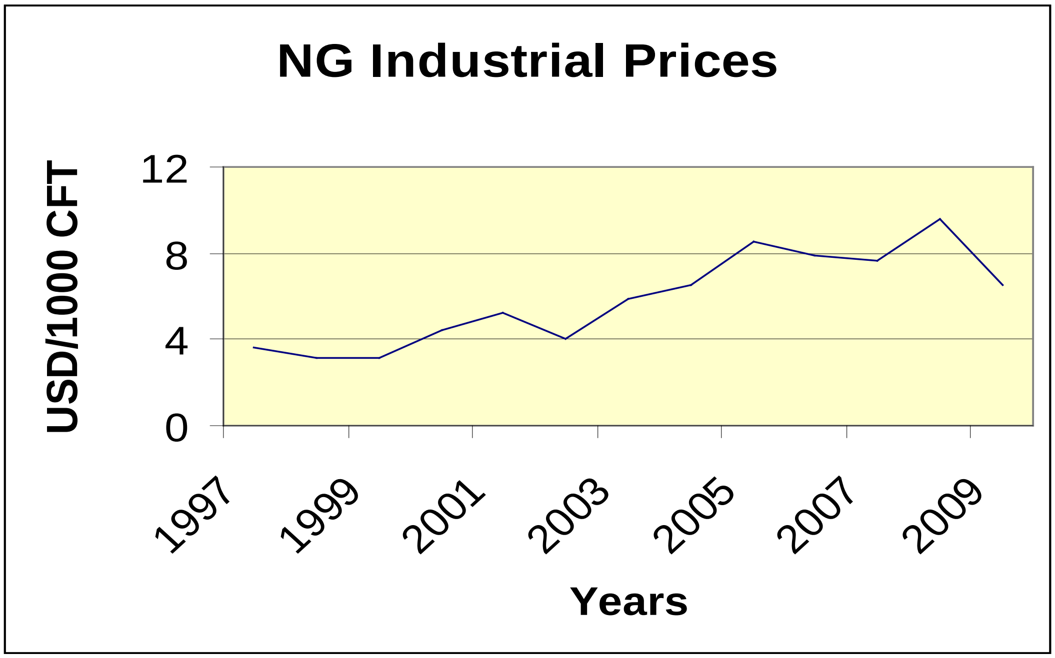


Figure 1: NG industrial Prices for last 12 years

3. Energy Optimization Team Efforts:

PIC top management formed a team from different concerned departments to identify, study and execute all feasible opportunities to reduce energy consumption in the fertilizer complex. The team is meeting on monthly basis. The team has established Energy Management Strategy based on Top Management commitment & support, as shown in Figure 2. The top management is reviewing and discussing the team activities and the progress on quarterly basis and recommending the required improvements on the Energy Management Strategy Cycle elements.

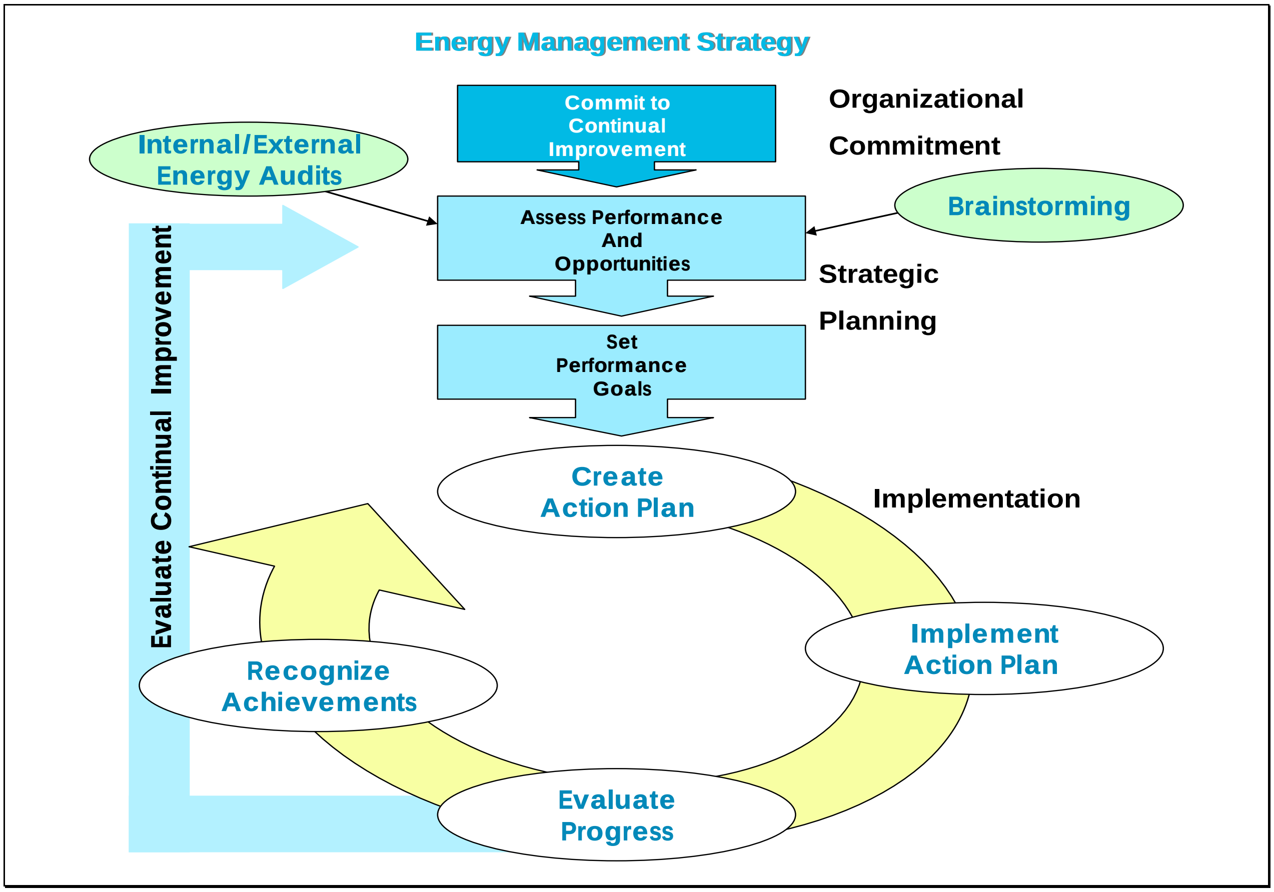


Figure 2: Energy Management Strategy

The efforts of the team can be summarized in the followings:-

3.1 <u>Conducting Energy Optimization Study by External Consultant:</u>

The team selected an external consultant to conduct an energy optimization study to identify all possible opportunities in Ammonia & Urea plants for energy saving. The consultant met the concerned process engineers, maintenance engineers and chemical engineers, revised the energy & material balances & conducted walk through energy audit on PIC plants.

Based on his study, the consultant identified 53 opportunities for energy saving based on the international prices for natural gas and electricity. The team studied these opportunities technically and conducted feasibility studies based on logic prices. The feasible and technically accepted opportunities were implemented. During four years 25 opportunities were executed as shown in Figure 3.

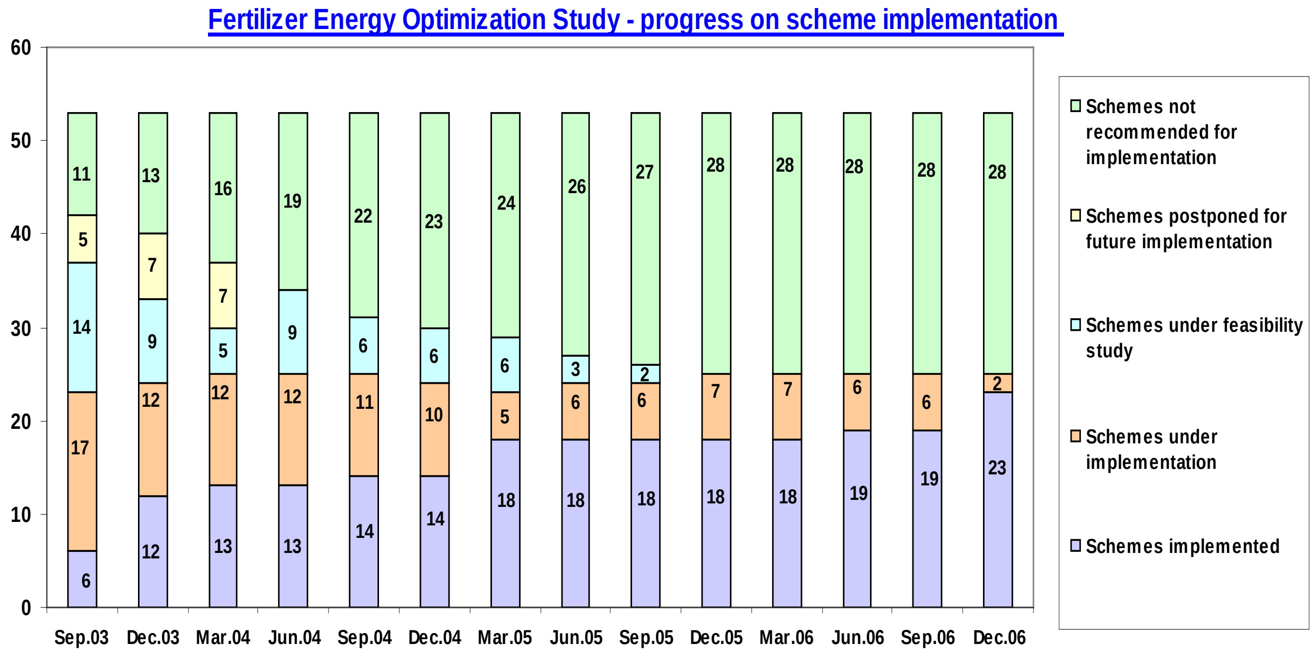


Figure 3: Energy Optimization opportunities status

The team monitored the saving from each implemented opportunity for one year to ensure that the gain is sustained. Examples of monitored opportunities are shown in Figure 4.

Follow Up - Implemented Schemes Actual Saving (2007-2008)

Opp. #	Unit	Title	Annual Expected Saving	Actual Saving (2007/08)				
				Q1	Q2	Q3	Q4	YTD
PIC 1	Urea Plant-A	Use surplus LP Steam instead of MP Steam in Atomization Air Heater (E-752) to save 2.7 MT/hr of MP Steam imported from SG-905 boiler	12, 850 KD/Y	**4106**	**2700**	**2260**	**4283**	**13350**
PIC 2	Amm.II & IV	Controlling all boilers on auto mode 12 ton /h were saved	78,000 KD/Y	**16400**	**10245**	**17014**	**18095**	**61754**
PIC 3	Amm. IV	Replacing KKK turbines by motors 10 t/h	87,360 KD/Y	**20289**	**20512**	**20522**	**20463**	**81786**
PIC 4	Amm. II	Rerouting the control oil supply to DK-1303 CPC	38,640 KD/Y	**7400**	**2580**	**7740**	**7800**	**25520**
KBC 1.03	Amm II	Increase the natural gas inlet pressure to the natural gas compressor	12,000 KD/Y	**3590**	**917**	**3602**	**3780**	**11889**
KBC 1.05	Amm II	Use boiler feed water rather than cooling water to condense the overhead of the CO2 stripper F1207	49,000 KD/Y	**9500**	**2150**	**9066**	**9100**	**29816**
KBC 5.13	Utilities	Use heat of OH of process condensate to preheat deaerator water to Ammonia III	55,000 KD/Y	**10,500**	**13,500**	**14100**	**14700**	**52800**
KBC 6.06	Other	Use the difference in density of the natural gas in feed forward control to compressors	56,000 KD/Y	**No Saving**	**No Saving**	**No Saving***	**No Saving**	**No Saving**

* Perojest is implemented but was not reliable.

Figure 4: monitoring the actual saving of the implemented opportunities for one year.

3.2 Setting Yearly Objectives:

Clear and smart objectives are very critical to improve the performance & to have continual improvement. The energy optimization team is setting yearly objectives and each member in the team is selected as champion for one or more objectives. He is responsible to set the action plan for the objective implementation, follow up the progress and report it to the team. Examples of 2008/2009 objectives are in Figure 5.

Energy Optimization Objectives for 2008/2009

#	Description	Action By	Date	Status & Remarks
1	Following up & implementing the pending energy & cost reduction items under study (minimum 6 items).	LN	March	5 out of 7 opportunities were implemented
2	Reducing the total energy consumption by 1.5%	F A	Monthly	Provide the monthly cons. report to the team. At least one day before the meeting.
3	Conducting 2 brainstorming sessions for each of Amm. & Urea production.	L N & A N	March 1st	L N finished, A N Plant A completed plant B still pending
4	Raising minimum 5 new feasible opportunities on energy & cost reduction.	L N & A B & A N	March 31st	* Brainstorming sessions & Energy Audit. * Ideas evaluation is to be carried out (60 Nos)
5	Zero steam & condensate leaks in all PIC plants.	LN & AN	On going	Could be counted in the energy report
6	Executing 90% of the Energy Audit plan. (New Schedule)	A N	Monthly	* E-mail reminding the auditor each month. * Follow up on corrective actions with area owner
7	Conducting 3 awareness campaigns on energy & cost reduction combined with Tech. support awareness.	A B & A N	March 31st	A N two shift left A B still pending
8	Monitoring & reporting the **saving** from the newly implemented schemes. (quarterly report, regarding the implement schemes)	F A	Quarterly	Add the new urea items, Savings to be communicated to all through Communication Group, monthly or quarterly
9	Issuing the quarter reporting of energy optimization committee **activities** & progress to top management on time.	S A	Quarterly	L N to discuss with S A
10	Recognizing the plant shifts/individual initiatives for optimizing the energy and reducing the cost.	A B & A N	Quarterly	A B completed A N pending A N & S R will discuss the issue

Figure 5: Energy Optimization Objectives for 2008/2009

3.3 Establishing & implementing internal energy Audit program:

The team established an energy audit program which includes energy Audit procedure, check list & energy audit yearly schedule. Awareness was conducted to all concerned staff in the energy audit program. The plants were divided into areas, each area is audited by team which includes the area process/chemical engineer, process supervisor & maintenance supervisor. Each area is audited twice a year. The coordinator fills the check list (check list is attached in the appendix) & includes the team remarks. The audit team coordinator sends the audit report by E-mailed to the area owner & to the energy optimization team. The area owner is responsible for taken the necessary corrective actions. One of the energy team members is responsible to ensure that the audits are conducted on time, the owner took the required corrective actions & high lights the major findings & any new energy opportunity which needs further investigation or study.

3.4 Conducting Awareness and Brainstorming Sessions:

Involving all operating and maintenance staff is critical for controlling the consumption figures and for having new ideas and opportunities for energy optimization. Several Awareness sessions were conducted to emphasize the consumption cost of each element (steam, NG, cooling water, boiler feed water,…) and the actual annual saving for controlling these element through zero steam & condensate leaks, optimizing excess O2 in flue gases of reformers and boilers, controlling the fuel support gases to flares, optimizing cooling water consumption, improving the vacuum on steam turbines, controlling steam/carbon to reformers & controlling the inlet steam temperatures & pressures to turbines to get optimum efficiency. The consumption figures for Ammonia & Urea production and energy optimization achievements are presented on quarterly basis to encourage the staff in improving the performance and optimizing the controls.

Four Brainstorming sessions were conducted last year, two for Ammonia staff & two for Urea staff. The aim of the brainstorming sessions is to collect maximum ideas from different levels (Operators, supervisors & engineers) for improving the performance and optimizing the energy consumptions, sample of brainstorming ideas are in Figure 6. The collected ideas are studied and evaluated by the concerned process engineers. The feasible ideas are considered as new opportunities for implementation & these ideas are captured and added to the team objectives for implementations.

Brain Storming Session on Energy Saving & Cost Reduction
Date 10:11:2008 Time 16:00 hrs to 17:00 hrs (Shift D & A)

#	Description of Ideas / Suggestions	Raised by Name	Evaluation
1	**Don't use pressure water for washing.**	**S.M.**	**Under study**
2	**CBD of boilers should be controlled automatically.**	**A.A**	**Rejected**
3	**Adjust seal steam to all turbines.**	**S. M.**	**Under study**
4	**Replace seal steam to Amm. II turbines from MPS to LPS**	**S.S**	**Under Study**
5	**Throttled SCW at ammonia-II condensers.**	**A.T.**	**On going**
6	**Flow of DMW from sample points of Mixed beds to be reduced & recycled.**	**N.K.**	**Under study**
7	**Improve Mixed beds efficiency**	**N.K.**	**Under study**
8	**Utilize gas of 12HIC-5, 32HV-30 & 32HV-40 vents at start-up.**	**M.G.**	**Under Study**
9	**Stop fire hydrant leaks.**	**H.A.**	**On going**
10	**Improve the reliability of oil skimmer pumps.**	**M.E**	**Not related**

Figure 6: Sample of Brainstorming raised ideas

3.5 Monitoring, Analyzing and Controlling the Consumption Figures:

The team is monitoring the consumption figures for each plant on monthly basis and key parameters (production, steam, natural gas consumption, SCW, FCW & raw water consumptions) are monitored on shifts basis to encourage the operating staff for optimum control. The deviations in the consumption figures are analyzed & proper actions are taken. Zero steam & condensate program was implementing through assigning process supervisor on specified area. His responsibility to issue a list for any steam or water leak once every two weeks to the area team leader and to issue maintenance work order. Priority is given to all energy work orders through Maximo System.

3.6 Six Sigma Projects:

The opportunities are studied and if they are feasible and technically accepted, they will be planned for implementation. If the opportunities due to defects in the process control and not requiring equipment modification, then it will be done through 6 Sigma project. The root causes for the defect will be identified, then the best solution will be implemented to get the required improve and control plan/procedure will be established to sustain the improvement. If the opportunities need modification & new installation then it will be executed through project by the engineering section. Several opportunities were implemented through 6 Sigma projects, for example, reducing steam and SCW consumption, increasing the production of two ammonia plants by 2%.

4.0 Example Case on energy saving: NG Flash Separator:

The NG supplied to PIC at 3.0 kg/cm^{2}g and contains 1% of high hydrocarbon (C_4, C_5 & C_6+). The supplied gas composition is not steady & changes continuously, the specific gravity of the gas changes between 0.64 to 1.0 and in several occasions above 1.0, in these cases the high hydrocarbon composition reaches 4%. The high hydrocarbon gases are condensing in the inter-stage coolers & especially at the anti-surge coolers during the compressing of the gas to 40 kg/cm^{2}g. The Natural gas condensate from the Ammonia plants was collected in 3" header & burned in ground flare. The expected amount of condensed gas during normal operation is 430 Nm^3/hr.

An opportunity was raised to utilize this amount of natural gas instead of burning it. The recommendation was to install flash separator to flash the condensate again at 2.5 kg/cm^{2}g and feed it to fuel gas header for boilers. One available unused separator was utilized for this purpose. The unit mainly consists of flash separator, level control valve, two shutoff valves at inlet and by pass of the flash separator.

The project was executed and after commissioning it in August, 2008, the flare was put off completely and kept to receive the water condensate only. The flare now is stand by. Several samples for combustible were taken to ensure the complete flash of the NG & it was nil. The unit is running smooth from commissioning. This project achieved two main objectives, energy saving and preventing the pollution due to natural gas burning to atmosphere.

The pay back of this project was 1.4 years.

5.0 Achievements:

PIC implemented total of 51 opportunities (External & in house) which achieved 3.8 MM USD accumulated saving in the year of 2008/2009, these opportunities include the commissioning of purge gas recovery unit and the implementation of 6 Sigma projects.

The energy consumption of one of the ammonia plant was reduced from 41.8 MMBTU/MT in the year 2006/2007 to 37.5 MMBTU/MT in 2008/2009, which is equivalent to 10% reduction in energy consumption.

6.0 Conclusion:

1. Top Management Commitment and support are key factors in energy saving success.
2. Establishing permanent Multi-discipline team for energy Optimization is essential.
3. Clear Energy Optimization Management Strategy is the way for achieving energy saving.
4. Involving Operating & maintenance staff in internal energy audits and brainstorming sessions and communicating the achievement with them improve the energy control & initiate new ideas.
5. PIC was able to save 3.8 MMUSD in 2008/2009 through the implementation of the energy optimization management strategy . The reduction of the natural gas consumption in one of the Ammonia plant was 10% during the last three years.

Appendix

Petrochemical Industries Company

ENERGY AUDIT: Walk-Through Audit Check List

Area		**Auditors**
Date/time		
Time spent		

S.No	Checklist Points	Yes	No	NA	Remarks
	Lighting				
1.	Are there lights in unwanted area?				
2.	Are the lights “on” during day time?				
3.	Are the light covers dirty / damaged?				
4.	Are there High Power light bubs in use? (filament bulbs)				
	Motors & drives				
1.	Is the motor fan cover clogged?				
2.	Is the motor is continuously operating less than 50% of its rated current?				
3.	Is the insulation on the turbine / pipelines damaged?				
4.	Is there any steam leak from turbine / pipelines?				
5.	Is the belt drive – loose / damaged?				
	Air & Steam System				
1.	Is there leak through glands, drains etc?				
2.	Is the insulation damaged?				
3.	Is the surface temperature on insulation high (>60° C)?				
4.	Is it possible to use low pressure service steam?				
5.	Are the steam traps functioning normal?				
6.	Are any drains / vents kept open un-necessarily?				
	Pumps & Compressors				
1.	Is the pump operated with discharge throttled continuously?				
2.	Is the pump bypass kept open for most of the time?				
3.	Are two are more pumps are operated in parallel (not as design)?				
4.	Is the fan / blower operated with discharge damper throttled?				
5.	Is the suction filter clogged / high pressure drop?				

Petrochemical Industries Company

ENERGY AUDIT: Walk-Through Audit Check List

S.No	Checklist Points	Yes	No	NA	Remarks
	Boilers & fired heaters				
1.	Are the flame conditions alright?				
2.	Are there any hot air leaks?				
3.	Are the blow downs operated to the extent required only?				
4.	Is the stack temperature more than design?				
5.	Is the excess air % (in control room) more?				
	Heat Exchangers				
1.	Is there cooling water circulation – un-necessary or more than required?				
2.	Is there indication for fouling of heat transfer surface?				
3.	Is there damage of hot/cold insulation?				

Other Observations:

Remarks & Signature	
Shift Supervisor:	**Plant Team Leader:**

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Arab Fertilizers Association

Since 1975

PIC Zero Ammonia Emission Project
A Novel Idea

S. Raghunathan

Petrochemical Industries Company (PIC)
Kuwait

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Author
S. Raghunathan

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1. Project Abstract

Petrochemical Industries Company (PIC), Kuwait has implemented an environment friendly project titled “Zero Ammonia Emission Project” to eliminate gaseous ammonia pollution in its Urea Plants caused by both continuous and discontinuous emission sources.

The discontinuous ammonia emission sources are ammonia handling emergency relief devices (PSV/Rupture Disc/Emergency Vents). A huge quantity of ammonia is vented within a short span of time during severe plant upset situations. Currently ammonia gases from these relief devices are disposed off directly to atmosphere through a stack venting at high elevation. In the new project, all these emergency relief devices are connected to a Flare System wherein the ammonia containing process gas is flared with the injection of Natural Gas as support gas.

The continuous ammonia emission source is Urea Solution Storage Tank. The vent line of this tank is at present discharging to atmosphere. Ammonia emission from this source is a nuisance to plant operating staff due to high ground level concentration. It is eliminated by installing a absorber.

The major benefits of the project are

- Pollution free working environment in the plants at all times
- Eliminating ammonia pollution in neighboring companies
- Protection of environment

2. Introduction

Petrochemical Industries Company (PIC), Kuwait is currently operating two Ammonia Plants based on Haldor Topsoe technology and two Urea Plants comprising Plant-A & Plant-B based on Stamicarbon Stripping/HFT Granulation technology. The total capacities of Ammonia plants and Urea Plants are 1880 MTPD and 3150 MTPD respectively.

Traditionally, the disposal of ammonia bearing process gases from emergency relief systems in Urea plants has been done by discharging directly to atmosphere. This was the accepted practice for this type of facility and continues to be the accepted practice at many locations around the world till date. Although direct discharge to atmosphere can be done in a safe way, it causes considerable pollution to direct plant environment and companies located in the vicinity of PIC Plants. PIC as a socially responsible corporate citizen decided to eliminate ammonia pollution both inside and outside the PIC plants caused by such a discharge by implementing the **"Zero Ammonia Emission Project".**

When PIC decided to implement this project, there was no process readily available to adopt. Hence PIC worked very closely with Stamicarbon in developing cost effective solutions from scratch that is most appropriate for PIC plants.

Zero Ammonia Emission Project was successfully commissioned in both Urea Plants during the 2nd quarter of year 2009. The process flow scheme employed for both the plants is different due to plant layout/design but conceptually they are same. In this paper, only the solutions applied in PIC Plant-A Zero Ammonia Emission Project is presented.

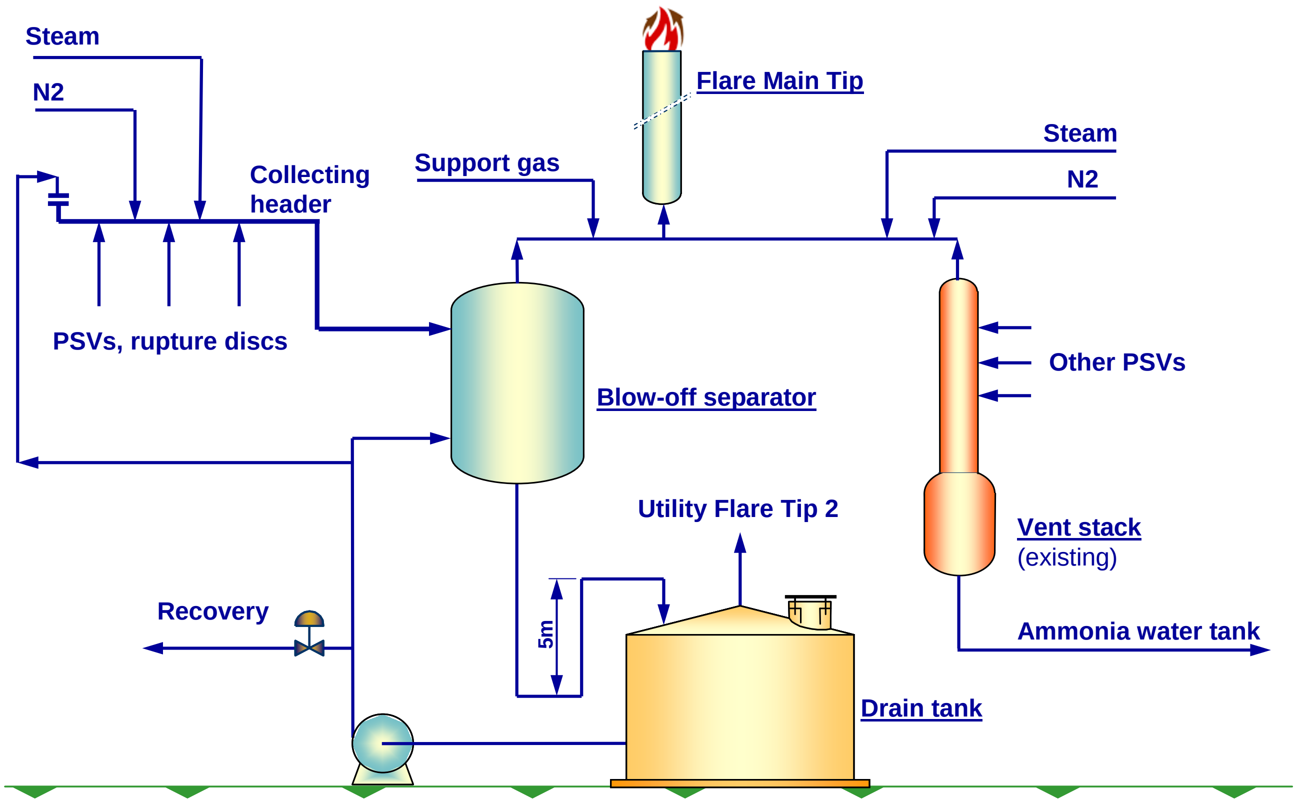
3. Flaring Process Vapors from Emergency Relief Devices

After thoroughly evaluating the merits and demerits of absorption and flare systems for the disposal of NH_3-CO_2-H_2O mixtures discharged from emergency safety relief devices, the flaring was selected as the viable and appropriate solution.

The design included following steps:

- Design and implementation of a major collecting system for the ammonia handling PSVs in the plant
- Replace all Rupture Discs with PSVs
- Review and analysis of the relief devices and sources in the plant to determine the impact of their relieving into a collecting system vis-à-vis discharge to atmosphere
- Analysis of the possible relief scenarios to determine sizing of the collecting system
- Analysis of the collecting network for both hydraulic and mechanical considerations

Figure 1



In case of a PSV blow-off, the process gas enters the new Blow-off Separator or existing PSV Vent Stack depending on the location of the PSVs. All the PSVs of synthesis section are connected to new Blow-Off Separator while the PSVs of other sections are connected to existing PSV vent stack. No modification to existing PSV Vent Stack was proposed since it was found to be adequate to handle the PSV discharges and supply entrainment free gas to Flare System. The existing PSV Vent Stack that is discharging to atmosphere is modified and connected to Flare System.

Liquid if any present in synthesis PSV discharge is separated in Blow-Off Separator and fed into the drain tank. The entrainment free ammonia containing gas mixture is sent to the Flare Main Tip after mixing with support gas in order to increase its heating value for nearly complete destruction of ammonia by combustion. The Blow-Off Separator is a cyclone type device with tangential liquid inlet and designed for the tube rupture case of the HP Stripper.

The liquid from the Blow-Off Separator is discharged to the drain tank via a 5 meter liquid seal to prevent vapor slip into the drain tank. The flare system and interconnecting piping is designed such that the maximum pressure in the Blow-Off Separator does not exceed 0.3 barg. Because of this overpressure, the liquid from the Blow-Off Separator will flash in the atmospheric drain tank, and the vapor will be directed to a dedicated Utility Tip 2 of flare. The pressure drop of this utility flare is such that the mechanical design pressure of the tank is not exceeded. However in order to protect the tank from possible over pressure, a manhole water seal is provided on the tank roof.

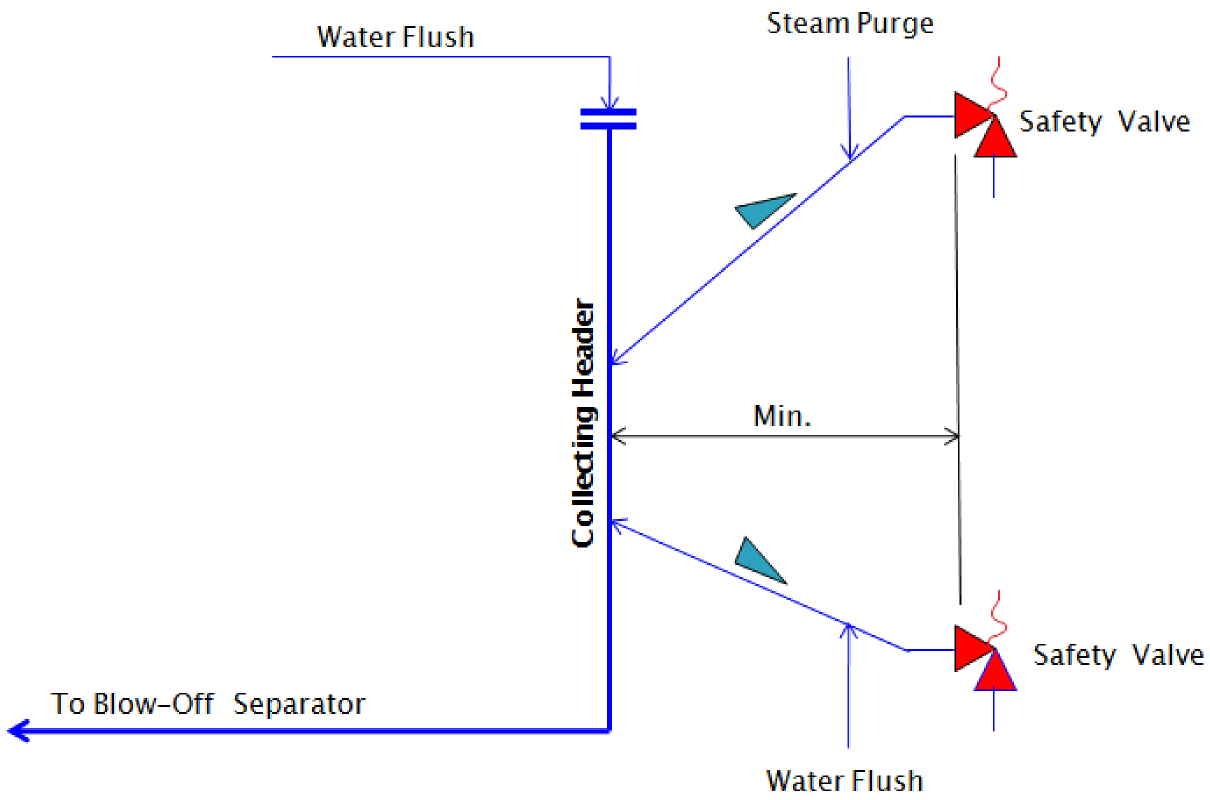
The volume of the drain tank is designed to accommodate a complete synthesis drain that might occur in case of tube rupture in the high pressure heat exchangers. To avoid blocking of the liquid outlet line from the separator to the drain tank and to maintain the exhaust systems and drain tank free of solid carbamate, a continuous water circulation is maintained.

In case of contamination of the tank with urea and/or carbamate due to PSVs blow-off or passing, the liquid can be recovered in the process by sending it to either process condensate tank or rectifying column depending on drain tank composition. During recovery, the minimum liquid level in the drain tank should be maintained by supplying fresh steam condensate.

New Purge System for PSVs connected to Flare System

Traditionally, the safety valves of the reactor and the synthesis rupture discs are not connected to PSV Vent Stack and provided with short discharge pipe to ensure that these critical safety valve outlets are not obstructed by solid carbamate due to passing of safety valves during normal operation. In the new design, all safety valves are connected to a collecting header routed to Blow-Off Separator.

Figure 2



Having connected the safety valves outlet to a closed collecting header, it is imperative to ascertain that the exhaust systems are free of solid carbamate. To achieve this each safety valve is provided with a purging system, refer figure 2 above.

Blow-off lines sloping upwards are purged with water, while blow-off lines sloping downwards are purged with steam. Each purge is provided with a flow meter and a high priority low flow alarm in the DCS for close monitoring and taking quick corrective action in case flushing flow is interrupted.

In order to obviate problems associated with PSVs passing, the flare header temperature (measured close to flare stack entry point) is maintained at 100°C with injection of auxiliary LP steam. The injection of this auxiliary steam is regulated with a temperature control loop. The flare header is also completely steam traced and insulated to minimize LP steam consumption.

For safety reasons, the ingress of oxygen (air) into the flare system should be avoided when flare is in operation. This is achieved by installing purge seals in each of the three Flare tips with nitrogen gas being used as purge medium.

Flaring of liquid/vapor ammonia

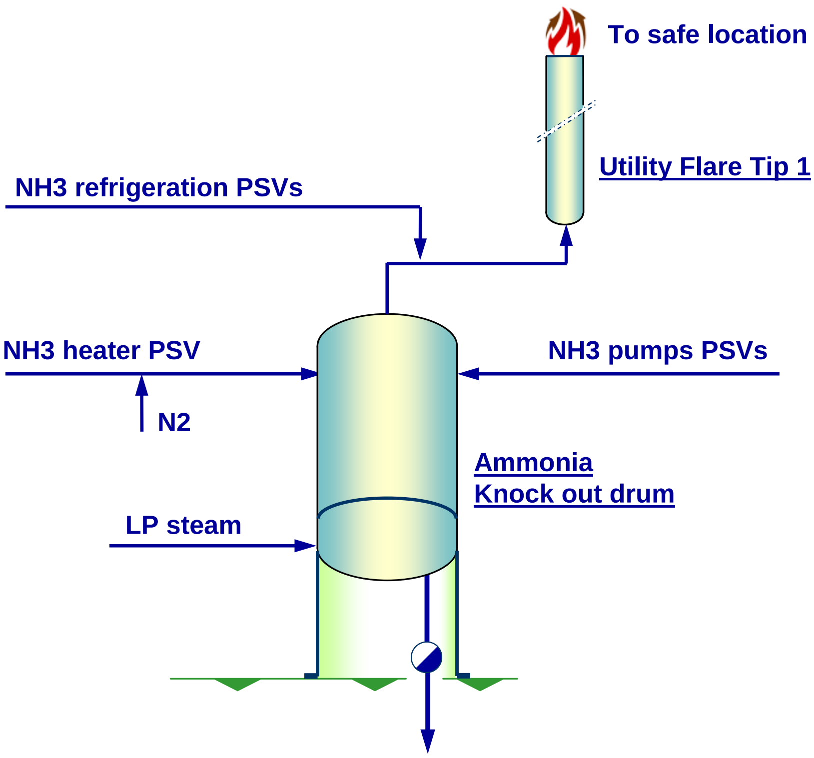
As might be known, liquid ammonia and water have a strong affinity. A sudden release of liquid ammonia into water produces enormous pressure waves. Hence to protect the drain tank, safety valves discharging pure liquid/vapor ammonia are treated differently as compared to process safety valves discharging NH_3-CO_2-H_2O mixtures. These safety valves are connected to a separate tip of the flare system dedicated for flaring only ammonia vapors (called Utility Tip-1).

The safety valves at the following locations fall under this category:

- Safety valves on HP Ammonia pumps
- Safety valves on Ammonia Refrigeration Unit of Granulation Unit
- Safety valve on HP Ammonia Heater shell side

In case of blowing-off of the above safety valves, only part of the ammonia will evaporate downstream the safety valve. The majority of the ammonia will cool down to a temperature of -33°C. The time needed to evaporate all ammonia depends on insulation and the ambient temperature.

Figure 3:



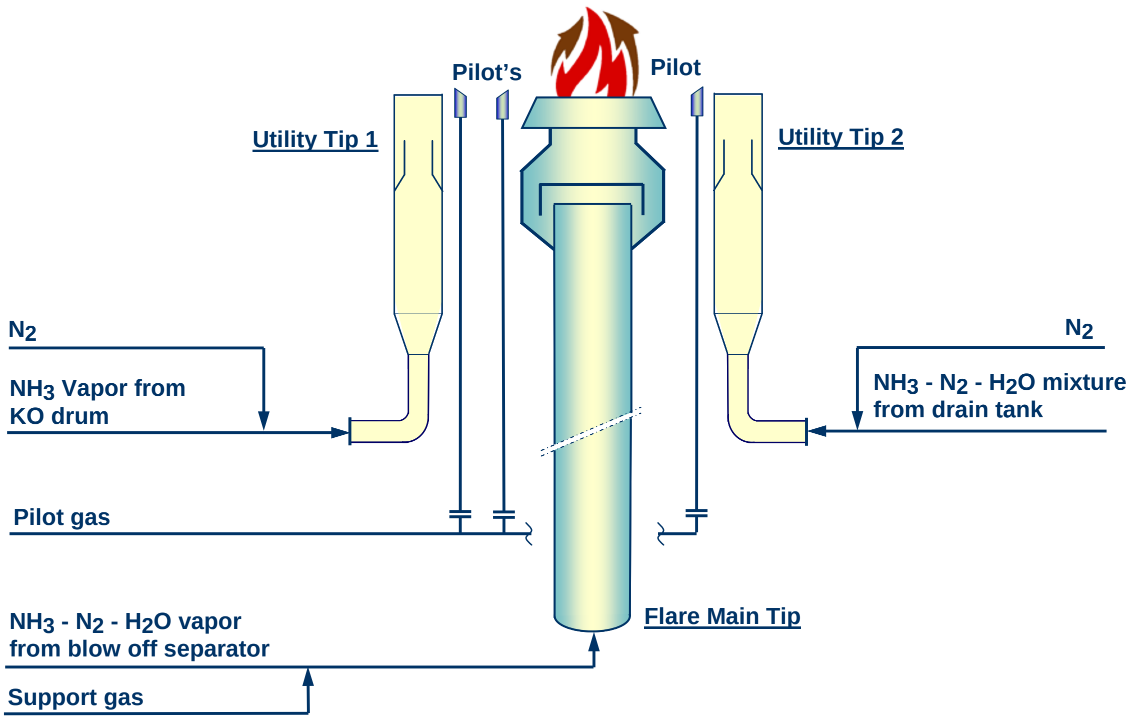
In order to avoid carry over of liquid ammonia to Flare Utility Tip 1 and to accelerate the evaporation of liquid ammonia, the blow-off lines from the safety valves are connected to a heated ammonia knock-out drum.

The volume of the drum has been optimized taking into consideration the liquid hold-up for each blowing-off case. However in order to preempt overfilling of the knock-out drum and consequently the flare header, an interlock has been incorporated to cut-off ammonia feed to Utility Tip 1 of the flare system, which does not require support gas.

General Arrangement of Flare System

The new flare system is installed on the top of the existing Prilling Tower that is no longer in operation. The Flare Main Tip will use natural gas as a support gas for combustion of the vent gases from the blow-off separator. There will be one utility flare tip (Utility Tip-1) for ammonia vapors from Ammonia Knock-Out Drum and one (Utility Tip-2) for the vent gas from the Drain Tank.

Figure 4



The Main Tip is provided with a Molecular Seal while the two Utility Tips are provided with Velocity Seals to avoid ingress of ambient air into flare system. The type and design of seals were chosen taking into consideration both the fixed and operating costs. The seals are continuously purged with nitrogen.

Natural Gas is used as support gas only in Main Tip and it is not required in both Utility Tip-1 and Utility Tip-2. Natural Gas injection will be normally kept isolated and presence of Natural Gas in Flare Header is monitored with online analyzer installed in the Flare header close to inlet flange of Flare Stack. When PSVs blow-off into collecting header, an online Ammonia Analyzer installed in the Blow-Off Separator gas outlet line senses presence of ammonia and initiates a process interlock by which support gas is automatically injected into flare header.

4. Absorber for Urea Solution Tank Vent

In Urea Plant-A a large Off-line Urea Solution Tank is provided for intermediate storage of urea solution during routine cleaning or upsets in Granulation Unit. While storing urea solution in tanks, emission of ammonia is unavoidable due to the breathing of the tank (continuous rise of liquid level) and urea hydrolysis and biuret formation. The ammonia emission from the tank increases with tank level and it is significant enough to cause serious ground pollution. It is a major nuisance to plant operating staff at times of unfavorable wind direction.

The following two options were explored to eliminate ammonia pollution from tank vents.

1) A dedicated small flare on tank top
2) Low pressure drop Absorber

The possibilities for flaring tank vent vapors were rejected for the following reasons:

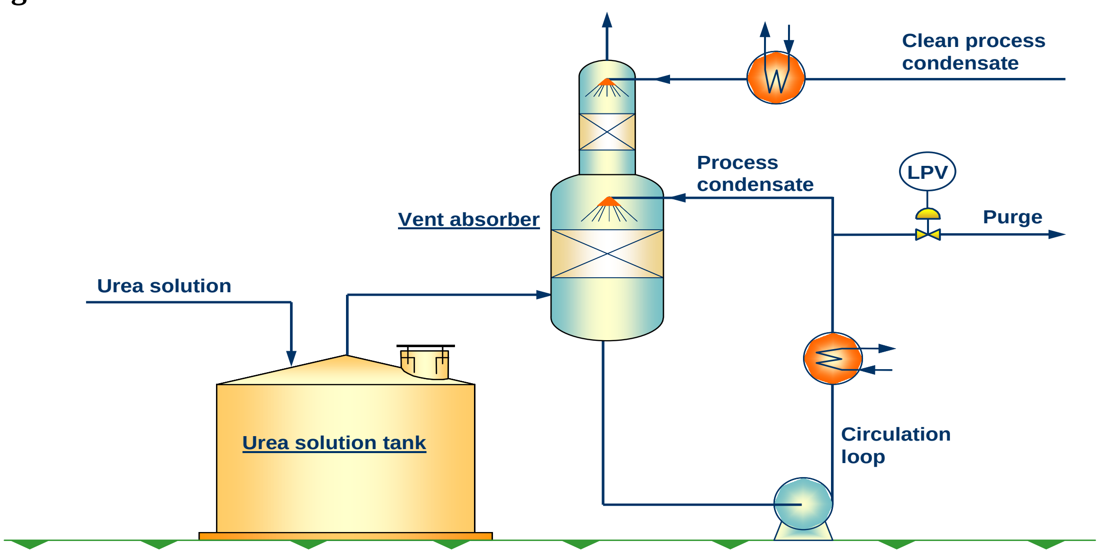
- The mechanical design pressure of the tank is limited to 150 mm H2O which was lower than the required back-pressure from the flare.
- Since emission of ammonia vapors from the tanks is almost always continuous due to urea solution transfer to the tanks during plant upsets and/or Granulation plant shutdown, installing a flare to destroy ammonia will not be a meaningful proposition
- The cost of flare system was much higher than that of absorber system

Hence it was decided to employ a “low pressure drop” absorber to knock-off ammonia vapors.

Off-line Urea Solution Tank

As already stated above, ammonia emission occurs due to hydrolysis and breathing when urea solution is stored during upsets in back-end section of urea plant and routine cleaning of the granulator. A detailed process calculation was carried out to arrive at the basis of ammonia emission rate for the design of absorber. The design of the absorber system was a challenge because of the maximum allowable pressure in the tank. The tank is foreseen with a water seal that breaks at an over pressure of 100 mm H_2O.

Figure 5



Ammonia and urea vapors from Urea Solution Tank is fed to the absorber wherein bottom bed is irrigated with circulating solution while the top bed is fed with steam condensate to scrub the residual ammonia before venting to atmosphere. The expected emission of ammonia at design load is 0.0 kg/h. This absorber system will be in operation only when urea solution is stored in the tank.

5. Conclusions

The successful design and implementation of PIC Zero Ammonia Emission Project is a good example of how both the continuous and discontinuous ammonia emissions from the urea plant can be captured and disposed off safely employing flares and/or absorbers for ensuring pollution free environment both within PIC plants and its neighbors at all times.

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Arab Fertilizers Association

Since 1975

Alexfert Experience in Commissioning and Operation of Ammonia Storage Tank

Eng. Mohamed Hasan Mowena
Eng. Mohamed Mousa Zamel
Eng. Abdel Qodos Gamal Fadl

Alexandria Fertilizers Co. (ALEXFERT)

Alexfert Experience in Commissioning and Operation of Ammonia Storage Tank.

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Alexandria Fertilizers Co. (**ALEXFERT**)
Alexandria, Egypt

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Alexfert Experience in Commissioning and Operation of Ammonia Storage Tank.

Alexfert has an ammonia storage tank with capacity of 10,000 ton, equipped with modern protection system, and loading facilities.

The paper describes the unit design, start-up experience, case studies, improvements and the recommended following-up for the safe operating conditions.

Introduction:

Alexandria Fertilizer Co. (Alexfert) - was established as in October 2003 on the coast of Abu Qir bay, on the Mediterranean coast of Egypt, with the preference of exporting its production (liquid ammonia and urea granules) via the nearest sea ports to Europe, America and West Africa.

The ammonia plant designed by Uhde with capacity of 1,200 T/D, while the urea plant was designed by Stamicarbon with capacity of 2,000 T/D. The urea production is exported via Alexandria ports, while the surplus ammonia production is exported via marine terminal at Abu Qir coast.

The plants were commissioned in August 2006.

Ammonia Storage System Overview:

The capacity of ammonia plant is 1,200 MTPD, of which, 1,100 MTPD is fed to the urea plant directly, to produce 2,000 MTPD urea. The surplus of about 100 MTPD has to be sent to the tank.

The accumulated surplus being exported via marine terminal for ammonia exporting, and for that purpose, the tank has two transfer pumps with capacities of 59 t/h (each), that can be used to feed ammonia to urea plant in case of ammonia synthesis section shut down or to feed the export marine terminal via a separate line.

Ammonia storage tank design:

The ammonia storage tank has a capacity of 10,000 ton liquid ammonia at atmospheric pressure. The principle of the tank design, erection and installation strictly follows the German & European standards. The tank was designed as a single wall tank with suspended deck inside (See figure 1), and specially insulated with foam glass at the tank bottom, PU-foam at the tank shell, and its roof is insulated with mineral wool.

The tank is equipped with a set of alarms and interlocking instrumentation system, along with safety detectors on-line analyzers to detect traces of ammonia in the surrounding area that keep the tank level and pressure monitored safely.

The tank is surrounded by a bund wall suitable for containing the spilled ammonia in case of emergency. Over the bund wall, there is fire water spray system to build up water curtain similar in height to the tank in case of ammonia spillage to absorb the emissive ammonia gas.

Ammonia storage tank safety and reliability System:

The ammonia storage containing liquid ammonia is highly protected against over & under pressure, over & under level; by a very restricted safeguard system, as follows:

I. Pressure Reliable Safeguard:

a. First safeguard (Ammonia Booster Compressors):

Two NH_3-booster compressors (One in operation and the other as stand-by). The NH_3 tank vapor at the boosters compressor suction, being compressed and sent to the main refrigeration unit of the ammonia plant. The pressure is controlled by the load of the compressors.

b. Second safeguard (Stand-by Refrigeration unit):

The stand-by refrigeration unit start to operate, during ammonia plant total shutdown, while the tank pressure exceeds the permissible fault range, this unit takes the vaporized NH_3 from the tank, reliquify it and direct the liquid NH_3 to the tank.

c. Third safeguard (Ammonia liquid feed valve)

The NH_3-liquid feed valve to the tank to be closed to stop filling of the ammonia tank if the tank pressure still increased.

d. Tank pressure control

The NH_3-tank is provided by instrument pressure control system with three pressure transmitters, which controls the operation of the two booster compressors, the standby refrigeration compressor, and tank vent.

e. Pressure control valve (vent valve)

The tank is equipped by pressure control valve, which directs the ammonia vapor to ammonia flare in case of tank pressure exceeds the permissible fault range.

f. Safety valves

The tank is equipped with two safety relief valves used for protecting the ammonia storage tank from unallowable over pressure and two safety valves for protecting the tank from under pressure.

II. Level Reliable Safeguard:

The ammonia tank level monitored by three level transmitters, with a set of alarms and interlocking loops to protect the ammonia transfer pumps even in case of low level, and to protect the tank even in case of high level.

Ammonia tank cooling down:-

After checking that all equipments and instruments are all ready for operation, the following steps were performed:

1) Nitrogen - Air Gas Exchange:

This step is very important as air and ammonia make explosive mixture at ammonia concentration of (15 - 27 %).

2) Leak Test & Pressure Safety Valves Test:

3) Nitrogen Purge for Storage Facilities:

This step aims to purge all the connected pipe lines to the ammonia tank with nitrogen.

4) Ammonia - Nitrogen Gas Exchange:

This step was done by controlled displacement for nitrogen with the preheated ammonia.

5) Ammonia Purge for Storage Facilities:

This step aims to displace nitrogen in the connected pipes to the ammonia tank with nitrogen.

6) Ammonia Tank Cooling down:

This process aims to cool down the ammonia storage tank at the operating conditions of - 33 ºC with the rate of 2 ºC/h. 100 ton of ammonia was utilized in this step.
The cooling down period depends on the climatic condition.

Potential Improvements in Unit Safe Operation:

The ammonia storage tank vent & safety valves have a pressure control valve, which in some rare cases may open to control the tank pressure to the atmosphere. The ammonia gases from this pressure control valve is directed to an ammonia flare far away (90 m) from the tank to ignite the ammonia gases emissions prior venting to the atmosphere, and this ammonia flare is fully equipped with automated ignition system for the flare safe operation.

Case Studies: Ammonia gas leakage from tank manhole:

During routine checking for ammonia tank base, it is observed that condensate with ammonia odor is coming from the anchors base plates.

A. Investigating the cause of accumulated condensate:

1. Action Taken:

   a. Checking the anchors down the ammonia storage tank base, that shows the presence of water condensate amounts varied from anchor position to the other one.

   b. Samples were collected from the condensate accumulated at the anchors to detect the source of ammonia odor.

2. Problem Analysis:

   a. By investigation, it was found that the daily changes in climatic conditions due to the humid marine atmosphere besides the location near to the urea plant cooling tower, leads to vapor condensation at the tank wall, which moves down to the concrete base (with larger diameter than that of the tank as shown by figure 2), escapes under the tank base insulation, and getting collected with time which appeared later when opening the anchors base plate.

   b. The problem was solved by installing aluminum plates all around the tank base to spill-off any collected condensate away from the tank base as shown by the following figure (3, 4).

B. Detecting the ammonia leakage source:

i. The analysis results for the samples taken from the anchors at the ammonia storage tank base revealed that the ammonia concentration was 1500 ppm, and this condensate exists at the anchors (8 – 12), localized underneath the tank manhole, with no ammonia odor detected in the collected condensate from the rest of anchors, that is shown by figure (5).

ii. Back to the history of the tank, during the tank inspection, all welds were inspected 100 % by X-ray, except for the welding of the weld seal gasket of the tank manhole, as it was just inspected by dye-penetration due to narrow gap between the two flanges, with difficulty of inspecting it by X-ray. So, it is suspected that the weld seal gasket may sustain pinhole or crack.

iii. Exploration was done around the manhole insulation by doing inspection holes revealed that the ammonia concentration at the manhole lower part was 500 ppm, while it amounts to 50 ppm at the top part of the manhole, which matches with the idea that the manhole is the source of ammonia in the collected condensates.

iv. Special clamp was installed around the manhole, and then injection was done by suitable sealing material for such purposes, for the flanges and its bolts.

v. The ammonia concentrations at the anchors base are monitored regularly, and it decreased gradually during 5 months to about 2-5 ppm.

Conclusions:

1. The ammonia tanks which are located in humid marine areas preferred to be with the same diameter as its concrete base, to avoid condensate collection underneath the ammonia tank base plates.

2. Intensive inspection should be applied for all welds of the ammonia tanks, including the manholes weld seal gaskets.

3. Close monitoring and routine inspection for the whole ammonia storage tank & associated facilities, are of great importance for all aspects such as tank insulation, tank base, electric and instrumentation utilities,…etc.

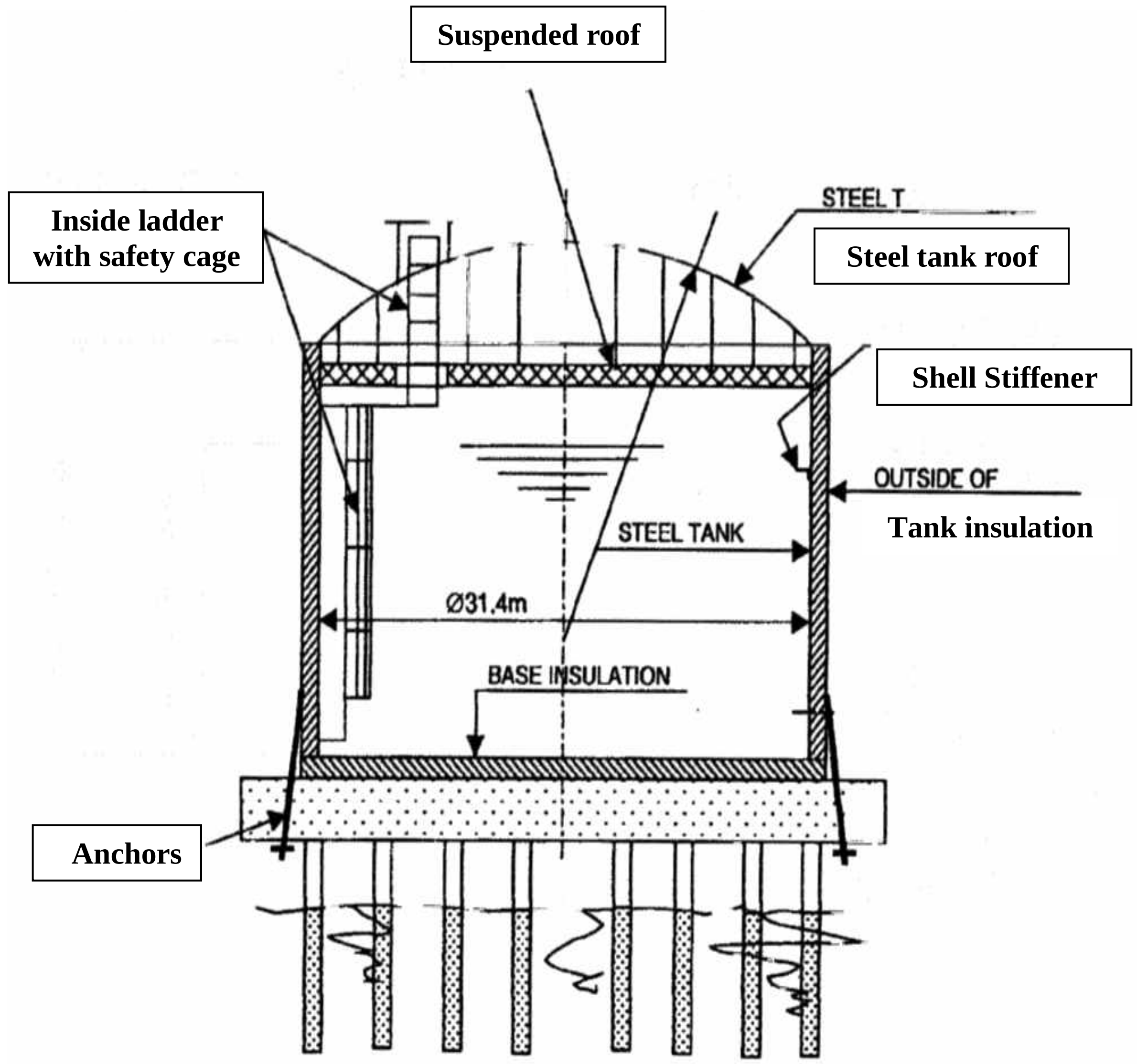


Figure (1): Ammonia Tank Design

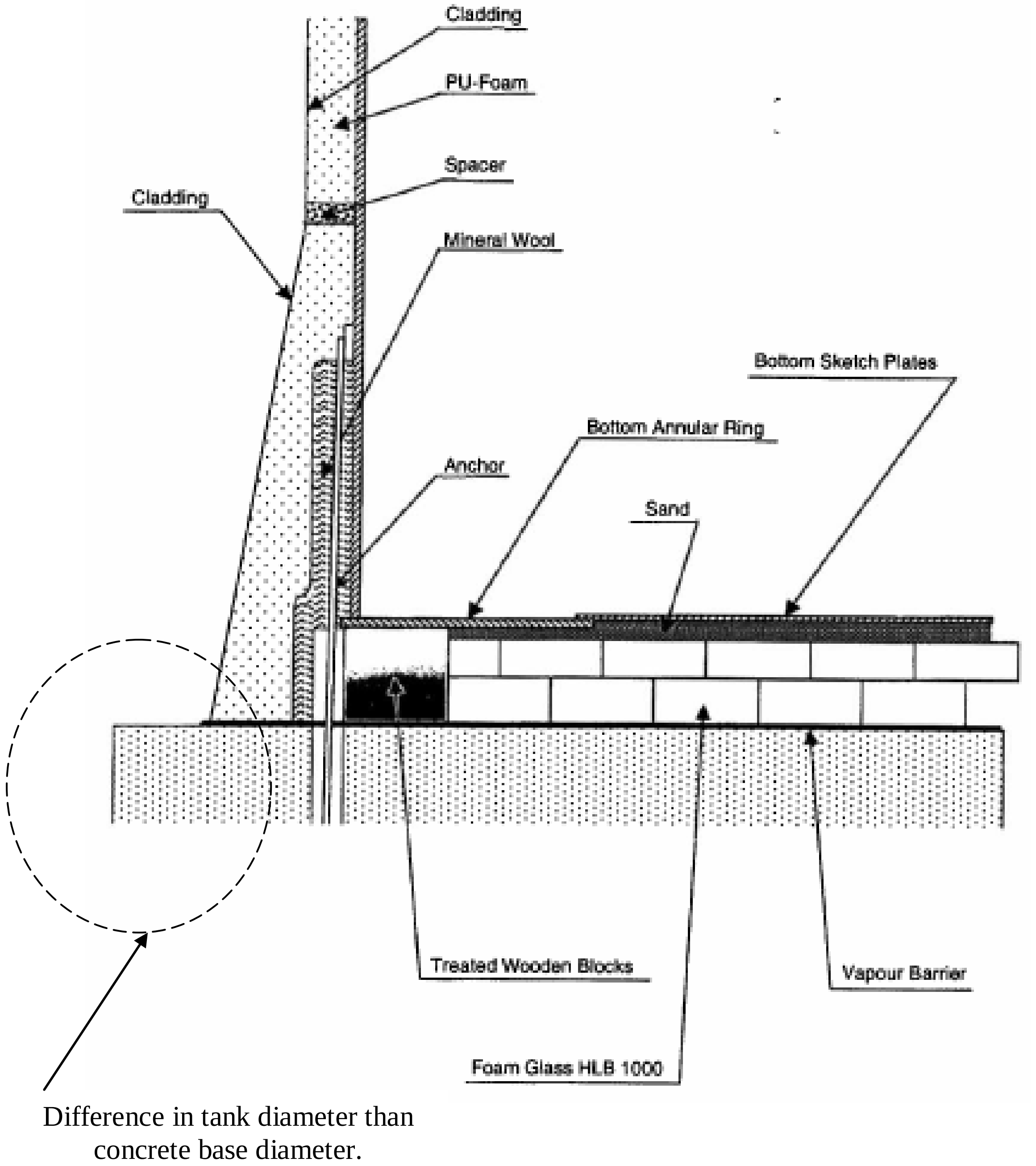


Figure (2): Ammonia storage tank insulation sketch.

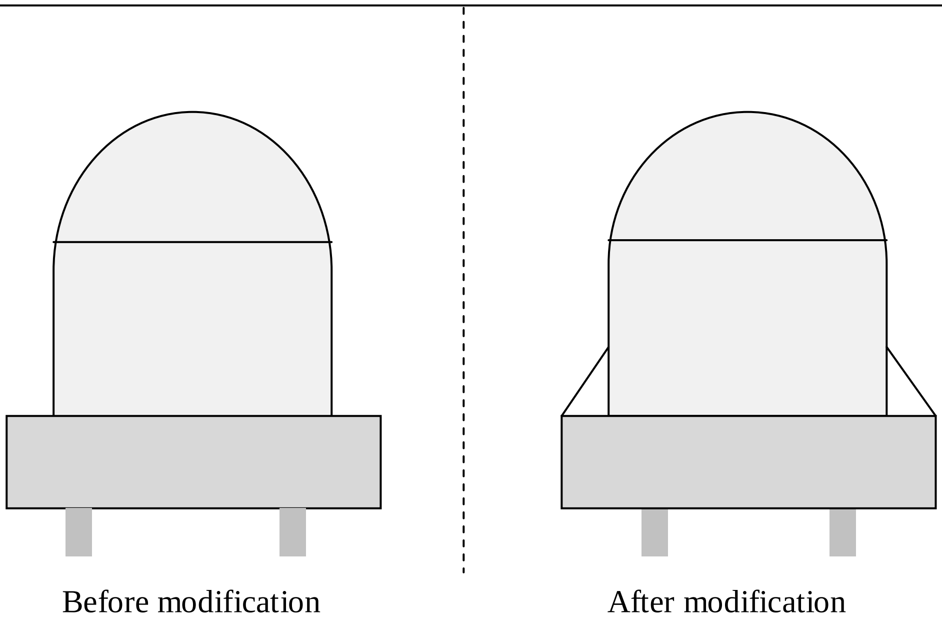


Figure (3): The modification in the tank base by installing aluminum sheets

Figure (4): The installed aluminum sheets around the tank base.

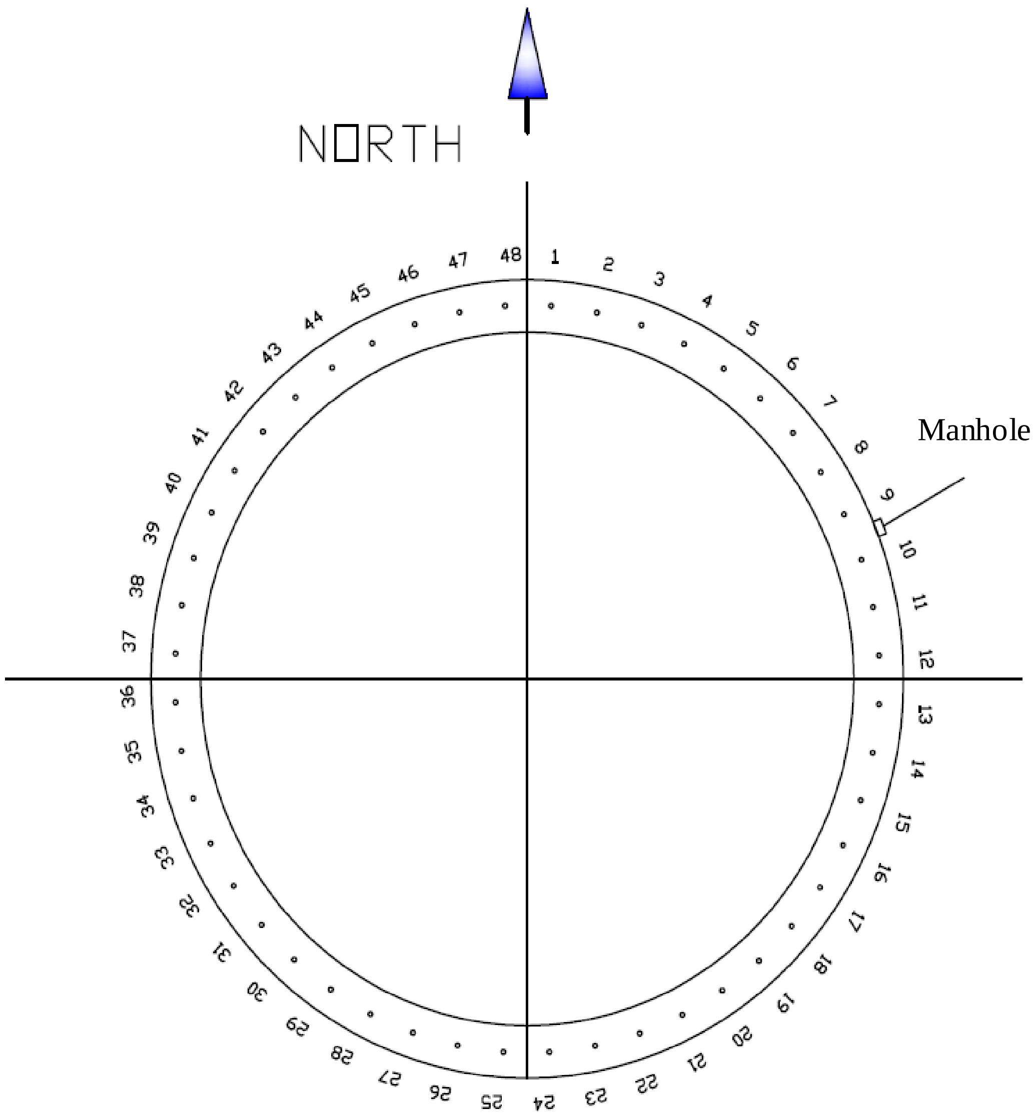


Figure (5)
Ammonia Tank
Base Anchors

Since 1975

GPIC experience in changing the hydraulic to Electronic Governor

Jamal Al Shawoosh
Methanol Plant Superintendent

Gulf Petrochemicals Industries Co. (GPIC)- Bahrain

GPIC experience in changing the hydraulic to Electronic Governor

Prepared by: Jamal Al Shawoosh

Methanol Plant Superintendent jshawoosh@gpic.net

Gulf Petrochemical Industries Co. (GPIC) - Bahrain

Introduction:

GPIC started to produce Ammonia and Methanol in 1985 with name plate capacities of 1000 MTPD each. Both plants have undergone a debottlenecking project to increase their production by 20% each in 1989. In 1998, Urea plant was commissioned utilizing ammonia product and CO_2 side product from Ammonia Plant with a nameplate capacity of 1700 MTPD.

Methanol Plant was built with UHDE technology and ICI technology for the Synthesis unit. The operating pressure for ICI reactor is 80 barg which could be achieved by a steam turbine driven centrifugal compressor. The steam turbine is a condensing/extraction type turbine with a maximum governor speed of 10410 rpm. The speed was controlled by a woodward PGPL hydromechanical governor with linear output and pneumatic speed setting.

This governor was in service since 1985 till 2007 and has given the best of its performance over that period of time which is evident from the uninterrupted Methanol Plant running records that has reached to 931 days of continuous running. However, the new turbines are fitted with electronic governors due to their technical superiority to achieve finer controls compared to mechanical governors. Moreover, the compressor control can also be embedded with the electronic governor control to achieve higher efficiency from such a high speed rotating compressor by running them closer to surge curve as will be detailed later. In addition, it is a known fact that the specialist to overhaul and calibrate the woodward governors are few only and hard to get them whenever required. From that angle, GPIC decided to replace the hydraulic governor to Electronic Governor in 2007.

Electronic Governor Configuration – fig (1):

The woodward 505E is standardized extraction –turbine controller, fixed hardware and application that can be configured to suit different turbine setups and characteristics. The design of Electronic Governor meets the requirements of API 612 for Installation in Petroleum and Chemical Industries.
Data based on the turbine specification, included steam map, and starts up sequence information supplied to the manufacturer are configured in the Electronic Governor software.

The Electronic Governor Cabinet is installed in the Local Control Room and a Local Operator Panel (LOP) was mounted near the turbine. An operator station was provided at the central control room for remote operation with an interface with 505E via Modbus. To interface the 505E controller with the two hydraulic actuators on the turbine Voith I/H convertors. These convert the mA valve demand signals from the 505E into a 1.5-4.5 bar oil pressure. This controlled pressure will be the position demand signal for valve servo which, together with the feedback lever, will position the steam valves (HP speed control& LP extraction control).

The Voith redundant I/H consist of one skid, a manifold block with max-selected valve and two Voith I/H convertors with manual override.

The extraction pressure controller was modified as manual loader and the same analog output serves as remote extraction pressure feedback from DCS and wired to the Electronic Governor Cabinet.

The new system was provided with comprehensive self diagnostics such that all permanent and transient faults are identified, alarmed, reported and retained by the system till acknowledged by the user. GPIC planned to retained the existing emergency trip device, stop valves and HP/LP actuators of the steam turbine.

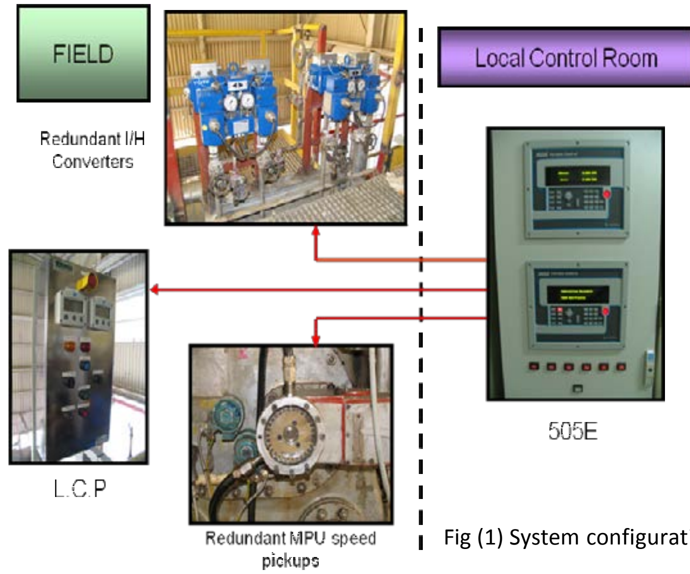


Fig (1) System configuration

Improved Safety in the Electronic Governor:

- HP valve opening is limited to 30% in case of speed not detected until 505E trips.
- HP valve maximum opening was limited to 93.75%, to avoid disturbances to turbine on account of opening of the 5th nozzle's plug (the turbine is manufactured with five steam inlet nozzles).
- LP valve minimum opening set at 35% during start-up, to ensure better loading on LP during Start-up – Refer to Fig (2).

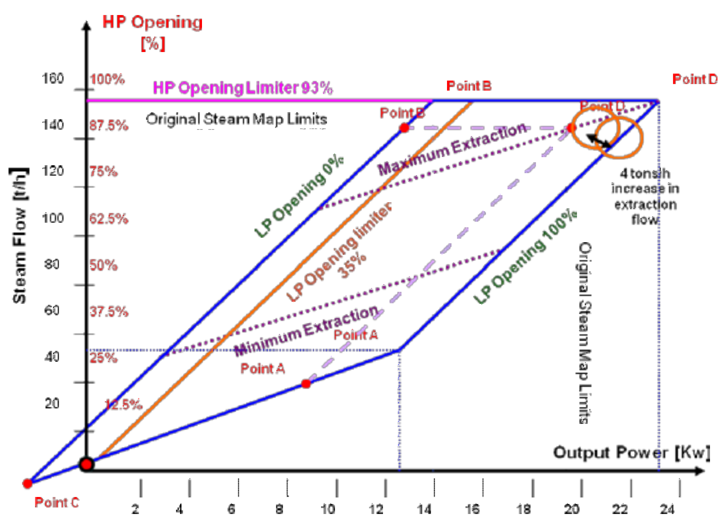


Fig (2) Turbine Characteristics Curve shift

Improved Extraction Pressure Control

- Originally Extraction feedback was kept in manual, to avoid disturbances to turbine operation in case of fluctuation in extraction pressure. After the upgrade the extraction pressure feedback is enabled, and 5% droop characteristics is introduced to minimize the disturbance. And turbine efficiency was improved by introducing extraction pressure feedback which was not possible by manual control.

During the said job, some challenges were faced that have been resolved internally in consultation with the vendor. Those challenges can be categorized with respect to their nature to either mechanical/fabrication or instrument/electrical.

Mechanical/Fabrication

1. The control oil lines had to be modified to install the Vioth converters (I-7H).
    a. The oil lines had to be properly flushed free from welding particles to avoid damage to vulnerable hydraulic components.
    b. Identification and Installation of blinds for control oil system as it is linked to main oil console.

Instrumentation / Electrical aspect

c. Selection of the model; to go for simplex or TMR. Then decided to go for simplex as space is limited and it is cost effective. However, redundancy is not available. GPIC came up with a custom design to improve the availability of the system by providing another 505E as hot spare.
d. Start up limits of the HP/LP lifts changed to new settings. (full open to limited setting to enhance safety)
e. The need to extrapolate the steam map of the turbine due to higher output requirements as shown in the characteristics curve.
f. Laying of control/signal cables from main control room to the LCR and installing an HMI in the methanol DCS. This is a pre turnaround activity that needs a lot of attention to avoid disturbing the live system.
g. Modifying DCS emergency shutdown signals and I/O signals for analogue and digital signals.
h. Installation of redundant MPU speed pick-ups. For this the speed gear detector had to be modified along with the housing for installation of the probes.

Innovation and implementing the best practices is one of our pillars in GPIC towards the continuous improvement. That's why we have moved strongly toward implementing this change regardless the biggest challenge we have faced which was the fear from change and the people resistance.

Benefits of Electronic Governor:

- Highly reliable system at reasonably low cost and limited space requirements.
- Perceived benefits such as:
    - Eeasy calibration and tuning,
    - Fast/smooth start-up.
    - Advance diagnostics features.
- More safety features, valve limiters.
- Automatic more reliable extraction pressure control than before and adjusts automatically at different variation of speed also absorbs pressure fluctuations.

- The new electronic governor has enhanced the reliability of turbine.
- Accurate control of speed at all operating conditions.
- In case of failure in the signals coming from DCS, the command signal will be frozen at the last valid value and speed & extraction set point can be controlled through OS in MCR or 505E front panel in LCR.
- The machine can be started from either Local control room, Local Operating Panel or from Main control. With the predefined start up curves.
- New governing system calculates the time of shut down and defines the start up as hot or cold start up.
- Speed detection system is dual magnetic pick ups (MPU) in case of one MPU failure the other will be used for controlling the speed automatically.

The Governor replacement project was implemented in 2007 during the annual turnaround, and it was adapted to the turbine controls and commissioned very smoothly without any major problem. This is mainly due to having a clear scope of work and job assignments prior to the implementation phase.

الإتحاد العربي للأسمدة

Arab Int'l. Organization هيئة عربية دولية

Arab Fertilizers Association

Since 1975

Successful Completion Off Carbon Dioxide Recovery (CDR) Project at GPIC

Gulf Petrochemicals Industries Co. (GPIC)- Bahrain

Successful Completion
Of Carbon Dioxide Recovery (CDR) Project
at GPIC

24 December 2009

Gulf Petrochemical Industries Company
Post Box 26730, Kingdom of Bahrain

Successful Completion of Carbon Dioxide Recovery (CDR) Project at GPIC

Executive Summary

GPIC is one of the first Petrochemical Companies in the Middle East to embark on a Carbon Dioxide Recovery (CDR) Project, to cut down green house gas (GHG) emissions and to improve overall efficiency of natural resources by enhanced production of Methanol and Urea in its complex.

GPIC awarded the contract to Mitsubishi Heavy Industries (MHI) Japan, for the Carbon Dioxide Recovery Technology License and to Tecnimont ICB (TICB), Italy, for the Engineering, Procurement, Construction (EPC) for setting up the Carbon Dioxide Recovery Unit.

The contracts were signed on 25th October 2007. The CDR Project construction work was inaugurated by HE. Mr. Yousef Al Zamel, GPIC Managing Director, on 27th August 2008.
The Project was scheduled as a "Fast Track" project to achieve completion within 27 months to enable GPIC reaps the financial benefits of early completion.

The success of this project is mainly attributed to the following:

1. Support and guidance of the GPIC Board of Directors throughout the Project.
2. Selecting the Best technology
3. Selecting good EPC Contractor with prior experience in similar work
4. Identifying and carrying out tie-ins with the existing plants in Turnaround 2007
5. Involvement of GPIC, for selection of Vendors for all equipment and for selection of Sub Contractors for the site works.
6. Visit of GPIC Project Team key Personnel to other CDR Units prior to awarding the contract to identify the requirements and improvements
7. Involvement of GPIC Project team from Engineering Phase for all disciplines to ensure the design commensurate with GPIC and International standards.
8. Involvement of GPIC Project Team in construction and commissioning work
9. Project Management was carried out by GPIC Project Team by close monitoring of all activities related to project execution by the EPC Contractor
10. Involvement of young Bahraini Engineers from the initial stages of the Project to give them good exposure and to develop them for future assignments.
11. Involving a Safety Specialist from the Construction stage at site to ensure the construction work is carried out safely and with compliance to GPIC Permit to work system. This is reflected in project site completing more than 900,000 man hours without LTA, from commencement to completion of the project.
12. Monitoring and witnessing inspection activities of all critical equipments on site and off site at vendors' workshops to ensure the quality control at all stages of fabrication of critical equipments.
13. Regular visits to vendors workshops and EPC Engineering offices to monitor and verify the progress of the work and to draw out strategies to avoid delays
14. Cash flow plan was drawn from the beginning of the project, to ensure sustained liquidity for payment to the Contractor Invoices on time, without any delay.

15. Training and familiarization visits of GPIC personnel were arranged at similar technology plants, in preparation for commissioning and start up.
16. The project was completed within the allocated budget without any variation in cost and ahead of schedule by one month.

Commissioning of the CDR Project is another important milestone in the history of GPIC. Addition of the CDR unit will contribute significantly to the enhancement of the existing high levels of production and augment over responsibility and care towards the environment.

Abdulrahman Jawahery
General Manager

<u>Project Milestones:</u>

- 19/02/2007: GPIC Board of Directors approval for the CDR Project
- 17/04/2007: Request for LSTK Proposals
- 28/06/2007: Receipt of Technical Proposals
- 31/07/2007: Receipt of commercial Proposals
- 21/08/2007: Technical & Commercial negotiations with EPC Contractors
- 03/09/2007: Receipt of Revised offers
- 08/09/2007: Request for additional budget
- 25/10/2007: Signing of contract with MHI & TICB for the CDR Project construction
- 04/04/2008: Signing of KS1 Agreement with MHI, Japan
- 29/07/2008: Start of Test Piling Activities
- 10/08/2008: CDR Project site handover for construction
- 27/08/2008: Inauguration of CDR construction work by GPIC MD
- 18/09/2008: Issue of daily Reports CDR – Daily Bulletin
- 31/01/2009: Completion of Installation of CDR Columns
- 27/07/2009: CDR Model to Training Centre
- 25/11/2009: Mechanical Completion
- 20/12/2009: Start of CO_2 Production
- 24/12/2009: Inauguration of CDR unit by GPIC Board

1. Carbon Dioxide Recovery Project at GPIC

Gulf Petrochemical Industries Company (GPIC), located at Sitra, Kingdom of Bahrain, was incorporated in 1979 as a Bahraini Joint Stock Company in the Kingdom of Bahrain with equal participation by the Government of Bahrain, PIC Kuwait and SABIC group of Industries, Saudi Arabia. GPIC is a fine example of a successful joint venture in the Arabian Gulf. The company owns and operates a petrochemical processing complex comprising a single stream Ammonia, Methanol and Urea Plant (granulation route) with associated utilities, offsite and material handling plants.

The Ammonia and Methanol plants were originally designed for 1000 metric ton per day each. Subsequently to the debottlenecking of these plants in 1989, their capacity increased to 1200 metric ton per day each. In January 1998, GPIC commissioned its Urea plant having a capacity of 1700 metric tons per day. For Ammonia and Methanol Plants, Uhde GmbH, Germany was the Technology Licensor and Snamprogetti, Italy was the Engineering Contractor. The Technology Licensor of the Urea Plant was Snamprogetti and the Engineering Contractor was MHI, Japan. Urea Granulation Technology License was from Hydro Fertiliser Technology, which was later acquired by Uhde Fertiliser Technology, Germany.

Prior to the Urea plant commissioning, Methanol plant had been utilizing about 275 metric tons of carbon dioxide every day, out of the total quantity of 1240 metric tons generated as a by-product of Ammonia plant. Rest of the Carbon Dioxide, 965 metric tons per day was being vented. Subsequent to the commissioning of the Urea plant, the production capacity of the Methanol plant dropped to 1080 metric ton per day owing to the diversion of all the carbon dioxide for Urea production.

The commissioning of Urea greatly helped in cutting down the emission of greenhouse gases to the environment and significantly contributed towards the economy of the Kingdom of Bahrain.

With the availability of proven CO_2 capture technology and its positive impact on the environment, GPIC decided to install a Carbon Dioxide Recovery (CDR) Unit in the year 2007, to recover Carbon Dioxide from the Methanol reformer flue gas. In addition to further minimizing emission of Green House Gases (GHG) and ensuring GPIC's commitment to efficient utilization of the natural resources, the addition of CDR Unit will also augment Methanol production capacity by 120 metric ton per day and also enhances Urea production capacity.

The configuration of Production Capacities post CDR Unit is shown in Figure 01 below:

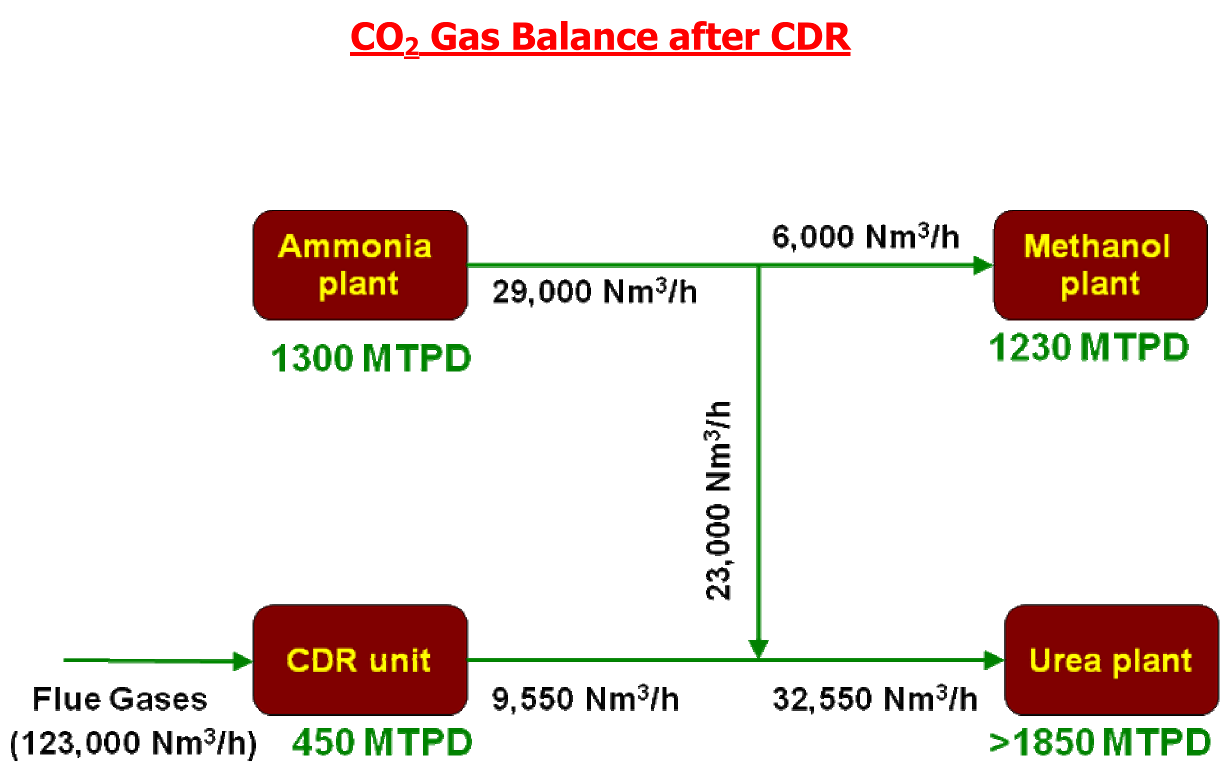


Figure 01

2. CDR Project Conceptualization

CDR project was conceived in the year 2006 as a strategic development plan for enhancing the production of Methanol and Urea plants. This was identified as a very promising environmental friendly project, as it helps to minimize the Green House Gas emissions and also contributes towards the National economy.

3. Feasibility Study

The objective of the study was to evaluate the CDR Project proposal covering both the technical and economic aspects of the project. Accordingly, the Pricing mechanisms and the price outlook for Methanol and Urea were reviewed keeping in view the market outlook for these products. The study also covered the technology which GPIC aim to adopt for the CDR Unit. An assessment was carried out of the likely investment costs for the proposed project and its economic evaluation.

The cost benefit analysis of the CDR Project revealed favorable return of 20.6% on the investment of US $ 52 million.

The project did not call for outside expertise. In-house project and operating experience was more than adequate to handle this project and operate the unit. GPIC constituted a team of highly experienced engineers dedicated to this project. The team played a pivotal role in decision making in every aspect of this project.

4. Invitation to Bid (ITB)

Invitation to Bid documents were prepared in-house by a team of GPIC Engineers. ITB was prepared based on GPIC's Experience of operations and maintenance of the Ammonia, Methanol and Urea Plants for over 25 years.

Some of the important issues covered in the ITB included:

a) Specifications
b) Standards
c) Scope of Work
d) HAZOP review during development, engineering and implementation of the Project
e) Risk assessment of the project
f) Environment impact study
g) Establishment of SHE management system's during construction.

ITB was prepared and issued to shortlisted EPC contractors in May 2007.

5. Project Risk Assessment:

Project Risk Assessment was carried out in July 2007. This was prepared using the "Risk Matrix – Probability versus impact" method.

It was essentially a "Project Execution Risk Register". The report covered all the possible risks associated with the Project execution. Following are some of the risks which had been identified:

1. High EPC cost for the Project
2. Regulatory Approvals
3. Unclear responsibilities between EPC/ Licenser/ GPIC
4. Price Escalation Agreements
5. Financial failure of selected EPC
6. Financial failure of equipment vendor
7. Financial failure of key sub-contractor
8. Force Majeure
9. Inadequate ITB
10. EPC bid non-compliant
11. Delays in getting the equipment at site
12. Poor quality of equipment/ material

13. Transportation of large equipment
14. Difficult tie-ins
15. Serious accident or emergency on construction works… etc

The majority of the identified risks (43 nos.) were classified under "Low probability with low impact". There was no risk under "Medium or high probability with high impact" category. GPIC by carrying out the Risk Assessment assured that CDR Project had no major risks.

6. Environment Impact Assessment (EIA)

GPIC prepared the Environment Impact Assessment Report (EIAR) for the Carbon Dioxide Recovery (CDR) Project. Since this project was under category B of the World Bank EIA guidelines, full EIA was not required; however environmental analysis was necessary.

The assessment had revealed that this project had a clear positive environmental impact. At its full capacity on 20 December 2009, the CDR plant recovered 450 MTPD of CO_2 that was otherwise being vented into the atmosphere. In addition to CO_2, the unit also removed 355 kg/day of SOx from the flue gas in the pretreatment section.

It will also enhance the process efficiencies of production of Methanol and Urea, in terms of product per unit of natural gas consumed. In this assessment report, all potential impacts on the environment during the development and operation phase, based on MHI Technology have been identified.

The main aspect of this project is the accidental leakage of chemicals. Study revealed that care should be taken to avoid such spillage during the transporting, handling, storing and use of associated chemicals.

The CDR area has been specially designed to contain any accidental spillage of chemicals. Containment bunds have been provided for all the pumps and a slop tank has been provided for collecting the spillages. The auxiliary units for the running of the CDR unit and in particular the package boiler and the Incinerator are monitored closely, to ensure full compliance with the relevant environmental legislations of the Kingdom of Bahrain.

The waste liquid stream which is not toxic, require no treatment and therefore routed to the sea water return header. The exhausted gases either from CO_2 Absorber, Incinerator or the Package Boiler of the CDR Unit, are released to the atmosphere as they meet the Environmental Standards.

The project has a positive socio-economic impact, as it will add to the profitability of GPIC; hence its direct contribution into the National economy.

7. Strategic Decisions

GPIC took the following decisions to channelize all actions to remain focused for steering the Project:

- **Selection of Capacities**: GPIC decided to construct a 450 MTPD Plant to match its capacity similar to other recent plants. This allowed contractors to bid for the project on the basis of replicating recent projects elsewhere, reducing the risks associated with the project. The new capacity was compatible with raw materials and space availability.

- **Selection of Technology**: Based on the technical review of the technology providers, GPIC selected a proven technology taking in to account the efficiency of CO2 absorption as well as reliable operation and maintenance, having minimum environmental impact.

- **Project Management**: Considering the size of the project, GPIC Management decided to carry out Project management function by the Project Team itself.

- **Form of Contract:** GPIC after review of various types of contracts, decided to opt for a lump sum turnkey (LSTK) contract with single point responsibility of the EPC contractor. GPIC preferred the LSTK type of contract because GPIC could reasonably estimate the amount of work and risks involved. The progress and the performance etc. could be quantified, measured and demonstrated.

- **Project Insurance:** It is very important to design an insurance program which mitigates all risks during the project stage, in avoiding loss due to delay in project completion. Without limiting the EPC contractor's liabilities in the project, we had to arrange for insurance covers to mitigate various risks faced by the organization. GPIC on the advice of the Insurance Consultant's took the Construction / Erection All Risks Insurance Cover.

  The main advantages of the above insurance cover is better control, breadth of coverage, cheaper rates and control over claims recovery.

8. Signing of Agreement between GPIC, MHI and Tecnimont ICB

GPIC considered the well known EPC contractors having strong partnership with technology providers and relevant experience with proven record in the business of constructing the CDR Plants to ensure success of the project. The final selection was made based on techno-commercial offer.

Prior to GPIC's CDR project, MHI had been working with Tecnimont ICB of India who was the EPC contractor for the two CDR plants in India. TICB is an approved MHI EPC subcontractor and is a member of the Tecnimont Group of Italy.

A Memorandum of Understanding (MoU) among the three parties i.e. GPIC, MHI and Tecnimont ICB (TICB) was signed that became an integral part of the Engineering, Procurement and Construction (EPC) Contract between GPIC and TICB.

The objective of this MoU was to clarify each party's respective obligations with respect to the License Agreement (between GPIC & MHI) and Lump Sum Turn-Key (LSTK) EPC Contract (between GPIC & TICB) for the successful execution of the CDR Project in a smooth and effective manner. The contracts with MHI and TICB were signed on 25 October 2007. The contract schedule was prepared for a 'fast track' project (27 Months) to enable GPIC to reap the financial benefits of early production.

The kick-off meeting was held between GPIC and TICB in the presence of MHI in Mumbai during the last week of November 2007, to clear all outstanding commercial and technical queries carried over from the agreement negotiations. In addition, the project co-ordination procedures were discussed and agreed upon.

9. Project Control

To ensure proper control of the CDR project, the project co-ordination procedures between TICB and GPIC were developed. The development of GPIC Internal quality procedures was another factor that enhanced the project control. One of the key success factors for the project was to have an integrated project organization between EPC contractor and GPIC project team. The objective was to ensure that GPIC team was completely involved during the various stages of the project and that the know- how was imparted effectively to GPIC team besides ensuring GPIC theme of TEAM WORK.

The team kept a close monitoring on various activities related to project execution by the EPC contractor on day-to-day basis and developed strategies of "next plan of actions".

The team reviewed and approved Contractor's detailed design and engineering documents, participated in Hazop studies, monitored fabrication work of critical equipment, supervising of construction works, commissioning and performance tests.

10. Engineering

All basic engineering was carried out at MHI, Japan. The documents were received by GPIC for comments and approval. This was in line with the agreed procedures as it is the only effective method of assuring cross discipline checking and the flow of supplied data into the design. Detail engineering was completed at TICB Mumbai. TICB carried out the design of all processes, piping, electrical and instrumentation facilities, civil foundations and structures in Mumbai. GPIC's team of experienced engineers who were dedicated to this project visited TICB's office's to streamline all aspects related to this Project.

The visits were made until the team of TICB engineers shifted to Project site in Bahrain. GPIC also deputed Inspection and Mechanical Engineers to monitor the quality control of critical equipment.

GPIC applied more stringent management level controls than is the norm for this type of contract. Generally, in a lump sum contract 'due diligence' style of client management is applied which means relatively few personnel are involved in reviewing selected key documentation. However, in case of the GPIC CDR project, additional experienced Bahraini engineers of all disciplines, together with the Senior engineers reviewed all drawings and documents.

As CDR project was to be integrated with the existing GPIC complex facilities, it was important to apply more than adequate engineering supervision level by GPIC to meet the required interface with the existing complex. A number of actions were taken to assist in co-ordination of the engineering activities, including the use of regular conference calls and the electronic transfer of data between Japanese, Indian and Bahrain Offices. This helped to greatly improve the speed and accuracy of communications. However, hard copies of correspondence and documents were also transmitted as a permanent record.

11. GPIC CDR Project Profile:

Following are the highlights of the CDR Project

▪ CO_2 recovery capacity	:	450 MTPD
▪ Flue gas source	:	Methanol reformer flue gas
▪ Use of CO_2	:	To enhance Methanol production by 120 MTPD To enhance Urea production by 80 MTPD
▪ Project duration	:	27 months
▪ Project location	:	West side of Methanol reformer
▪ Total Cost of the Project	:	US $ 52,000,000
MHI – Technology Licenses Basic Engineering		US $ 2,150,000
TICB – EPC Contractor		US $ 44,850,000
GPIC - Spares, Insurance Training		US $ 5,000,000

12. Brief Process Description:

The CDR Unit is basically a low-pressure CO_2 recovery unit in which flue gas from the Methanol Stack at a temperature of 206^oC is first quenched with demineralised water in a direct contact quencher. Water is supplied to the packed column using structured packing, and then treated with caustic soda to remove the sulphur oxides present in the flue gas. The flue gas is then compressed in a flue gas bowler, and fed to CO_2 absorber. The CO_2 absorber is a two bed column with structured packing's. Bottom bed is for CO_2 absorption and top bed is for washing of exhaust gases.

In this column, CO_2 is absorbed in a special solvent (KS-1), supplied from the top of the absorption section. Flue gas after washing is then exhausted to the atmosphere. Rich solution is regenerated in the regenerator by supplying heat through LP steam reboilers.

Lean solution from the bottom of the regenerator is cooled in the lean solution cooler using cooling water and re-circulated back to the CO_2 absorber. Overhead vapors from the regenerator are condensed and separated condensate is returned back to the top of the regenerator. The cooled CO_2 is sent to the network.

Incinerator

GPIC CDR Unit is the first project of this capacity to have an integrated incinerator for the treatment and disposal of reclaimed waste generated in the CDR Unit. This was installed as a commitment to the environment to safely dispose off the waste generated from the unit. The incinerator package has been exclusively designed and built by TSKE, Japan to safely dispose off the KS1 containing heat stable salts generated in the CDR unit. MHI have conducted tests and have confirmed that the byproducts of combustion from the incinerator are safe for the environment.

Typical Process flow Diagram

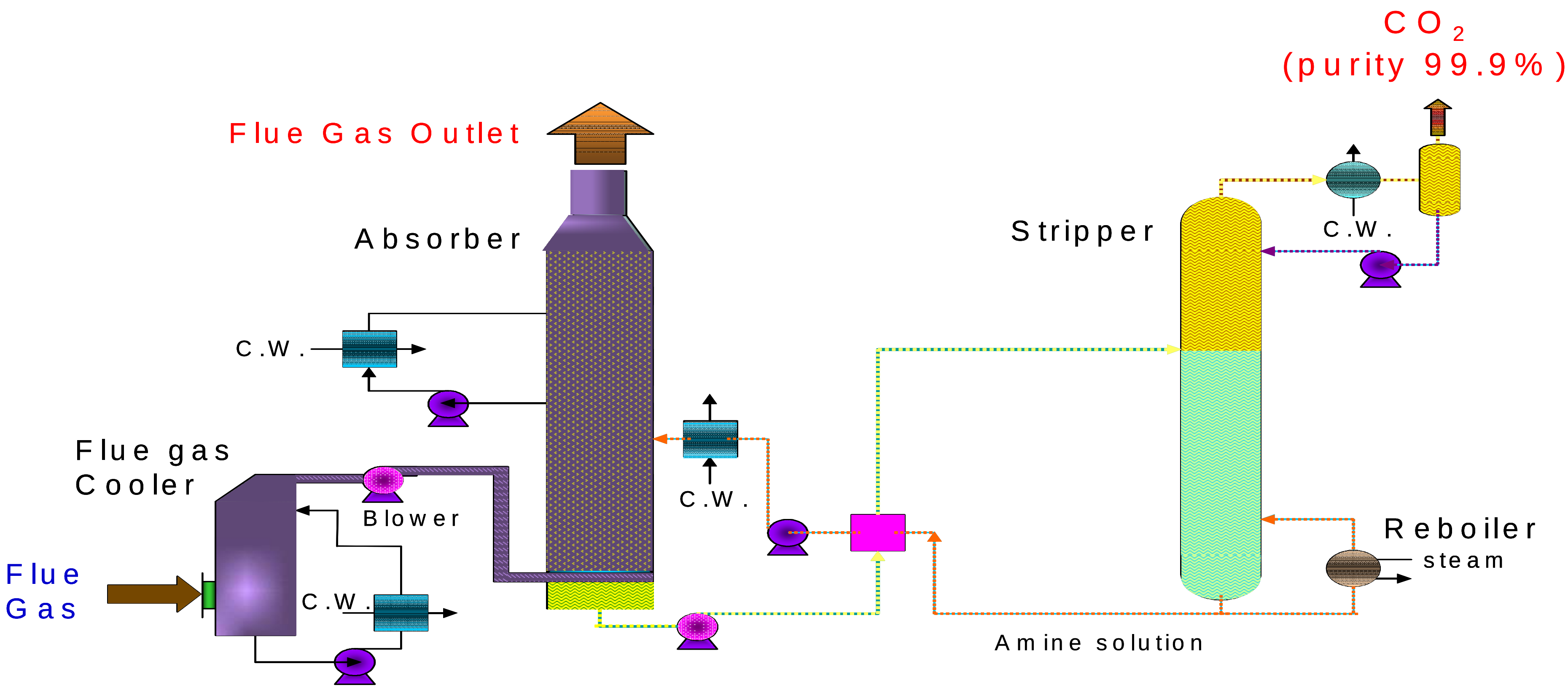


Figure 02

13. Project Challenges:

Transportation of Three Major Columns:

Three major columns for the CDR Project were fabricated at AMC, Malaysia. These columns are ~4.5m in diameter and ~50m in length. To avoid site welding, TICB wanted to bring each of them as single piece. An exclusive cargo ship brought all the three columns to Bahrain. Transporting such huge columns on Bahrain roads was a great task. Exclusive road survey was conducted by specialists to identify the bottleneck areas on the road and with the help of concerned Directorates, all the bottlenecks were overcome and the columns were transported to site safely. This was a major achievement was accomplished with the cooperation of all the concerned Directorates.

Clearance on export of Titanium Exchanger from India:

Export restriction was imposed by Government of India for Titanium Materials for internal security reasons. The critical exchangers were manufactured in India and due to the above restrictions the exchangers were not cleared for export. GPIC had to present the case with the foreign ministry and other officials and could get the clearance ultimately without causing any delay to the project.

Installation of Sea water GRE lines in the existing units area:

Installation of sea water lines was a great task. Excavation for burying the pipeline had to be carried out within the vicinity of the existing pipe racks, cables and road crossings. This was a very challenging task. Great care was taken to execute this work with good planning coordination and proper risk assessments. The total work was carried out successfully without any incidents.

14. Importance of Safety, Health & Environment during CDR Project:

Safety culture alignment is not simple when a project involves different contractors with a large work force; it involves people's values and beliefs, guiding their behavior, developing and maintaining effective safety at the work place. To achieve "Safety Excellence" we aimed a very positive Safety Culture that added significant financial value to the project and continued work without any delay. It was a huge challenge that consumed a great deal of time and hard work for Safety Personnel including contractors and sub contractors.

To achieve a world-class safety culture in the CDR project, it was vital to develop a safety coordination and understanding between GPIC and the contractors. Early safety statistics clearly identified need of regular awareness trainings and safety talks on daily basis to aim for ZERO Lost Time Accident. GPIC management recognizes the importance of safety in the initial stages itself and provided a dedicated Safety specialist to the CDR Team. To achieve this goal great deal of efforts were put by GPIC in making everyone understand the GPIC's Permit to Work, Emergency procedures and the most import value was "Care for others".

One of the main challenges was to maintain a hazard free work place where dozens of cables for electrical welding machines and air compressors were running everywhere and workers were involved with welding, cutting and fabrication activities. Four cranes and couple of heavy vehicles were also operating in a limited area. Major lifts for installing three columns, boiler and exchanger were carried out safely without any incident. All jobs were discussed regularly; Risk Assessments were carried out to identify smallest possible hazards and was well communicated to all for a smooth and safe operation. All safety inspections, audits, meetings and emergency drills were well recorded and communicated.

Till now CDR has successfully reached a mile stone of more than **900,000** LTA free safe man hours that clearly portrays the efforts of GPIC SHE department with a strong support of Management and commendable coordination of contractors.

15. Finance:

Finance played an important role in supporting the project by fulfilling its financial obligations, whilst protecting the company interests, thus ensuring the successful completion of the project. To achieve such goal, a cash flow plan was formulated that ensured sustaining the required liquidity and attaining the "zero payment delay” objective. Attaining such goal would have been extremely difficult without preparing an accurate cash flow plan, considering the global recession experienced in early 2009 and thus resulting in a relatively lower cash inflow.

A comprehensive reporting and monitoring system was established that ensured guaranteed availability of the funds as per the contractual agreed terms. The three layered level of cost control reporting ensured that data is available on operational level as well as management control level.

16. Training & Visits:

GPIC established great emphasis on training of Bahrainis from the project stage itself. Dedicated Engineers from every discipline were involved and were given tasks to review, monitor and report on regular basis. They worked along with TICB Engineers and got exposure of Project work throughout the construction activities.

During the Engineering phase, concerned discipline engineers were greatly involved in reviewing various documents and participating in Hazop studies at TICB offices. Every document was reviewed and comments were communicated regularly with MHI & TICB to ensure all the review comments are addressed.

During the fabrication of critical equipments, GPIC Engineers visited the vendors workshops for quality assurance, quality checks to ensure the fabrication work is to the standards as per the ITP Documents. GPIC Engineers participated in Factory Acceptance Tests (FAT) for DCS System, Boiler, Blower and Motor Control Systems.

The details of the Training and visits are as below:

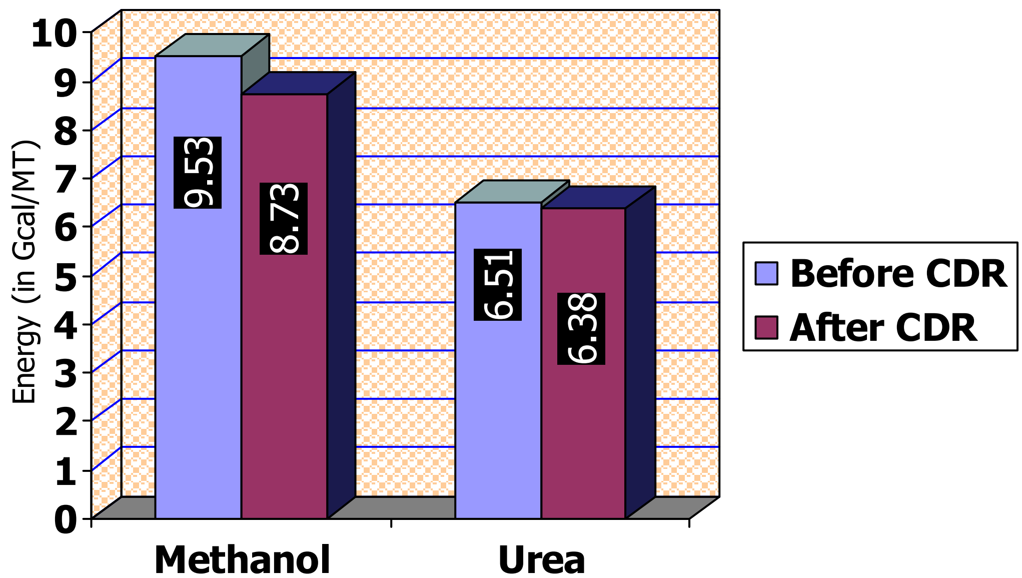
Visits to CDR Plants, Vendor's Workshops and TICB Engineering Offices

Activity	Number	Number of People
CDR Plant Visits	**8**	**34**
Visits to Vendor's Workshops and FAT	**22**	**24**
Visits to TICB Engineering Offices for Hazop, Training and Engineering	**11**	**46**
Familiarisation Lectures for GPIC Personnel	**9**	**130**
Total number	**50**	**234**

17. Benefits of CDR Project:

The CDR unit has helped in bringing GPIC's Methanol production back to post-debottlenecking capacity. The additional Methanol and Urea production would increase the overall annual saleable production by about 4%. Since the plant is located outside the existing production processes, its operation does not affect existing operations in any way. The increased removal of Carbon Dioxide from the Methanol Stack emissions to the atmosphere has both a psychological and environmental benefit to GPIC. The installation of CDR plant at GPIC will have a beneficial effect in the long term as the Natural gas will gradually be "Lean" in terms of Hydrocarbons, resulting into lower Carbon Dioxide production from Ammonia Plant.

Thus, the additional Carbon Dioxide from CDR Plant will be required for the total conversion of Ammonia to produce Urea. The specific energy consumption per ton of Methanol and Urea will reduce post CDR operation. Please refer to the trend below:



The CDR unit as an add-on provides ample flexibility in operation. It can be isolated whenever required without any disruption to mainstream plants. In-house project and operating experience has been more than adequate to handle this project and operate the plant.

18. Conclusion:

From the foregoing, it is evident that the construction and the successful commissioning of the CDR unit at GPIC will have long term benefits to the company. The technology involved is proven, reliable and the returns are attractive. The project will assist in expanding GPIC's business while cutting down the emission of the greenhouse gas in to the atmosphere.

CDR Project Photo Essay

Signing of Contract with MHI and TICB, 25th October 2007

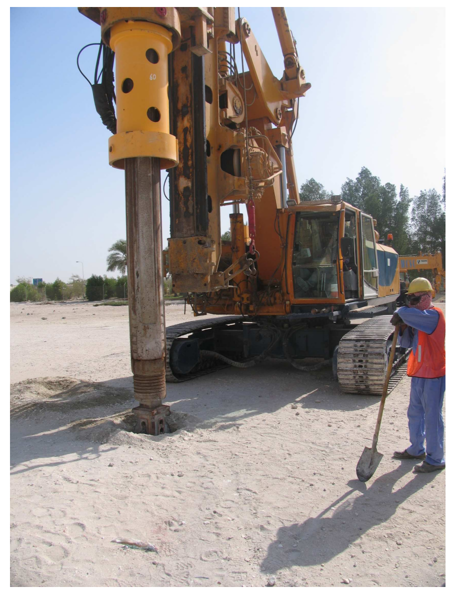
Inauguration of CDR Project Offices, 7th January 2008

KS1 Solution Agreement Signing with MHI, 4th April 2008

Inauguration of CDR Construction, 27th August 2008

Pilling Activities

August 2008



Visits to CDR Units 2007 & 2008

Inspection of columns at AMC
Malaysia 2008

Electrical Switch Gear FAT
at Mumbai, India 2008

FAT at BONO Italy
January 2009

Inspection at Alfa Laval, India
April 2009

FAT at Yokogawa, Bangalore, December 2009

Columns Transportation to Site January 2009

Columns Installation,

January 2009

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Diaphragm Plates Failure of Synthesis Exchangers in Ammonia Plant

Eyad Rafiei
Ammonia Plant Superintendent

Gulf Petrochemicals Industries Co. (GPIC)- Bahrain

Diaphragm Plates Failure of Synthesis Exchangers in Ammonia Plant

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Gulf Petrochemicals Industries Co. (GPIC)- Bahrain

Introduction:

Leaks in synthesis loop joints in general and specifically in heat exchangers' channel covers are among the major challenges that ammonia plants face due to their larger cover size, high pressure, thermal expansion and long-term service.

Manufacturers of high pressure heat exchangers generally recommend two main methods of sealing these end covers: either by seal weld of the diaphragm (using plate diaphragms which ensure zero leakage) or by ring joint (which requires less work and preparation when opening and closing the cover compared to the first method). The type of sealing used also depends on the process designer and the plant owner's preference and experience. Irrespective of the sealing method used, it is not uncommon for these kinds of joints to leak.

Ring joint sealing requires less maintenance & down-time as no welding or grinding is involved although machining could be required in some cases. During operation, minor leaks could be rectified if more torque is allowed to apply on the bolts and it is possible to arrest the leak without plant shutdown.

A modified ring joint type that has been used lately in some of the high pressure hydrogen services in plants uses the principle of the pressure-energized seal ring. Its drawback is that it does not have enough user references, especially in the petrochemical industry. Moreover, if machining is required for the ring seat, it has to be done by the vendor as it is a designer's patent product.

The welded Diaphragm Plate is one of the most common sealing methods that are recommended by many manufacturers, especially for equipment that contains hydrogen at high pressure. It is widely used for channel covers of exchangers in an ammonia synthesis loop. It has zero leaks once it is fitted and welded properly. However, it is time consuming in comparison to the ring joint as it involves grinding, machining and welding. Also the welding procedure differs according to the manufacturer's standards. Some vendors recommend placing the diaphragm in position and fixing the cover on with bolts tightened with full torque before welding. Other procedures require only holding it firmly in position and fixing it in position with tack weld before starting the root pass welding. Before welding, it is essential to check the straightness of the diaphragm by blue contact check and the channel surface where the plate diaphragm sits is to be machined to ensure full contact.

Diaphragm welding at GPIC:

- Welding procedure followed at GPIC for diaphragm plates welding:
- All bolts are tightened at full torque at 980-1000 barg as per the bolts tightening procedure and tag welding is done.
- Alternate bolts are removed and welding is performed. Welding procedures developed by the manufacturer propose to weld either with SMAW or GATW. Present
- GPIC practice is to use SMAW process with 3.25mm dia. electrode due to access restriction.
- Alternate removed bolts are repositioned and tightened.
- The balance bolts that were not removed earlier are then removed and the welding of the 1st pass is to be completed.
- The cover is removed and DP check is carried out for the root pass. All indications, if any (i.e. porosity, slug etc.), in the weld seam are removed by grinding.
- Welding of the hot pass and filling passes is then completed.
- The total number of filling & capping passes that are carried out are 3-5 to maintain a minimum of 7.0 mm throat thickness.

Diaphragm seat surface machining

Diaphragm plate (DP check after route pass welding) in position

Despite the above stringent control parameters and the time consuming procedure, a number of welds failed (leaked due to pin hole / weld cracks) which is something that necessitated unit shutdown and redoing the welding.

Two possible disadvantages / drawbacks of the above procedure are:

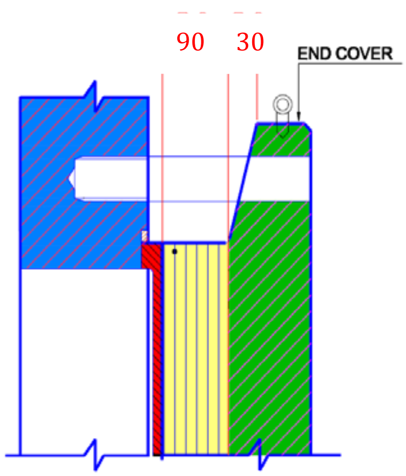
- Using a big diameter welding electrode (3.25 mm) will not allow proper penetration and fusion of the root pass. Smaller electrode diameters are shorter in length and cannot be used with the available working space. 3.25 mm dia longer electrodes are used to reach the welding area.
- SMAW welding method produces slag that affects the weld quality. It also has less focus penetration and fusion in comparison to GTAW (Gas tungsten inert arc welding) weld. With the channel cover in position, there is no sufficient space to do GTAW (TIG) welding.

Any indications of slag or porosity detected during the DP test should be ground out. Excessive grinding could however weaken the root pass and raise the possibility of root weld failure during the hot pass without this being noticed. Moreover, even the DP check will not show defects if they are embedded in the weld.

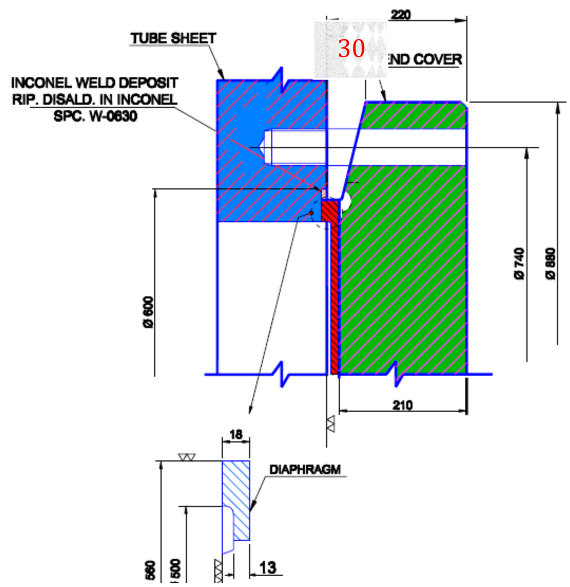
Modified procedure:

By communicating with the manufacturer and other users, we have modified the welding procedure in order to eliminate welds failures of the plate diaphragms. Basically, the welding method has been changed from SMAW to GTAW to avoid slag formation and for better penetration and fusion. TIG process allows the welder to have more control over the welding parameters than the SMAW.

The viability & practicality of the above procedure was proven after demonstrating in the workshop with the insertion of thicker temporary plate (spacer- 90mm) behind the end cover, which provided sufficient space for welding the root pass. GTAW was performed successfully with a 2.4mm electrode.



Modified temporary cover for root pass welding, with additional 90mm gap



Normal channel covers with 30mm gap only

Conclusion:

We believe that this improved welding procedure and arrangement will overcome the plate diaphragms leakage issue. However, we need to perform a number of diaphragms weld renewals before declaring the success of this procedure.

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Fertil Urea Debottlenecking Project (UDP)

Ruwais Fertilizer Industries – FERTIL - UAE

Introduction:

As a part of our commitment for continuous improvement, Plant Integrity Study was carried out for FERTIL - 1 production facilities viz, Ammonia, Urea, Utilities & Jetty loading facilities. The objective of the Plant Integrity Study was to get a comprehensive report from a professional independent consultant regarding the existing plant equipment condition and to plan for future cost investment to sustain safe, un-interrupted and reliable plant operations for the next 25 years.

The Study:

The Plant Integrity Study carried out by the consultant comprised of meetings with FERTIL's Plant Operations personnel, data collection, site visit etc., A specialist team comprising of 5 people from the consultant office were at FERTIL's Ruwais Plant for 21 days to collect the required data, made several site visits to the plant areas, held meetings with plant personnel etc., Apart from that, an off-site team of 9 people from the consultant office evaluated the data from their office in Europe. The study started during August 2009 and final report was received on 31st May 2010. The study was coordinated by the Asset Integrity Section of the Technical Support Department and fully supported by all other concerned Plant Operations Departments.

Methodology:

The Plant Integrity & Life Assessment Study was conducted in 4 stages:

Stage 1 – Identification Of Critical & Cost Relevant Equipment.

Stage 2 – Data Collection & Evaluation.

Stage 3 – Risk & Remaining Life Estimation.

Stage 4 – Capital Investment Cost Estimation.

Stage 1: Identification Of Critical And Cost Relevant Equipment:

The objective of this stage was to determine the list of equipment to be included in the study. The selection criteria of the equipment is that either it should be "Process Critical" and / or cost relevant or with a known deterioration mechanism.

The process critical and cost relevant equipment were identified by the consultant based on the information provided by FERTIL (i.e., P & I D, equipment list, history of old reports etc.).

The equipment list includes the following units / facilities.

1. Ammonia Production Unit.
2. Urea Production unit for the old capacity.
3. Utility Systems within the FERTIL Battery limits including cooling water system, sea water system, steam production units, electric power substations & distributions systems, fire fighting systems etc.
4. Logistic facilities including Ammonia tanks, Urea bulk storage, jetty conveyors and loading facilities.

Note: Urea plant revamp equipment (Medium Pressure Section & Granulation) and the Carbon Dioxide Recovery Unit equipment were excluded from the study.

The final equipment list contains generic equipment as below.

a. Static equipment & piping (vessel, exchangers, reactors, piping etc.)
b. Relief device (PSV, POSV, etc).
c. Electrical equipment & instrument control.
d. Rotating equipment (compressors, pumps, fans etc).
e. Instrument protected functions.
f. Civil structures and installations.
g. Logistic equipment (Conveyors, Re-claimers, Ship-loaders etc).

The outcome of the above critical equipment list comprised of 412 items and the list was communicated by the consultant to FERTIL for concurrence. This list was circulated among various Plant Operations Departments within FERTIL for their review. And accordingly the comments were communicated back to the consultant, where the final list of item was agreed upon between FERTIL and the consultant in order to proceed to the next stage of the study.

Stage 2: Data Collection & Evaluation:

The objective of this stage was to compile the existing equipment condition, damage mechanism, process data etc., in a way that is suitable for progressing to stage 3 and stage 4.

The utilized data sources include:

1. Maintenance history documentation (Repair history, Inspection Reports, etc.,).
2. P & I D's and Process Flow Diagrams.
3. Equipment list.
4. Soil analysis.
5. Existing mechanical integrity studies.
6. On-site investigation.
7. Discussion with FERTIL's Plant Personnel.

Stage 3: Risk & Remaining Life Estimation:

Equipment remaining life estimations were made based on the principles of Risk Based Inspection (RBI) as outlined in API RP 580 and API RP 581.

API RP: American Petroleum Institute Recommended Practice.

RBI is a systematic and analytical approach that assists in:

a. Ensuring compliance with statutory, regulatory and corporate requirements in relation to operational safety, reliability and mechanical integrity of equipment.
b. Supporting business decisions regarding inspection and maintenance expenditures.
c. Identifying the equipment that has a high probability of failure or limited remaining life by addressing all potential damage mechanisms with its past and present operating conditions.
d. Providing future inspection strategies and intervals for maintaining mechanical integrity of static equipment.

For static equipment and piping, a quantitative RBI analysis was performed using the API RBI software. For all other assets a qualitative RBI approach was applied to asses the risk.

The Consequence of each asset in the critical list was determined on the basis of:

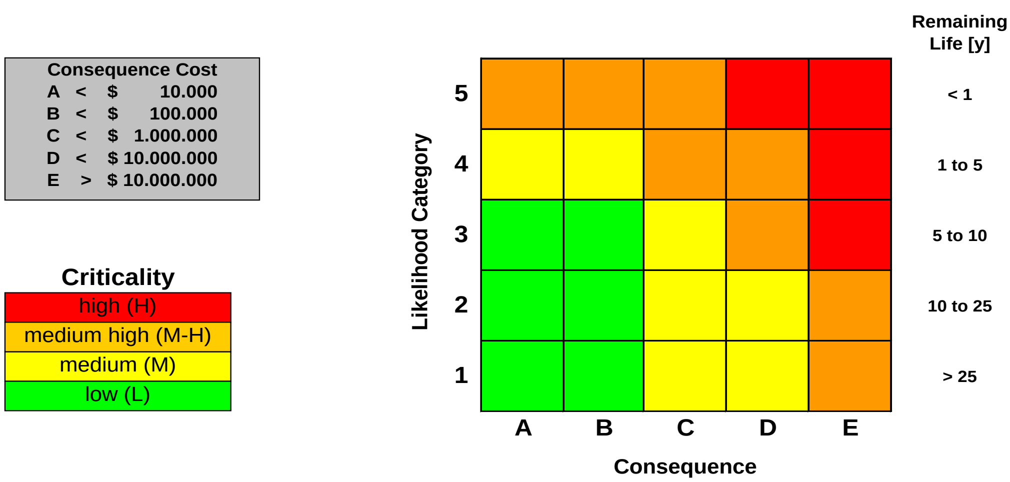
1) HSE cost based on RBI conditions on the types of fluid handled (ammonia, natural gas, synthesis gas etc.,) and the effect on environment conditions.
2) Equipment value based on the data from Curie & Brown (2009).
3) Estimated production loss values provided by FERTIL.
4) Financial consequence categories were defined as follows:

A- Consequence: < $ 10,000
B- Consequence: < $ 100,000
C- Consequence: < $ 1,000,000
D- Consequence: < $ 10,000,000
E- Consequence: > $ 10,000,000

Probability of failure was adjusted to fit the needs for a remaining life of next 25 years. It is used to provide information of the remaining life calculations and is divided into the following likelihood categories:

- 5-Catogory: Remaining life < 1year
- 4-Catogory: Remaining life 1 to 5 years
- 3-Catogory: Remaining life 5 to 10 years
- 2-Catogory: Remaining life 10 to 25 years
- 1-Catogory: Remaining life > 25 years

The risk was determined based on the probability of failure and its consequence and plotted in a 5X5 matrix as shown below:



The overall criticality results of all critical assets (416 items) are represented as given below:

Likelihood Category	A	B	C	D	E	∑
5	0	4	7	3	1	15
4	10	45	41	20	17	133
3	4	7	13	6	17	47
2	12	33	20	15	10	90
1	10	10	25	56	30	131
∑	36	99	106	100	75	

Consequence

The study determined the following distribution of equipment based on criticality ranking:

Equipment Type	Count	Overall Criticality Distribution			
		H	MH	M	L
Static Equipment	186	20	57	99	10
Piping	27	2	16	4	5
Electrical Equipment	54	0	13	15	26
Rotating Equipment	59	16	17	25	1
Civil & Structural Works	36	0	0	5	31
Logistic Equipment	48	0	13	35	0
PCS	6	0	2	1	3
Total	416	38	118	184	76

Stage 4: Capital Investment Cost Estimation:

Based on the above analysis, capital cost for the equipment requiring replacement, repair, upgrade etc., were provided.

To maintain high level of plant reliability and availability till year 2034 an extra ordinary investment costs are given below:

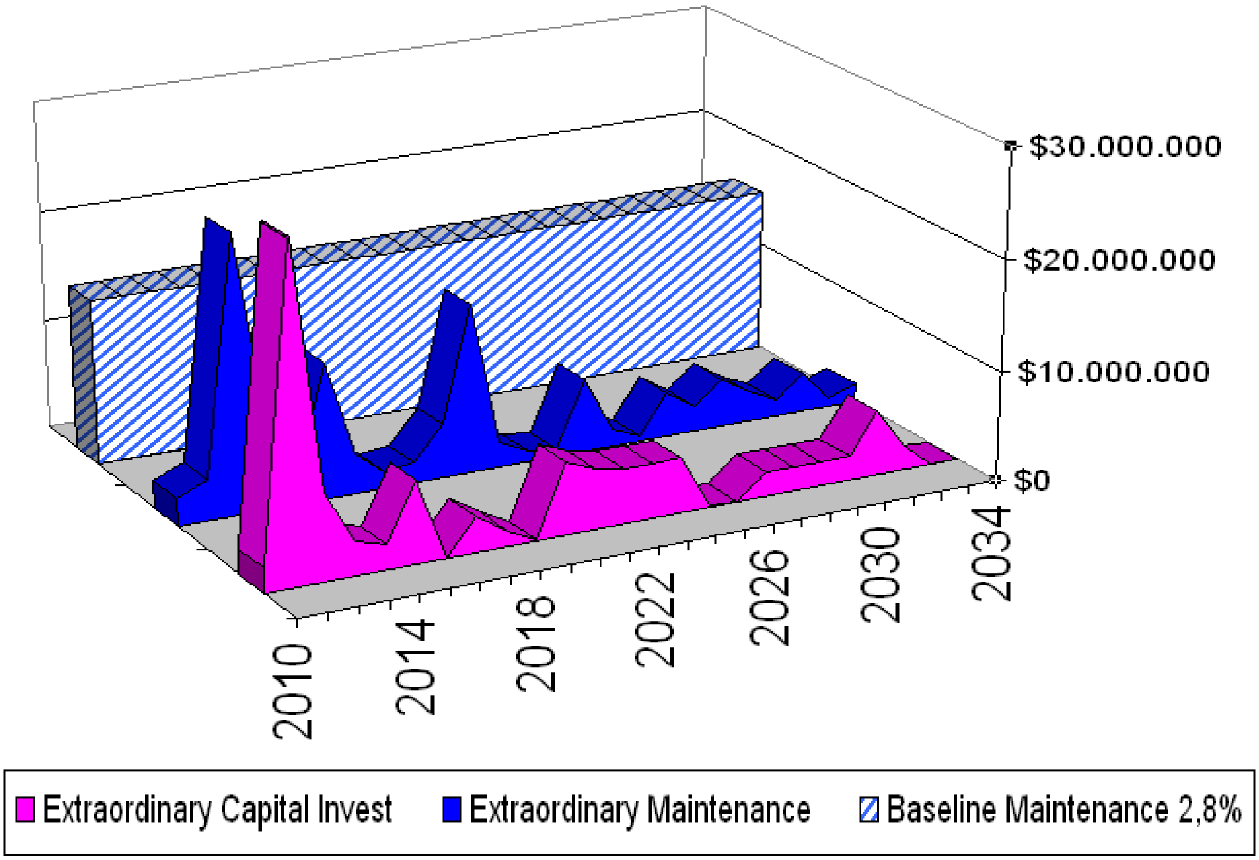
Capital Investment Cost	:	US $ 100 Million
Maintenance Extraordinary Cost	:	US $ 114 Million

During the study it was noted that the maintenance cost index prior to year 2009 was 0.5%, which is significantly below the best practice bench mark of 2.8%. To cover the low maintenance cost prior to 2009, the consultant recommended for an initial investment cost of US $ 71 million ($ 41M for capital items and $ 30M for Maintenance) by year 2012.

The following basic assumptions were made for estimating the cost::

- No major process changes
- Plant utilization at current levels.
- No significant changes in maintenance quality or intensity for the next 25 years.
- No future changes in HSEQ rules or regulations.
- Standard vessels will be imported from Asia.
- More complex equipment will be imported from Europe / USA.
- Equipment weight and unit prices are based on global BTS data base.
- Cost of inspection and engineering based on global BTS data base with the assumption that 50% of the specialists are expatriates.
- Cost for construction, insulation, painting and scaffolding are based on global BTS data base and adjusted with local factors of UAE

The cost distributions for the next 25 year are as below:



The Study Recommendations:

1. Based on the study of the critical assets, individual recommendations are provided for the replacement / repair and further action.

2. Due to potential internal and external corrosion probability foreseen in the analyzed critical equipment, it is recommended to implement RBI program for static equipment including the piping.

3. Establish long term maintenance and service agreement for process control equipment.

4. Electrical equipment was found in good maintained condition.

5. Effectiveness of external corrosion mitigation programme to be increased.

6. For the new FERTIL-2 project, the RBI assessment and material review in the engineering phase is recommended to reduce the start up problems and increase reliability.

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HAZOP STUDY

Ruwais Fertilizer Industries – FERTIL - UAE

HAZOP STUDY

FERTIL - UAE

INTRODUCTION

FERTIL carried out a comprehensive HAZOP study by a third party consultant for process integrity by reviewing the plant process design in order to identify the potential Hazards, failures and operating problems.

The objective of this HAZOP study review is to highlight the process hazardous deviations, their causes, consequences and safeguards against them. Corrective actions and recommendations are proposed based on this study in order to improve the operability and safety of the facilities.

A formal systematic rigorous examination to the process and engineering facets of a production facility was carried out, which mainly emphasizes upon the operating integrity of a system, thereby leading methodically to most potential and detectable deviations which could conceivably arise in the course of normal operating routine, start-up or shut- down.

It accommodates the status of recognized design standards and codes of practice but rightly questions the relevance of these in specific circumstances where hazards may remain undetected.

CONTRACT AWARD

Various specialized consultants were contacted as per FERTIL procurement Division guidelines to carryout HAZOP study as per the scope of work. Finally, on the basis of techno commercial evaluation, contract was awarded to M/s. Germanisher Lloyd (GL) on 25th Sept 2009.

The scope of work was limited to Ammonia, Utility and Site Logistic Plants. The Urea Plant was excluded from this study as Urea HAZOP was already completed under Urea De-bottlenecking Project. . The HAZOP study sessions were held at FERTIL plant, during the period from February 22nd till March 11th, 2010 and extended during the period from April 5th till April 18th 2010. Personnel from FERTIL and GL Noble Denton participated in the HAZOP study.

The HAZOP study was conducted in accordance with HAZOP study international guidelines and conventions, typically:

- IEC 61882 Hazard and Operability Studies (HAZOP Studies) – Application Guide-First Edition.
- BS EN ISO 17776 Offshore production installations. Guidelines on tools and techniques for hazard identification and risk assessment.

The PHA WORKS -5 Software was used by GL for this study.

STUDY / WORKSHOP MEMBERS

HAZOP study sessions were organized FERTIL and headed by GL representative at the plant premises and brain-storming to a set of guide words was applied to all parts of the system. There were five Participants frpm GL and 18 participants from FERTo of different disciplines.

METHODOLOGY

The purpose of the HAZOP study is to identify credible deviations from the design intent; **it is not to resolve the action**. The method identifies hazards and postulates possible accident sequences resulting from such hazards; afterwards, innovative thinking identifies the consequences of these scenarios. The process demonstrates to the management that prudent steps have been taken to provide a safe installation.

By defining appropriate nodes each system or equipment is divided into sub-systems by consensus of the HAZOP study team. The selected system is identified by a study node number and for easy reference; a color code can also be inset on the related P&ID prior to the study and Work Sheet during the study.

The HAZOP study process should proceed as follows:

1. Select the appropriate node;
2. Apply the first or next parameter;
3. Apply the first or next guideword, which in combination with the parameter gives the deviation;
4. Determine deviation;
5. Identify all potential causes of the deviation;
6. Appraise the consequences of the deviation;
7. Appraise the safeguards preventing or mitigating the deviation and its consequences;
8. Agree a recommendation for action or further consideration of the problem where applicable;
9. Once that all causes and consequences for a given deviation have been identified and the requirement for action discussed, the procedure returns to step 3. This process iterates until all guidewords have been combined with a selected parameter;
10. Once that all guidewords have been considered the next parameter will be selected (step 2) and the process will be repeated until all parameters have been applied; and
11. The discussion moves to the next node and the process will be repeated until all nodes are applied.

An action item is entered on the Work Sheet if it is the team's consensus that the existing precautions (protection) are inadequate or there is a concern.

Recommendations may be recorded to suggest a prevention or mitigation of the consequences. An Action Sheet is generated for each action item for recording and tracking responses.

COMMON DEFINITIONS USED IN HAZOP STUDY:

1. CAUSE:

The reason(s) why the DEVIATION could occur. More than one CAUSE can be identified for one DEVIATION.

COMMENTS**:**

Any remarks to be given to the RECOMMENDATIONS or which, in another way, showed up during the HAZOP study sessions.

2. CONSEQUENCE:

The results of the DEVIATION, should it occur. CONSEQUENCES may comprise both process hazards and operability problems, e.g. plant shutdown. More than one CONSEQUENCE can follow from one cause and, one CONSEQUENCE can have several CAUSES.

3. DEVIATION:

A way in which the process conditions may depart from their INTENTION.

4. INTENTION:

Description of how the process is expected to behave at the STUDY LINE. This is qualitatively described as an activity (e.g. feed, reaction, sedimentation) and/or quantitatively in the process parameters, e.g. temperature, flow rate, pressure, composition, etc.

5. GUIDEWORD:

A short word to create the image of a DEVIATION of the INTENTION.

The most commonly used GUIDEWORDS are:

- NO;
- MORE;
- LESS;
- AS WELL AS;
- PART OF;
- OTHER THAN; and
- REVERSE.

The GUIDEWORDS are applied to all the PARAMETERS, in order to identify unexpected but credible DEVIATIONS from the INTENTION.

6. PARAMETER:

The relevant parameter for the condition(s) of the process, e.g.:

- Flow;
- Temperature;
- Pressure;
- Composition;
- Phase;
- Level;
- Sampling;
- Corrosion/Erosion;
- Maintenance;
- Reaction;
- Contamination;

- Leakage;
- Spillage;
- Toxicity
- Start-up / Shutdown; and
- Others.

7. RECOMMENDATION:

Activities identified during a HAZOP study for follow-up. These may comprise technical improvements in the design, modifications in the status of drawings and process descriptions and, procedural measures to be developed or further in-depth studies to be carried out.

8. SAFEGUARD:

Facilities that help to reduce the occurrence frequency of the DEVIATION or to mitigate its CONSEQUENCES. There are, in principle, five types of SAFEGUARDS:

- Facilities that identify the DEVIATION, e.g. alarm instrumentation and human operator detection;
- Facilities that compensate the DEVIATION, e.g., an automatic control system that reduces the feed to a vessel in case of overfilling it (increase of level). These usually are an integrated part of the process control;
- Facilities that prevent the DEVIATION from occurring, e.g. an inert blanket gas in storages of flammable substances;
- Facilities that prevent a further escalation of the DEVIATION, e.g., by (total) trip of the activity. These facilities are often interlocked with several units in the process, often controlled by logical computers; and
- Facilities that relieve the process from the hazardous DEVIATION, e.g. pressure safety valves (PSV) and vent systems.

9. STUDY LINE:

A specific location in the process in which (the DEVIATIONS of) the process intention are evaluated.

<u>UNITS INCLUDED IN HAZOP STUDY:</u>

The Ammonia Plant facility consists of following systems:

1) DEA section for sulphur removal
2) Desulphurization section
3) Reforming section
4) High and low temperature shift conversion
5) CO_2 removal section
6) Methanation section
7) Synthesis gas Compressor, Refrigeration gas Compressor, NG compressor and CO_2 Compressor
8) Ammonia Synthesis and Purification section
9) High , Medium and Low Pressure Steam Sections
10) Hydrogen Recovery unit
11) Process condensate recovery Unit.

The SLD facility consists of following systems:

1. Ammonia storage tank
2. Ammonia Refrigeration system
3. Flare system

The Utility facility consists of following systems:

1. Instrument / Plant Air system.
2. Boiler Feed water (BFW) Treatment facility
3. Nitrogen generation Unit
4. Hydrogen Generation Unit
5. Medium Pressure Steam Boilers
6. Steam turbine Generator
7. Effluent water Treatment System
8. Sea Water, Cooling water & Fire water facility

THE STUDY RECOMMENDATIONS:

All the out come of the study were logged on PHA WORKS-5 software worksheets. The HAZOP team after a brain storming of 66 Ammonia Plants Nodes and 73 Utility and SLD plants Nodes have come up with total 310 Ammonia Plant, 154 Utility Plant and 44 SLD Plant Recommendations.
On the nature of these Recommendations these were segregated on different basis for the ease of work out.
The table shown below categorized the Recommendations on the basis of updating P & ID and SOP's, Recommendations based on further study and implementation, configuring the alarms on DCS and Repeated or Duplicated Recommendations.

Recommendations	**Ammonia**	**Utilities**	**SLD**
For Updating P&ID and SOP's	24	14	07
For Study, Improvement & Implementation etc.	150	87	28
For Configuration of Alarms on DCS	73	-	-
Repeated/Duplicate Recommendations	63	53	09
Total Recommendations	310	154	44

Based on the Safety, Operability and Financial basis the Recommendations in percentages is as given below:

	Ammonia	**Utilities**	**SLD**
SAFETY	43%	43%	50%
OPERABILITY	42%	40%	26%
FINANCIAL	15%	17%	24%

On the basis of ADNOC Risk Matrix as given below the Recommendations are further categorized on the basis of **HIGH**, **MEDIUM** and **LOW** Risk Ranking:

Risk Ranking	**Ammonia**	**Utilities**	**SLD**
High(Before) - Medium(After)	10	3	_
High(Before) – Low(After)	13	8	_
Medium(Before) - Medium(After)	10	3	6
Medium(Before) - Low(After)	225	114	30
Low(Before) - Low(After)	30	8	2
Updates in Documentation / Comments	22	18	6
Total Recommendations	310	154	44

FERTIL ACTION PLAN

FERTIL received the final soft copy of HAZOP report. Before receiving this we had started working on this. We started with Ammonia Plant. Action Plan is prepared to review and to implement all the recommendations.

- A committee is assigned from different Plant disciplines like Process, Inspection, Operations, Instrument, HSE, Electrical, Planning and Maintenance to review all the HAZOP Recommendations.
- Action personnel are assigned for the preliminary check of each listed recommendation. Weekly meeting is conducted to review all the Recommendations.
- After review by the committee the agreed step/status is logged and communicated to all Managers
- HAZOP committee is scheduled once in a week to follow-up and review.
- All recommendations related to alarms configurations in DCS and updating of P&ID to be implemented and reported to the committee for follow-up and closure.
- The Recommendations which are not in agreement with Fertil are closed with proper justification and documentation.
- Licensor will be conducted wherever the external agency explanation is required.
- When all Ammonia plant recommendations have been reviewed by the committee, the same process will be followed for Utilities and Site Logistics.

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Fertil Urea Debottlenecking Project (UDP)

Ruwais Fertilizer Industries – FERTIL - UAE

Fertil Urea Debottlenecking Project (UDP)

INTRODUCTION:

Ruwais Fertilizer Industries (FERTIL) has implemented UDP (Urea Debottlenecking Project) by revamping its Urea Plant and adding CO_2 Recovery Unit and a new Granulation Units.

FERTIL has set up and commissioned a 400 MTPD CO_2 recovery unit at its site at Ruwais based on technology licensed by MHI, Japan.

FERTIL strongly believes in environmental protection and aims to have a cleaner environment by recovering carbon dioxide and use it for productive purpose.

Fertil is committed to reduce the ammonia inventory in the ammonia tanks and keep the ammonia level always at minimum.

CARBON DIOXIDE AND GREEN HOUSE GASES (GHG)

One of the main things that make the greenhouse effect possible is the carbon dioxide along with methane and other gases. The gas goes up to the upper layer of earth atmosphere and form an isolation layer that prevent the reflected heat from the earth surface to escape out of the earth atmosphere region. Due to the increase in greenhouse gases, the temperature of the earth rises and is one of the main factors that increases the global warming.

UREA DEBOTTLENECKING PROJECT (UDP):

FERTIL Management decided to achieve higher urea production, reduce carbon dioxide emission, urea dust emission & pollutants in the liquid discharge and also stop ammonia export and keep the ammonia level in the ammonia tanks at minimum. FERTIL was producing about 250 MTPD of excess ammonia, which was stored in ammonia storages & exported.

To achieve these objectives, UDP project was launched and is consisting of following components:

1. Setting up of 400 MTPD CO_2 recovery Unit.
2. Revamp existing urea plant, to increase the production capacity from 1800 MTPD to 2300 MTPD.
3. Build a new Granulation unit to produce granular product in place of prilled Urea.

CARBON DIOXIDE RECOVERY UNIT.

Before implementing this project, the waste flue gases from the Primary Reformer of the Ammonia Plant were vented to the atmosphere which contained about 8-10% CO2 (total CO2 venting was about 800 MTPD).

FERTIL decided to recover the carbon dioxide from these flue gases by installing a new unit called Carbon Dioxide Recovery Unit (CDR), which is the first step of the whole Urea Debottlenecking Project.

The technologies, which were considered, were:

1. Econamine FG Plus technology from M/s. Fluor of USA.

2. M/s. MHI-technology using KS-1 solvent.

A critical element of this project is the process which is to be selected to recover the CO_2 from the flue gas. The amine-based system and related utilities make up a significant portion of the total project capital and operating costs

Based on the technical & commercial evaluation, commercial experience, references, operability & reliability, service factor etc, Mitsubishi Heavy Industry (MHI) technology based on chemical absorption method by KS-1 patented solvent was selected for CO2 removal from flue gases.

<u>Brief Description Of the Process.</u>

The main process blocks are:

- Flue gas cooling
- CO_2 absorption
- Solvent regeneration;
- Waste heat boiler to produce low grade heat for regeneration;
- Amine storage and make-up;

The following block flow diagram shows the plant configuration.

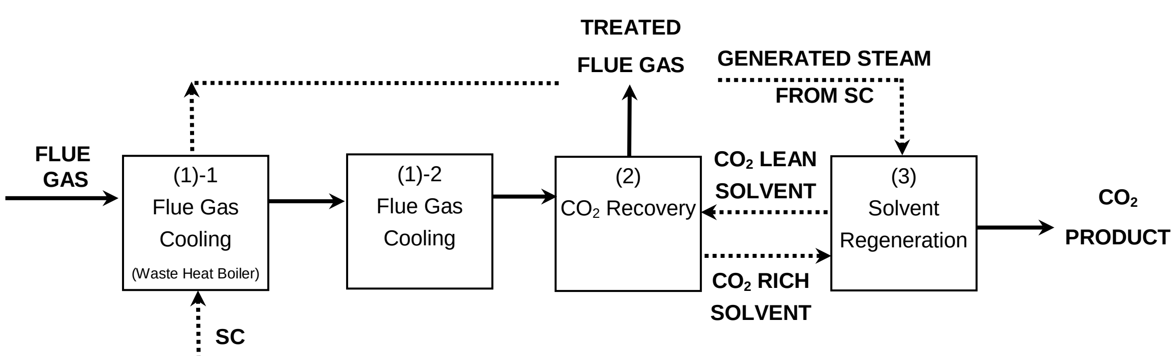

Figure 1 : Block Flow Diagram Of the CO_2 Recovery Unit

1. Flue gas cooling:

The incoming flue gas is relatively hot, about 280°C and must be cooled before entering the absorber to improve absorption efficiency and reduce solvent degradation. In general, amine degradation and losses increase as the temperature of the absorber increases.
The flue gas temperature of 280°C from the Primary Reformer is used for generating Low Pressure Steam in the Waste Heat Boiler unit, and is cooled down to 170°C where Generated steam is used for the regenerator's re-boiler for solvent regeneration.

A direct contact flue gas quencher with a cooling water re-circulation system is used to further cool the gases to about 46°C. The flue gas contains a maximum of 5 ppm of SOx. To minimize solvent degradation of KS-1 solvent, SOx in the flue gas is reduced below 1 ppm before entering the CO2 absorber. In the lower packing section of flue gas quencher, SOx in the flue gas is removed by caustic solution.

The cooled flue gas from flue gas quencher is introduced into the bottom section of CO_2 absorber through the flue gas blower.

2. CO_2 Absorption :

The flue gas moves upward through the packing, while the lean KS-1 solvent is supplied from the top of the absorption section onto the packing which absorbs CO2 from the flue gas.

The rich solvent from the bottom of CO_2 absorber is directed to the regenerator for regeneration by application of heat.

3. Solvent Regeneration

The rich solvent from absorber is steam-stripped by heating the solution in the re-boiler and the CO_2 is removed from the rich solvent.
The overhead vapor is cooled to 45°C by the regenerator's condenser to be supplied to the reciprocating compressor which compresses the CO2 gas and sends it to the Urea Plant.

4. Solvent reclaiming (Intermittent Operation)

SOx and NO_2 reacts with the KS-1 solution in CO_2 Absorber, and this reaction forms heat stable salts (HSS). The accumulation of HSS causes the solution foaming.

When the HSS content or SS in the solvent reaches to the maximum limit, the re-claimer is operated to heat the solvent with caustic soda and reflux water to release KS-1 from HSS and the remaining of HSS is concentrated to sludge to be discharged.

The advantage of this technology consists of:

- The low heat input requirement for the regeneration of fluids.
- The low consumption of absorbing solution.

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Recycling of Ammonium Nitrate Neutralizers Vapor Condensate to Nitric Acid Absorption Columns

EL-DELTA COMPANY FOR FERTILIZER AND CHEMICAL INDUSTRY
EGYPT

EL-DELTA COMPANY FOR FERTILIZER AND CHEMICAL INDUSTRY

EGYPT

Recycling
Of
Ammonium nitrate neutralizers vapour condensate
To
nitric acid absorption coloumns

Introduction

Due to the nature of the reaction between ammonia and nitric acid which is shown in the neutralization curve Fig (1) , from this curve we notice that :

1 – The neutralization point at PH = 4 approximately .

2 – The curve is divided to three regions :

2.1 – The upper region in the alkali side can be considered as linear relation between PH and the excess ammonia .

2.2 – The middle region seamed to be vertical line (this in the neutralization region)

2.3 – The lower region in the acidic side and can be considered as a linear relation between PH and the excess acid .

If we discuss the middle region, at the neutralization point the PH = 4 , we can notice the following :

A – Any small increase in ammonia , increase the PH suddenly from 4 to 6 or 7 and also any small increase in acid decrease the PH suddenly to 3 or 2 .

This means that we cannot operate the neutralizers at the neutralization point ,otherwise the automatic control value of nitric acid which adjust the PH (hunting) open suddenly or closed suddenly.

Therefore the ammonium nitrate neutralizers are divided to two types (from the neutralization point of view).

1- Neutralizers working at the alkali side in the linear distance of the curve PH 5.5 – 6.5 .

The outlet ammonium nitrate from neutralizers are alkaline and there is ammonia loss with the vapor from the vent of the neutralizer .

2 – Neutralizers working in the acidic side (the lower region of the curve at PH = 2 – 3 which can be considered as a linear relation between PH and excess acid .

Because the ammonium nitrate are acidic these neutralizers need a rundown tank at which ammonia are injected to neutralizers the acidic solution of ammonium nitrate out of the neutralizer , these neutralizers working at PH from 2 – 3 and the acidity of the ammonium nitrate solution is about 0.02 % .

The problem

EL-Delta company for fertilizers and chemical industries has two neutralizers working at the acidic side of the neutralize action curve at PH = 2 – 3 , they also working at atmospheric pressure .
According to the design and guarantee figures of the losses from the neutralizers and the rundown tank (combined vent) :
* Ammonia 1.2 kg / ton of ammonium nitrate produced .
* ammonium nitrate 0.6 kg / ton of ammonium nitrate produced .
After condensation of the vapor in direct contact condenser (scrubber) Fig .3 with 125 m3 / hr cooling water , total 250 m3 / hr , thus according to design and guarantee figures there are 30 kg of ammonium nitrate (rate of production 50 t / hr) and 60 kg of ammonia are dissolved in 250m3 / hr water i.e the percentage of ammonia is 300 mg/ m3 and 150 mg/ m3 for ammonium nitrate in the water which leaves the scrubber to the Tawilla drainage canal , also because of the oldness of the acid and ammonia spargers and some deviations in the controlling system this percentage increased and reached to about 250 mg / m3 ammonium nitrate and 400 mg /m3 ammonia . According to environmental laws specially the law No 48 for the year 1982 , these figures are not convenient .

The idea of the project

Due to the injection of ammonia in the rundown tank , the vent of the tank is alkaline (free ammonia) and also the vapor of the neutralizers is acidic , so after combination between the two vents , a reaction the ammonia and nitric acid takes place in the vapor phase to produce ammonium nitrate . Thus the vent of neutralizer contains ammonia and ammonium nitrate in addition to some ammonium nitrate escapes from the neutralizer due to the circulation and boiling of the solution in the neutralizer .

To avoid the reaction between the ammonia from the tank and the nitric acid from the neutralizer (in the vapor phase) , the project is divided into two stages in ammonium nitrate plant beside one stage in nitric acid plant .

1 – First stage : (fig .4)

It has the following steps :

a- Vapor from the vent of the tanks are condensed in surface condenser (shell & tubes), the water in the tubes and vapor in the shell .
b- The condensed vapors which contains ammonia are collected in a collecting tank (ammonia concentration between 8 – 10 %) (aqua ammonia) .
c- This aqua ammonia are recycled to neutralizers by centrifugal pumps .

2 – The second stage : (fig. 5)

a – The acidic vapors from the vent of the neutralizers are condensed in a surface condenser (shell and tubes – water in the tubes and vapors in the shell) .

b – Collecting the condensed water (which has temperature of 50 – 60 Co) in the collection tank , capacity 80 m3 .

c- Pumping this condensed vapor to the nitric acid plant .

3 - The nitric acid stage : (Fig .6)

a- Cooling the water in the ammonia chiller to 10 Co .

b- Collecting cold water in acollecting tank 25 m3 .
c- Pumping this water to absorption towers of the nitric acid instead of the dem water .

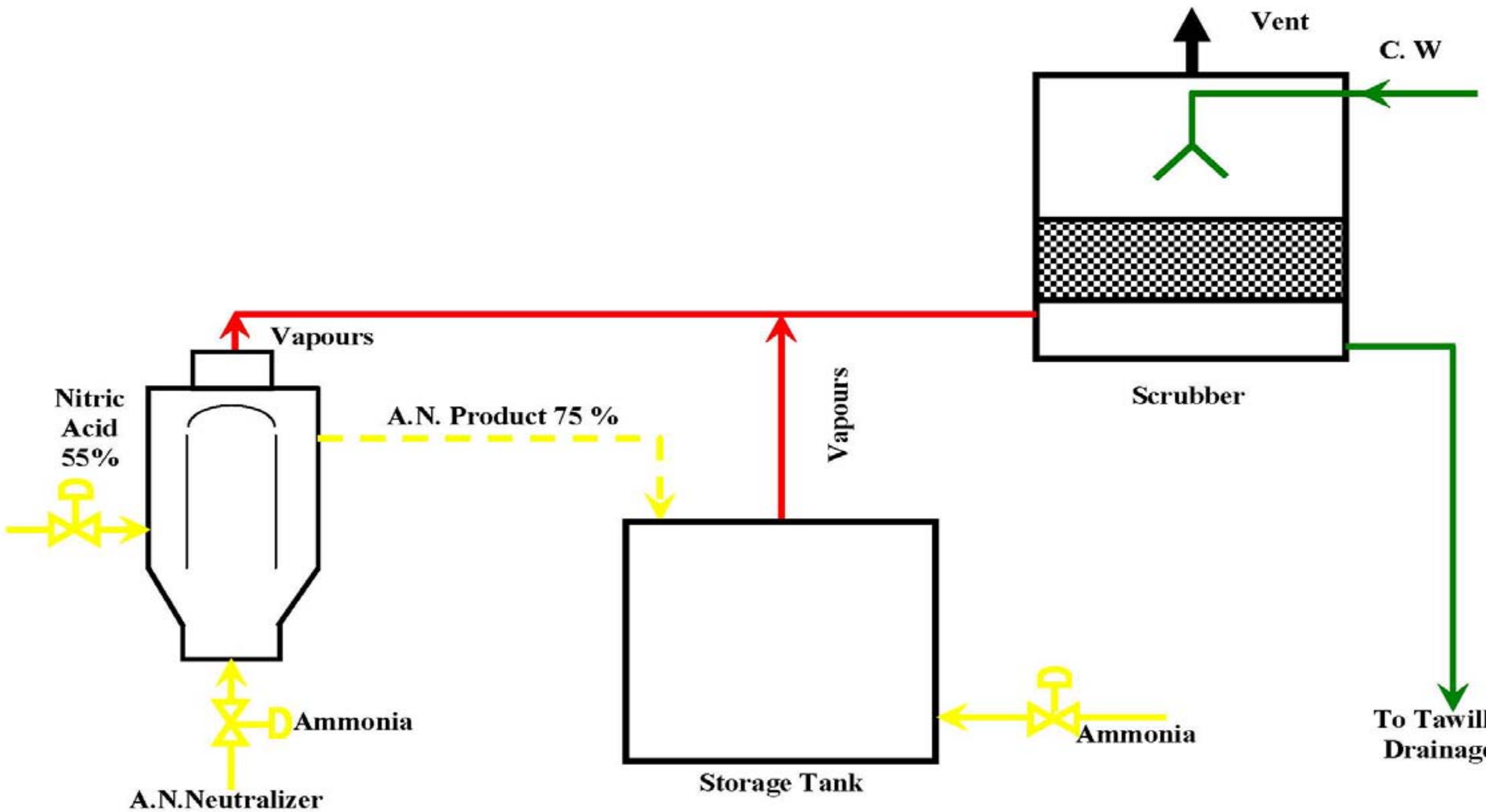
Environmental impact :

Compliance with law limit .
Wastewater recovery.
Reducing pollution load .

Economic benefits :

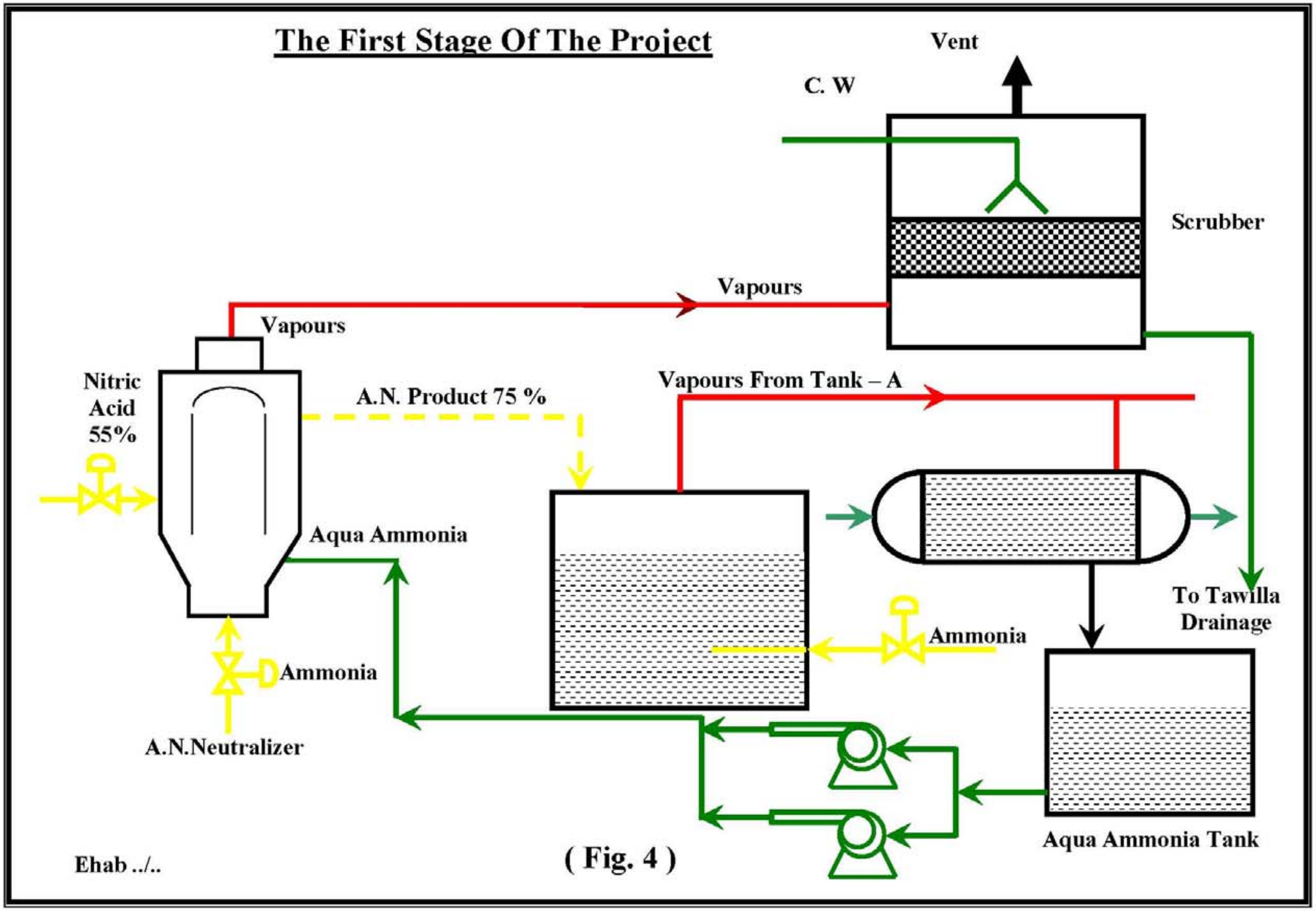
Recyling about 6 ton ammonium nitrate / day .
Saving on 15 m3 / hr of demineralized water .

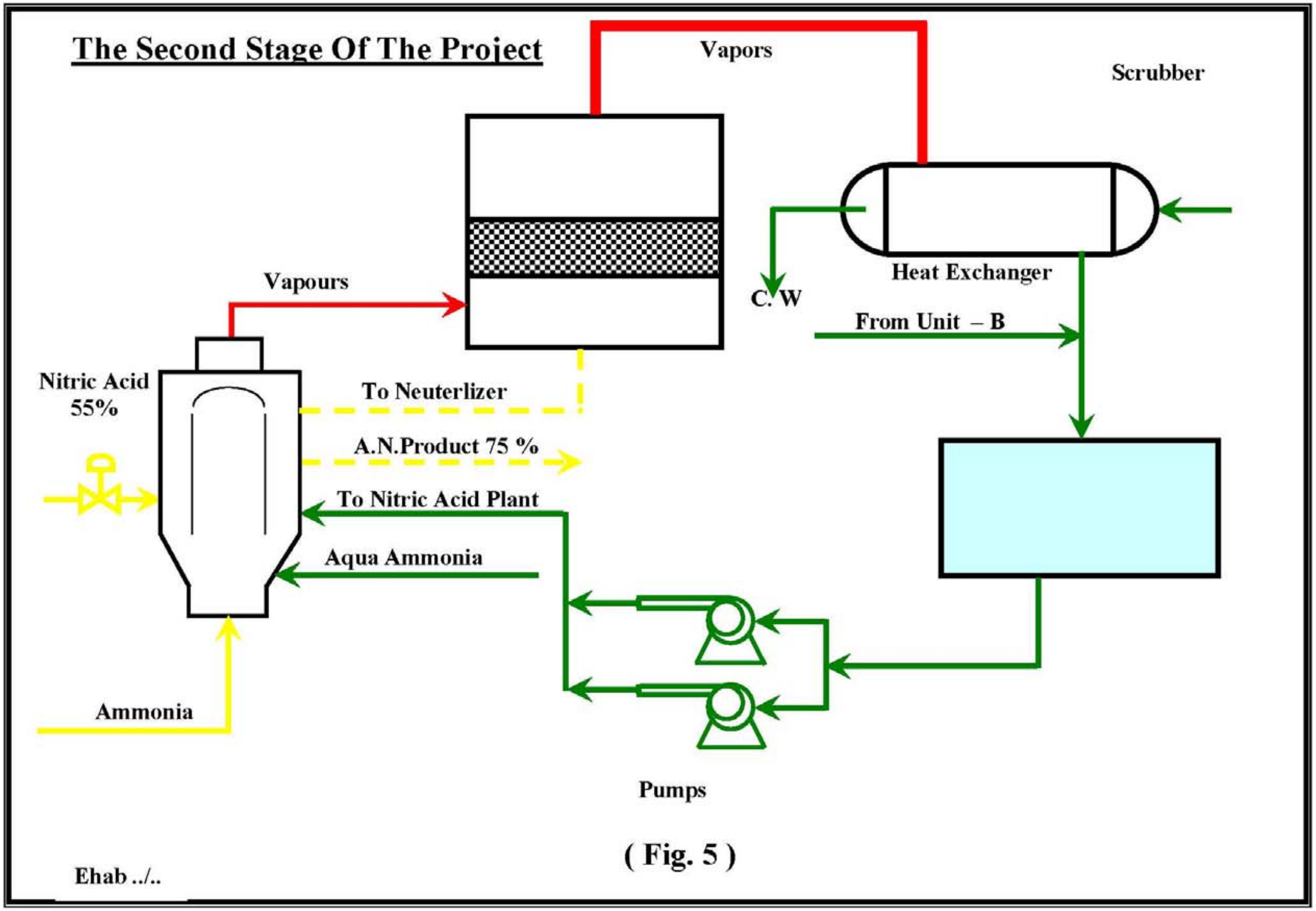
The Unit Before The First Stage Of The Project



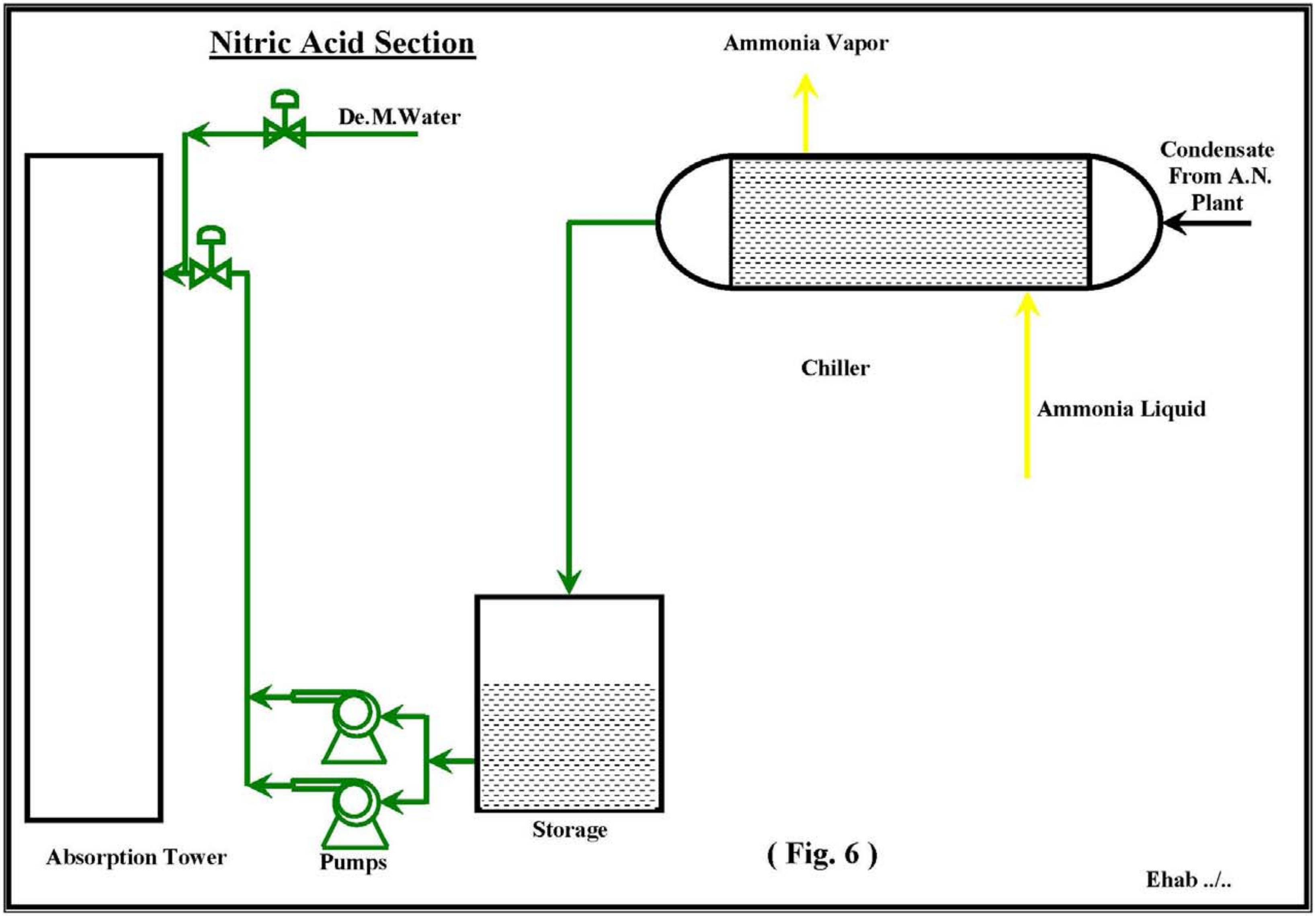
Ehab ../..

(Fig. 3)


The First Stage Of The Project
Vent
C. W
Scrubber
Vapours
Vapours
Nitric
Acid
55%
A.N. Product 75 %
Vapours From Tank – A
Aqua Ammonia
Ammonia
Ammonia
To Tawilla
Drainage
A.N.Neutralizer
Aqua Ammonia Tank
Ehab ../..
(Fig. 4)


The Second Stage Of The Project
Vapors
Scrubber
Heat Exchanger
Vapours
C. W
From Unit – B
Nitric Acid
55%
To Neuterlizer
A.N.Product 75 %
To Nitric Acid Plant
Aqua Ammonia
Ammonia
Pumps
Ehab ../..

(Fig. 5)


Nitric Acid Section
Ammonia Vapor
De.M.Water
Condensate
From A.N.
Plant
Chiller
Ammonia Liquid
Absorption Tower
Pumps
Storage
Ehab ../..
(Fig. 6)

Recycling of Ammonium nitrate neutralizers vapour condensate to nitric acid absorption coloumns :

Due to injection of ammonia in the rundown tank, the vent of the tank is alkaline (free ammonia) and also the vapour of the neutralizer is acidic , so after combination between the two vents , a reaction between the ammonia and nitric acid takes place in the vapour phase to produce ammonium nitrate ,then the vent of neutralizer contains ammonia and ammonium nitrate in addition to some ammonium nitrate escapes from the neutralizer due to the circulation and boiling of the solution in the neutralizer .

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The three stage (IN nitric acid plant) :

a – Cooling the water in the ammonia chiller to 10 C .

b – Collecting cold water in a collecting tank 25 m3 .

c – Pumping this water to absorption towers of the nitric acid instead of the dem water .

The High Pressure Carbamate Condenser

Figure (1) schematically outlines the high pressure carbamate condenser. It is mainly a shell and tube exchanger in which the stripper off gases consisting mainly of CO_2 are fed concurrently with liquid ammonia to the top channel of the exchanger at a pressure of 140 bar. The formed carbamate outgoing from the bottom channel is fed to the urea reactor. The shell side is fed by boiler feed water which is converted to steam by the heat liberated by the condensation reaction taking place inside the tubes.

Inspection of the carbamate condenser revealed the presence of cracks in the tubes owing to stress corrosion cracking. It is obvious that frequent starts-stops for tube plugging resulted in an accelerated rate of crack propagation. Tube rupture also involves the contamination of the shell side and the subsequent water and air pollution resulting there from. This carbamate condenser has been replaced in 2006 and has been financed through the World Bank EPAP-I project.

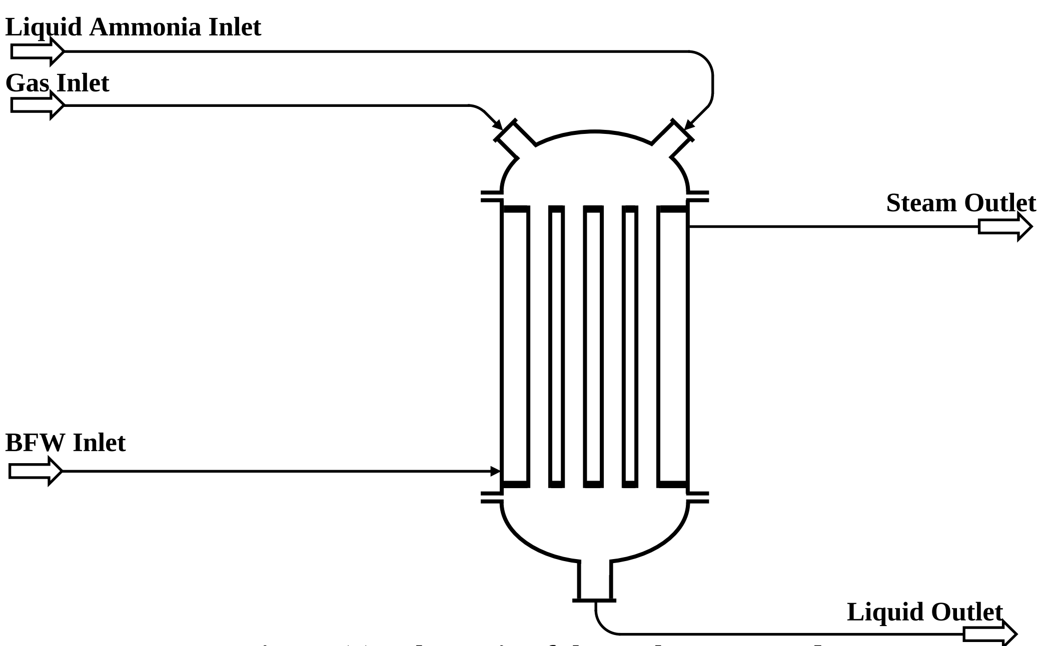

Figure (1) Schematic of the carbamate condenser

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Assessment and Remedy of Severe Corrosion and Separation Cracks observed in Separator-to-Evaporator Connecting Flange and Internal Liner

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Damietta, Egypt

Assessment and Remedy of Severe Corrosion and Separation Cracks observed in Separator-to-Evaporator Connecting Flange and Internal Liner

By: Mr. Mohamed M. Mansour Badran

Inspection Department Manager

at Misr Fertilizers Production Company (MOPCO), Damietta, Egypt

Table of Contents

1. Abstract

In April 2010, Urea Plant' operating staff indicated vacuum losing in Separator (324F001) which reduced urea quantities obtained from urea recovery process and increased the washing rate of granulation unit (production time loss).

This paper presents how the damages were detected, damages description, problem root cause analysis, remedies executed and conclusion.

Observed damages were had the following characteristics:

1. No previous experience was recorded for this problem in similar local operating plants.
2. External on-steam inspection (by inspection, operation and maintenance staff) was not indicating any problem seriousness.
3. Internal off-stream inspection indicating severe chemical corrosion attack of carbon steel parts as well as severe longitudinal separation cracks follows the fusion line of welding seams in both of SS internal liner and external welding of CS flange.
4. If the corrosion was propagated more than observed damages, it could lead to catastrophic disaster, *falling of Evaporator* (consequences could be: personnel death/injuring, damaging of other equipment/piping, environmental pollution, production interruption….etc).

1 Introduction

Misr Fertilizers Production Company (MOPCO) is large Ammonia and Urea Fertilizer Complex located in Damietta General Free Zone, Damietta, Egypt. The complex is consists of three identical Ammonia and Urea plants in addition to their utilities, storage and loading facilities. The complex is engineered, procured, constructed and commissioned by Uhde GmbH (Thyssen-Krupp, Germany) with Stamicarbon CO2 Stripping Urea Plants.

The first plant (MOPCO 3) is on stream since August, 2008 with a capacity of 1200 MTPD Ammonia Liquid and 1925 MTPD Granulated Urea and includes all utilities and offsites. Other new MOPCO plants (MOPCO 1 & 2) are currently under commissioning.

1.1 Process Description Summary & Function of Separator/Evaporator

After synthesis of urea and recovery of the non converted ammonia and carbon dioxide a urea solution remains. To condition urea solution for the finishing section, being granulation, it needs to be concentrated in an evaporation section. The mixture of Water/Urea from recirculation section is further concentrated in the evaporation section in the Evaporator (324E001) where urea solution is heated by means of LP steam, accordingly urea concentration is increased to about 96% by wt. at a temperature of 130 $^{\circ}$C and a pressure of 0.3 bar .

Low operating pressure causes the urea solution to boil at relatively low temperature and minimize hydrolysis and biuret formation. Urea solution flows upwards inside the heat exchanger tubes (tube side; process side) where LP steam is condensing on the outside surface of these tubes (shell side; steam side).Vacuum is obtained by the application of steam ejector/condenser system.

From Evaporator 324E001 the boiling urea solution enters the separator, where most of the water evaporates out of the solution.

The separator consists of vanes mounted on a ring, when passing the vanes, droplets of urea dragged along with the vapors will be caught and fall back into the separator. Most of mist of urea passing the vanes will form droplets above the top of the separator, these droplets will be collected at the side of the separator and drop down into the bottom part via four sealed tubes placed in circumference of 324F001. Fig. (1)

The vanes, ring on which vanes are mounted and top part of the separator have to be flushed every eight hours by using process condensate pumped through cone sprayer and spray ring header with flat jet sprayers installed inside the separator.

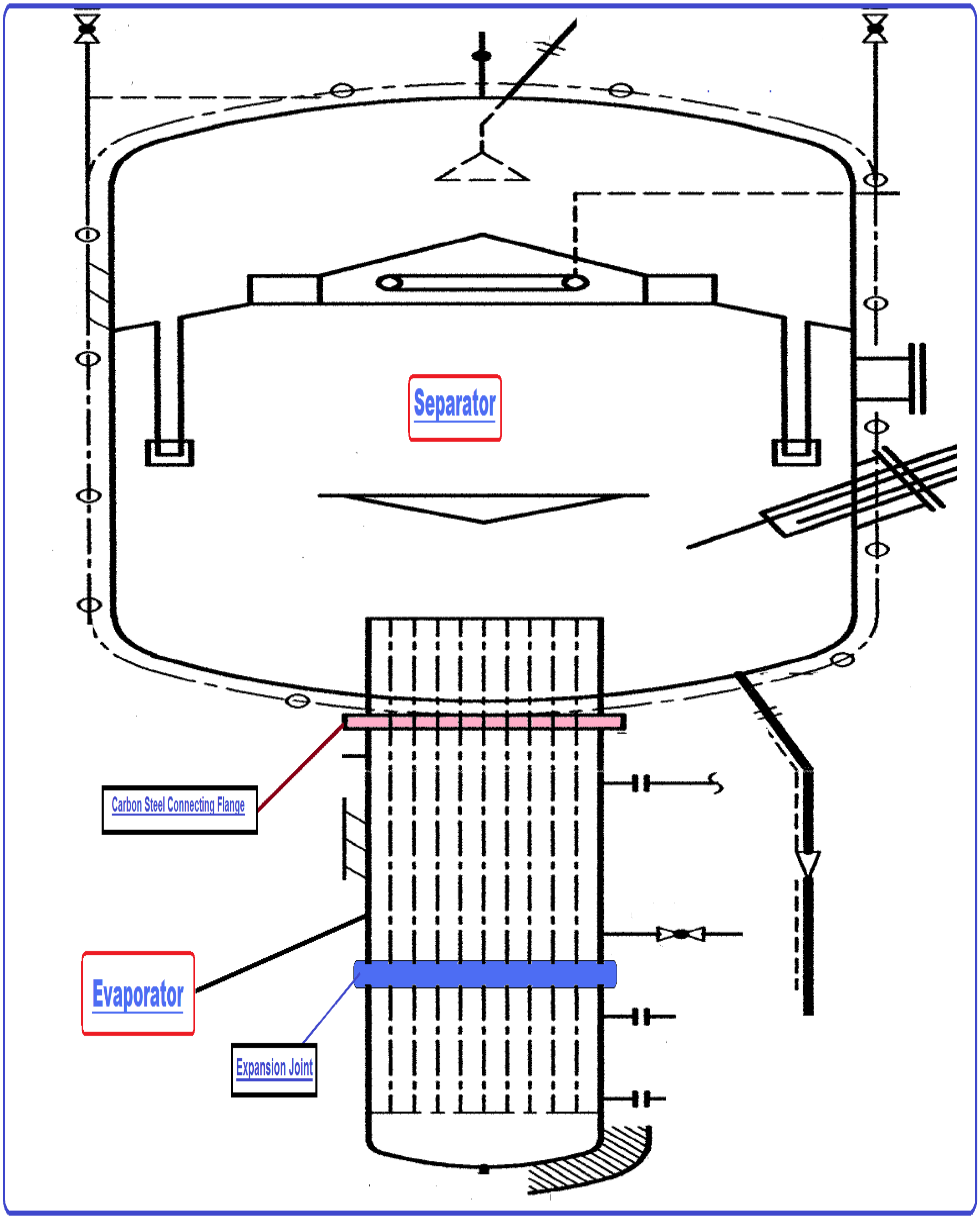


Figure (1): Schematic illustration for Separator-Evaporator Arrangement

1.2 Problem History

Although urea plant was operated above its design capacity, no problem was experienced in the evaporation section (Unit 324) or Separator 324F001.

However, in 17th April 2010, operating experience indicated a vacuum losing in Separator (324 F001) which cause reducing of urea obtained from urea recovery process as well as increasing the washing rate of granulation unit.

By conducting external on-stream inspection on both of equipment and connection area, no clear evidence was found to explain the reason behind vacuum losing, also no previous experience recorded for this problem in similar local operating plants.

Therefore the preliminary assessment concluded that vacuum losing in the Separator could be resulted from leakages through the gasket or gasket sealing faces of connecting flanges for Evaporator (324E001) and Separator (324F001). Recommendations were advised to dismantle the connecting flanges of Separator & Evaporator during nearest plant turnaround to carry out an off-stream internal inspection on the suspected area.

As a temporary repair, maintenance staff had injected liquid silicon around the flanges, which leads to reduce vacuum loss in Separator.

2 Design Features

2.1 Evaporator (324E001)

Type	Shell and Tube Heat Exchanger			
Position	Vertical			
Design Code	AD-2000 Merkblatter, TEMA CL. R			
Special Feature(s)	Shell contains expansion joint			
	Tube Side		**Shell Side**	
Process fluid	Urea Solution		LP - Steam Saturated	
Design Pressure, bar g	-1	6	-1	6
Design Temperature, ºC	165		165	
Operating Pressure, bar g	0.3		3.7	
Operating Temperature (in/out), ºC	99	130	144	144
Mean Metal Temperature, ºC	119		139	
Material	SS		CS	
Corrosion Allowance, mm	0		3	

2.2 Separator (324F001)

Type	Pressure Vessel
Position	Vertical
Design Code	AD-2000 Merkblatter
Process fluid	Urea Solution
Design Pressure, bar g	-1 / 2
Design Temperature, ºC	165
Operating Pressure, bar g	130
Material	• **Shell, Nozzles and Internals: SS** • **Connecting Flange with Evaporator: CS + SS internal liner.**
Corrosion Allowance, mm	0 (Shell)

2.3 Evaporator-to-Separator Connection Features

Evaporator (324E001) is vertically connected and hinged with the Separator (324F001) through carbon steel connecting flange and leaving evaporator bottom with free-end movement (i.e. C.S flange is the main carrying element for the Evaporator). Figure (2)

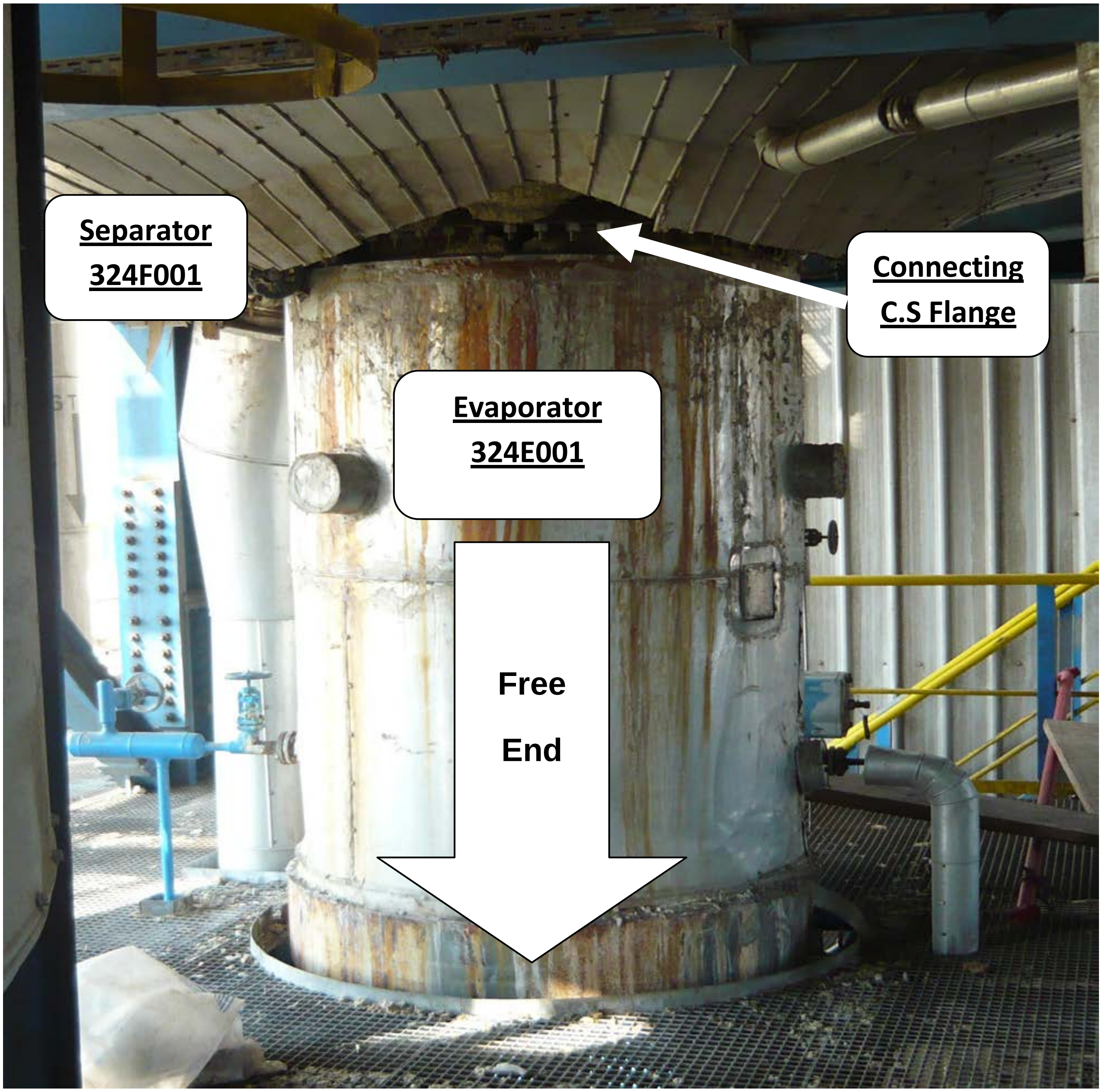


Figure (2): Evaporator-to-Separator Connection and Loading Features

3 Inspection Activities during Plant Major Turnaround

In May 2011, the plant was totally shutdown for major overhauling. Separator was opened, connected flange between Evaporator and Separator was dismantled and evaporator was downed for inspection.

Internal visual inspection and dye penetrant test were conducted which indicating the following conditions:

1. Circumferential separation cracks (fractures) with wide gaps and a min. length of 60 cm were observed at welding fusion line of SS liner plate-to- head of Separator, Liner Plate Side. Photo (A)

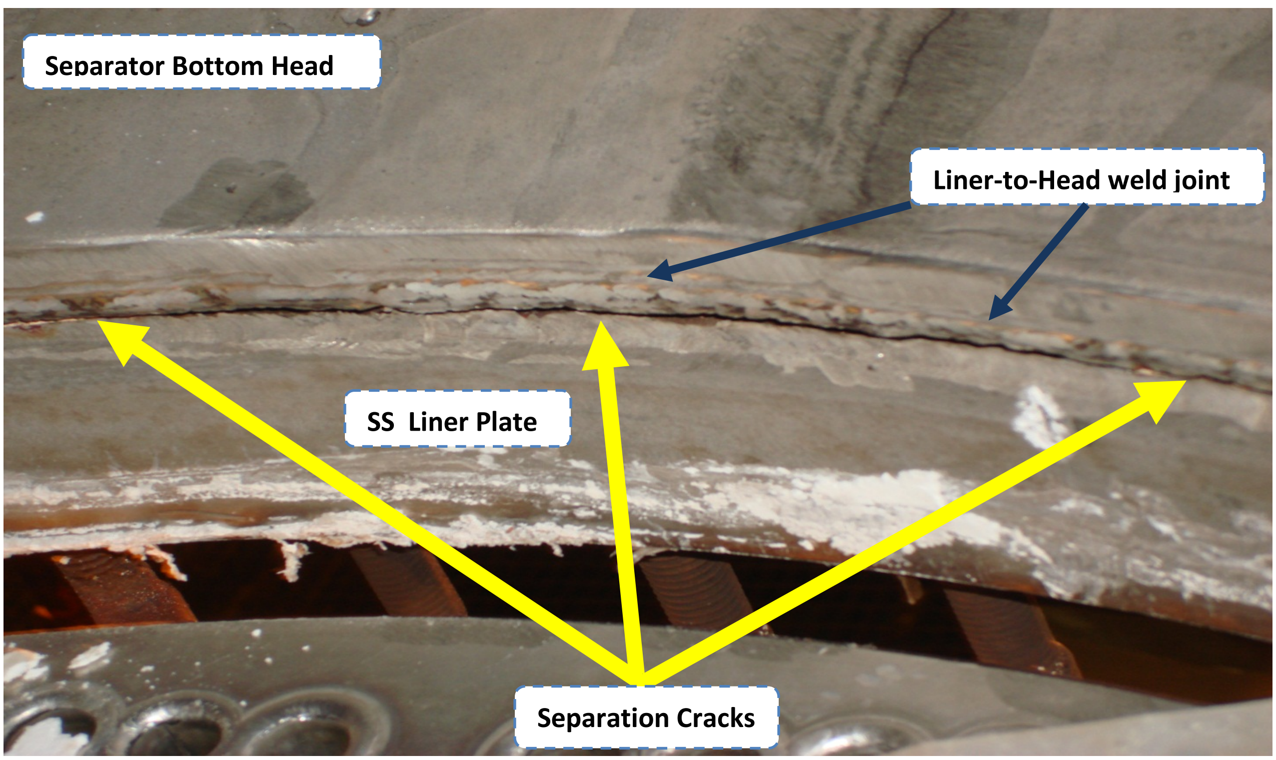


Photo (A): <u>Circumferential separation (fracture) at liner plate weld fusion line</u>

2. No evidences for corrosion or hair cracks around or near the separation cracks in the stainless steel parts.
3. Severe corrosion of upper carbon steel flange, Separator side, at flange' body, bolt holes and faces. Photo (B)

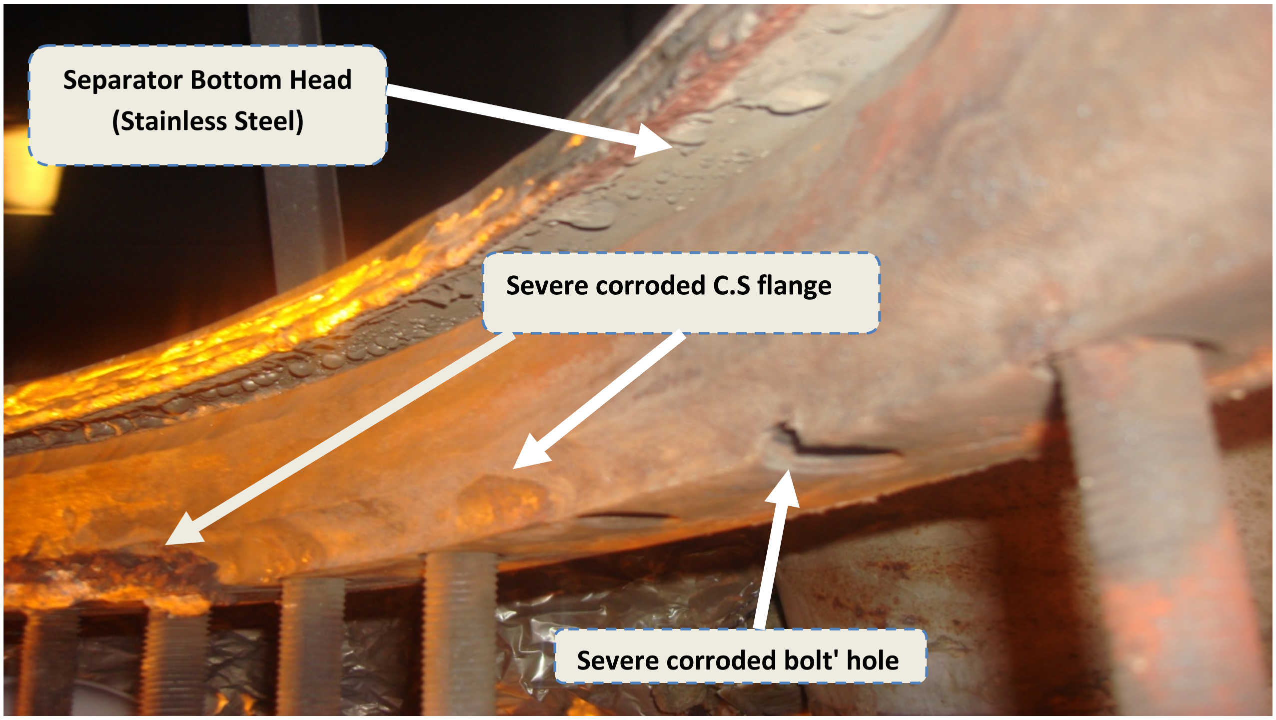


Photo (B): **<u>Severe corrosion of upper carbon steel flange, Separator Side</u>**

4. Corrosion was initiated and propagated from flange internal side, as shown in Photo (C):

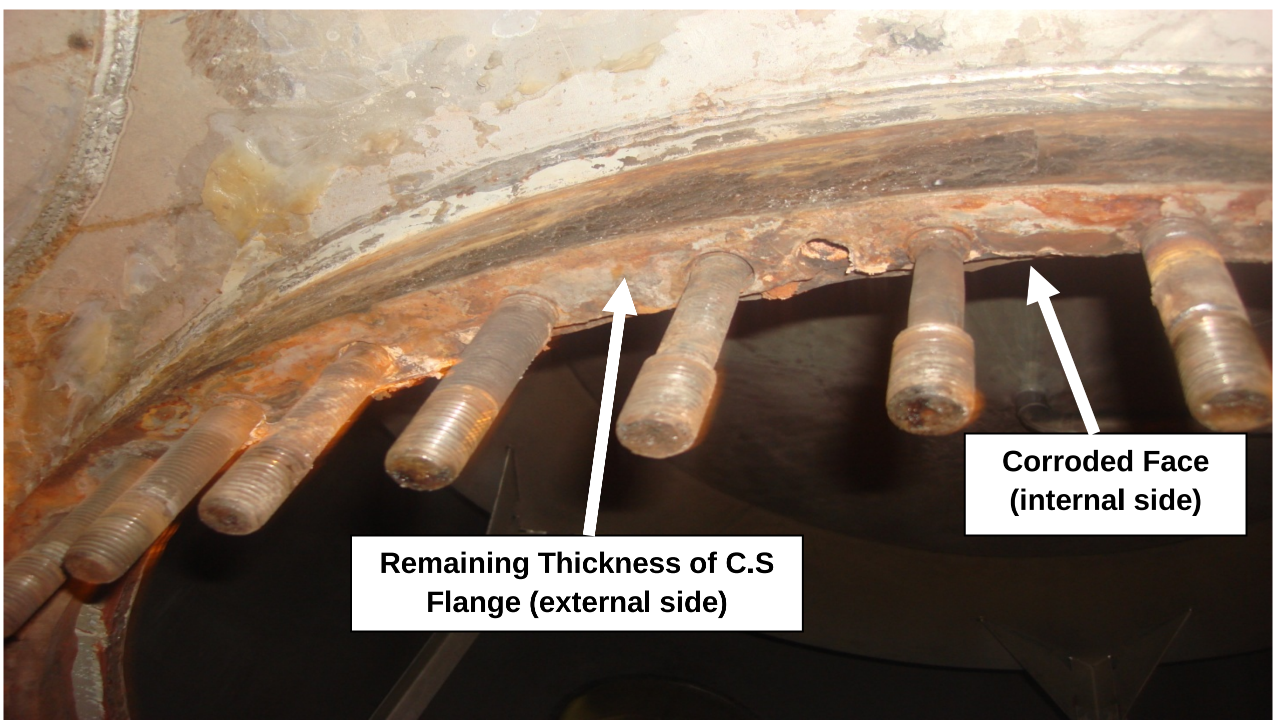


Photo (C): **<u>Flange' Cross Section showing corrosion initiated and propagated on internal surfaces</u>**

5. External Separation crack (fracture) of C.S flange-to- SS head at welding fusion line, C.S flange side. Photo (D)

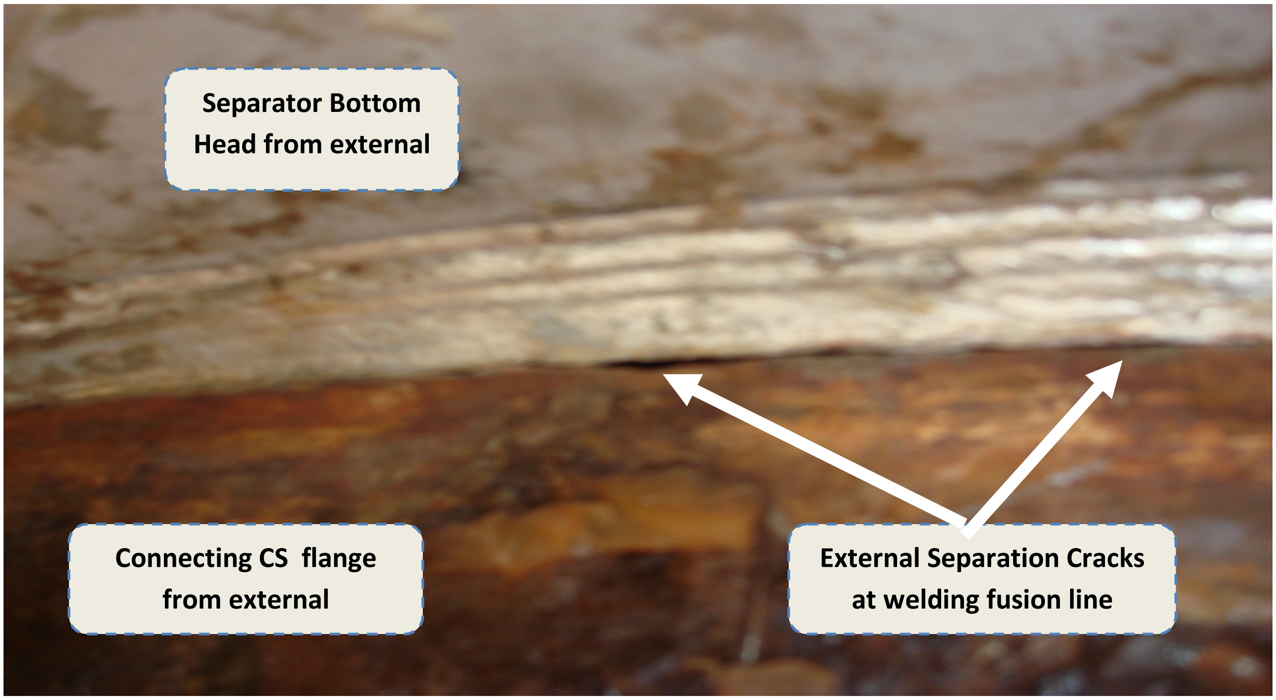


Photo (D): <u>External Separation of flange-to-head at welding fusion line</u>

6. Location of internal separation on SS metallic liner (Photo A) around the circumference was in the same area (mirror reflection) of external separation of flange-to-head welding line (as shown in Photo D).

7. Severe localized corrosion of lower carbon steel flange faces (evaporator side). Photo (E)

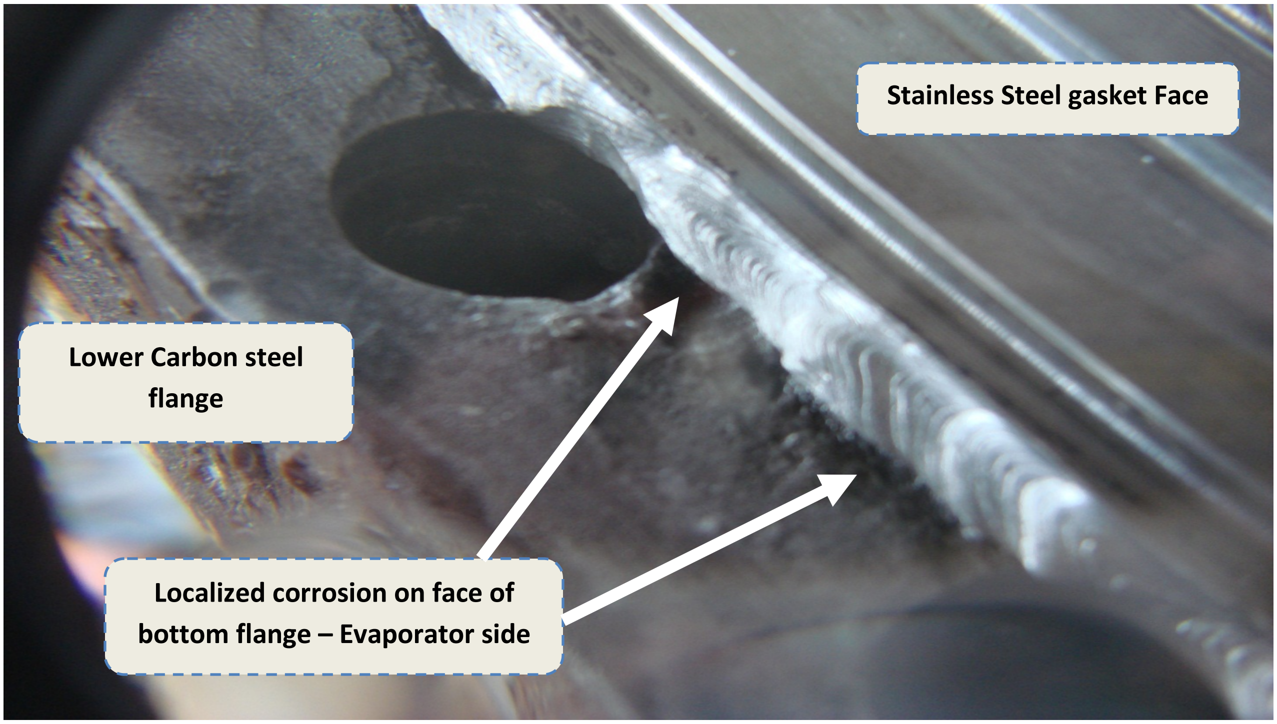


Photo (E): <u>Localized corrosion on lower carbon steel flange, Evaporator Side</u>

4 Damage' Root Cause Analysis

i. By reviewing of operating conditions and DCS Trends since beginning of leakage, no abnormalities are observed.

ii. By reviewing of manufacturing QC documents and site erection reports for both of separator and evaporator, reports were including satisfactory testing and checking results.

iii. Valuable information for understanding the damage mechanism was collected from reviewing and evaluation of following documents and conditions:

a. Separator design features:

Design Feature	Probability of Failure
To protect the carbon steel flange from exposing to hot corrosive urea solution, the design utilized 6 mm THK. SS liner plate welded at its top (with 14 mm SS flange) and its bottom (with weld overlay on CS flange (See Sketch 1).	• If defect(s) existing in liner welds (e.g. pinhole..etc.), it will lead to urea solution leakage and direct exposing of CS flange to corrosive urea solution. • Welding size of liner plate-to-head will not withstand tension loads in case of C.S flange corroded.
External connection of Separator and Evaporator (SS materials) by using of external carbon steel flanges.	• Carbon steel materials can't withstand corrosion effect of hot urea solution; any damage in liner welds will consequently cause severe corrosion of flanges.
Totally supporting and hinged of evaporator on the upper separator.	• High tension load stresses will be exerted on the upper flange welds and connection parts.

b. Possible defects which could be resulted from manufacturing/erection activities and lead to hair cracks/opening in service:

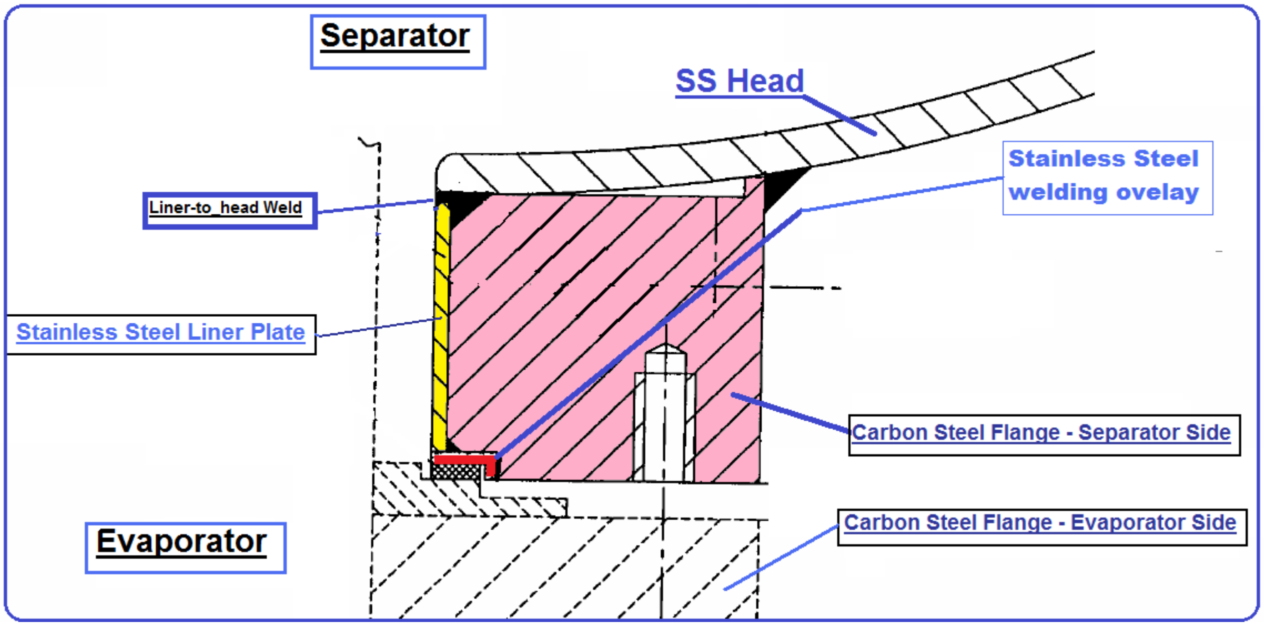
- Undetected welding pinholes, subsurface porosity, subsurface slags…etc.
- Misalignment, deviation in verticality…etc.
- Scratches, friction…etc.
- High mechanical residual stresses.

c. Linking between locations of internal separation on metallic lining plate and external separation of CS flange weld.

d. Corrosion resistivity of carbon steel material to hot urea solution.

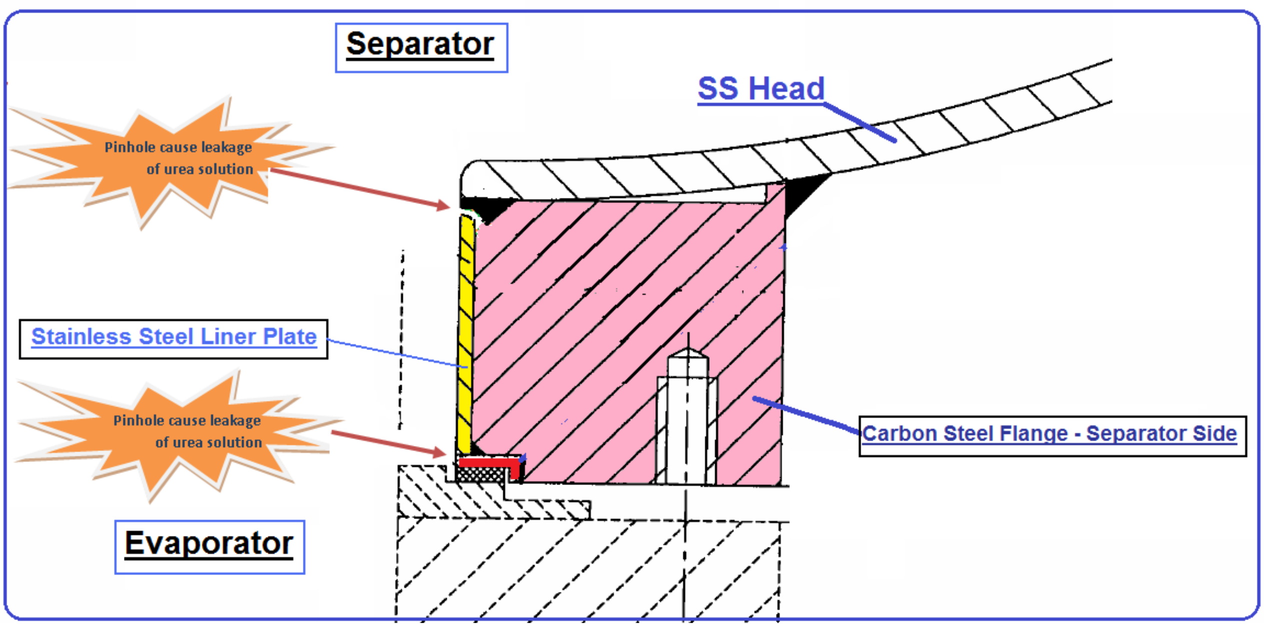
Upon reviewing and evaluating of data above detailed data, the following damage mechanism could be the most probably scenario that can explain the observed damage and its consequences:

1) The design of connecting flange arrangements and welding details is shown in sketch (1) below:



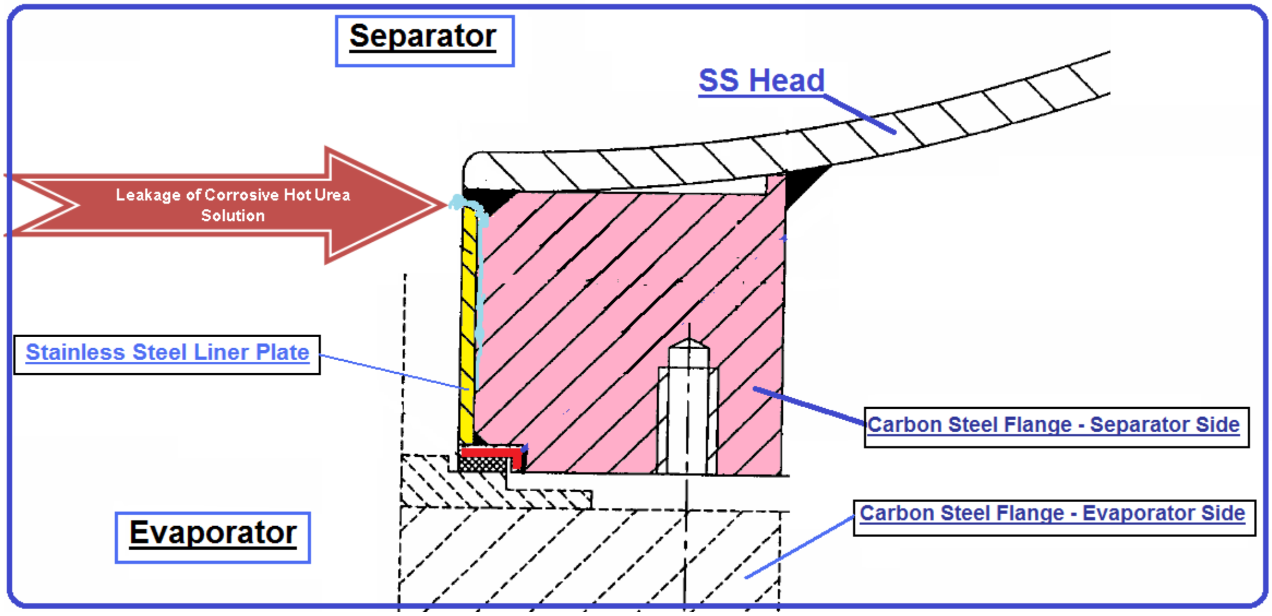
Sketch (1)

2) If welding defect (e.g. pinhole…etc.) existing, it could be propagated and opened through thickness:



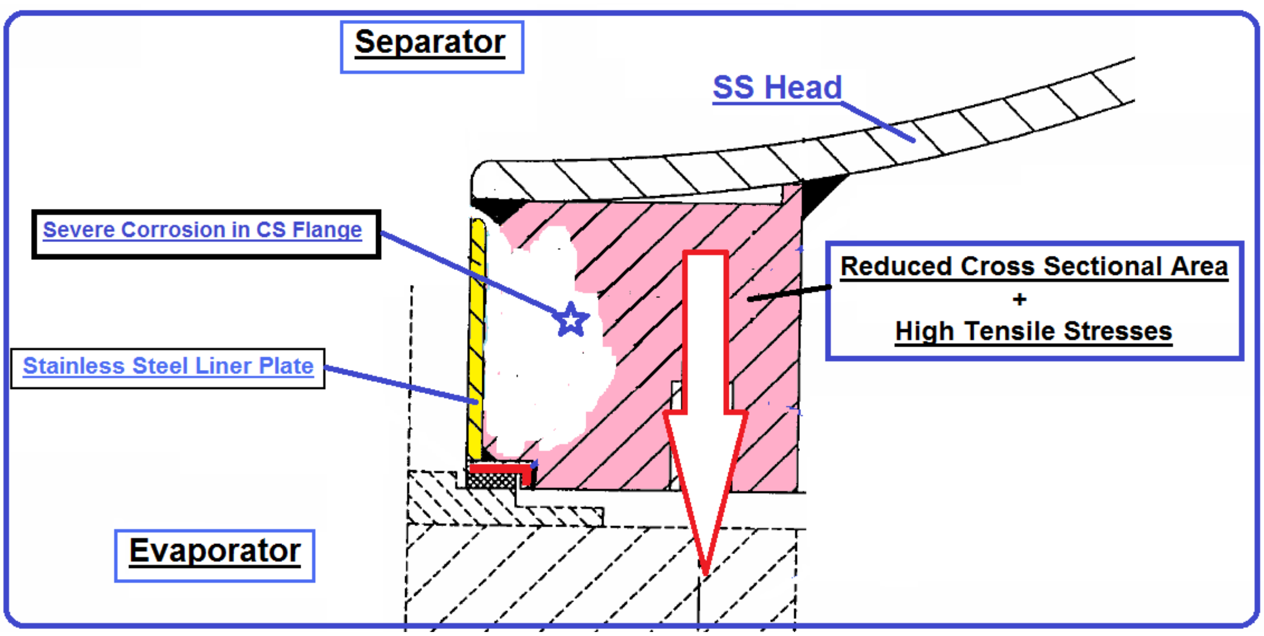
Sketch (2)

3) Urea solution will passing through the opened hole and CS parts will be directly exposed severe corrosive media – Sketch (3)



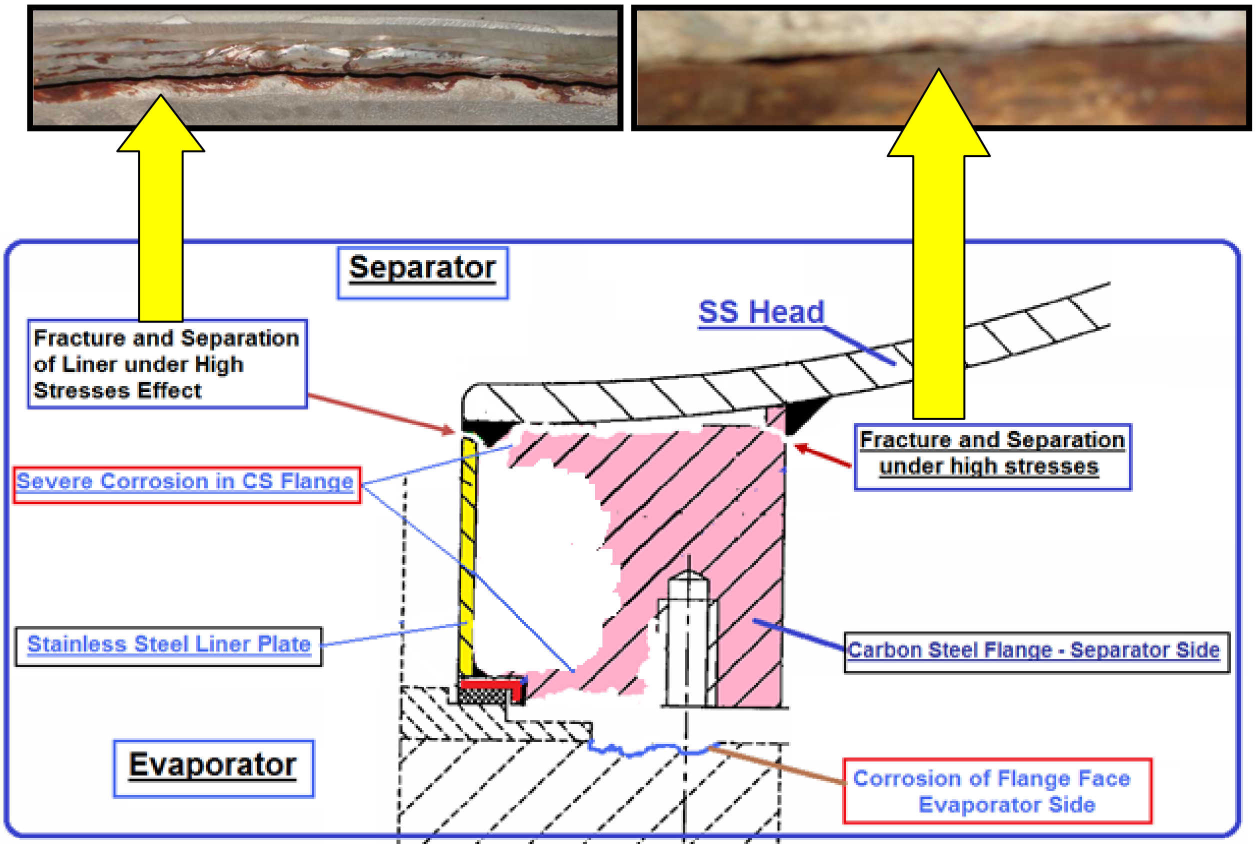
Sketch (3)

4) Carbon steel parts (flanges & bolts) will severely corroded, causing reduction in flange cross section thickness which lead to raising of tensile stresses over the remaining cross sectional area – Sketch (4)



Sketch (4)

5) With continuous reduction in cross sectional area and under the effect of tensile stresses, SS liner plate will undergo high tensile load causing fracture & separation of welding fusion line at the thinnest area (Liner Plate Side). Also, external dissimilar weld will separate at flange side (under double effect of tension stress and corrosion) - Sketch (5).

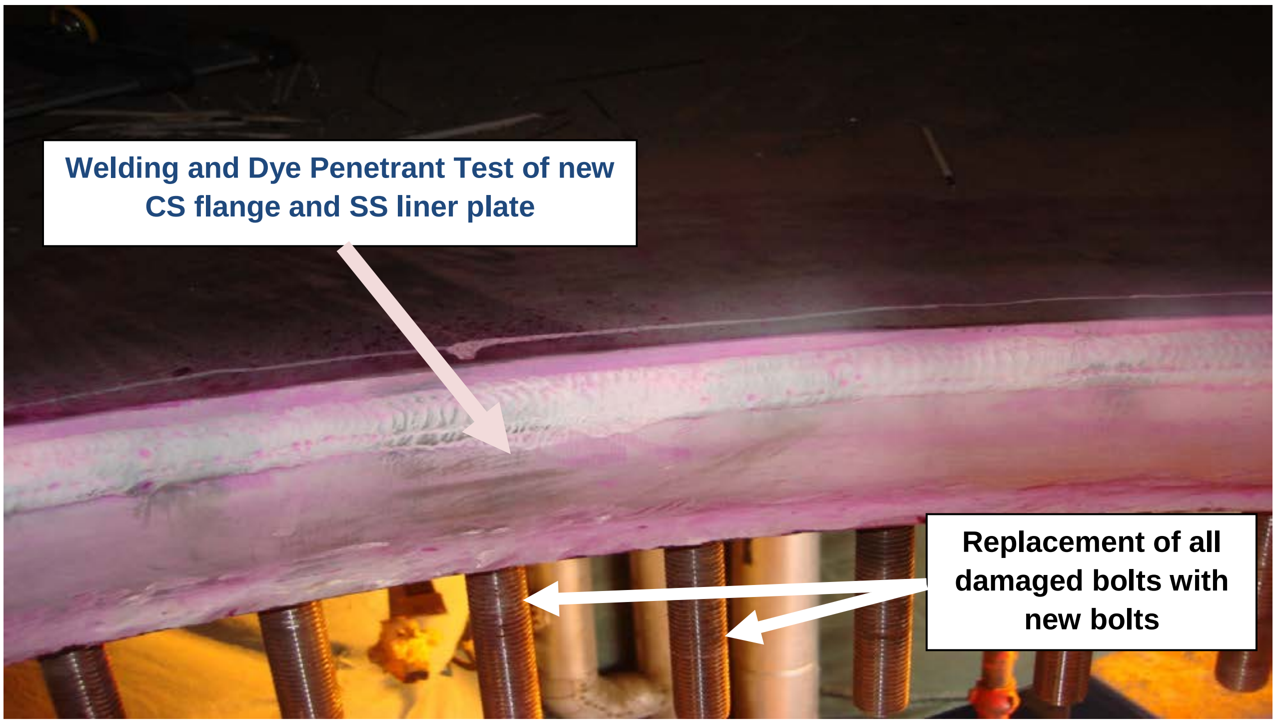


Sketch (5)

5 Remedies

The following remedies were executed during plant turnaround period:

- ✓ Replacement of corroded CS flange and bolts with new parts.
- ✓ Replacement of damaged SS liner plate with new plate.



- ✓ In future if same problem repeated, recommendations detailed in item 6.2 below will be executed.

6 Conclusion and Recommendations

1) A leaking from internal SS liner inside Separator or from gasket at connecting flange with evaporator will cause severe corrosion to carbon steel materials, which could lead to catastrophic failure (disaster of equipment falling and exposing to harmful materials).
2) The valuable recommendations for similar operating equipment are:
   a. Material selection should consider upgrading material type for external flange and bolts to be suitable stainless steel grade.
   b. Design considerations should be reviewed to include additional flexible supporting features for the Evaporator (to reduce risk of falling).

7 Acknowledgement

Urea Production Manager, Urea Operation Staff, Maintenance Staff and Inspection Team helped to compile this paper.

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Failure of Ammonia converter Heat Exchanger

Ministry of Industry State Company of Fertilizer South Region / Basrah
Iraq

Ministry of Industry

STATE COMPANY OF FERTILIZERS

South Region / Basrah

Failure Analysis of Ammonia Converter

Heat Hxchanger (E-401)

In NH_3 Plant 1000 Tons/Day

Failure of Ammonia converter Heat Exchanger

*S.Z. Yousif, **N.J. Al-Mudeer, *M. Hussain, *H. Taher

Abstract

The failure developed in the gas inlet channel (3Cr-1Mo ferritic steel) of ammonia converter heat exchanger after 15 years of operation was investigated. The investigation indicated nitriding of the internal surface throughout the increase of hardness to >600 HBN .Transgranular cracking of the nitrided surface associated with pitting corrosion showed the characteristics of corrosion fatigue.The probable causes were discussed.

Introduction

The failure of ammonia converter heat exchanger 2A/E- 401, SCF / Basra - Iraq, at Sept. 2005 were investigated. Two cracks were detected in the channel of gas inlet . One upper crack (12 'clock position)of 65 mm length and 100 mm depth. Two other cracks (6 o'clock position) at the bottom; one extended horizontally to a length of 65 mm and then directed perpendicularly to a length of 180 mm.The second crack extended horizontally parallel to the first with a length of 70 mm, and it's depth of penetration exceeded 100 mm. However, the general feature, location and size of cracks occurred in converter heat exchanger are shown in Figure.(1). During the last five years, the ammonia converter R-401 operated at a reduced load of ~ 60-70%.

The gas enters the exchanger tube at 470 °C and the outlet temperature is ~ 315C,while the gas temperature in the shell side is ~200 °C. The gas mixture consisted mainly of ~ 66% hydrogen and ~ 24% nitrogen which is heated up to 400 °C. Similar events were presented at AICHE Symposium[1,2] concerning failure of 3Cr-1Mo steel channel by internal cracking after 3 years of service.

The cracks originated near the inlet bore through the forging of heat exchanger channel is subjected to a comparatively sever thermal shock[3] during an unscheduled shut down. However, it is possible that hydrogen damage resulted in complete destruction of the vessel wall by:

1-Hydrogen blistering,

2-Hydrogen embrittlement,

3-Decurburization and

4-Hydrogen attack at high temperature.

These resulted in loss of ductility and tensile strength of steel[3-5].

The present study concern with the cracking problem occurred in 3Cr-1Mo steel inlet channel shell of ammonia converter heat exchanger nozzle (N3) after 15 years of service.

Ammonia plant are subjected to a thermal cycle with each shut down and start-up. This results in creation of thermal stresses[6-8]. The location of cracks at the bore of the channel which is the area of relatively high mechanical stress bearing an internal residual stresses.

The cooling procedure of a thick wall component in high-temperature high-pressure hydrogen service involved the possibility of hydrogen attack[4-7] . Internal cracks may developed if the cooling procedure did not allow the hydrogen to diffuse out of the metal[8] .

The aim of the present investigation is to study the causes and characteristics of cracking of 3Cr-1Mo ferritic steel of converter exchanger 2A/401.

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* State Co. of Fertilizers – Southern Region(SCF).

**University of Basra- College of Engineering.

Experimental Procedure And Results

The following procedure adapted in the present study is to investigate the problem of internal cracks,the probable changes in mechanical propertie and microstructural features.

1.Visual examination

The top crack No.1 and lower crack No.3 were found parallel to the direction of the inlet gas. Crack No.2 is perpendicular on crack No.3 (see Fig.1). The internal surface of the channel was covered with grey-black coloration of ~3 mm thick passive film.

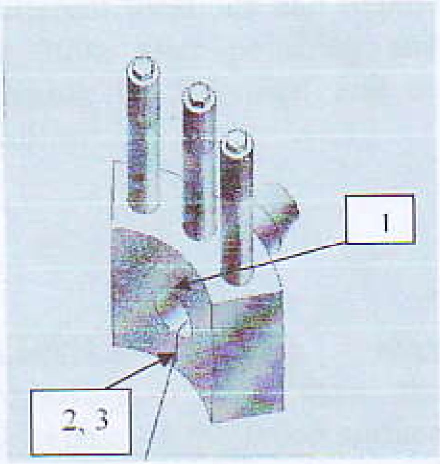


Figure 1

Cracking on the channel inlet nozzle (N3 , 2A-E-401) , 1) Upper Crack , 2,3) Bottom Cracks .

2.Dye-penetrant testing

The application of the dye-penetrant to the failed region gave no indication for surface cracks or hairline cracks present on the hard layer of inner surface. Also, there were no defects observed on the outside surface of the exchanger; that's the welding of stub and nozzles were found sound.

3.Ultrasonic waves testing

Vertical and angular probes type USM2-UT tester was used. No sub or internal cracks observed through the shell wall (360mm).Also, the area near the cracks showed no evidence of internal cracking.

4.Hardness testing

The hardness test using hardness tester portable type MIC-10Lfor the specimen taken from area near the cracks of channel surface **(Fig.2&3)** indicated very high values compared to the original values of (156-192 HBN) given by the instructor[8] .**Table(1)** showed the variation of hardness values along the exchanger. A maximum value of 650 HBN was detected on the grey-black surface film.

Testing of the bare metal; after removal of 3 mm from the hard surface (by grinding), showed normal values of ~170 HBN. However, it is apparent that the channel surface experience hardening effect probably imposed by nitriding process during prolonged service life.

The hardness of the external surface did not show any variations.

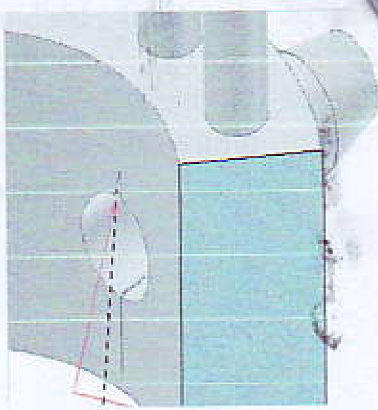


Figure 2

Feature of the upper crack after taking the spedimen (N3 , 2A-E-401)

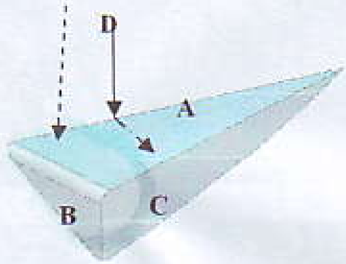
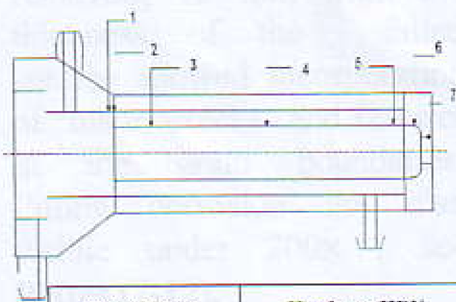


Figure 3

Specimen from upper crack region .
(A&B) fluid side,
(C) adjacent to crack perentration &
(D) cuting surface

Table 1

Hardness testing results at different location along the exchanger 2A-E-401



Tested Point	Hardness HBN
1	650
2	650
3	550-600
4	380
5	270-280
6	275
7	343
8* JIS-Std value	240

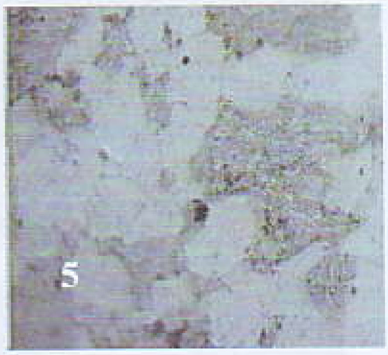
5.Tensile Test

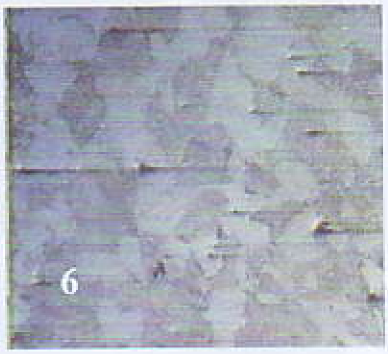
Testing of specimens taken from the failed region below 10 mm from the cracking surface showed no remarkable change in the tensile strength; the $\sigma_{uts} = 53.0 kg/mm^2$ compared to the standard limit of $51.02 kg/mm^2$ (as minimum)[8] Moreover, the elongation was found 28%compared to standard limit of 20% (minimum)[8]. This indicates that there were no structural deformation within the alloy texture.

Microstructural Examination

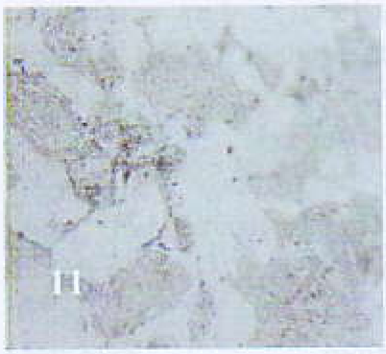
Optical microscopy was employed for microstructural examination using the " Modified Optical Microscope", (Olympus, Japan) which provided by photographic system through CPU (Pentium IV). The failed region were examined at different locations and depths at 200x after polishing and etching by 5% nital and as follows:

a.Cracked region after removing 3 mm from the thickness of the failed surface showed intergranular and transgranular cracking on the hard nitrided surface. Black particles may indicate the presence of carbides as observed in **Plates (1-6).**

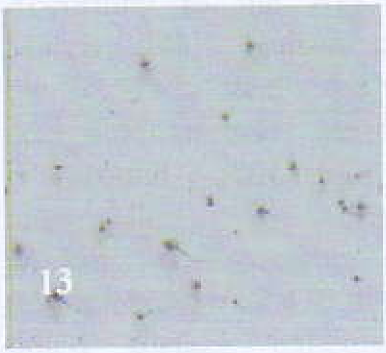


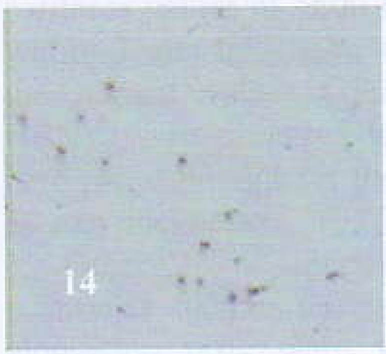


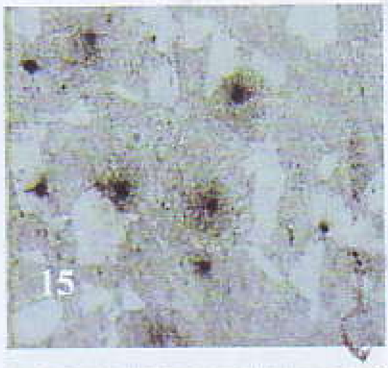
b.Cracked region after removing 10 mm from the thickness of the failed surface showed incorporation of micro cracks and fissures in the grain boundaries. Pitting corrosion are also visible under 200x , see **Plates (7-12).**

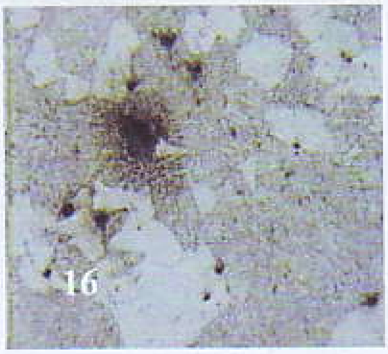


c.Cracked region after removing 25 mm from the thickness of the failed surface showed that the presence of pitting corrosion on the freshly polished un-etched specimens surface (**Plate 13 & 14**). Normal structure of ferrite & pearlite associated the pitting corrosion can be seen in **Plates (15& 16)** .For etched specimens ; the nitrided surface showed blistering ,as indicated in **Plates (17&18)** ,probably due to hydrogen gas. Furthermore ,the surface showed high hardness of > (635 HBN),

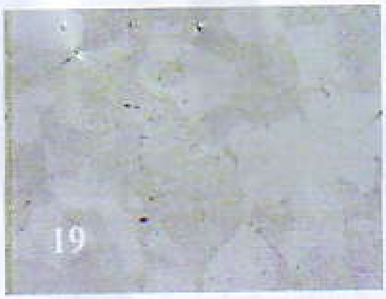


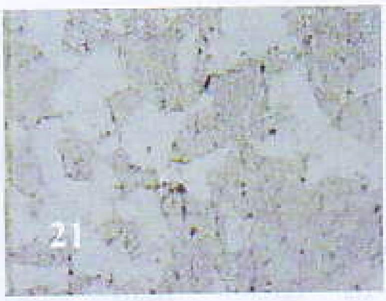


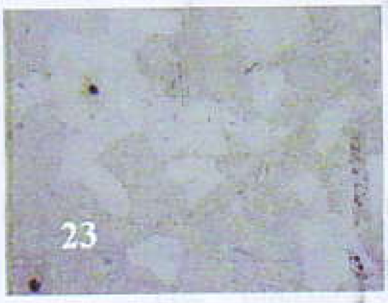


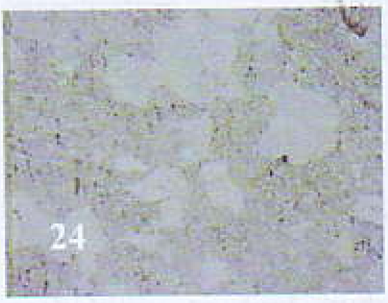


d.Cracked region after removing 30 mm from the thickness of the failed surface showed the tow phases of steel; the ferrite and pearlite (**Plates 19-20)** which are associated with the presence of micro cracks and fissures in the pearlite phase **(Plates 21-22)**. In addition, carbide particles scattered on pearlite phase are evident **(Plates 23-24).**









Discussion

By reviewing the total number of shut-downs during the operation cycle from June.2004 to Jan.2005 **(Table 2)**; it is obvious that eleven times of shut-downs occurred within a period of seven months . These involve faster rates of cooling resulted in creation of thermal stress throughout the external to internal surface. However , the location of the cracks at the bore of the channel shell both at 6&12 O'clock positions gave evidence for the directional stress; as the bore it's self is of relatively high mechanical stresses. The combined effects of thermal stresses and mechanical stresses led to surface cracks instead of being below the surface)[9-11]. Hence, the absence of subsurface crack deduced from ultrasonic test dictated that there was no hydrogen embitterment. However, hydrogen embitterment is possible for high-strength steels during shut-down conditions [(4,10,11)].

For high temperature hydrogen attack during service; the hydrogen that diffuses throughout that steel wall reacts with carbon in carbides to form methane that led to surface or internal decarburization resulted in deterioration of mechanical properties[12].

According to the API 941, March 2004- Nelson curve for 3Cr-1Mo steel[7], the max. design temperature permitted is around 520̊C. In the meanwhile the nominal working temperature for this exchanger ~ 470 ˚C. The failed surface indicated a hardness values of >600 HBN within 3 mm thickness, while the normal values (170-190 HBN)[8] were observed in the bare metal throughout the 25-50 mm thickness.

Other mechanical properties such as tensile and elongation tests were found within the normal ranges. It was concluded that the increase of surface hardness were attributed to the possibility of nitriding by N_2 gas at a temperature of 470 ± 5 ˚C .These observations were confirmed by several investigators working on chemical industries [1-3].

.. The microscopical examination results for the failed regions showed the presence of micro cracks of transgranular type which indicated the characterization of corrosion fatigue ,see **Plate (1-6).** The presence of pitting corrosion on the filmed surface act as a stress raisers for crack initiation (13) as appeared in **Plates(7-12).** Moreover, intensive pitting is clearly evident in **Plates (13-16).** Very limited local blistering can be observed associated with the presence of pitting corrosion on the nitrided hard surface (>600 HBN) as appeared on **Plates (17&18).**

Recent publications provide new class of high strength Cr-Mo-V ferritic steels to overcome the cracking problem in high pressure vessels [(14-17)].

Summary

The results showed that cracking on the channel nozzle gas inlet which is a region of previously cold-worked with a residual stress was subjected to additional alternating thermal stresses . In addition, the converter service life exceeded 15 years and subjected to frequent shut-downs of ~ eleven times during seven months. This has imposed faster cooling rates than that of the programmed shut-down.

The over all surface hardening by nitriding process indicated by increase of hardness values to >600 HBN facilitate crack initiation under the effect of operating pressure 200 kg/cm^2 at 470°C. Moreover, the presence of pitting on the hard surface serve as stress raisers for the crack initiation.

The microstrrctural examination indicated transgranular cracking associated with pitting and corrosion products which is the characteristic of "corrosion fatigue". It is concluded that there is less probability to find hydrogen attack in the vicinity of the failed region.

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Reduction of SO2 from gaseous emissions in sulfuric acid production plant

A. Benazzouz, Maroc Phosphore, OCP Group, Jorf Lasfar, Morocco

Reduction of SO2 from gaseous emissions in sulfuric acid production plant

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Table of Contents

1. INTRODUCTION

The principal activity of OCP group at Jorf Lasfar is the production of phosphoric acid and fertilizers. The phosphoric acid production is done using sulfuric acid which is produced in a workshop composed of 06 identical units. The process used is Monsanto with double absorption and is composed of 03 main phases:

- **The combustion** which consist on burning sulfur "S" in a combustion chamber to form sulfur dioxide ($S + O_2 \rightarrow SO_2$)
- **The conversion** which consist on combining sulfur anhydride to oxygen « O_2 » in a converter to produce anhydrous sulfuric acid ($SO_2 + 1/2O_2 \rightarrow SO_3$)
- **The Absorption** which consist on washing anhydrous with water in absorption towers to give sulfuric acid at a concentration of 98% ($SO_3 + H_2O \rightarrow H_2SO_4$)

Currently, the site contains 9 units of sulfuric acid production. The monitoring of funnel gas emissions show that the SO2 concentration is in accordance with regulation.

The development plan of the site expected that a dozen of other units of sulfuric acid production will be built. Even if the regulatory requirements for gaseous discharges will be respected, the simulations of ambient air quality have shown that the risk of deviations could happen.

So, it is imperative to limit concentrations of SO_2as low as possible

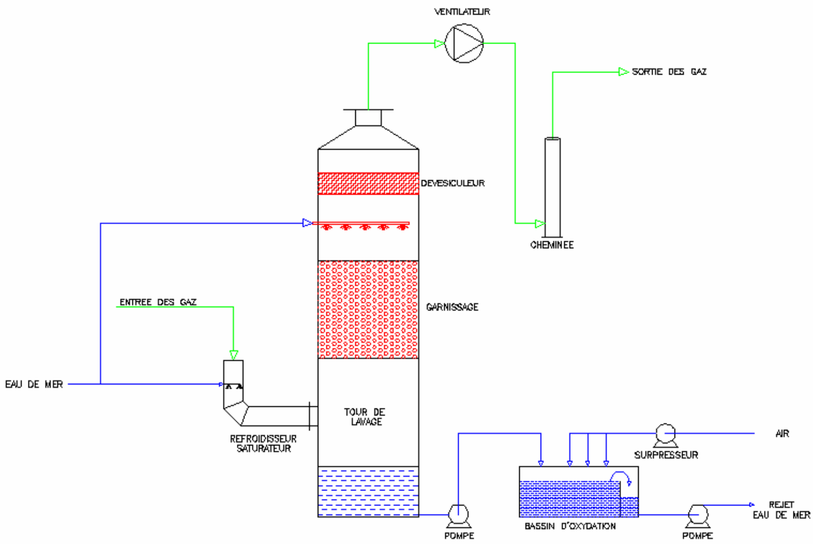
2. DIAGRAM.

On the final washing's Tower, the gases are washed by contact with sea water which absorbs SO_2 according to the following mechanism:

- SO_2oxidation by dissolved oxygen in seawater $SO_2 + H_2O \rightarrow SO_4^{2-} + 2H^+$

- Neutralization of H^+ions by HCO_3^-ions dissolved in seawater $H^+ + HCO_3^- \rightarrow CO_2 + H2O$

Subsequently, the oxygen is supplied in sufficient quantity for the aeration of sea water before discharge.



3. PROCESS

The Reverse Jet scrubbing system is illustrated in Figure 1. The heart of this system is the Reverse Jet, a gas-to-liquid contactor that creates a zone of intense mixing. The feed gas stream enters the top of a vertical duct and collides with the scrubbing liquid that is injected upward through large bore injectors.

A standing wave of highly turbulent flow, called the Froth Zone, is created at the point the liquid is reversed by the gas. The Froth Zone creates a very high rate of liquid surface renewal and efficiently quenches the gas to the adiabatic saturation temperature, removes the particulate and absorbs the SO_2. Even under upset conditions, the scrubber is capable of quenching hot gases.

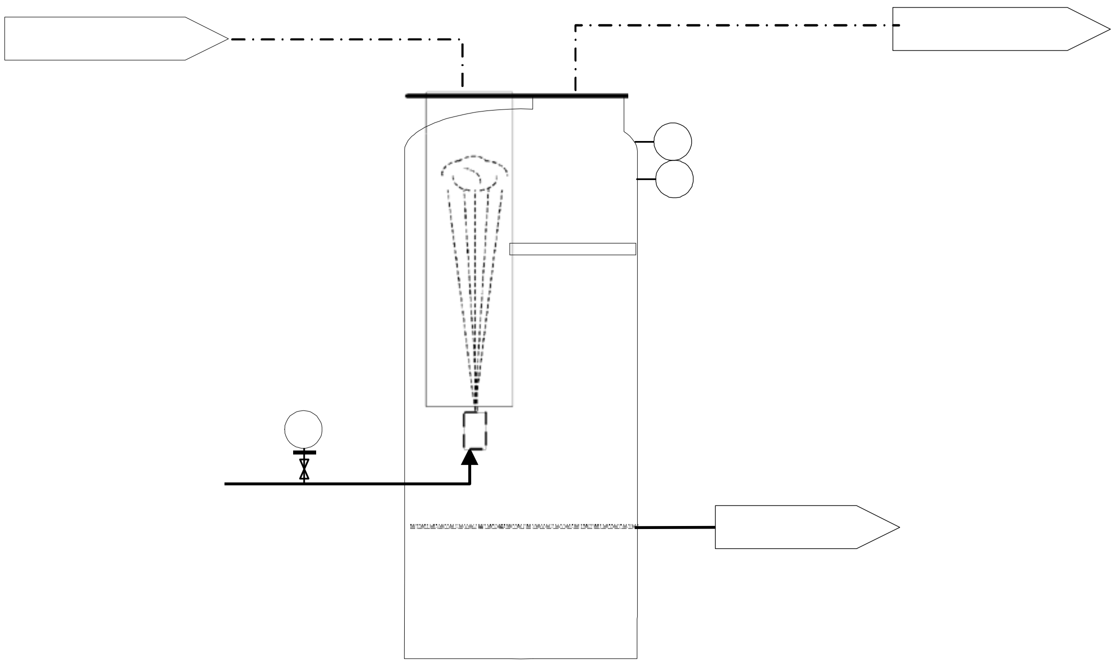
After contacting, the gas-liquid mixture enters a separation vessel where the liquid drops to the sump of the vessel and the gas exits the vessel through a vane demisting device.

The Reverse Jet nozzle is a very large bore, open throat nozzle that creates a full cone liquid flow that is essential to producing the required Froth Zone. The nozzle is fabricated of SiC to resists erosion.

The Reverse Jet scrubber is a particularly effective device for seawater scrubbing. The scrubber is designed to handle large, suspended solids, without plugging through the use of very large open bore nozzles and slurry type pumps. Thus, only very minimal screening of the water is required at the seawater intake.

Figure 1: Reverse Jet Scrubber

Process Gas Outlet Gas



The flue gas is fed to the gas cleaning system at the flow rate and temperature specified in the design basis. The feed gas enters the Reverse Jet and flows downwards through a vertical duct where it collides with the seawater, which is injected upward through the large-bore injectors. In this Froth Zone the gas is quenched and SO2 removal takes place in the gas.

The gas exiting the Reverse Jet enters the bottom of the disengagement vessel, where gas and liquid are separated. The gas passes through a chevron demister for liquid droplet separation before exiting the top of the disengagement vessel and continuing on to the stack.

The seawater is dropping in the sump of the disengagement vessel and is by gravity overflowing to the effluent treatment.

In the effluent treatment system, air is pushed through the seawater to reduce the Chemical Oxygen Demand of the seawater. Additional fresh seawater is mixed with the 'used' seawater to keep the pH and the water temperature within the limits of disposing.

The fresh seawater send to the Reverse Jet nozzles is controlled by flow or by pressure at the nozzles.

SETUP

Instead of working normally in closed circulation, with a small bleed stream; the system has been operated in a once through mode. Meaning, fresh sea water (from the seawater cooler supply) is sent via a booster pump to the Reverse Jet injectors. The liquid is injected counter current with the gas, forming a Froth Zone, which will absorb the SO2 out of the gas. Gas and liquid are falling in the disengagement vessel, where gas and liquid are separated. The liquid is sent via level control pump to the holding tank, where the seawater is discharged by gravity to the pit and goes back to the sea. The treated gas in the pilot plant is a small bleed stream coming from the stack of line B acid plant.

In optimum conditions, the gas from the acid plant would contain less than 1000 ppmSO2, it would not contain any water nor solids and it would be at a temperature not exceeding80°C. Except for the SO 2 content, the gas could be considered as clean.

The seawater is normally used for the sea water coolers and is coming from the AtlanticOcean.SO2 concentrations were measured with the analyzer, between the gas cleaning system disengagement vessel and the fan. To measure the inlet concentration, the gas was pulled through the gas cleaning system pilot plant, without injecting any seawater. The analyzer was taking samples every 10 seconds, and the result was send to a computer. The accuracy for SO2 is ± 10 ppm.

SEAWATER USED:

The Atlantic Ocean seawater used is coming from the header pipe of the seawater fed to the coolers.

Sea water can only be used to scrub gases upon condition that the returned sea water must be of good quality. One parameter affecting the sea water quality is the temperature. The average sea water temperature is varying from 16°C till 23°C, depending on the month season. During the tests the temperature at the header pipe of the seawater was 17-18°C. The samples taken at the inlet of the gas cleaning system pilot plant were varying between 18° and 20°C.The temperature of the returning sea water may not differ more than a couple of degrees from the surrounding water.

The measured pH of the incoming sea water is between 7.7 and 7.95.

GAS INLET CONDITIONS:

The average SO2 loading is 1424 ppm with 3.15 % of oxygen and the gas inlet temperature is 80°C.

SO_2 ABSORPTION:

In the current set up of the pilot plant the inlet concentration of SO2 could not be modified, only the gas flow, number of injectors and flow to the injectors could be changed. If we look at the results reached with only one Reverse Jet operating, we notice that the more seawater we use to treat the gas, the higher the efficiency is. On the other hand the more seawater we use (at a fixed gas flow rate) the higher the gas pressure drop and energy consumption will be.

It was also noticed that a high pressure only at the second injector causes lower efficiencies as if we put it on the higher Reverse Jet injector. This is because at these high pressures, the Froth Zone (contact zone where absorption takes place) formation of the bottom injector is impeded by the top injector. This could be of course avoided when a new system is designed for this purpose.

The highest efficiency reached with one stage Reverse Jet was 98.6 %. The gas cleaning system pilot plant has however some limitations, and higher as 3.5 bar could not be achieved at a single injector. A second injector was switched on and verified if as much sea water was required as with one single injector. To reach similar efficiencies with 2 injectors, compared to one, there is more liquid flow required (30-40%), however there is less gas pressure drop generated.

PERSPECTIVE

Some additional trials will be carried out in order to define modalities of a turnkey study to Supply an industrial SO_2 washing system to set up at a chimney of a sulfuric acid production unit.

The expected objective is to set up the system on one line, then make the necessary improvements to reduce SO_2emissions and to master the main parameters before generalizing to all sulfuric acid production lines by 2013

الإتحاد العربي للأسمدة
Arab Int'l Organization هيئة عربية دولية
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Since 1975

The Arab Potash Company Hot Leach Plant Up – Grading and Process Improvements

Eng. Jamal Amira - Technical Manager
The Arab Potash Company

The Arab Potash Company Hot Leach Plant Up –Grading and Process Improvements

By: Eng. Jamal Amira   Technical Manager

About the Company

Arab Potash Company (APC) was founded in 1956 to produce potash using the minerals of the Dead Sea. The site is located 110 kilometers south of Amman and is a solar evaporation ponds system of an area of 120 square kilometers and processing plants for the ore.

Potash production began in 1983 at a capacity of 1.2 million tons of product. This was expanded in the late eighties to 1.4 million tons. A second plant based on different technology was built in 1994 and this brought the total design production capacity to 1.8 million tons for APC. . The actual production capacity in 2008 was a record 2.0 million tons per year. A new cold crystallization plant is currently being constructed and will be on line in 2010. This will bring the actual capacity of APC plants up to around 2.5 million ton per year. The Arab Potash Company employs almost 2000 personnel with offices in Amman, Safi and Aqaba.

Dead Sea & Solar Pond System

Main Intake Pump Station

APC Plants

One of the operating goals of the Arab Potash Company is to attain the best performances, efficiencies and recovery of equipment. Consequently intensive studies had been carried

out to determine the major bottlenecks in the plant, and to evaluate ways to resolve all bottlenecks and obstacles in refineries.
This article will highlight on two of the major de-bottlenecks in the hot leach plant (Plate heat exchanger and screening unit).

Falling Film Heat Exchanger

The existing plate heat exchanger is used to heat up the circuit. The existing plate heat exchangers are not reliable and experience too many failures during start up/ pumps switching. As well, the wear and tear on the rubber components has made them fragile as a result of high temperature and long service. This results in increasing operating costs as a result of losses of steam and frequent maintenance.

Existing brine heaters

Based on, the followings three alternatives have been studied to increase reliability of the heat exchangers: -
- **Maintain the current plates.**
- **Replacement the existing type with other different types.**
- **Replace the material of construction.**

The above three alternatives have been studied technically and cost wise; the recommendation is to replace the existing plate heat exchanger with falling film heat exchanger. This will reduce the maintenance cost, the operation cost by saving around 10 TPH of steam, and avail more safety working area

The key to success in the HLP plant to increase efficiency is ensuring the brine feed to crystallizers is always saturated, thus increasing their KCl content and thus crystallizers are operated at their optimum, with the proper control of brine temperature. This will both increase production and reduce the current specific steam consumption numbers.

An order was issued for Whiting/ Canada on December 27th, 2007 to supply falling film heat exchanger (FFHX) of a design capacity 2.0 MMTY of product.

The material of construction is Titanium Grade (16) & (17) for tubes and 516 – 70 carbon steel for shell

FFHX shipped on Feb. 22nd, 2009 from Canada; and delivered to site in April.

FFHX Installation has begun:

- **Tie-in (brine, steam, condensate & air) works are completed.**
- **All auxiliary equipments are purchased: -**
- **FFHX installation tender document is ready for awarding.**
- **Foundation construction is executed by local contractor.**

HLP Screening Revamp Project

APC product Handling area operates with various solids handling equipment, including bucket elevators, screw conveyors, screens, product cooler equipment, bins, etc

The area of most concern in the Product Handling is the product screening area in which the product at the exit of the dryer is conveyed to the screening section where it is classified into different grades, i.e., standard, and fine, while part of standard, fines and dust are directed to the compaction unit where they are compacted to produce a granular product.

The existing screens were built on 1982 with a capacity of 1.2 MMTPY., In 1987, HLP production capacity was increased from design Capacity of 1.2 to 1.4 MTPY, the modifications were on the carnallite and sylvinite areas and no modification has been carried out on the screening unit and till now no major modification has been carried out on the screens themselves to increase the capacity.

The most significant problem which has an adverse effect on the screens' performance is the critical condition of the frame, body and cover of the screens. The screens cover show signs of deterioration as a result of corrosion and erosion, inspection report shows that covers of number 14 and 16 primary screens and number 21 and 25 secondary should be changed.

Therefore and based on the critical situation of screen covers, capacity, infrastructure and available space; APC take decision to revamp HLP dry screens by replacing the existing six primary and six secondary screens with fewer, more efficient new screens with 270 TPH capacities.

Old Rotex Screens1 Figure

The main objectives of this project are: -

- **Decrease the running cost of the screening and compaction units by decreasing the number of operated equipments such as screens, screw conveyers.**
- **Decrease the down time which is resulted of using old and deteriorated equipment.**
- **Improve the product quality by increasing the efficiency of the screens.**
- **Obtain more free area.**
- **Improve the environment by decreasing dust emissions.**

Project alternatives have been studied, and a comparison between the proposed screens drawings and the field is carried out, the findings are: -

- **The main feed bins will replaced by two chutes.**
- **No. 71, 72 and 73 screw conveyers will be removed and use chute for fine material to fed fine bin.**
- **Replace six primary screens model Rotex 81 and six secondary screens model 521 by two new screens on elevation 24.95 m.**

  The Two mineral Rotex multi-deck screens model 4240-2 of a capacity of 135 TPH per each with their auxiliaries (chutes, magnetic separator, automatic slide gates) are installed at HLP screening unit to replace the existing 12 screens (6 primary + 6 secondary) with their auxiliaries (screws, bunkers).

The projected is executed now by local contractor within of 75 calendar days by starting dismantling and installation the screeners on July 13th, 2009. The screener machines were put into service ______.

تهدف شركة البوتاس العربية إلى الوصول إلى المستوى الأفضل من الأداء التشغيلي والكفاءة، لذا فقد تم إجراء دراسات مكثفة لتحديد معوقات العمليات الإنتاجية في المصانع وتقييم الطرق الأمثل للتغلب على تلك العقبات. وتتحدث هذه المقالة عن مشروعين بهذا الصدد: المبادل ا لحراري الجديد ووحدة الغربلة.

المبادل الحراري الجديد:

يستخدم حاليا مبادلات حرارية نوع (Plate Heat Exchanger) لرفع حرارة المحلول الملحي الداخل إلى وحدة النزع الساخن. وهناك العديد من المشاكل المترتبة على هذا النوع مثل الفشل التشغيلي أثناء فترة بداية التشغيل أو تبديل المضخات، إضافة إلى تآكل الأجزاء المطاطية نتيجة درجات الحرارة العالية، مما يزيد من معدلات الكلفة التشغيلية.

وقد تم دراسة الخيارات الفنية التالية:

1. عمل صيانة للمبادلات الحالية
2. استخدام نوع جديد من المبادلات
3. استبدال نوعية المواد

وخلصت الدراسة إلى أن الخيار الأفضل هو استخدام نوع آخر من المبادلات الحرارية يسمى (Falling Film Heat Exchanger) بدلا من النوع الحالي لتخفيض الكلفة التشغيلية وتكاليف الصيانة ورفع مستوى السلامة في منطقة العمل.

يتطلب رفع معدل فاعلية مصنع البلورة الساخنة ضمان تغذية المبلورات بمحلول مشبع بشكل يؤدي إلى زيادة الإنتاج وتقليل معدل استهلاك البخار النوعي. وقد تم إصدار أمر شراء مبادل حراري من شركة (Whiting) في كندا خلال شهر أيلول 2007 لضمان إنتاج 2 مليون طن من البوتاس سنويا. وتدخل مادة التيتانيوم في صناعة المبادل الحراري الجديد. وقد تم شحن المبادل الجديد إلى الموقع خلال شهر نيسان من هذا العام.

مشروع الغربلة:

تم إنشاء وحدة الغربلة عام 1982 بطاقة إنتاجية تبلغ 1.2 مليون طن بوتاس سنويا. وفي عام 1987 تم رفع الطاقة الإنتاجية إلى 1.4 مليون طن سنويا من خلال إجراء تعديلات على وحدة الكارنلايت ووحدة السلفنايت، إلا أنه لم يتم إدخال تعديلات على وحدة الغربلة التي تعاني معداتها من عوامل التأكل. ولذلك فقد تم اتخاذ قرار باستبدال غرابيل المنتج وعددها 12 واستخدام غربالين بدلا منها من شركة (Rotex) وبطاقة 270 طن في الساعة. ويهدف مشروع الغربلة إلى:

1. خفض الكلفة التشغيلية لوحدتي الغربلة والرص
2. خفض معدل توقف المعدات
3. رفع جودة المنتج
4. توفير مساحة إضافية من خلال الاستغناء عن عدد من النواقل اللولبية ومحاقين التخزين المغذية للغرابيل.
5. خفض معدلات الغبار

وقد تم تنفيذ هذا المشروع خلال 75 يوما من قبل مقاول محلي قام أولا بتفكيك المعدات القديمة وإزالتها من الموقع، ثم قام بتركيب وحدتي الغربلة الجديدتين. وقد تم تشغيل وحدة الغربلة الجديدة في مطلع شهر تشرين الأول الحالي بعد انتهاء أعمال الصيانة لمصنع البلورة الساخنة.