

Best Available Technology in Fertilizer Industry:

Energy/Water Optimization - HSE - Operations and Equipment - R&d

Since 1975

JORDAN



24th AFA International Fertilizers Technical Conference & Exhibition

November 22 - 24, 2011

L MERIDIEN Amman Hotel

24" AFA Int'l. Technical Fertilizers Conference & Exhibition 22 – 24 November 2011, Amman, Jordan

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الإتصاد العربك للأسمدة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

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Program

Registration & Help Desk:

Monday: November 21th, 2011

09 hr:30 - 16 hr:00

Tuesday: November 22th, 2011

09 hr:30 - 14 hr:30

Wednesday: November 23th, 2011

09 hr:30 - 12 hr:30

Committees Meetings: Restricted to members only

Monday: November 21th, 2011

10 hr:00 **AFA Technical Committee Meeting** 11 hr:00 **AFA Economic Committee Meeting** 12 hr:00 **AFA HSE Committee Meeting**

14 hr:00 - 15hr:30 Lunch

Hosted by: AFA General Secretariat

Sponsors



Indo-Jordan Chemicals Company (IJC)







Arab Fertilizers and Chemicals Industries Ltd.

الخطوط البحرية الوطنية الأردنية م.ع.م. Jordan National Shipping Lines P.L.C.

Nippon Jordan Fertilizer Company



DAY 1: Tuesday: November 22 th, 2011

10:00 Opening Ceremony & Exhibition Inauguration

 Welcome From AFA : Dr. Shafik Ashkar, AFA Secretary General

OPENING ADDRESS :

Mr. Mohamed S. BADERKHAN, Representative of Jordanians Fertilizer Industries Eng. Mohamed El-Mouzi, AFA Chairman

11:00 Networking Coffee / Tea

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11:30 Session I

Chairperson: Faisal DOUDIN - Managing Director - Indo-Jordan Chemicals co. Ltd

1	DAP & Phosphoric Acid Plant Improvement Mr. John Wing - Phosphate Consultant	John Wing, P.E.	USA	
2	Phosphate Plant Yield Comparisons Mr. Richard D. Harrison – Process Supervisor / Fertilizer Consultant PegasusTSI Inc.			
3 Novel Large Scale Energy Efficient Technology for Urea Production Mr. Rinat Anderzhanov, Deputy Technical Director of Innoviations R&D Institute of Urea				
4	Guaranteed (Risk Free) Energy Savings in Water and Steam Systems through Avanceon's Proprietary "iwater" & "iboiler" Mr. Armaghan Yusuf – Business Manager	Avanceon	Pakistan	
5	Utilization of Satellite Image To Improve Solar Ponds Production Mr.: Zaid Halasah - Senior Chemist	APC	Jordan	

14:00 Networking Lunch Sponsored By:



do-Jordan Chemicals Co



Jordan Phosphate Mines (JPMC)

Indo-Jordan Chemicals Company (IJC)

20 :00 GALA Dinner Sponsored By :



The Arab Potash Company

Jordan Phosphate Mines (JPMC)

Wednesday: November 23th, 2011

10:00 Session II

Chairperson: Mr. John Wing - Phosphate Consultant - USA

1	The major research activities of the Research Institutes for Fertilizers (JSC "NIUIF") Mr. Yuri Chernenko – General Director	JSC "NIUIF"	Russia
2	FSA Neutralization with Calcium Compounds Mr. Salah Albustami - Process Engineer	JACOBS	USA
3	Catalysts for Sulphuric Acid and Ammonia Plants Mrs. Ayten Y. Wagner – Arae Manager – Catylest Devision Mr. Henrik Larsen - General Manager , Marketing & Sales	Haldor Topsoe	Denmark
4	IJC Experience on Revamping of Sulfuric Acid and Phosphoric Acid Plants Mr. AWINASH PESHWE, PLANT HEAD	IJC	Jordan
5	Replacement of High Pressure Scrubber in SAFCO-II Urea Plant Mr. Bellary Muhammad Usman – Maintenance Superintendent	SAFCO	S. Arabia

12:00 Networking Coffee / Tea Sponsored By:



12:30 Session III

Chairperson: Saed Bokisha - Plant Manager - Ruwais Fertilizer Industries (Fertil) - UAE

1	Meeting environmental issues facing new and existing urea Fluid – bed Granulation with Plants Mr. Harald Franzrahe – Process Manager fluid-bed granulation plants	Uhde Fertilizer Technology B. V.	Netherlands
2	Revamping of a Conventional Total Recycle Urea Plant Mr. Narayansamy Selvaraj – Head of Urea -1 Plant	QAFCO	Qatar
3	Best-practice on RBI driven Integrity Assurance from Concept to Implementation Mr. salah Abdulaziz Zainaldin - Senior Inspection Engineer (Designated).	GPIC	Bahrain
4	Health, Safety and Environment in Fertilizer Industry Story behind APC Success in achieving 4000000 MHW Free of LTI-s Mr. Sami Amarneh/ QES Manager	APC	Jordan

14:00 Networking Lunch Sponsored By :



DAY 3: Thursday, November 24th, 2011

10:00 Session IV

Chairperson: To be Advised

1	10 Years of Safurex Experiences in Stamicarbon Urea Plants Mr. Joost Roes – Acqisition Manager Mechanical Engineer	Stamicarbon	Netherlands
2	Capacity Increase of Urea Plants Mr. Thomas Krawczyk – Senior Process Engineer	Uhde GmbH	Germany
3	M.P. Boiler Super Heater Coil Failure and Replacement Mr. Adel Mohammad Al Wahedi - Mechanical Engineer	FERTIL	UAE
4	Carbon Dioxide Recovery Plant at GPIC - A Sustainable Option Mr. Jamal Ali Al Shawoosh - Methanol Plant Superintendent	GPIC	Bahrain
5	Latest improvements in Indirect Cooling Technology for Granular Fertilizer Ms. Marietta Mansvelt - Technical Service Manager	Solex Thermal Science Inc.	Canada

12:00 Networking Coffee / Tea Sponsored By:





12:30 - 14:30 Session V

Chairperson: To be Advised

1	Analysis of Safety Performance of Indian Fertilizers Plants Mr. Manish Goswami - Dy. Chief (Technical)	FAI	India
2	Commissioning and Revamping Fertilizer Plants Through an Objective Oriented Approach Mr. Gian Pietro Testa – Consultant for Saipem (Italy) - Business Development Manager O.V.S (Italy)	K&T	Monaco
3	Environmental friendly way of spent catalyst recycling Mr. Clemens Kuhnert - Area Manager Middle East & Africa	Nickelhütte Aue GmbH	Germany
4	A new approach for Urea Plant Optimization using Advanced Process Control Mr. Christiaan Moons – Sales Director Mr. Luc Dieltjens - Process Engineer	IPCOS-Stamicarbon	Belgium

14:00 Closing Session

14:30 Networking Lunch Sponsored By :





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DAP & Phosphoric Acid Plant Improvement

الإتحاد المربحي للأسمدة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

Mr. John Wing

Phosphate Consultant - John Wing, P.E.

USA

DAP & PHOSPHORIC ACID PLANT IMPROVEMENTS

Proven Winners for Capacity, Profitability, Quality, By-Products, and Clean Operation

John Wing, P.E.

Arab Fertilizer Association
24th International Fertilizer Conference
& Exhibition

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DAP & PHOSPHORIC ACID PLANT IMPROVEMENTS

Proven Winners for Capacity, Profitability, Quality, By-Products, and Clean Operation

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ABSTRACT

A selection of attractive modifications are described, based on successful projects. DAP innovations include:

Dual Mole Reactor-Granulator Acid Scrubbing

BFL Vaporizer/Scrubber - Vaporizes all ammonia with free heat from air leaving the reactor-granulator acid scrubber. This unit provides a 3rd stage of scrubbing – potentially eliminating need for any tail-gas scrubber.

Product Screen Diverter Systems – easy capacity increase

Automated Recycle Control - continuously monitors recycle particle size and adjusts process to keep size in mid-range.

Dual diameter reactor (pre-neutralizer)

Pipe Reactor

Cooler Air Chiller

Tran-Tech Product Cooler

Phosphoric Acid plant projects to consider include:

Conversion from Dihydrate to Hemi: Makes acid at 42% concentration vs. ~27% No need for most evaporation. Usually no rock grinding is needed.

Conversion to Hemi-Di – similar benefits plus 98.5% recovery & clean gypsum

Utilize gypsum - many ways to make gypsum an asset rather than liability

Recover uranium – major investment with high profit potential

Recover fluosilicic acid – high-purity grade for AIF3 feed

A variety of profitable uses for phosphogypsum

Advances in dry gypsum stacking

Purify phosphoric acid to technical or food grade

Project management and start-up issues are discussed.

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DAP & PHOSPHORIC ACID PLANT IMPROVEMENTS

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DAP PLANT MODIFICATIONS

Several features should be included in most new granular diammonium phosphate (DAP) plants. They often provide attractive payout as modifications to existing plants. These innovations reduce capital and operating cost, cut ammonia loss and steam use to near zero, facilitate operability and product quality, and reduce air emissions at minimum cost.

- X Dual Mole Reactor-Granulator Scrubbing: Fumes from granulator and reactor (pre-neutralizer) are scrubbed with acid in two stages of counter-current scrubbing providing near zero ammonia loss.
- X **BFL vaporizer-scrubber:** All ammonia feed can be vaporized with free heat eliminating the cost of steam heat. This ammonia vaporizer doubles as an efficient tail-gas scrubber, cleaning and cooling the exit air.
- X **Screen Diverter System:** Screening equipment is minimized with a system that routes only enough material as is required to the product screens.
- X Automated Recycle Control System: This system continuously monitors particle size of the recycling stream and adjusts the process to keep size in the middle range.
- X **Dual-Diameter Reactor:** This reactor is large at the top to minimize entrainment, and small at the bottom to minimize formation of an insoluble phosphate compound.
- X Pipe Reactor: Ammonia mixes with phosphoric acid, and the reacting mixture spews into the granulator. Benefits are reduction of insoluble phosphate and energy savings.
- X Cooler Air Chiller: Part of the ammonia feed becomes the refrigerant to chill cooler inlet air. Cooler and associated air handling equipment can be much smaller. Existing plants can boost capacity and/or reduce product temperature.
- X **Tran-Tech Cooler:** A simple device supplements cooling of the product as it enters the storage pile.

DUAL-MOLE REACTOR/GRANULATOR SCRUBBING

Most of the ammonia and fluoride fumes in a DAP plant originate at the reactor and granulator. These fumes are cleaned with 2-stage counter-current acid scrubbing, controlled at two different N/P mole ratios. Advantages of Dual Mole Scrubbing are:

- X Ammonia losses are greatly reduced.
- X It is much easier for the main acid scrubbing system to operate at optimum mole ratio, because it is protected from excess ammonia.
- X A tendency to emit sub-micron ammonium fluoride mist is avoided.
- X When this is followed with a BFL Vaporizer-Scrubber, exit air is so clean that no tailgas scrubber is needed.

The first stage of Double Mole Scrubbing is controlled at an N/P mole ratio which is well above 1.0, and the second stage is done at well under 1.0 mole ratio. Mole ratio near 1.0 is always avoided, because that is a minimum solubility point, where severe scaling and fouling occur.

This 2-stage counter-current scrubbing system is highly effective in removing the two serious contaminants in this gas stream - ammonia and fluorides. Ammonia loss will be well under 1%, versus typically 2-5% for single-stage scrubbing. Double Mole Scrubbing is more tolerant of high ammonia emissions from the reactor and granulator - a situation which could cause serious fouling problems by driving the mole ratio to 1.0.

Double Mole Scrubbing should be standard equipment in all new DAP plants, and it is frequently an attractive modification for existing plants, depending on actual ammonia losses and its value.

BFL VAPORIZER-SCRUBBER

This system uses waste heat from the reactor-granulator acid scrubbing system to vaporize all ammonia feed a DAP or MAP plant. The system is located in the gas stream exit reactor-granulator acid scrubbing. Condensate from the hot gas side is separated and recirculated as scrubbing water. An important side-benefit is that so much heat is removed from effluent air that ammonia removal is enhanced.

The effluent condensate contains very low concentrations of ammonia, fluoride, and phosphate, so surplus condensate is discharged with minimal loss of valuable material. Typically the surplus condensate would be sent into acidic pond water or other impure water stream.

A recent advancement uses a plate type vaporizer, instead of the original shell-and-tube type. Advantages include improved scrubbing, lower cost, and very low pressure drop for process air.

The combination of 2-stage acid scrubbing, the BFL vaporizer-scrubber, and efficient cyclone and scrubber design eliminates the need for a separate tail-gas scrubber. With efficient cyclones and well-designed acid scrubbers, the system will meet rigorous air emission standards. Vent gasses from the dryer, cooler, and equipment vents contain lesser amounts of contaminants, and emission standards can be met without tail-gas scrubber. Any new DAP plant design should be seriously consider this opportunity to eliminate the expensive tail-gas scrubbing system. However, it might not be practical to take advantage of this opportunity when retro-fitting an existing plant.

"BFL" refers to Belledune Fertilizers Ltd., where an early version was successfully employed in the gas stream directly from the reactor (before acid scrubbing). That early arrangement is suitable only for plants that can handle issues involving water balance and ammonia.

The essential rule for vaporizing ammonia is to use free heat. Ammonia is so volatile that many forms of free heat can be employed, rather than valuable steam. The BFL Vaporizer is only one of three methods of vaporizing ammonia with free heat that I have designed for DAP plants. Another source of free heat is warm tail-gas scrubber water. Like the BFL Vaporizer this cools the gas stream, which helps remove ammonia and fluorine from the air leaving the DAP plant. Ambient air works in tropical climates, and I designed ambient air vaporizing for the Philphos plant in the Philippines. Warm water from the sulfuric acid area or other sources could also be considered for vaporizing ammonia.

SCREEN DIVERTER SYSTEM

This innovation allows use of fewer screens to achieve separation of fines and on-size material. In conventional granulation plants, product screens receive all recycling material after the coarse screens have removed oversize. The Screen Diverter System utilizes a system of diverters and by-pass chutes to limit the product screen feed to no more feed than is required to provide enough product. This minimizes the number of products screens that are needed, and it improves product size distribution.

AUTOMATED RECYCLE CONTROL SYSTEM

This system continuously monitors particle size of the recycling stream. The resulting information on particle size distribution enables computerized adjustments of the process to keep size in the middle range. It was developed by HiTech Solutions Inc. and successfully implemented in the USAC Bartow DAP plant at rates exceeding 150 STPH DAP, making DAP of exceptionally high quality at 2-4 mm particle size.

DUAL-DIAMETER REACTOR

The reactor (pre-neutralizer) where phosphoric acid slurry is ammoniated should have a large upper diameter to reduce entrainment of slurry to the vent duct. This large diameter would be detrimental if it increased the slurry residence time, because of a side reaction which renders some of the phosphate insoluble. Therefore, the lower part of the reactor is smaller in diameter, to limit slurry residence time and minimize the undesirable reaction. This innovation was pioneered at the W R Grace (now Mosaic) #4 DAP plant at Bartow, Florida, USA.

PIPE REACTOR

Ammonia mixes with phosphoric acid in a pipe reactor, and the reacting mixture spews into the granulator. Benefits are reduction of insoluble phosphate and energy savings.

Various versions of the pipe reactor principle are offered by Jacobs, PegasusTSI, S A Cros, TVA, Uhde, Grande Paroisse, ERT-Espindesa, and others. Some do part of the ammoniation in a pre-neutralizer reactor, and some route acid and scrubber acid directly to the pipe reactor without a pre-neutralizer.

COOLER AIR CHILLER

Part of the ammonia feed is borrowed to become the refrigerant to chill cooler inlet air to about 5 degrees C. This cold air is much more effective for cooling DAP than ambient air.

New plants can be designed with a much smaller cooler and associated air handling equipment. Existing plants can boost capacity and/or reduce product temperature by routing the cold air from a cooler chiller to the cooler.

TRAN-TECH PRODUCT COOLER

A simple machine is utilized along with special procedures to supplement cooling of the product in the storage building. It is a mechanical device that cools product with ambient air. Optional enhancements can involve distributing the product over an extended area in the storage pile and ventilating the storage building. This provides a modest increase in product cooling system at less expense than alternatives such as using an ammonia cooler-chiller or increasing the size and air flow thru the conventional cooling system. The Tran-Tech Cooler was invented and patented by Mr. Sa Cao Tran (stran@agrifos.com). It proved successful in operation in the Royster DAP plant in Florida, which had no other cooler whatsoever.

PHOSPHORIC ACID PLANT MODIFICATIONS

COMPARING DIHYDRATE, HEMI, & HEMI-DI

IT=S ALL IN THE GYPSUM

We call them phosphoric acid plants, but they make much more gypsum than phosphoric acid. Various phosphoric acid processes are named for the type of gypsum that is produced. Gypsum is calcium sulfate with various amounts of water of hydration attached to the calcium sulfate molecules. The key to good operation of a phos acid plant is to make good gypsum. Characteristics of good gypsum are large crystals that filter well and a minimum of phosphate content in the gypsum.

Gypsum crystals are in the Di (dihydrate) form at lower concentration and temperatures, and in the Hemi (hemihydrate) form at higher concentration and temperature. The Dihydrate (Di) process makes gypsum in the form of calcium sulfate dihydrate, which has two water molecules per calcium sulfate molecule. The Hemi process makes gypsum in the form of calcium sulfate hemihydrate, which has half a water molecule per calcium sulfate molecule.

Either a hemihydrate or dihydrate process can have stable operation if the conditions are clearly in either the hemihydrate or dihydrate zone. Problems occur between the zones, because the crystals don=t know which form they are supposed to be, resulting in poor crystals and formation of scale. Think of the transition zone boundary as a Aline of dragons@ that needs to be avoided. Special techniques are necessary where conditions must cross this transition zone, such as occurs on a Hemi filter. The Hemi process became successful only after good Adragon-fighting@ techniques were developed for filtration and gypsum disposal.

DIHYDRATE PROCESS

This was the conventional process for most of the 20th century. Dihydrate plants have made the phosphoric acid for most of the high analysis phosphate fertilizer that has ever been produced. This process has a long track record or reliable operation, but it lacks the energy efficiency and many of the operating advantages of the Hemi process. Most phosphate rocks must be finely ground before processing.

Operating conditions in the Di process stay below the Hemi/Di transition boundary, but it is economically necessary to push as deeply as practical into that boundary zone. The filter product phosphoric acid is typically only 25-29% P_20_5 , so substantial further concentration of product acid is required before making phosphate fertilizers. Innovations have been used to expand capacity of some dihydrate plants to more than double their original capacity.

Dihydrate process advantages include:

- X Long track record of experience
- X Predictable performance
- X High capacity relative to equipment size
- X Moderate recovery and sulfuric acid requirement
- X Proven potential for recovery of uranium by-product
- X Best for recovery of fluosilicic acid by-product

Disadvantages include:

- X Fine grinding of rock is normally required
- X Acid must be further concentrated to make most phosphate fertilizers.
- X Large steam and cooling water requirement

HEMI PROCESS

The Hemi (hemihydrate) process produces phosphoric acid directly from filtration at 40-45% P_2O_5 concentration. Most Hemi plants use phosphate rock as received B without drying or grinding. Two entire plant sections are usually rendered unnecessary:

- X Evaporation to \sim 42% P₂0₅
- X Rock grinding (when using concentrate or other rock smaller than 2 mm)

Cooling water, acid storage, clarification, and steam distribution systems are reduced to a fraction of their conventional size. Capital cost for the phosphate complex is roughly 20-25% less than for a dihydrate-based complex, which would require rock grinding, evaporation, larger cooling water and steam distribution systems, and often elaborate acid clarification systems.

Modern Hemi phosphoric acid plants tend to be easier to operate and require less cleaning than dihydrate plants. One reason is that the reaction takes place in a stable range of hemihydrate crystals. In contrast, dihydrate plants must (out of economic necessity) operate near the unstable transition between dihydrate and hemihydrate.

Hemi process advantages include:

- X Minimum capital cost
- X Energy benefit from needing little or no steam to concentrate acid
- X Eliminate 27-42% evaporators
- X Usually eliminate rock grinding
- X Low cooling water requirement, because of eliminating evaporators
- X Moderate phosphate recovery
- X Added recovery benefit where gypsum water is recirculated
- X Low sulfuric acid requirement
- X Easy to run and maintain; tolerant of process upset
- X Higher analysis fertilizer, due to purer acid

Hemi has become the preferred process for making phosphoric acid in the 21st century. Early Hemi plants were difficult to operate because of scaling problems that occurred

because of having to cross the zone of transition between Hemi and Di gypsum crystals. During the last few decades people have developed ways to enjoy hemi=s high concentration advantage without suffering its potential chaos.

HEMI-DI PROCESS

This advanced process begins with a Hemi reactor and Hemi filtration section, but it adds a transformation reactor and a second filtration. The payoff for the added cost and complication is extremely high recovery and high quality gypsum.

Hemi-Di advantages include:

- X 98-99% P_20_5 recovery
- X Very low sulfuric acid requirement
- X Energy benefit from needing little or no steam to concentrate acid
- X Eliminate 27-42% evaporators
- X Usually eliminate rock grinding
- X Low cooling water requirement
- X Gypsum purity is suitable for making a wider variety of by-products
- X Potential for enhanced uranium recovery (to be confirmed)
- X Higher analysis fertilizer

Each of the three processes has its strengths and weaknesses. The following table briefly compares the Dihydrate, Hemi, and Hemi-Di phosphoric acid processes.

DI, HEMI, & HEMI-DI PROCESS COMPARISON TABLE

(Ratings with 5 being excellent)

CRITERIA	DI	HEMI	HEMI -DI	REMARKS (for typical or average situations, with exceptions)
Capital Cost, Reactor & Filters	5	4	2	Di has smallest Reac. & Filt. H-D has 2 Rx & Filter stages
Capital Cost, Other Sections	2	5	5	Hemi & H-D need no rock grinding, less evaporation,
Operating Cost & Benefits	2	4	5	Di needs rock grinding & much evap. H-D: high recovery
Energy Efficiency, Total Plant	1	5	4	Di needs rock grinding, much more steam & cooling water
Product Acid Concentration	1	4	5	Di 25-29% P ₂ O ₅ , Hemi 40-45%, H-D 40-50%
Evaporators & Steam Req=t	1	4	4	Hemi & Hemi-Di make DAP with little or no evaporation.
P ₂ O ₅ Recovery at Filter	3	2	5	Di ~96%, Hemi ~95%, Hemi-Di ~98.5%
P ₂ O ₅ Losses Other Than Filter	3	4	3	Hemi & H-D avoid handling 27% acid. H-D has 2 nd Rx & Filter
Recovery of Losses from Recirculated Water	3	5	1	Works only where water recirculates from gypsum stack.
Sulfuric Acid Consumption	3	3	5	2% benefit to Hemi & H-D due to low SO_4 in product, etc.
Rock Size Requirement	1	4	4	Di needs <0.4 mm (35 mesh). Hemi & H-D can use <2 mm (9 mesh)
Cooling Water Requirement	2	4	4	Hemi & H-D need no 42% evap. condenser water
Product Clarification, Storage	1	4	4	Hemi & H-D have no 27% acid; often need no clarification
Capacity per Size of Eqip.	4	3	2	Di has smallest equip. H-D requires 2 nd reactor & filters
Reagent Requirements	4	3	3	Hemi may need anti-scalant Hemi & Hemi-Di may use clay or silica.
Familiarity & Experience	5	4	3	Most existing plants are Di, but many are Hemi & H-D.
Complexity of Operation	2	4	2	Di needs grinding, much evaporation, etc. Hemi-Di has 2 nd Reactor & Filters
Uranium Recovery	4	0	5?	Hemi-Di may be best, but needs development.
Gypsum Utilization	2	2	4	Hemi-Di gypsum is purest.

CONVERTING FROM DI TO HEMI OR HEMI-DI

When should one consider converting an existing Di plant to Hemi or Hemi-Di? A key issue is that the Hemi process requires very little evaporation of product acid. The huge quantity of steam that had been going to the evaporators becomes available, so the decision is largely based on how much value can be obtained from all of that steam. The surplus steam would normally be used to generate electric power. If there is surplus capacity in an existing power co-generation facility, and if this power can be used effectively or sold at a good price, then there is major justification for converting the plant to the Hemi process. When electric power was cheaper, it was difficult to justify the expense of new power co-generation facilities. Now electricity is so valuable that this old rule of thumb no longer holds true.

If a Di plant needs another evaporator, one should consider converting to Hemi instead of buying the evaporator. Since a Hemi plant avoids the need to concentrate acid from 27 to $42\%~P_2O_5$, conversion to Hemi would eliminate any shortage of evaporation capacity. The capital that is saved by avoiding one new evaporator may cover most of the cost of a Hemi conversion. Furthermore, a Hemi conversion would greatly reduce need for steam, cooling water, and acid storage facilities $\tt B$ potentially bringing additional capital cost savings.

If a Di plant is having difficulty meeting grade with DAP or TSP, a Hemi conversion would increase P_20_5 content in DAP, TSP, or MAP by 2 percentage points. It should also help N concentration, depending on ability of the product to consume ammonia. Where there are two or more phos acid plants, converting only one of them to Hemi may solve DAP or TSP grade problems for the entire facility.

The Belledune Fertilizer plant in New Brunswick Canada is an example of a very profitable Hemi conversion. The plant might have been shut down because of high cost and difficulty in meeting DAP grade. After converting an old Prayon Mark 2 dihydrate to Hemi in 1986, cost were slashed by totally eliminating the evaporation section and associated fuel cost for generating steam. Recovery averaged 95%, and capacity easily topped the modest increase in design rate B limited only by raw material and product requirements. The superintendent called it Aone sweet plant to run. Belledune continued to operate for a decade, and was considered one of the world=s easiest running phosphoric acid plants. DAP grade became easy to reach, using 40% acid that needed no settling to remove solids.

Further conversion to Hemi-Di involves major expense for the second reaction and filtration facilities. Justification for this expense comes from the major reduction in raw material cost that is achieved by Hemi-Di=s 98-99% recovery efficiency and often by the improvement in quality of the phosphogypsum by-product. Recent increases in phosphate rock and sulfur prices make Hemi-Di especially attractive.

CONVERTING TO HEMI OR HEMI-DI WHILE EXPANDING

Additional economic opportunities arise when simultaneously converting an existing dihydrate plant to Hemi or Hemi-Di while expanding capacity. First, a major expansion can be made without adding evaporators, because Hemi needs so little evaporation. Second, the existing cooling water system will accommodate a major expansion, because of savings in evaporator condenser cooling water requirements. Third, the rock grinding section is likely to be eliminated, so no expansion is required there.

The acid storage tank area may not need expansion when a Di plant is converted to Hemi or Hemi-Di of substantially greater capacity. Tanks that had been used for 27% acid storage will become available for other acid storage service. Acid clarification requirements are reduced or eliminated, because the Hemi acid will be purer.

Arcadian (now PCS) in Louisiana made good use of those down-stream advantages when they expanded capacity by a third while converting to the Hydro Hemi process. After hearing of Belledune=s success, Arcadian converted its Prayon Mark 2 plant with Bird filter to Hemi. Expenses beyond the reactor and filter sections were minimized because:

- X Rock Grinding was totally abandoned and by-passed, with un-ground BuCraa rock feeding from a rock washing filter directly to the reactor.
- X Elimination of the requirement to concentrate acid from 27 to 42% P₂0₅ allowed existing evaporators to make more capacity.
- X One evaporator was dedicated to boosting concentration from 54% to 60-62% P_20_5 for feeding a super-phosphoric acid facility, thus increasing super-acid rate.
- X Requirements for cooling water were reduced.
- X No new phos acid storage facilities were required.

The Arcadian Hemi plant started very easily B achieving design capacity and conditions within two days. The plant easily performed so well that the client accepted it without doing the customary performance test run. It frequently ran at 110% of design capacity, and occasionally achieved up to 130% of design capacity. Recovery consistently exceeded 96%. Arcadian and Belledune=s experience demonstrated that Prayon reactors and tilting pan filters are well suited to conversion to the Hemi process.

The exceptionally high quality Hemi acid was welcome as feedstock to a food-grade phosphoric acid plant and a super-phosphoric acid facility. Arcadian=s liquid fertilizer product was considered to be the best in the domestic industry.

Expansion while converting a Di or Hemi plant to Hemi-Di can be facilitated by using the existing filters in the dihydrate section of the Hemi-Di process. Dihydrate filtration in a Hemi-Di plant needs only about 60% of the filter area as hemi filtration. The old filters may be big enough to act as dihydrate filters in a new and larger Hemi-Di plant.

URANIUM RECOVERY

Much of the world's phosphate rock has about half a kilogram uranium per ton of P_2O_5 . Uranium was recovered from most central Florida phosphoric acid a quarter century ago, before a sudden downturn in price forced recovery plants to shut down when their sales contracts expired. A few years ago I was involved in an assessment that predicted that uranium recovery would be profitable at prices over \$25/pound U_3O_8 . Fertilizer International reported \$25-30/lb operating cost in its May-June 2011 issue. Uranium prices have climbed to nearly \$53/pound, so prospects are bright. Furthermore, Urtek of Australia recently piloted its advanced PhosEnergy process in the USA and has another pilot plant nearing start-up. Substantial benefits in cost, recovery, and environment are claimed, compared to previous technologies.

The Di process has a proven track record of successful uranium recovery. The Hemi process is not attractive for uranium recovery. Its high product acid concentration makes uranium extraction difficult, and uranium content in the acid is low. Uranium recovery might be even more attractive with a Hemi-Di process. A very high uranium/ P_20_5 ratio occurs in a certain weak acid filtrate stream within the Hemi-Di process. It should be far easier to extract uranium from this stream than from the conventional extraction from 27% P_20_5 acid. However, this procedure has yet to be proven and developed.

Nuclear power is finding favor as an economically and environmentally attractive source of electric power. Major nuclear power expansions with are proceeding worldwide for modern 4th generation nuclear reactors, which are inherently far safer than the 40-year-old plants at Fukushima, Japan. China targets 43 million kwh of nuclear power by 2015 and 100 by 2020. India plans a 13-fold increase by 2030. Asia is expected to expand from current 4% of all nuclear power to 30% within the foreseeable future. Both political parties in America are supporting major expansion of nuclear power.

Potential recovery of uranium from phosphoric acid has been estimated to be 20 million pounds of U_3O_8 annually. Uranium extraction requires substantial capital investment, but it could prove financially attractive for phos acid plants which consume rock with good uranium content.

FLUOSILICIC ACID RECOVERY

Fluosilicic acid (FSA) is often recovered from phosphoric acid plants. When it contains relatively high concentrations of P_2O_5 (0.1-0.25%), it is sold at relatively low price for use in fluoridating municipal water. When P_2O_5 is limited to a few hundred ppm, it is sold at a higher price for making aluminum fluoride.

The Di process excels in opportunity to recover FSA, because FSA can be recovered from the evaporators that concentrate acid from 27-42% acid, as well as from the higher concentration evaporators. Hemi and Hemi-Di processes eliminate the need to evaporate acid from 27 to 42% P_2O_5 , so this opportunity to recover FSA from 27-42% evaporators

does not exist. Some FSA is recovered from Hemi reactor fumes or from flash cooler vapors, as well as from evaporators for higher acid concentrations.

GYPSUM STACKING & UTILIZATION

Within the phosphate industry we rightfully take pride in the many benefits of phosphate to people throughout the world. The most important benefit is the vital role of phosphate fertilizer in feeding people. It's easy to ignore the fact that our primary product in terms of tons produced is gypsum. We make about five tons of phosphogypsum for every ton of P_2O_5 . What do we do with our biggest product? Usually nothing – well, actually less than nothing. We usually pile it up (at considerable cost) and hope to leave it there forever. Unfortunately, "forever" comes too soon! Even after a phosphoric acid plant permanently shuts down, complex procedures must be enacted to close the gypsum stack. In the US the acidic water in a wet stack must be neutralized, and then the stack is capped and closed, at costs running into the tens of millions of dollars per stack. The standard practice of throwing phosphogypsum away can be quite expensive.

Phosphogypsum can be utilized in many ways. It is superior to limestone as roadbed material. Farmers use it as soil conditioner, and they reap the benefits of its sulfate content plus significant quantities phosphate and minor plant nutrients. Relatively pure gypsum can be utilized in cement or processed to make such valuable product as sulfuric acid, ammonium sulfate, calcium carbonate, wallboard, or even hydrogen and glass. The Hemi-Di, Hemi-Di-Hemi, and Di-Hemi processes provide such high recovery (98-99%) that the gypsum has very low $P_2 O_5$ content. The low $P_2 O_5$ content is essential for many phosphogypsum uses.

The Florida Industrial and Phosphate Research Institute (FIPR) is involved in a comprehensive program to promote and support utilization of phosphogypsum for a variety of uses worldwide. The Stack Free program aims to eliminate the cost and environmental hazards of stacking gypsum by utilizing phosphogypsum in profitable ways. Progress can be followed at the website www.stackfree.com.

The Stack Free effort faces a major task, because the great majority of phosphogypsum is stacked. Some is discharged to the sea, and very little is utilized for anything. Petrokimia Gresik was an early leader in phosphogypsum utilization, having built a hemi-di phosphoric acid plant about 30 years ago, with all gypsum being utilized for either ammonium sulfate plus calcium carbonate, or as cement retarder. Mobil Chemicals in Texas provided several months' production of phosphogypsum for roadbed material near Houston Texas, until the US EPA banned all gypsum utilization, citing environmental concerns. The EPA has since softened objections, but has been very slow to permit phosphogypsum utilization.

Most phosphogypsum is pumped as slurry to "wet" stacks. Some is stacked "dry", and some is piped into the ocean. In a wet stack gypsum and water separate within an area that is confined by gypsum dikes, and the water decants and is returned and re-used. Wet stacking is considerably less expensive to install and maintain than dry stacking. Wet

stacking enables major recovery of water-soluble P_2O_5 losses when returned pond water is employed for washing filter cake. This re-recovery effect boosts overall P_2O_5 recovery by about 1-3% with a Dihydrate plant. A Hemi plant will re-recover nearly 2% additional P_2O_5 from returning gypsum stack water, because (unlike dihydrate gypsum) most of the citrate-soluble P_2O_5 in Hemi gypsum becomes water-soluble in a wet stack. Thus, roughly half of the citrate-soluble losses in Hemi filter cake can be re-recovered when washing filter cake with water that is returned from the gypsum stack.

Phosphoric acid plants in desert regions sometimes find it more practical to transfer the gypsum to "dry" stacks using belt conveyors and slingers. Dry stacking prevents water loss, which is a major concern in a desert. Jordan Phosphates Mines Co. (JPMC) has much experience with dry stacking at their Aqaba plant, using a series of belt conveyors on the stack, which is on a hill far above the plant. Indo-Jordan Chemicals Co. has an advanced gypsum stacking system that employs large conveying machines that move on rails on gypsum stacks. HiTech Solutions designed a third generation gypsum stacking system that would use very large movable conveying and stacking equipment that moves on the ground, without getting onto the gypsum. That system has been demonstrated with other materials, but not yet with phosphogypsum.

HIGH PURITY PHOSPHORIC ACID

Most phosphoric acid is processed as fertilizer grade material. Higher purity phosphoric acid is required for other uses, and purer acid brings higher prices.

Animal feed requires that fluorine be limited to less than 100 P/F ratio. Defluorination processes remove part of the fluorine from fertilizer grade acid to meet this higher grade. The acid is then processed into feed grade phosphates, typically dicalcium phosphate (dical). Feed grade dical can be produced while neutralizing acidic pond water with lime.

Exceptionally pure phosphoric acid demands greatly higher prices. There are various technical and food grades for phosphoric acid. They are usually produced by removing impurities from wet process phosphoric acid using ion exchange and other procedures. Several licensed technologies are available for purifying phosphoric acid.

Thermal processes make high purity phosphoric acid directly from phosphate rock. An interesting thermal process is the Improved Hard Process, which employs break-through technology to produce high purity acid from exceptionally impure phosphate material. Overall cost to produce technical grade phosphoric acid is expected to be very attractive. The process has been demonstrated in lab and pilot plant scale by JDC Phosphate, and a demonstration plant is likely to be operated in Florida soon.

PROJECT MANAGEMENT & START-UP COMMENTS

I'm a strong believer in a team approach to projects. Everyone should care about everything – especially the parts they know something about yet are not directly responsible for. Be ready to help your colleagues do their jobs better, and don't be too proud to receive their support in return. Keep the overall goals of the project clearly in mind. That helps you see how much you and your colleagues share the same objectives. Sometimes I wonder why the owner's people sit on one side of the conference table and the engineering/construction people sit on the other. We all have so much in common when it comes to what we want to happen.

There's no glory in start-ups. In the rare case where everything goes according to plan, and the plant starts up nicely, people just yawn and say, "That's the way it was supposed to happen." Reality is that every mistake that anyone ever made in engineering, construction, training, operation, management, maintenance, etc. rears its ugly head, and there are problems. There's lots of wailing, scurrying, re-figuring, re-planning, re-designing, re-doing, and retrofitting. This is a time for all to work as a team to do whatever is need to get the job done.

EFFECTS OF RECENT TRENDS

Some recent trends provide opportunities to benefit from modifications and expansions of existing phosphoric acid and granular phosphate plants.

Increased demand for phosphate fertilizers will spur new granular phosphate plants, and will encourage expansion of existing facilities. Many innovations that minimize ammonia losses and operating costs, improve product quality, save steam and electric power, and keep plants environmentally friendly will be implemented in new and existing plants.

Recent sharp increases in cost of sulfur and phosphate rock make it more attractive to invest in the added recovery benefit of the Hemi-Di process. Soaring fuel costs have turned emphasis to the energy-efficient Hemi and Hemi-Di processes. Other incentives for Hemi & Hemi-Di processes are that they need only a fraction as much evaporation and cooling water as dihydrate, and they usually need no rock grinding.

A flurry of interest in new nuclear power plants has escalated the value of uranium, thus enhancing prospects for extracting uranium from phosphoric acid. The Di process and probably the Hemi-Di process produce acid from which uranium can be extracted economically.

Upgrading of the quality of phosphoric acid to animal feed grade, food grade, or other high purity forms should be considered to enhance revenue, relative to fertilizer production.

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ABOUT THE AUTHOR

John Wing - President of the consulting firm John Wing, P.E. - has a Bachelor of Chemical Engineering degree with Honors from University of Florida and a Master of Engineering in Administration from University of South Florida. He has served the phosphate industry for decades in process design, consulting, project management, technical service, process development, and production supervision. He was vice president of HiTech Solutions and was employed in other engineering and phosphate production companies.

He does process engineering for new plants, modifications and expansions for phosphoric acid, DAP, MAP, & TSP plants. John designed fluosilicic acid recovery systems at Conserv in Florida; PPL, Sterlite and Hindalco in India; and IJC in Jordan. He provided conceptual design for six phosphoric acid evaporators and several dozen fume scrubbers.

For Hemi plants he performed the process design for the Belledune Hemi conversion, the 3-train Ma=aden plant, and conversion of the huge Oswal dihydrate plant to Hemi-Di (a project that was never completed). He was project manager and process engineer for the Arcadian Hemi conversion. He consulted as owner=s engineer for the Indo-Jordan Chemical Co. Hemi plant in Jordan and has been providing subsequent services for the same plant.

He has written technical papers on:

Hemi and Hemi-Di processes (7 papers)

The future of the phosphate industry

Phosphoric acid reaction and evaporation

Cooling pond systems

ACan a Little Altruism Enhance an Engineer=s Career Satisfaction?@

Article segments for Fertilizer International journal

He is a Fellow of AlChE, a registered Professional Engineer, and past Chairman of the Central Florida Section of AlChE.

в#в

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Phosphate Plant Yield Comparisons

الإتصاد العربج للأسمدة هيئة عربية دولية Arab Int'l. Organization

Arab Fertilizers Association

Richard D. Harrison

Process Supervisor / Fertilizer Consultant - PegasusTSI Inc.

USA



Phosphate Plant Yield Comparisons

Presented at the 24th Meeting of the Arab Fertilizer Association Technical Conference In Amman, Jordan

> Richard D. Harrison November 22, 2011

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<u>Outline</u>

- A. Introduction
- B. Estimate Range of P₂O₅ Losses to Gypsum Stacks
- C. Process Changes to Reduce Phosphate Losses:
 - Eliminate off-site discharges
 - Reduce phosphate flow to gypsum stack
 - Identify opportunities to recycle process water
 - Redirect fresh water make-up to gypsum stack
- D. Process Alternatives
 - Site selection and climate
 - 2. Open Circuit Processes no recovery of pore moisture P₂O₅
 - 3. Closed Circuit Processes some recovery of pore moisture P₂O₅
 - 4. Process Water Recycling
 - 5. High Strength Fluoride Recycle
 - 6. Improved Washing and/or Double Filtration
 - 7. Non-Contact Evaporator Condenser Cooling
 - 8. Calcination
 - 9. Isothermal Phosphoric Acid Reactor Technology
 - 10. Water Treatment Systems Electro Dialysis Reversal vs. RO
- E. Conclusions
- F. References

<u>Introduction – Business Activities</u>

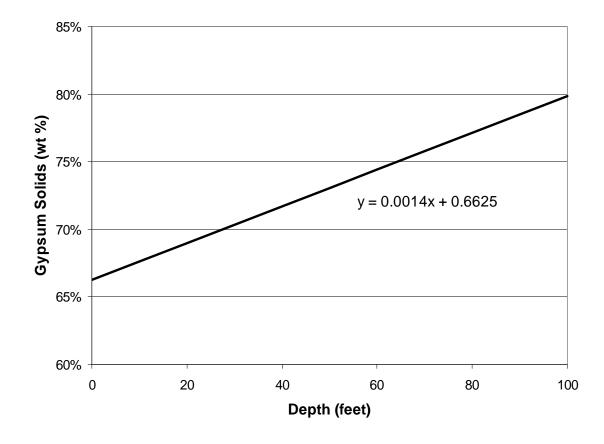
- Process Studies
- Identify & Compare Alternatives
- Capital Cost Estimates (+/-) 50%, 30% & 10%
- Project Management
- Front End Engineering
- Detailed Engineering
- Procurement
- Construction Management

For more information on our commercial activities please refer to the following publication on capital project cost estimation in the phosphate industry:

http://www.aiche-cf.org/Clearwater/2010/Paper1/10.1.6.pdf

Estimated Range of P₂O₅ Loss to Gypsum Stacks

Manufacture of phosphoric acid produces from 5 to 6 tons of phosphogypsum for each ton of P_2O_5 produced. Additionally, each ton of gypsum that is sent to the impoundment is only 67 weight % solids initially, with the remaining 33% made up of process water that occupies the capillary space between the gypsum crystals (pore moisture). The older, lower strata dewater as the pore moisture is expressed by the weight of the newer deposits above. The following graph shows the weight percent solids for a typical gypsum stack for different strata.



Estimation of water soluble phosphate losses to the gypsum stack depend on three variables:

- 1. Concentration of water soluble P₂O₅ in the pore moisture solution
- 2. Quantity of water acting as pore moisture
- 3. Quantity of phosphogypsum produced per ton of P₂O₅ produced

The typical range of these three variables is:

- 1. P₂O₅ concentration in gypsum slurry water is between 1% and 2.5%
- 2. Water acting as pore moisture is initially about 0.5 times gypsum weight
- 3. Gypsum weight per ton P₂O₅ is usually between 5 to 6, depending on ore

Water soluble P₂O₅ lost to the gypsum stack initial pore moisture is therefore:

```
Low = 5 t gypsum/t P_2O_5 x 0.5 pore H_2O/gyp. solids x 1% P_2O_5 = 2.5%
Average = 5.5 t gypsum/t P_2O_5 x 0.5 pore H_2O/gyp. solids x 1.75% P_2O_5 = 5%
High = 6 t gypsum/t P_2O_5 x 0.5 pore H_2O/gyp. solids x 2.5% P_2O_5 = 7.5%
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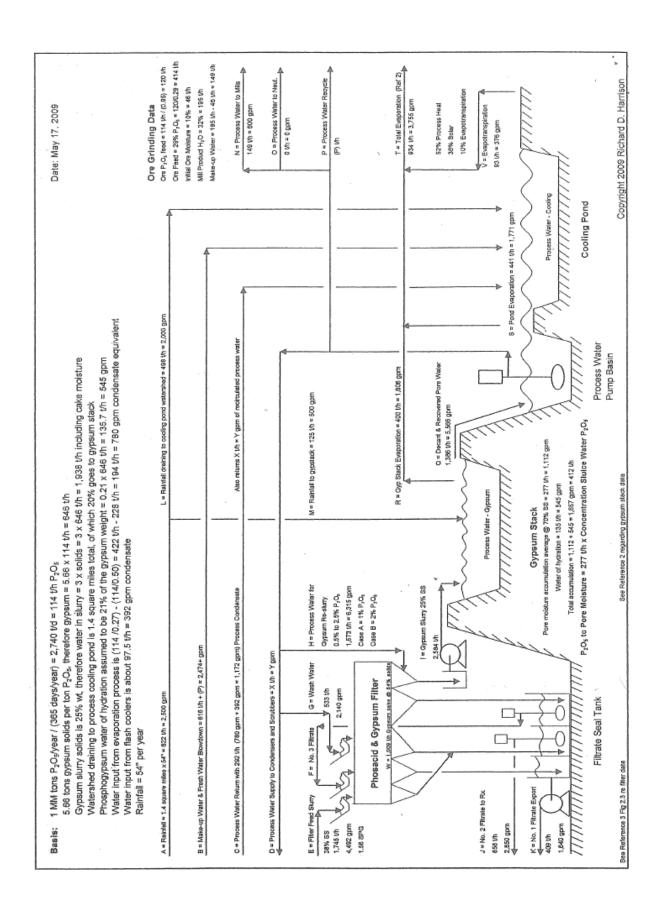
The water soluble P_2O_5 in the gypsum stack can be accounted for in two different ways. If the facility is near the end of its life, then water discharges from the gypsum stack may have to be neutralized at significant expense for surface discharge. Alternatively, if the facility a going concern for the foreseeable future, any water discharges from expressed pore moisture can be recycled and the P_2O_5 value recovered.

The limiting ideal case is where all future P_2O_5 flow to the gypsum stack is eliminated, and all pore moisture from past gypsum production recovered – creating the possibility for P_2O_5 production to exceed P_2O_5 input for the facility while pore moisture from the prior gypsum stack is being reclaimed.

For the purposes of this paper Phosphate Facility Yield will be defined as tons P_2O_5 sold as products / tons ore P_2O_5 brought on site. Using this definition it will be possible to achieve yields above 100% if future P_2O_5 losses to the gypsum stack are significantly reduced and P_2O_5 from the existing gypsum stack is reclaimed.

Gypsum must be washed and transported to the gypsum stack with fresh water (0% P_2O_5) in order to minimize water soluble P_2O_5 losses to the gypsum stack. Due to water balance constraints, this ideal is not achievable without the installation of a second stage gypsum filtration system. The PegasusTSI team is fortunate to have been able to design a double filtration system for an phosphoric acid plant for a confidential client in the middle east.

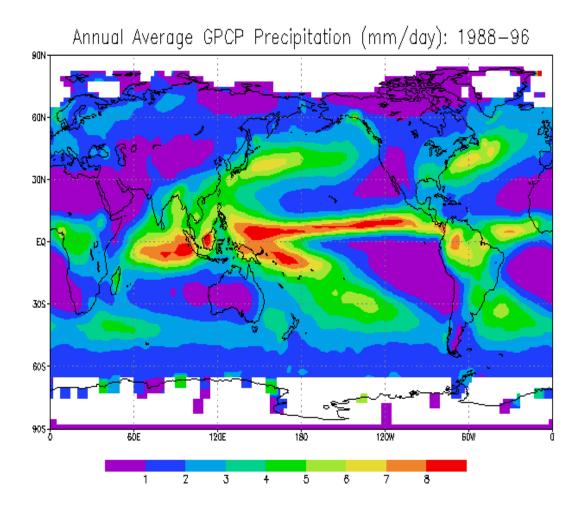
Please refer to the process schematic diagram on page 5 for a representation of a typical 1 MM ton P_2O_5 / year facility. The water balance shown is typical for a wet location like Florida that receives 137 +/- cm of rain per year.



Process Alternatives

1. Site Selection and Water Balance

Site selection has an important bearing on phosphogypsum disposal techniques. Two general classes of plant sites are "dry" locations receiving less than 37 cm of precipitation per year, and "wet" locations that receive 1 to 1.5 meters of precipitation per year. Typical "dry" locations include plants in Western USA, Morocco, Tunisia, Jordan, Saudi Arabia, and Australia. These plants do not usually employ gypsum slurry transport for gypsum stacking disposal because evaporation is much greater than precipitation.



The above graphic from NOAA uses purple to show areas with less than 1 mm/day precipitation average, and aqua to display areas with 3.5 mm/day precipitation average. Please consult the online version of this paper for a color version of the graphics in this paper.

Most "wet" locations that receive over 100 cm per year in precipitation practice slurry transport for gypsum stacking. Despite the water from rainfall, these

"wet" locations also require significant input of either well water or river water to maintain the water balance.

2. Open Circuit – no recovery of gypsum effluent P₂O₅

Open circuit gypsum discharge practices include: slurry with sea water for discharge to the ocean, conveyor transport to rail cars or barges for transport to uses such as agricultural application, mine backfill, or ocean discharge. Additionally, some sites use belt conveyors for construction of gypsum fields. Please refer to the attached satellite photos of OCP's Jorf Lasfar complex and GCT's Sakhila plant for examples of open circuit gypsum disposal.



The above photo shows the Jorf Lasfar plant in Morocco that uses seawater for process cooling and for gypsum slurry transport to the ocean. The approximate scale is 8 kilometers across the bottom of the photo.



The above photo shows the Sakhila plant in Tunisia that uses belt conveyors to transport gypsum to railcars, or to a gypsum field adjacent to the Mediterranean. A close-up of the same plant's gypsum conveyor and gypsum field is attached below. While gypsum can be conveyed by belt conveyer, experts such as the late Dr. Anwar Wissa have previously recommended slurry transport even for desert climates, please see http://www.aiche-cf.org/Clearwater/2011/Paper1/11.1.5.pdf when it becomes available.



3. Closed circuits - lined gypsum stack systems - most "wet" locations

Plants that operate a closed circuit process water and gypsum storage system use process water to slurry gypsum discharge from the filter for transport to the phosphogypsum landfill. Every ton of product P_2O_5 is accompanied with the generation of approximately 5 tons of byproduct gypsum solids. Accompanying these gypsum solids are 2 to 3 tons of process water occupying the space between the gypsum crystals after filtration and stacking. Most plants operate with process water between 1% to 2% P_2O_5 , resulting in a 2% to 6% loss of water soluble P_2O_5 with the pore water accumulating in the gypsum stack.

The next picture shows the IFFCO plant in Paradeep, India as an example of a plant operating with gypsum stacks (scale 3.2 km across bottom).



The next photo shows a plant of approximately 1MM P_2O_5 t/year capacity with a gypsum stack (scale 3.2 km across bottom) in Florida, USA.



4. Process water recovery (neutralized or as-is)

The concentration of P_2O_5 in the process water can be reduced in part by maximizing the quantity of process water consumed in the process. The two largest consumptive uses include filter wash water and ball mill make-up water for wet rock grinding. These two applications account for approximately 409 m³/h and 136 m³/h respectively for a plant with 1 MM tons P_2O_5 / year capacity operating on 68% solids rock slurry.

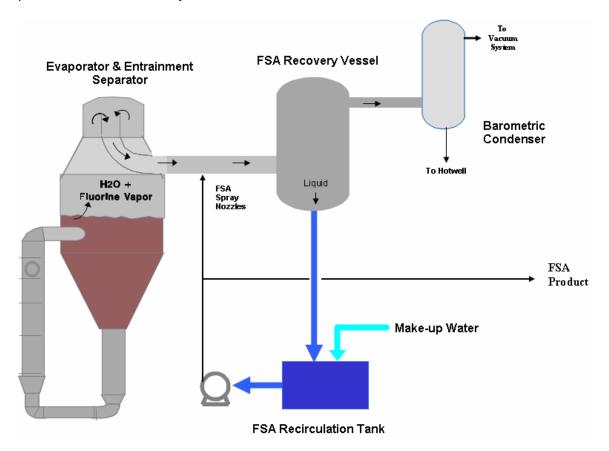
Two alternatives exist for using process water in the ore grinding area. The preferred solution is to specify materials of construction compatible with low pH (2 to 3 pH) operation. This allows water soluble P_2O_5 and accompanying fluosilicic acid to react with carbonates present in the phosphate ore to liberate CO_2 gas. Typical phosphate ore contains 3% to 5% CO_2 .

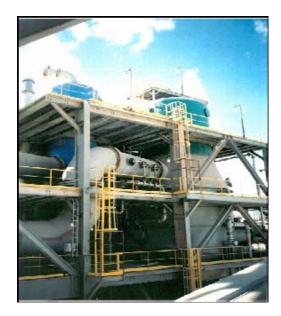
The least preferred method of enabling process water use for mill water addition is to add a neutralizing agent such as lime to the process water. The cost for ongoing purchase and transport of a neutralizing agent, along with the reduction in P_2O_5 capacity for the facility make the economics for this process inferior.

5. High Strength Fluoride Recycle Processes

Fluosilicic acid can be recovered for introduction into the ground ore storage area to further dissolve carbonates and liberate additional CO_2 gas. Implementation of both process water addition to mill feed and FSA addition to rock slurry storage will allow increased P_2O_5 production for a facility with a limited sulfuric acid production capacity by neutralizing some of the carbonates in the incoming ore (Reference 5).

My associates are please to have produced the most commercially successful fluoride recovery technology currently available, with eighteen successful installations in the USA since 2007. Fluosilicic acid (FSA) recovery of 0.07 ton F per ton P_2O_5 is typical (Reference 1). A 1 MM P_2O_5 t/year facility can produce 192 tons F/day.







FSA Graphics are from a previous AFA paper specifically addressing FSA given at the 2008 Jeddah AFA meeting: http://www.afa.com.eg/Uploads/teconf21 papers/02 003%20TSI.pdf

An additional benefit of implementing this strategy is that the barometric condenser water can then be isolated for final filter wash and gypsum slurry make-up water.

This FSA recovery technology has been retrofitted to fourteen existing evaporators, as well as being installed in the last four new evaporators designed by my associates and built in the USA.

6. Improved Washing and/or Double Filtration

One opportunity to reduce P_2O_5 losses is to replace the process water that proceeds with the gypsum to it's destination with fresh water. A 1 MM ton P_2O_5 / year plant will require about 227 m³/h of water to report as gypsum stack pore moisture. Reducing the P_2O_5 content of the gypsum slurry water by 1% will reduce P_2O_5 losses by 58.5 tons/day or 21,350 tons/year. The value of recovering this P_2O_5 is on the order of \$700/t * 21,350 t/year = \$15MM/year.

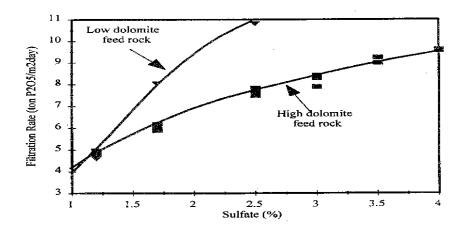
Additional to the immediate savings from reducing P₂O₅ flow to pore moisture, some clients also may benefit by reduced escrow funds required to cover future closure costs.

The technology to permit fresh water to displace process water as pore moisture make-up is site specific. We have developed water management plans for dry climates with 300mm precipitation in both the US and Internationally. Similar techniques can be used to design your facility to enable the plant water balance to be controlled while allowing process water to be replaced with fresh water for pore moisture service. Our team has

installed double filtration and other technologies for clients that are still in successful operation after more than 10 years of service.

Another opportunity to improve filter washing is to feed scalped unground wet rock fines to the digester instead of 68% solids rock slurry. This will allow an additional 136 m 3 /h of filter wash for a 1 MM t/y P $_2$ O $_5$ capacity plant. This alternative is ore and digester specific and is not practical for all facilities.

One additional technique to improve gypsum crystal size is to operate with higher sulfate concentrations in the digester. The following graph from Reference 6 illustrates the significantly adverse impact that low sulfate digester conditions can have on gypsum crystal size and resulting wash rates.



7. Non-Contact Evaporator Condenser Cooling

Evaporator condenser secondary heat exchangers are another technology that our co-workers have successfully implemented in world-class phosphate fertilizer facilities. This technology can be used to separate fresh evaporative cooling water from process condensate formed in a contact barometric condenser, and has been in ongoing industrial use for more than 10 years. Condenser secondary heat exchangers offer an alternative to allow sea water for cooling while eliminating the transfer of phosphate and fluoride into the ocean in climates where fresh water availability is limited.

8. Calcination

Some ores contain high concentrations of organic matter that dilutes chemical analysis. Calcination of these ores assists improving P_2O_5 yield in the following three ways:

- 1. Removes combustible organic matter and some carbonate CO₂
- 2. Reduces the tons of gypsum solids (and pore moisture) per ton of P₂O₅
- 3. Produces a dry rock that allows more filter wash water to be introduced

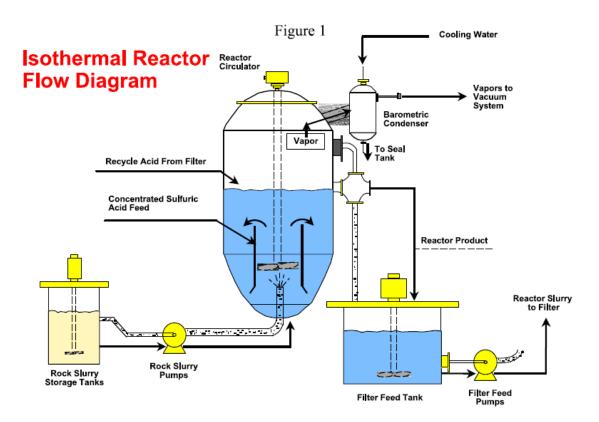
9. Isothermal Phosphoric Acid Reactor Technology

The lowest capital cost phosphate reaction technology available on the market today is once again available for consideration for future phosacid installations. The improved single vessel reactor technology is the latest generation of ore digestion equipment that offers equivalent process performance at much lower capital and operating costs than competing technologies (Reference 8). This technology was used for the latest phosphoric acid reactor installation in the United States by Simplot in Wyoming, with vessel engineering completed in Tampa, Florida. (See Figure 1 below).

Particulars of the Isothermal system performance relative to conventional Dihydrate (Prayon/DorrOliver/Jacobs) are:

Phosphoric Acid Reactor Comparison	Conventional DH	Isothermal DH
Reactor + Filter Feed Tank Volume (M ³ /T/D)	2	1
Slurry Cooler Circulation (M ³ /h/T/D)	15	54.5
Cooler Temperature Change (C)	1.8	0.5
Specific Power Consumption (kWH/T)	27	9
Number Operating Motors	15	3

All of the Badger/Raytheon/Pegasus Isothermal phosphoric acid reactors that have been built have been designed in Tampa, Florida.



Graphic from www.aiche-cf.org/Clearwater/1998/papers/98.1.1.pdf (Ref. 8)

Location – Owner	No.	Ton/Day	hp	Dia. (m)	Start
Bakersfield California – American Fertilizer	1	25			1966
Bartow Florida – Farmland	1	1,000	200	10.7	1971
Helm California – Valley Nitrogen	1	255	100	7.9	1977
Bartow Florida – USS AgChem	2	1,600	350	10.7	1982
Rock Springs Wyoming – Chevron	1	1,300	Pvt.	Private	1986
Lazaro Cardenas Mexico – Fertimex	2	1,500			1986
Negev Israel – Rotem	1	1,000			1996
Luzhai Guangxi Zhuang China – CNTIC	1	400			1998
Rock Springs Wyoming - Simplot	1	1,300	Pvt,	Private	2012

Isothermal Reactor Installations List

Historical note: Raytheon Engineers and Constructors closed their Tampa office in 1998, and effectively no longer offered the Isothermal Reactor System to the market. The staff that remained in Tampa formed Mustang Tampa Inc. that later became PegasusTSI in 2007. Mustang Tampa, Inc. focused on project engineering services in lieu of process technology. Subsequently, the Tampa staff completed the design for the latest Isothermal reaction systems.

Biographical Note: My career in phosphates began in 1990 with International Minerals and Chemicals. Since joining Mustang in 2006 I have had the blessing to work with the team that designed the last phosphoric acid reactor installed in the USA, the last four evaporators installed in the USA, and eighteen of the last FSA recovery units installed in the USA, among other assignments.

10. Water Treatment Technology – Electro Dialysis Reversal vs. RO

Electro Dialysis Reversal is another emerging technology that is competitive, and in some cases superior to reverse osmosis treatment. Currently we are developing the economics to compare the two technologies, and hope to report more details in a future publication specifically addressing the applicability of electro dialysis reversal technology for brackish water treatment. This technology offers a cost competitive route for some water treatment applications. Power consumption for EDR is about 1 kWh per m³ of water. EDR offers very good water recovery of 94% for some applications. Additionally, the EDR unit is more tolerant of free chlorine and other contaminants than most RO systems.

Conclusions

In conclusion, there are many advanced processing technologies available to design the most cost effective and resource efficient phosphate production facility. Finding the optimum solution for a specific site requires a team with knowledge and experience.

Current fertilizer pricing is higher than historical norms, with better than normal margins for producers. Projects executed during this period will experience exceptional payback and returns. Investments in phosphate production will help to provide the nutrients required by the steadily increasing (83MM people/year) global population.

DAP Price 1966 to 2011

Year 1804 1927 1960 1974 1987 1999 2011 20?? Billions 1 2 3 4 5 6 7 8

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Best Available Technology in Fertilizer Industry :
Energy / Water Optimization – HSE - Operations and Equipment – R&D

Novel Large Scale Energy Efficient Technology for Urea Production

الإتصاف الصربحي للأسمدة Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

Mr. Rinat Anderzhanov,
Deputy Technical Director of Innovations
R&D Institute of Urea
Russia

ОТКРЫТОЕ АКЦИОНЕРНОЕ ОБЩЕСТВО «НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ И ПРОЕКТНЫЙ ИНСТИТУТ КАРБАМИДА И ПРОДУКТОВ ОРГАНИЧЕСКОГО СИНТЕЗА» (ОАО «НИИК»)



NOVEL LARGE-SCALE ENERGY EFFICIENT TECHOLOGY BY R&D INSTITUTE OF UREA

Rinat Anderzhanov, R&D INSTITUTE OF UREA



R&D INSTITUTE OF UREA being a leading Russian engineering company in the field of urea, is focused on development and improvement of urea process aimed at feedstock and energy saving and improvement of its environmental attractiveness and industrial safety.

R&D INSTITUTE OF UREA has licenses and know-hows in urea process and offers state-of the art technologies and advanced technical solutions to its customers.







Presently R&D INSTITUTE OF UREA has two proprietary technologies in grass-root construction and revamping of urea plants.

The first technology URECON 2006 [®] is an improved total liquid recycle process for small-scale urea plants. URECON 2006 [®] is aimed at construction of a small-scale urea unit in case when a small excess of ammonia can be used for production of urea.

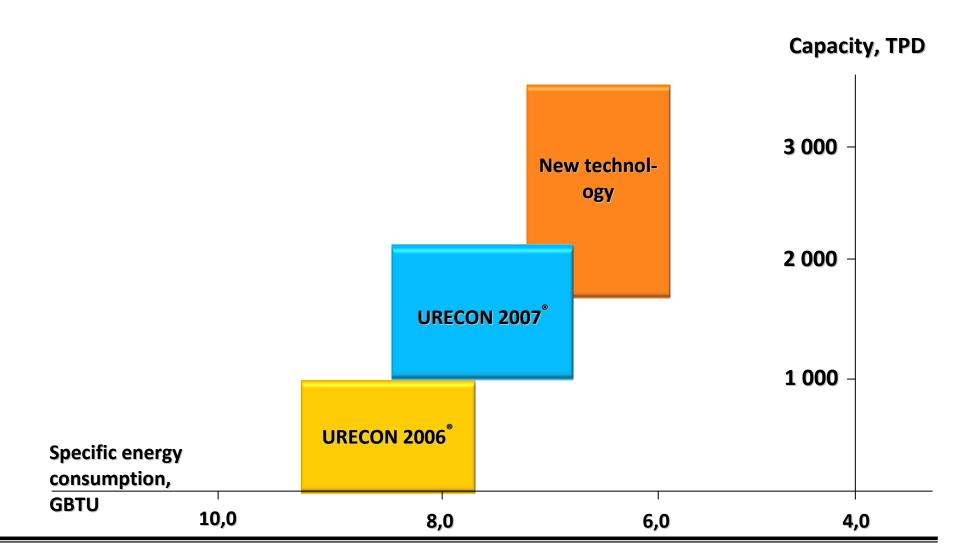
The second one URECON 2007 ® is an improved CO₂ stripping process for grass-root construction of urea plants with capacity over 1000 TPD.

The critical equipment of URECON 2006 [®] technology was numerously used for revamps of urea plants with TLR, capacities 300-500 TPD. Besides that, our specialists performed a frontend engineering of a urea plant with capacity of 600 TPD.

Speaking about URECON 2007 $^{\circ}$ technology, the key section of the technology is HP synthesis section. Due to the PFD including a submerged condenser, patented by R&D INSTITUTE OF UREA, the synthesis section operates more efficiently as compared to the conventional CO₂ stripping process.

Notwithstanding the fact that URECON 2007 ® can be used for grass-root construction of urea plants, we are mostly promoting it as a revamping concept. The technology can help to increase the capacity of a urea plant with conventional CO₂ stripping process by 50 %. If the MP section is added to the PFD the capacity can be increased twice (for example, from 1000 TPD up to 2000 TPD).





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So R&D INSTITUTE OF UREA has technologies for small-scale and medium-scale urea plants. To achieve the comprehensive capacity range, R&D INSTITUTE OF UREA lacked a large-scale energy-efficient urea technology (over 2000 TPD).

Our specialists had the following challenges when developed the new technology:

- Capacity enhancement of a urea unit
- Increase of a reactor specific capacity
- Distillation efficiency improvement
- Process heat utilization
- Reduction of effluents and emissions
- Cost reduction and reliability improvement of the equipment

The PFD comprises the following sections: synthesis, HP distillation, LP distillation, preevaporation, vacuum evaporation, absorption, desorption and hydrolyses, finished product section.

Let's dwell upon the key sections of the process – synthesis and distillation.

In this slide you can see the dependence of equilibrium CO_2 conversion rate to urea on the mole ratio NH_3/CO_2 .

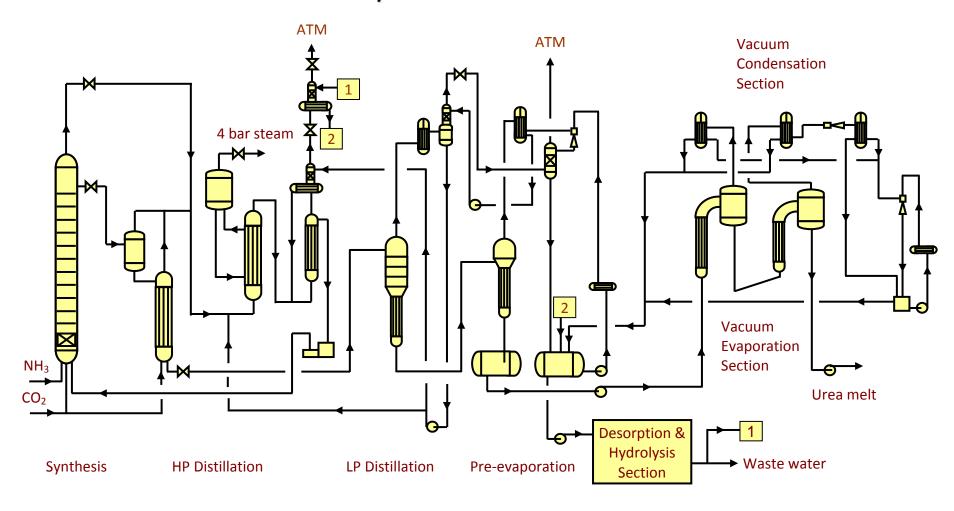
In all the popular urea technologies, urea synthesis is performed with mole ratio L in the range of 3.0-3.6 and water content (W) about ~0.5.

Yet, as a rule, the actual conversion rate in the reactor is much lower that the equilibrium one, since the reactor pressure is lower than the equilibrium pressure. Our objective was to achieve maximum specific capacity of a synthesis reactor with high conversion rate. It was done by application of the following technical solutions.

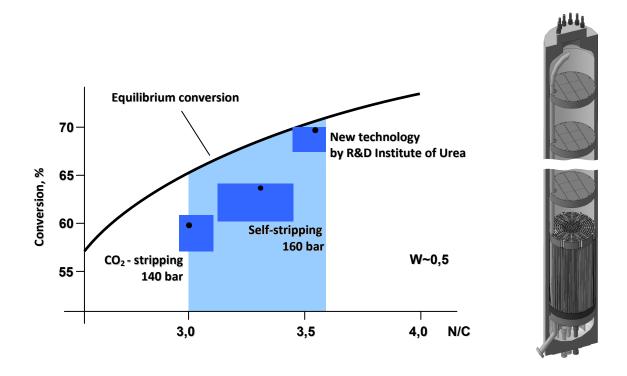
The synthesis process conditions were selected to enable maximum approximation of the actual conversion rate to its equilibrium value. To achieve a high specific capacity of the synthesis reactor or in other words – reduction of its size, its hydrodynamic mode was as much approximated to the plug flow as possible. The task was solved by zonal sectioning of the reactor based on our patented design – a vortex mixer, a longitudinal sectioning element and trays. As a result, a very high specific capacity of the synthesis reactor was achieved, about 70 %.



Process flow diagram of the new technology by R&D Institute of Urea





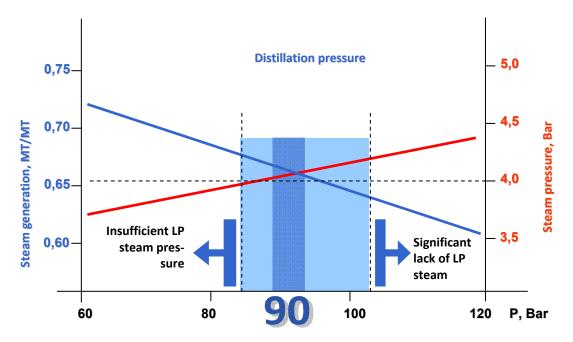


HP distillation section includes a separator, a stripper, 2 carbamate condensers (of 1st and 2nd stages) and an absorber. One of the methods for load reduction on HP distillation section is a multiple separation of the synthesis solution before its supply to the stripper. Preseparation of the solution is performed in the reactor. Due to removal of the excessive gaseous ammonia in the reactor, the heat loss during throttling is reduced, i.e. the solution is supplied to the distillation at more high temperature which reduces steam consumption supplied to the stripper.

High efficient HP distillation and recycle section should meet the following requirements:

- Heat utilization from ammonia carbamate production by means of steam generation with pressure of 4 Bar (min).
- Efficient removal of NH₃ and CO₂ from the synthesis solution with minimum energy consumption.
- High reliability and long lifetime of the equipment. Few equipment items and their low cost.

Since we intensified the synthesis process by increase of the reactor pressure, we had to select the optimal pressure of HP distillation.



The main criterion to assess the energy efficiency of the stripping process is optimal ratio of utilization efficiency to efficiency of unreacted components stripping. A proven method of internal process heat utilization is generation of low-grade steam with its further utilization for the urea process.

The pressure of the generated steam which is process and economically sound to be used in the urea process is 4 Bar min.

I'd like to speak about the dependence of the pressure and amount of generated steam on the distillation pressure.

If the distillation pressure is under 80 Bar, the generated steam pressure is reduced, since condensation is carried out at low temperature. At the same time, stripping efficiency increases as well as the generated steam amount. But utilization of such steam is limited, firstly, and, secondly, results in increase of heat exchangers' size.

If the pressure is above 105 Bar, the generated steam pressure increases, but reduction of the stripping efficiency results in significant reduction of the generated steam which leads to increase of the total steam consumption due to increase of the external steam consumption.

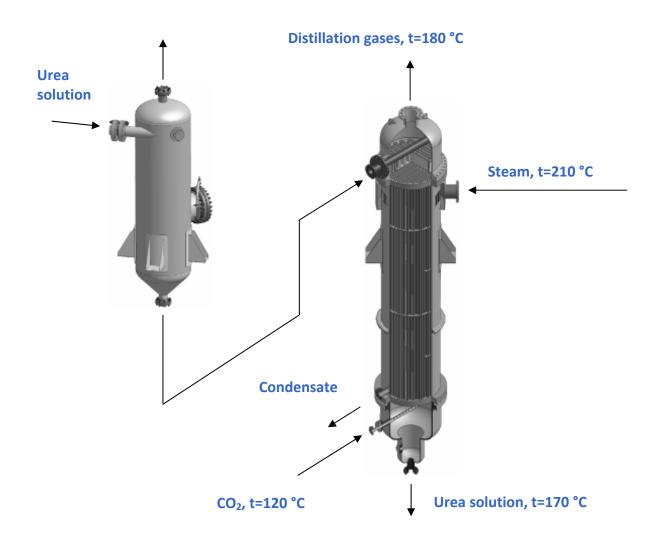


Our calculations show that the optimal distillation pressure for the above process based on the ratio of the total steam consumption to the heat exchangers' size is 90-95 Bar.

In order to improve the distillation efficiency we used the CO₂ stripping process.

The gaseous phase removed after throttling of the solution from 200 to 90 Bar and containing ammonia, carbon dioxide and a little is separated in a separator. After the separator the mole ratio NH_3/CO_2 in the urea solution is 2.9-3.0 which enables its efficient CO_2 stripping distillation.

Part of original CO₂ is fed to the stripper as stripping agent. The rest carbon dioxide is supplied to the synthesis reactor.



CO₂ supplied to the stripper ensures efficient ammonia stripping. NH₃ concentration after the stripper is 8 % by wt. max. Besides, due to stripping agent supply the required tempera-

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ture in the stripper is reduced, i.e. the so-called cold stripping is performed which reduces corrosion rate in the vessel and increases the stripper lifetime.

The gaseous phase stripped in HP distillation section is condensed in two cascade carbamate condensers. The gaseous phase from the synthesis reactor is also delivered there. The condensation in the first condenser is performed to generate a low-grade steam (pressure of 4 bar) in the shell-side. In the second condenser the condensation heat is removed in a special cooling loop. The carbamate solution produced during the condensation is delivered by HP pumps to the synthesis reactor.

Reasonable combination of high-output synthesis, high-efficient distillation, distillation gases condensation under optimal conditions enabled arrangement of further distillation in one stage and exclusion of a recycle ammonia system.

The process is performed in a distiller – a vessel combining a tray distillation column and a film-type heater which ensures high-efficient distillation of unreacted components. The heat to the distillation section is supplied as 4 Bar steam generated in the HP condenser.

The gaseous phase from the HP distiller is condensed to produce carbamate solution. The produced carbamate solution is delivered to carbamate pumps which supply it to the HP condenser and to spray the HP absorber.

When the new technology was being developed, a special attention was paid to environmental friendliness of the plant, i.e. gas emissions and effluents treatment.

For effluents treatment a system with 3 Bar two-stage desorption and 22 Bar two-zone hydrolyses is used. The heat to the hydrolyser and 2nd stage desorber is supplied as a direct steam.

The effluents treatment value for ammonia and urea is 2 ppm.

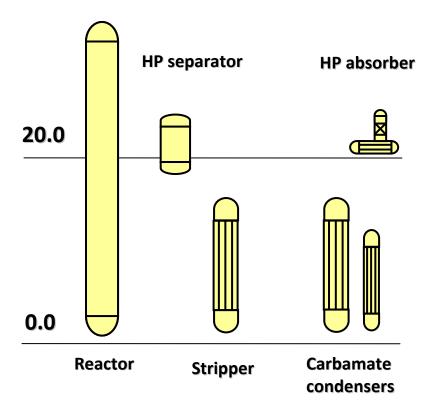
Once again I would like to dwell upon the process peculiarities of our new technology which ensure its high efficiency:

- The synthesis reactor operates under pressure of 200 Bar and is equipped with a set of internals comprising a vortex mixer, a longitudinal sectioning element and trays.
- Multi-stage separation of the synthesis steam reduces heat loss and improves distillation efficiency.



- CO₂ stripping-distillation under pressure of 90 Bar ensures efficient NH₃ and CO₂ stripping.
- Submerged carbamate condenser under pressure of 90 Bar ensures efficient recuperation of the process internal heat to generate 4 Bar steam.
- A two-stage urea solution distillation results in the equipment cost reduction versus the other technologies.

Synthesis section and HP distillation section operate under different pressures which results in simplification of the equipment layout – the equipment elevation is lower. Finally, the cost of construction and assembly works is reduced as well as total investment cost of the urea plant construction.





R&D INSTITUTE OF UREA has proprietary technologies for prilling in a prilling tower and granulation in a high-speed drum granulator (HSDG).

Prilling Granulation





The prilling technology developed by our company ensures production of high-quality prills and good treatment of the exhaust air while the capital and operational costs are relatively low

High performance of the prilling process is based on the following technical solutions:

- Vibro-dispersion of the urea melt
- Prills cooling in a fluidized-bed cooler
- Treatment of the exhaust air in an injection-type scrubber
- Conditioning agents added to the melt and reagents for prill surface treatment

For production of granulated urea with good consumer properties we offer our proprietary granulation technology – granulation in a High-Speed Drum Granulator (HSDG). The HSDG technology can be used for both – for granulated urea production and prill fattening to impart granulated urea properties to the prills. Besides that, the HSDG unit can be used for production

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of urea-based compound fertilizers. The HSDG unit enables production of high-performance granulated urea and what is very important – with no formaldehyde addition during the granulation process.

In this slide you can observe consumption indices for our new technology.

Parameter	Unit	Value
Ammonia consumption	kg/MT	568
Steam consumption	Gcal/MT	0,45/0,79*
Energy consumption	kWh/MT	170/35*
Cooling water consumption	m3/MT	76/96*
Total energy consumption in terms of natural gas	m3/MT GBTU	178/194* 6.4/6.9*

Depending on the Customer's energy sources, their costs and the Customer's request, either an electric-driven compressor or a compressor with a steam turbine drive can be used.

The new technology developed by R&D INSTITUTE OF UREA can be used for revamp of a urea plant with TLR. The technology is especially efficient if the plant includes two or more urea units. The capacity enhancement can achieve 60 % along with reduction of steam consumption (to 50 %).

Revamping based on the new technology by R&D INSTITUTE OF UREA has relatively low investment cost, the more is the number of urea units under revamp the lower is the investment cost. Besides, revamping of the urea plant with TLR based of our technology simplifies integration between the urea and melamine plants.



Parameter	Before the revamp	After the revamp	Increase/
			Saving
Capacity, TPD	900	1 450	60%
Consumption indices:			
- steam, Gcal/t	1.13	0.73	35%
- power, kW	140	140	-
- cooling water, m ³ /t	175	136	22%

In this table you can see the expected revamping results of the TLR urea plants comprising 2 urea units, capacity – 450 TPD each. Besides the capacity enhancement and energy saving, integration between the urea plant and melamine plant (capacity – 20 000 TPY) is performed.

The estimated payback period of the investment cost for the revamping is 3 years max.

Value	Before the revamp	After the revamp	Increase/
			Saving
Capacity, TPD	1 100	1 500	36%
Consumption indices:			
- steam, Gcal/t	1.476	0.692	53%
- power, kW	156.5	156.5	-
- cooling water, m ³ /t	116.5	77.5	34%

You can observe the expected results of the revamping based on the technology by R&D INSTITUTE OF UREA – revamping of the urea pant with TLR comprising 4 urea units, capacity – 275 TPD each.

R&D INSTITUTE OF UREA is happy to offer a novel large-scale energy efficient urea technology.

The new technology by R&D INSTITUTE OF UREA can be used for both – for grass-root construction of urea plants and for revamping of the existing urea plants with TLR.

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Best Available Technology in Fertilizer Industry :
Energy / Water Optimization – HSE - Operations and Equipment – R&D

Guaranteed (Risk Free) Energy Savings in Water and Steam Systems through Avanceon's Proprietary "iwater" & "iboiler"

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Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

Mr. Armaghan Yusuf Business Manager - Avanceon

Pakistan

Guaranteed (Risk free) Energy Savings in water and steam systems through Avanceon's proprietary "iwater" and "iboiler"

Presenter: Armaghan Yusuf

Business Manager – Energy Management Solutions (EMS)

ayusuf@avanceon.com

Company: Avanceon, Regional Operational Center Pakistan (<u>www.avanceon.com</u>)

Abstract:

Water and steam systems are big energy cost centers in a fertilizer plant. Most of the applications use much more than minimum amount of energy needed leaving huge margin for improvements in process and energy optimization. In the modern day world, every manufacturing facility has to continuously work to reduce energy consumption as part of its corporate objectives for improved quality, profitability and environment sustainability.

However certain questions do arise while initiating energy savings projects

- · Who guarantees the savings?
- Will my manufacturing process be disturbed?
- · How would the high capital investment be financed
- There is a corporate policy for ROI or IRR hurdle rate; Energy optimization is not my business and am not sure if I can manage it to achieve my financial goals

Avanceon, a US based system integrator and energy management company, offers a unique partnership to reduce energy consumption in water and steam systems with absolutely no financial risk to customers.

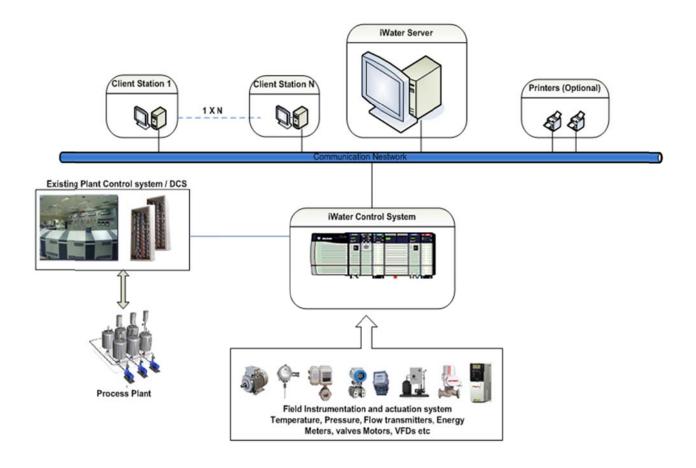
The paper briefly describes Avanceon's "iwater" and "iboiler" packages, the concept of guaranteed savings, and details of projects at Engro Fertilizer Limited and Nestle Pakistan respectively.

A. Avanceon's iwater Package

iwater is Avanceon's proprietary integrated package which optimizes energy consumption in water systems through efficient Demand-Supply management.

iwater project offers turnkey services, including feasibility analysis, detailed energy audit, design, equipment's supply, installation, engineering, project management, and financial guarantee. Offered energy savings are realized through pre and post project energy tests. All the financial, technical and project risks are borne by Avanceon

Typical iwater project architecture:



iwater project deliverables:

Typical iwater project supplies include:

- AVANCEON's proprietary iwater software which serves as main calculation engine and supervisory management
- iwater Control system
- Necessary field Instrumentation (Pressure, temperature and flow transmitters, flow control valves etc)
- Cascaded Variable Frequency Drives and motors where required
- System communications with existing plant control system / DCS for determining the process demand at different plant users
- Server and workstations for iwater and HMI software's

Typical iwater project services include:

- Energy audit, detailed analysis & calculations by Energy experts
- Process Hazard Analysis (PHA) study, analysis & reports by Energy experts
- Pre and post iwater project energy performance tests by Energy experts
- Energy savings guarantee (if savings are less, project cost will be adjusted downwards to meet the guaranteed IRR)
- Project engineering system design, programming, installation, erection, and commissioning services by project engineers on turnkey basis

Financial / energy savings guarantee concept:

As iwater project savings are guaranteed, balance project payment is contingent to successful realization and acceptance of energy tests by the customer's technical / process team after complete project commissioning. Following test case examples explains the financial model;

Projections:

Total Project cost (Turn-key basis)

Guaranteed first year Energy savings

Guaranteed IRR (risk free)

USD 3.0 M

USD 0.59 M

If the Actual Savings after Project Implementation are less than Projected:

Actual first year Savings (say)

Actual Project Cost for customer would be (to match IRR)

USD 0.55

USD 2.8 M

(Instead of 3 M)

Key points;

- a) Avanceon bears the financial risk of reduced energy savings as the balance project payable amount will be reduced to meet the guaranteed IRR
- b) Savings if more than projected would be retained by customer

Typical water applications:

iwater solution is designed to cater for specific requirements of respective industrial water systems and have offered guaranteed savings on the following applications;

- Chilled Water system
- Hot water system
- Cooling water system
- Raw water system
- Demin water system
- Soft water system
- Boiler feed water system, other
- Effluent water system etc

iwater control strategy:

Demand Based Supply Management is the main methodology used by iwater package to optimize the water system control.

iwater software acts as a supervisory management and calculation engine for energy calculations and determination of optimized control regime depending upon specific process requirements on different operating loads. It gathers process requirement of water flow, pressure and temperature by directly interacting with the field instruments or through communication with existing process control system / DCS to determine exact demand of water energy at different plant users including heat exchangers, process equipment, storage areas and other users. The optimized control set points are calculated in real time and the control regime is then implemented through iwater control system via cascaded speed drives and / or control valves.

Completed project at Engro Fertilizers Limited (EFert) Pakistan

About EFert:

Engro Fertilizers Limited, a wholly owned Engro subsidiary, is a premier fertilizer manufacturing and marketing company with products that focus on balanced crop nutrition and increased

yield. The company markets primary and secondary fertilizers like Engro Urea, Engro DAP,

Engro Zorawar, Engro Zarkhez and Zingro.

In 2010, the company achieved mechanical completion and started production of its urea

expansion project (Plant-2) at Daharki which is the world's largest single train urea-ammonia

plant. Company website: www.engro.com

Production capacities of urea and Ammonia plants are mentioned below;

Plant-1:

Urea-1: 850 MT/day Urea-2: 2,150 MT/day

Ammonia-2: 1,650 MT/day,

Utilities -1 and utilities 2

(Ammonia-1: closed)

Plant -2:

Urea-3: 3,835 MT/day

Ammonia-3: 2,194 MT/day

Utilities-3

iwater completed Project at EFert:

Avanceon and EFert teams successfully completed iwater project on cooling water system utilities-1, Cooling water system utilities-2, effluent water and canal intake water systems of

Plant-1 as first phase of energy partnership initiative in March 2009.

Cooling water system for utilities-1 has the designed flow rate of 32,000 GPM and supplies

water to Urea-1, Urea-2 and Utilities-1. While cooling water system for utilities-2 has the

designed flow rate 0f 75,000 GPM and supplies water to Ammonia-2, Urea-2 and utilities-2.

For easy reference iwater project at EFert's Plant-1 cooling water system for utilities-1 is

explained below;

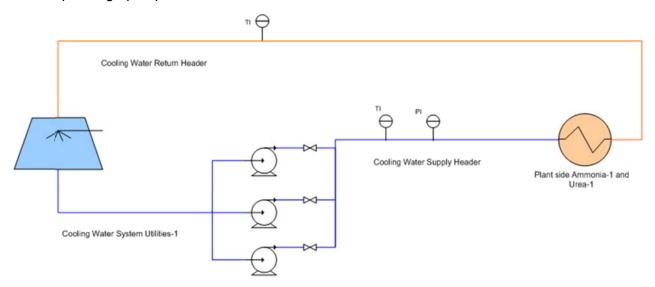
EFert Plant-1, Utilities-1 Cooling Water System:

Utilities-1 main cooling water system comprised of 3 cooling water pumps, one of which is

steam turbine driven and remains usually on standby. Each of the other two motor driven

pumps had 6.6 KV, 700 HP capacity motor each. Both motor driven pumps usually remained

operational throughout the year with varying average water flow rates of 21,000 GPM to 27,000 GPM depending upon plant load in winter and summer seasons.



Findings during the energy audit:

During the detailed energy audit of base plant, Avanceon and EFert energy teams studied the whole cooling water system, and the water flow requirement pattern at all critical users of Ammonia-1 and Urea-1 plants for year 2008 was studied in detail in context to the trend for last three years and the planned future modifications.

Below were the major findings;

- 1- In peak summer season the water flow requirement exceeded the running flow rate, however higher flow rates couldn't be achieved due to amperes limit of installed motors.
- 2- In moderate season there were times of low water flow rate requirement, though various flow control valves were installed in the field but still there was a need of energy efficient water flow control system to cater for daily variation of 2 4 degree centigrade in cooling water supply temperature during day and night times.
- 3- In winter season the need of efficient flow control system increased many folds even in conditions where different cooling tower fans were put to off.

Proposed Solution:

After the project was formally initiated based on successful Process Hazard Analysis review, Avanceon team installed its iwater package for optimization of cooling water system incorporating cooling water supply header pressure based flow control of pumps. The architecture was similar to the typical iwater project architecture as explained above.

Rockwell's (US based automation system OEM) MV variable frequency drives were installed at pump motors along with installation of control system, and field instrumentation where pressure and temperature transmitters were not already installed.

iwater software established different set points of cooling water header pressure in the iwater control system, based on;

- a. Different bands of cooling water supply temperatures and
- b. Cooling water flow, pressure and temperature requirements at all critical users of Urea-1, Urea-2, and Utilities-1

To support higher flow rate requirements during summer season, existing 6.6 KV 700 HP cooling water pump motors were upsized to 6.6 KV, 900 HP inverter duty motors for each pump. The unique proposition was the special base design of upsized 900 HP MV motors to fit the existing foundation of 700 HP motors thus minimizing the time of motor replacement. Avanceon accomplished this task through the support of its global partner WEG (a Brazilian motor manufacturing company).

Comprehensive pre and post commissioning Energy Tests were carried out jointly by Efert and Avanceon teams to measure energy consumption in summer, moderate and winter seasons.

Similar pressure based flow control strategy was successfully implemented on Cooling water system for Utilities-2 (Ammonia-2 and Urea-2), Effluent water system, Canal intake system of Plant-1.

Results

Results exceeded expectations and the Efert site was able to reduce its power consumption by 0.825MW with proven guaranteed (risk free) IRR of over 25 % directly adding to company's bottom line. Supplementary advantages included improved cooling water flows leading to reduced Ammonia losses at Urea plant, operator friendly operation, reduced carbon emissions on account of less fuel consumption and adequately meeting additional power requirements due to increased load of housing colony expansion to support Plant-2.

Successful implementation of first phase of iwater project in 2009 at EFert opened an avenue to unleash maximum potential in the existing system. Both teams initiated second phase of the energy project in process areas in year 2010. After successful Process Hazard Analysis review, the second phase project is under installation phase and will be commissioned in first quarter 2012.

B. Avanceon's iboiler Package

iboiler (Steam Management Solution):

iboiler is an integrated steam management solution which manages the energy usage in organizations with multiple boilers for the steam generation purpose. It optimizes the process by generating the most fuel efficient recipe table for steam generation from the different boilers. It's a unique managed care service offered by Avanceon for guaranteed energy savings of fuel fired boilers

Product Concept:

- Monitor boiler efficiency.
- Optimize load sharing of boilers.
- Monitor Steam Distribution.
- Optimize blow down management.
- Monitor Emissions.
- Optimize Combustion control.



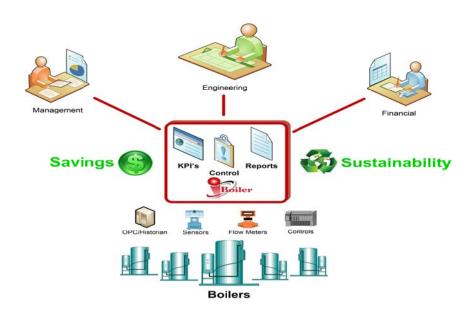
Product Features:

- Monitor Individual Boiler Efficiency
 - Benchmarks boilers performance to measure against all future enhancements.
 - Continually measures boiling efficiency throughout the firing range.
 - Calculate real-time KPI's i.e. Cost of Steam Production and Fuel to Steam ratio.
 - Alerts based on losses in efficiency
 - Proactively alerts operations team to take action when a loss is detected.
- Optimize Load Sharing of Boilers
 - Dynamically calculates how much steam each boiler should produce to give you the lowest cost per ton of steam.
 - Automatically sets up each boiler to its optimal combination or "recipe".
- Monitor steam distribution
 - Continually measures steam distribution efficiency throughout the entire plant.
 - Measures condensate return.
 - Accounts for steam usage at each department.
 - Alerts based on line and header losses.
 - Provides macro view of entire steam distribution system for optimal operation.

Other features

- Determine the trends of lost efficiency through weekly examination of I-Boiler data.
- Reacts to drops in efficiency based on set alert points in the system and determine corrective action initiatives.
- Integrates with Microsoft Sharepoint
- Dashboard of real time data, trends and events
- Issue weekly or monthly summary reports focusing on KPIs.
- Support service available from consultation through problem resolution.
- ❖ I-boiler allows you to focus on your business goals while we focus on keeping your system efficient.

iboiler Topology:



iboiler control strategy for guaranteed energy savings - (Load sharing module - LSM):

Economic Load allocation on parallel operating boilers is the main methodology to optimize the steam generation cost.

iboiler acts as supervisory management and calculation engine. Its Load sharing Module (LSM) automatically keeps the performance profile of individual boilers on different operating steam loads in terms of fuel usage per ton of steam generated. Optimum steam generation recipes for

economical load allocation on all the boilers are then calculated keeping in view the process total steam demands. The resultant load allocation regime (recipe) is then implemented on individual boilers through iboiler master control system by adding or subtracting bias to the existing fuel control signals.

Fuel usage per ton of steam is the biggest KPI (key performance indicator) that measures overall Fuel-to-steam efficiency of a boiler. The performance behavior of the boilers is very variable and it is variable in 2 ways: one is they behave differently at different steam loads, for example a boiler of 120 Tons/hr (TPH) capacity will have different fuel-to-steam efficiencies when it is running at 50 TPH, 60 TPH, 70 TPH, 110 TPH or any other load. The second dimension is that they even behave differently even when they produce the SAME load at different timings i.e. the current fuel-to-steam efficiency for same boiler at specific steam load may be different than the fuel-to-steam efficiency on the same operating load 5 months ago.

To better monitor boiler performance, iboiler LSM automatically generates following three tables containing the KPI data (fuel-to steam efficiency) of individual boilers at different steam load ranges.

- 1- KPI table for Design Data contains the KPI values provided by the boiler's manufacturer (manual entries)
- 2- KPI Table for best performance contains the KPI values indicating the lowest ever fuel usage per ton of steam at different steam loads within the specified time span
- 3- KPI Table for average performance contains the KPI values indicating the averages of fuel usage at different steam loads within the specified time span
- 4- KPI Table for latest performance contains the latest KPI values of fuel usage at different steam loads within the specified time span

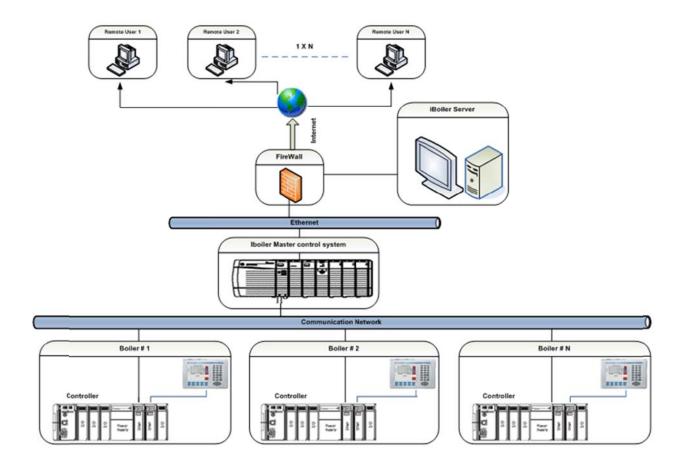
Every KPI table is generated considering stable operating condition; three quality values have been defined as High (H) for stable operation on particular load for 9 minutes (configurable) and above, Medium (M) for 3 minutes and Low (L) for all values without considering time constraint.

Based on the above tables, a Recipe table is then created to generate operational Recipes for economic load allocation on different boilers at different operating steam loads. The user then downloads the most suitable operational recipe into iboiler master control system so the boilers can be accordingly operated to meet steam pressure and flow requirements of the process at minimum operating cost.

iboiler LSM adds best value if the steam generation facility:

- 1- Runs more than one boiler in tandem
- 2- Uses fuel to produce steam
- 3- Has more than 10 Ton / Hour of average steam load. The higher the operating load, high is the benefit through iboiler LSM

Typical iboiler LSM project architecture



iboiler LSM project deliverables:

Typical iboiler project supplies include:

- AVANCEON's proprietary iboiler software which serves as main calculation engine and supervisory management
- Iboiler master control Control system
- Necessary field Instrumentation (Pressure, temperature and flow transmitters for steam and fuel)
- System communications with existing boiler control system / DCS
- Server and workstations for iboiler and HMI software's

Typical iboiler project services include:

- Energy audit, detailed analysis & calculations by Energy experts
- Stean Generation Recipie development and refinement by Energy Experts
- Process Hazard Analysis (PHA) study, analysis & reports by Energy experts
- Pre and post iwater project energy performance tests by Energy experts
- Energy savings guarantee (if savings are less, project payment will be adjusted downwards to meet the guaranteed savings)
- Project engineering system design, programming, installation, erection, and commissioning services by project engineers on turnkey basis

iboiler LSM as Managed service – Guaranteed energy savings:

Avanceon pledge to be an Energy Partner to work with its customers to better manage their boiler system, reduce fuel consumption, and achieve optimized steam production. Avanceon doesn't sell a product and assume that it might help save the costs; however we work hand in hand with our customers on continuous basis and prove the savings. A Partnership That Makes a Difference!

With this unique proposition, iboiler LSM project is offered based on guaranteed energy savings. Following test case example explains the financial model

Proposition

Avanceon will install the iboiler system which includes proprietary iboiler software, master control system, fuel instrumentation, installation and commissioning on turn-key basis.

Payment to Avanceon

- 9 to 15 months of proven savings; Avanceon will confirm the exact savings amount after site survey (energy audit) before the contract is signed

 AND
- Managed Service Level Agreement (MSLA) afterwards to ensure sustained savings.
 MSLA fee is a fixed small percentage of monthly proven savings.

Iboiler project at Nestle KBF Pakistan

About Nestle KBF:

Nestlé has been serving Pakistani consumers since 1988, when the parent company, the Switzerland-based Nestlé SA, first acquired a share in Milkpak Ltd. Today Nestle Pakistan is recognized as producers of safe, nutritious and tasty food, and leaders in developing and uplifting the communities in which it operates. Company website: www.nestle.pk

Nestle's products are manufactured in five facilities scattered around the country, from Islamabad in the north, to Karachi in the south. Two state-of-the-art multipurpose factories are located in the agricultural heartland of the Punjab in Sheikhupua and Kabirwala, and the remaining three are dedicated to producing our trusted brands of bottled water. Nestle's Kabirwala factory is abbreviated as Nestle KBF and is the largest Asian milk processing plant. The factory produces liquid and powered milk along with tea whitening powder and Noodles.

Steam generation system at Nestle KBF:

Nestle KBF has three boilers namely Boiler # 1 (16 TPH), Boiler # 2 (16 TPH) and Boiler # 3 (10 TPH) with average steam load requirements varying between 15 – 25 TPH (Tons per hour) depending upon production of food items that also varies w.r.t market demands depending on seasons. Natural gas is the fuel mainly used at boilers during summer and moderate season and is measured in units of Nm³/hr. During winters Furnace Oil is used as fuel (Kg/hr). Boilers 1 and 2 have individual PLC based control system while boiler # 3 has separate loop controllers.

Findings during the energy audit:

During the detailed energy audit Avanceon's and Nestle KBF team studied the complete steam generation facility, the control mechanism, boiler's duty cycle and fuel consumption trend. Below were the findings:

- 1- During times of total steam load between 25-32 TPH, sometimes three boilers used to run while the steam demand could be met by operating only two boilers
- 2- During the times when two boilers ran, the load used to be equally allocated on the two boilers 1 and 2 depending upon the steam pressure and flow requirements. Boiler # 3 having relatively lesser combustion efficiency was kept as standby. The scenario with two boilers in operation had the highest occurrence throughout the year.
- 3- There were times when only one boiler out of boiler # 1 / 2 was required to run, the decision about which boiler to operate was not based on operational efficiency rather it was made at random considering the same efficiency of boilers 1 and 2 being of same capacity, type and brand.

Proposed Solution:

After the project was formally initiated based on successful Process Hazard Analysis review with Nestle's team, Avanceon installed its iboiler's Load sharing module (LSM) package, field instrumentation and iboiler master control system for optimization of steam generation cost. The architecture was same as typical iboiler project architecture as explained above.

Following was the initial KPI (natural gas usage per ton of steam) table generated for boiler # 1 and 2 based on L quality values: (a similar table was also generated with HFO as fuel in winter)

Fuel Usage per Ton of Steam (Nm³/Ton)

Steam Load (TPH)	Boiler # 1	Boiler # 2	
15 < , ≤ 16	75.50	76.11	
14 < , ≤ 15	74.97	74.23	
13 < , ≤ 14	73.01	70.89	
12 < , ≤ 13	70.98	69.05	
11 < , ≤ 12	68.04	72.98	
10 < , ≤ 11	66.89	74.13	
9 < , ≤ 10	66.23	76.01	
so on till 2 TPH	***		

Table - A

The above table is the table for latest KPI values, similar tables were also generated for KPI values for Best and Average performance between the selected time span. Using the three tables, the final KPI table was then generated to be used as basis of steam generation recipe calculations.

For easy reference, let's temporarily use the above table in iboiler to produce steam generation recipes to cater for different steam loads as follows;

Total Steam load (TPH)	Load allocated on Boiler # 1 (TPH)	Load allocated on boiler # 2 (TPH)	Fuel usage per Ton of steam (Nm³/Ton)
29 - 30	16	14	73.35
28 - 29	16	13	72.61
27 - 28	14	14	71.95
26 - 27	13	14	70.93
25 - 26	12	14	69.57
24 - 25	12	13	68.57
23 - 24	11	13	68.06
22 - 23	10	13	67.82
21 - 22	10	12	69.91
so on			

Table – B (Steam Generation Recipe Table)

In actual scenario, different recipe tables are produced by incorporating combinations of individual boiler steam load band limits, boiler on / off states and other operational considerations.

The final Recipe table is then generated and refined to reflect smooth boiler operation for the whole range of steam running loads. The recipe table is then downloaded to the iboielr master control system for automatic implementation of recipe and optimized steam generation.

Significance of Steam generation Recipes:

Let's assume Plant total steam load (TPH) requirement is 24 TPH. There could be various combinations (recipes) to run the two boilers on different loads. Using Table – A, some of the combinations could be as follows;

Recipe #	Total steam load (TPH)	Load allocated on Boiler # 1 (TPH)	Load allocated on boiler # 2 (TPH)	Fuel usage per Ton of steam (Nm3/Ton)
1	24	10	14	68.95
2	24	11	13	68.06
3	24	12	12	70.51
4	24	13	11	72.42
5	24	14	10	74.26

Table - C

Recipe # 3 is the conventional recipe allocating same load on the two similar boilers. However of all the combinations, the best one is recipe # 2 which would result into savings of 2.45 Nm³ of natural gas per ton of steam translating into savings of USD 10.38 per hour if compared with recipe # 3. (Assuming 1 Nm³ of natural gas costs 17.65 cents)

For certain other loads allocating equal loads could be the best combinations e.g for total steam load of 28 TPH; allocating 14 TPH each on Boiler # 1 and 2 is the best recipe.

Please note that the best suited recipe at particular steam load would not remain fixed forever, but would change over time, based on individual boiler operating health – maintenance, tune up / calibration, problem with any part, fuel type, atmospheric conditions etc. iboiler automatically updates the recipe tables and allow the user to download the best suited recipe for that particular time.

Results for Nestle iboiler project:

iboiler helped Nestle KBF team to save 2 Nm3/Ton of natural gas on average for the total band of all operational loads due to implementation of iboiler recipes when two boilers were in operation. At certain loads iboiler also suggested to put one additional boiler off, the total resultant savings at Nestle translated into savings of around 2,400 TCO₂ reductions per annum.

iboiler at Engro Fertilizer Limited (Efert) Pakistan

In fertilizer plants fuel gas (called purge gas / process gas / factory gas etc) is produced as byproduct of urea manufacturing process. The purge gas is usually used as fuel at boilers along with the natural gas or other fuel.

Steam generation facility at Efert:

Efert has three fuel fired steam generators at Plant-1 Utilities-1 naming SG-1, SG-2 and SG-3 with 25 TPH capacities each. The percentage ratio of purge gas in total boiler fuel varies between 30 - 70 %. The calorific value of purge gas also varies over period of times depending upon various process factors. In the complex case like this, iboiler would generate the load allocation recipes based on natural gas in order to optimize the fuel cost of steam.

After the successful closure of the Process Hazard review with Efert team, the iboiler project is currently under commissioning phase and will be completed in December 2011.

Acknowledgment:

The author is thankful to Engro Fertilizer Limited and Nestle Pakistan Limited for providing the opportunity to publish and present the paper.

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Utilization of Satellite Image To Improve Solar Ponds Production

الإتصام الصربحي للأسممة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

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Senior Chemist - APC

Jordan

Utilization of Satellite Image To Improve Solar Ponds Production

By: Zaid Fajir Halasah- Arab Potash Company

Abstract

The use of satellite images is widely used in many applications all around the world. This paper reviews the usage of satellite imagery to improve the efficiency of the control and increase the productivity of the solar ponds system at the Arab Potash Company that used to produce Carnallite (the raw martial of potash).

Satellite images were processed using special software like Infogragh and Irdass to have density, thermal and depth profiles which used to improve the process control and predict for future actions. The data and the final images were saved in special software as an archiving and comparison system (ArcMap GIS)

Infrared layer of the image was used to check for seepage of the brine from the solar ponds and to locate the areas of any suspect sink holes.

The main benefits of processing the satellite images for the Arab Potash company are:

- 1- Improve the process control of the solar ponds system.
- 2- Plan the salt dredging works in the solar pond system by calculating the salt growth in each subarea, locating any closed area around high density brine and evaluate the dredged areas.
- 3- Locating any suspected sinkhole (coordinates) and the risk of these sinkholes on the system and the dikes.
- 4- Locating the reverse flow of the brine in the solar ponds system and set the right solution for this phenomenon.

The Aim

Insure that the solar ponds system production on the optimum conditions by improving the operation conditions of the system through the following actions

Identifying areas where specific gravity is higher than should be and providing solutions for this phenomenon.

Identifying reefs and salt mushrooms that are blocking or restrict the future brine flow in the ponds and providing solutions.

Monitoring of the nature and amount of salt mushroom, salt floor growth in the ponds, and performing an updated evaluation for the continued operation of the salt ponds.

Examining the compatibility of the dredging plans with the new findings that observed in the salt ponds and updating it accordingly.

Monitoring new salt growths in areas that have already been dredged;

Locating suspected sinkholes within salt ponds area and around the dikes.

Introduction

Remote sensing is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them. This process involves making observations using sensors (cameras, scanners, radar etc.) mounted on platforms (satellites), which are at a considerable height from the earth surface and recording the observations on a suitable medium (digital data). When electromagnetic radiation falls upon a surface, some of its energy is absorbed, some is transmitted through the surface, and the rest is reflected. Surfaces also naturally emit radiation, mostly in the form of heat. It is that reflected and emitted radiation which is recorded on digital sensor. Since the intensity and wavelengths of this radiation are a function of the surface in question, each surface is described as processing a characteristic Spectral Signature. If an instrument can identify and distinguish between different spectral signatures, then it will be possible to map the extent of surfaces using remote sensing. Satellite remote sensing is widely used as a tool in many parts of the world for the management of the resources and activities within the continental shelf containing reefs and nutrient rich waters associated with major estuaries.

A Geographical Information System (GIS) is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling,

representation and display of geo-referenced data to solve complex problems regarding planning and management of resources. Functions of GIS include data entry, data display, data management, information retrieval and analysis. The applications of GIS include mapping locations, quantities and densities, finding distances, mapping monitoring changes, and improving one's ability to make decisions.

Site of the study

The study area located to the south of the Dead Sea the lowest point at the surface of the earth with an area of about 112Km².

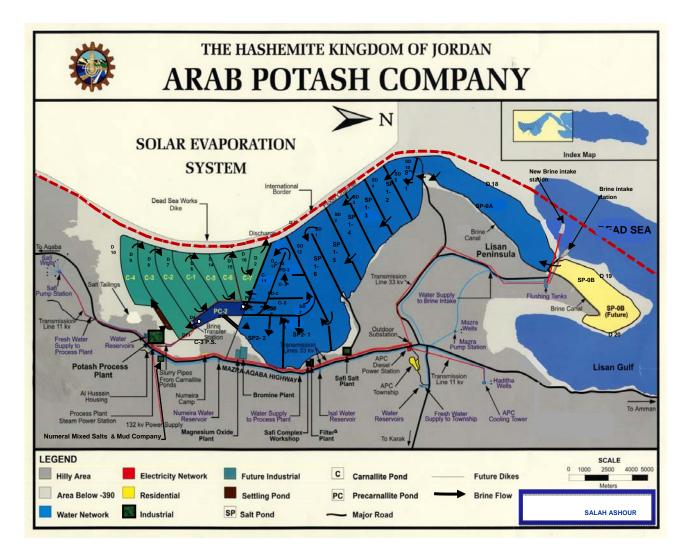
The main aim of the solar ponds system at the Arab Potash Company is to precipitate Carnallite (KCIMgCl₂.6H₂O) which is the raw material for the potash production. The brine which is a saline water with a total dissolved salts of 340g/l is pumped from the Dead Sea with four pumps each pump capacity around 5m³/sec to the solar pond system which is composed of two parts the salt ponds and the carnallite ponds.

The salt ponds of an area of 68Km² with a main roll of evaporating the water from the brine using the solar energy to reach the carnallite point (the point that the solution saturated with K ion), after this point the carnallite start precipitate at the carnallite system. As byproduct table salt NaCl precipitate in the salt ponds of an amount of 16-20 million tons per year.

The carnallite ponds of an area of 43Km² with a main roll of precipitating the raw martial the carnallite by evaporating the water by the solar energy then the carnallite is wet harvested and pumped to the refineries to extract the potash.



Orthophoto of the studying area



Solar ponds system

Methodology

A satellite image was captured, downloaded, corrected geographically and geometrically then the image analyzed randomly using special software to locate the check points location to calibrate the image.

Field calibration from the brine surface up to the 2.5m depth that it is the maximum dredging depth. Having checkpoints in order to verify the accuracy of image processing results. Estimating of salt growth during the year in SP1 and SP2.

Field calibration was done in two ways:

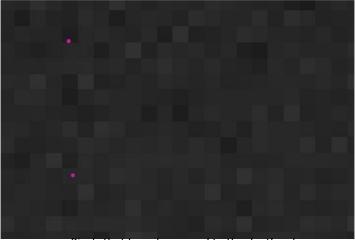
Identification of well-determined objects in brine (by RTK GPS). In each point depth, temperature and density of brine were checked in interval of 0.25 cm. Total numbers of 54 point were measured.

The following parameters were recorded at each point that was checked in the field during the surveys:

Density and temperature from brine level to pond floor at 25 cm intervals. The depth and shape of the salt mushrooms chosen as representing a growth area or phenomena detected through visual analysis of the satellite image. An average depth of salt floor in each sampling point. Brine level on the sampling days. Flow directions at the various depths in the salt dikes' weirs and in critical passages detected in the satellite image. Checking brine levels difference among the salt sub-ponds.

The principal of image processing is simple it is assumed that the color of pixel is reflecting change in depth. If we can confirm that each pixel gray scale representing one depth value, we can order the computer to search for this color and count the pixels of the same depth. Based on the depth values set for each gray scale value, computerized image processing has been done in order to determine the correct depth of each pixel of the QuickBird satellite image.

From the 4 available bands of 2009 image it was chosen to make the calculation using the green and panchromatic bands which have the best infiltration to heavy brine and it is the most informative one. The Ground Sample Distance of each pixel in the panchromatic is 0.7m X0.7 =0.49m2 .As a result each pixel got its own depth value.



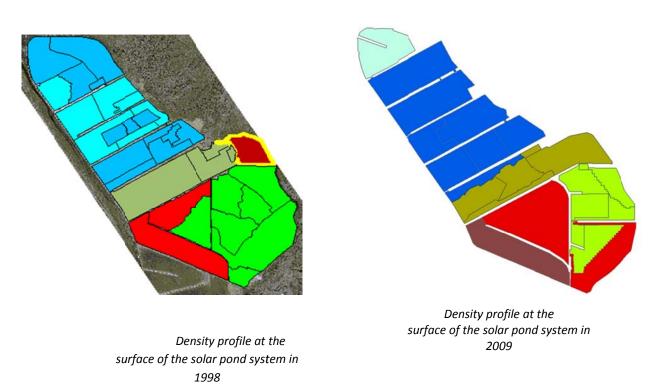
Pixels that have been used to the depth value

The principal of image processing is assumed that the color of pixel is reflecting change in the density. If we can confirm that each pixel color scale representing one

Density value, we can order the computer to search for this color and count the pixels of the same density value. Based on the density values a set for each color scale value, computerized image processing has been done in order to determine the correct density of each pixel of the QuickBird satellite image.

Results

When the project implemented for the first time 1998 there was areas with high specific gravity in the beginning or in the middle of the system and the brine in those areas some time passes the Carnallite point which mean a loss in the production also a loss in the evaporation area and a mess in the control so removing those areas by mechanical dredging leads to recover the trapped brine.

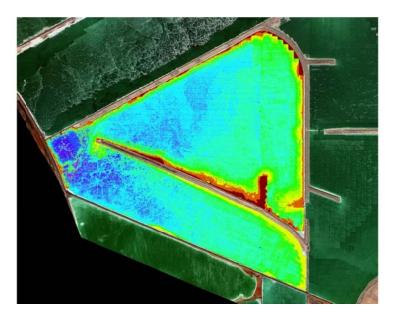


By analyzing the satellite image salt mushrooms and reefs that restrict or block the brine flow through the system where located and a suitable solution for each case was done to insure spontaneous brine flow through the system.

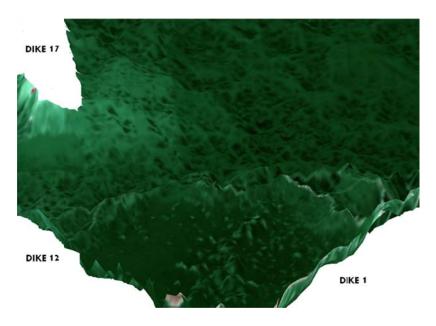


Salt mushrooms and reefs

Comparing to orthophotos that separated by a period of time (6months to one year interval) by the topography of the ground salt layer then extract the 3D model, the pond salt floor growth can be calculated.

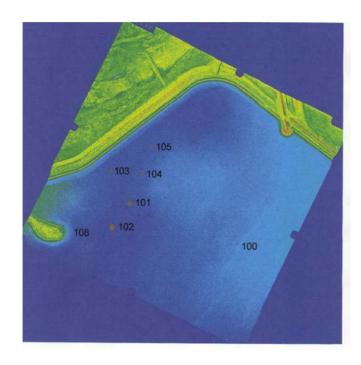


Floor model extracted from the orthophoto



3D demonstration of the deep area in west SP-2/3.

By analyzing the infrared layer of the satellite image any sink holes or brine seepage from the dikes can be located immediately.





Sink holes locations around SPO-A

Conclusion

Applying the suitable solution for the closed areas that contain the high specific gravity brine as dry equipments as a first emergency solution then the mechanical dredging of the accumulated salts this led to a uniform gradient profile of specific gravity along the system which means better control for the system and better productivity.

The data extracted from the orthophoto used to issue a dredging plan for the salt ponds, this plan insure a clear brain passage to feed the Carnallite ponds with the needed amount of the brine and insure that the salt ponds system has enough brine inventory (stock) for production.

Also the infrared layer of the orthophoto provides a good tool to locate the location of any sinkhole or seepage in the system or around it and also it is so efficient in predicting the location of any suspected new sinkholes.

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Arab Fertilizers Association

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Russia

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INFORMATION



The Research Institute for Fertilizers and Insectofungicides (NIUIF) was founded in 1919 and is considered to be the leading Institute of mineral fertilizers industry in this country.

In 1994 NIUIF was incorporated into Open Joint Stock Company — JSC "NIUIF".



The major research activities of the Institute



- > The development of competitive Russian technologies for:
 - o sulphuric and phosphoric acids
 - Phosphorous and nitrogen containing mineral fertilizers
 - Feed phosphates
 - Technical salts
 - Equipment arrangement to conduct basic chemical processes
 - Solving issues linked with the development of raw materials base for production of phosphate mineral fertilizers.
- Creation of ecologically friendly and resource saving technologies and equipment for :
 - **o** Wide range of phosphate and nitrogen mineral fertilizers
 - o Phosphoric, sulphuric, nitric and hydrofluorosilicic acids and their derivatives
 - **Technical salts and mineral fodder for animal husbandry**
 - Technologies for utilization of multy tonnage production wastes
 (spent sulphuric acid, hydrogen sulphide and sulphur containing gases)

>;

The major research activities of the Institute:



- **≻**Elaboration of measures aimed at saving electricity and using recoverable energy resources
- ➤ Development of initial data, design documentation, execution of field supervision, bringing the production capacities to design figures, rendering services to optimize the production parameters.
- > Development of technologies for complex processing of mineral raw materials
- >Complex technological testing of phosphate rock, technical and economic analysis to determine the practicability of its processing, expansion of raw materials base for production of phosphate fertilizers and products.
- >development and trial of novel catalysts to be used at sulphuric acid plants, selection of construction materials .
- >Standardization and certification of products
- >Offer of licenses and "know-how"
- >Issuance of research and development and methodological literature, normative acts in the field of specialization.

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The largest branch enterprises located in Russia and in CIS states

The largest branch enterprises located in Russia and in CIS states

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JSC "Ammophos", Cherepovets

LLC " Mineral Fertilizers Plant", Balfkovo

JSC "Azot", Cherepovets

LLC "PG "Phosphorit", (Evrochim company)

JSC "Azot", Nevinnomysk

JSC "Mineral Fertilizers Plant", Meleuz

Oil processing plants

JSC "Chemical plant", Gomel (Republic of Belarus)

TOO "Kazphosphat", "Mineral Fertilizers Plant", Taraz, Kazakhstan

Plants located in Lithuania, Ukraine, Turkmeniya, Vietnam, India and other countries More than 40 technological plants developed by JSC"NIUIF" for production of mineral fertilizers" are operating in Russia and abroad.

More than 40 technological plants developed by JSC"NIUIF" for production of mineral fertilizers" are operating in Russia and abroad.



Novel

ecologically friendly, resource saving technology for production of sulphuric acid from sulphur based on DC/DA



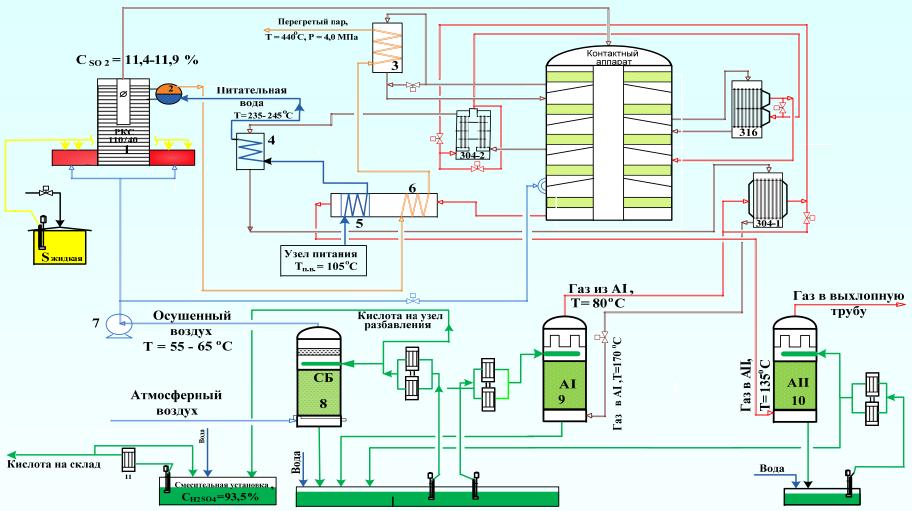
(Patent of RF No.2201393 dd. 18.09.2001)



The basis principles of the process

- Minimum guaranteed emissions of harmful gases into air
- Maximum recovery of the reaction heat to obtain maximum amount of power-generating steam and other heat carriers (hot water, steam=1,0 MPa)
- Reduced energy consumption
- Intensification of systems by increasing linear velocities in the reactor and tower equipment and SO2 concentration in process gas
- Simplification of process flow diagram by reduction of some equipment, i.e. pumps, coolers and etc.
- Installation of new equipment that consumes minimum electricity (pumps, air blowers, compressors).





Принципиальная технологическая схема сернокислотной системы ДК-ДА на сере.
1 -Котлопечной агрегат РКС -95 /40 2 -Барабан котла 3,6.-Пароперегреватели 4,5.-Экономайзеры
7 -Нагнетатель 8.-Сушильная башня 9,10 -Абсорберы 11 -Холодильники САО
304-1, 304-2, 316 -Теплообменники контактного узла



Advantages of the process offered for production of sulphuric acid

- Rapid achievement of design capacity
- Easy to operate
- Guaranteed minimum emission of harmful gases into
- air (the content of SO2 in off-gases does not exceed 2kg/t of product)
- Minimum energy consumption
- Simple and reliable modern equipment
- The rate of SO2 conversion into SO3 is not less than 0,997
- The rate of SO3 absorption is 0,9999



TECHNOLOGICAL PARAMETERS:

- Production capacity of one technological line -600 000 tpa of monohydrate or 1818 t/d. As per request of the customer a sulphuric acid plant of another production capacity can be designed (740; 1,1 m/t of monohydrate.
- Mode of operation continuous 340 (330) days in a year
- Raw materials- sulphur as per the state standard 2181-93, solid or liquid. The grade is not lower than 99.90. Sulphur consumption per 1 t of 100% sulphuric acid -0,328 t/t.



 Sulphuric acid of not less than 92,5% concentration, technical grade, produced as per the state standard 2184-77

BY-PRODUCTS:

- The specific feature of the process is a high degree of heat recovery released when burning of sulphur and conversion of SO2 into SO3 with generation of steam in the amount of 1, 22-1, 25 t/t of monohydrate. (P=4,0MPa, T=4400C).
- The power generating steam is used to generate electricity for the plant and also for other production purposes.

ECOLOGICAL DATA OF SULPHURIC ACID PLANT				
№ п/п	Description	Units	Consumption	
1	Gas emissions: Gas volume The content of harmful substances:	Nm ³ /h	120000	
	SO_2 -0,025 % Vol. SO_3 - 0,0005 % Vol Mist & splashes H_2SO_4 - 40 mg/Nm ³	kg/h kg/h kg/h	90 2,1 4,8	
2	Solid wastes: Sulphur cake Spent catalyst	kg/t kg/t	0, 2 0,08	
3	Liquid effluents: Acidic effluents		absent	

The technology offered and technical solutions have been implemented at:

☐ JSJ "Ammophos", Cherepovets:

Three plants of 620 000 tpa of monohydrate and one plant of 740 tpa of monohydrate in 2003, 2004, 2007 and 2009.

□ LLC " "Mineral Fertilizers Plant", Balakovo:

Two lines of 620 000 tpa of monohydrate each in 2003 and 2005.

In September 2010 года one more plant was put on stream of 650 000 tpa of monohydrate.



FUTURE DEVELOPMENT PROSPECTS OF THE TECHNOLOGY OFFERED

At present the following sulphuric acid plants are under designing and revamping:

- A sulphuric acid plant of 600 000 tpa of monohydrate is under designing for TOO "Kazphosphat" Taraz, Kazakhstan.
- A sulphuric acid plant of 700 000 tpa of monohydrate is under revamping in Gomel, Republic of Belarus



The technology for production of wet process phosphoric acid (WPA)



JSC"NIUIF"has been engaged for many years in the creation of WPA plants based on dihydrate and hemihydrate processes using different grades of phosphate rock. Our reference list includes more that 18 systems installed at 9 Russian enterprises and in the states of the former Soviet Union.

Technical offers are based on the technology developed by JSC "NIUIF" (patents of RF Nos.234366; 2322287; 2201287 and μ other applications for a discovery).





Reference list of WPA plants that have been revamped with implementation of hemihydrate process developed by JSC NIUIF"

Nº	Company, country	Enterprise	Q-ty of lines	Phosphate feedstock	Years of commissioning and revamp	Production capacity, P2O5 t/d
1	"Uralchim", Russia	JSC "Mineral Fertilizers Plant in Voskresensk, Russia	1	KOLA concentrate	1977, revamped in 2003	600
2	«Uralchim», Russia	JSC "Mineral Fertilizers Plant in Voskresensk, Russia	1	KOLA concentrate	2000, revamped in .2003	500
3	"PhosAgro" AG, Russia	JSC "Ammophos", Cherepovets	1	KOLA concentrate	1977, implementation of HH process in 1990, revamped in 2008	900
4	"PhosAgro" AG, Russia	JSC "Ammophos", Cherepovets	1	KOLA concentrate	1976, revamped in 2001, 2007	1000
5	"PhosAgro" AG, Russia	LLC"Chemical Plant in Balakovo"	1	KOLA concentrate	1978, revamped in .2005	1100
6	PhosAgro" AG, Russia	LLC"Chemical Plant in Balakovo"	1	KOLA concentrate	1977, revamped in 2008	1100
7	«Evrochim», Russia	OAO «Лифоса», Kedaenea, ,Lithuania	2	Kovdor apatite mixed with Morocco phosphorite	1981, revamped in 1998-1999	1300 (2 lines)
8	"Evrochim" Russia	LLC "PG "Phosphorit", Kingisepp	1	Kovdor apatite mixed with Morocco phosphorite	1980, revamped in 2011	850
9	JSC "ГХЗ", Republic of Belarus	JSC"Chemical Plant in Gomel	1	Kola apatite mixed with Kovdor apatite	The project is at the stage of realozation	850





PHOSPHATE ROCK:

- KOLA APATITE (39% P₂O₅, GOST 22275-90)
- phosphorites from different deposits
- -The products manufactured:
- Wet process phosphoric acid with the content as follows:
- •36-38% wt. P₂O₅ in liquid phase •1,5-2,0% wt. SO₃ in liquid phase 1,0-1,5% wt. impurities.



The method of WPA production

- Decomposition of phosphate rock in a multy-compartment attack tank with phosphoric and sulphuric acids in the presence of recycling slurry to obtain hemihydrate of calcium sulphate in the phosphoric acid;
- >two-stage cooling of slurry with air under foam conditions;
- >ageing of slurry;
- >separation of product from calcium sulphate by filtration;



> washing of the cake with countercurrent water to obtain the return phosphoric acid with sending it back to the stage of decomposition.



The advantages of hemihydrate process:

- high enough efficiency (up to 220 000 tpa P_2O_5), rapid achievement of design production capacity;
- High content of P₂O₅ in WPA (36-38%);
- P₂O₅ yield from phosphate rock is 95,5-96,5 %;
- High reliability: working time fund of technological system up to 325 days in a year.
- High intensity equipment utilization (specific volume of the attack tank is $0.85-0.95 \text{ m}^3/(\text{P}_2\text{O}_5\text{ t/d}^*\text{ yield of calcium sulphate hemihydrate from vacuum-filter is }1100-1300 \text{ kg/m}^2\cdot\text{h});$
- Low electricity consumption (75-85 Kw·h/t P₂O₅);
- Intensive circulation of slurry in the attack tank (circulation ratio to volume of slurry is 43-46);
- Intensive air cooling of the slurry under foam conditions provides maintains the temperature about 90°C in the attack tank;
- Reduction of capital costs due to decreasing of the reaction volume and filtration area and exclusion of slurry vacuum cooling system.

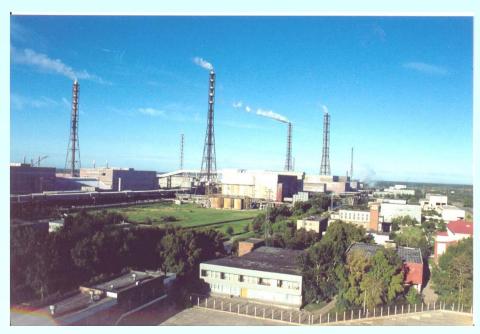
The technology offered of HH process and technical solutions developed by JSC :NIUIF" hqve been implemented at :

JSC "Ammophos", Cherepovets

– 2 lines of 900 μ 1000 P2O5 t₋/day at

- 2 lines of 900 и 1000 P2O5 t_t/day at LLC "Chemical Plant", Balakovo 2 lines(600 и 1100 P2O5 t/day); JSC 'Mineral Fertilizers Plant", Voskresensk
- 2 lines (500 и 600 P2O5t/day)





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PROSPECTS FOR DEVELOPMENT OF HH PROCESS TECHNOLOGY FOR WPA PRODUCTION At present HH process is developed at WPA plant in Kingisepp, JSC "Eurochim", after the revamp to increase the capacity from 350 to 850 P2O5t/day. The basic engineering project has been worked out for reconstruction of technological system with installation of a novel reaction unit at JSC "Chemical Plant" in Gomel, Republic of Belarus to increase the capacity based on HH process from 380 to 850 P2O5 t/day. The basic engineering project has been worked out for a novel hemihydrate technological system having the capacity up to 500 000 P2O5 tpa.



FLEXIBLE TECHNOLOGY FOR PRODUCTION OF PHOSPHOROUS-CONTAINING FERTILIZERS USING DRUM-GRANULATOR-DRYER



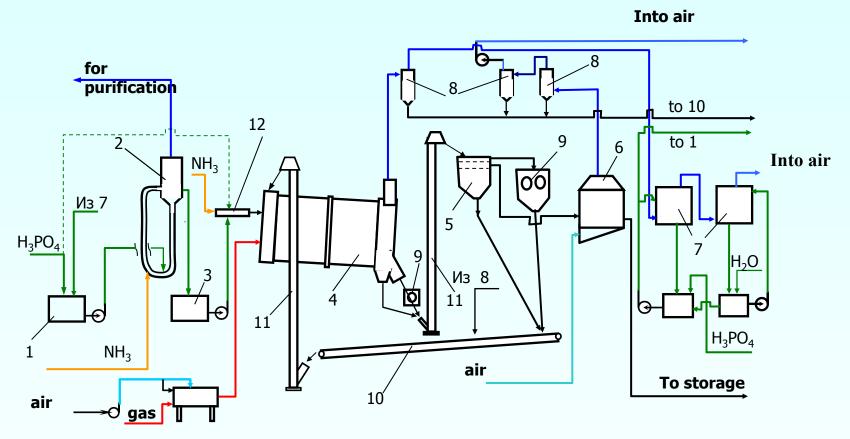
A flexible technology of phosphorouscontaining fertilizers is based on the improved pipe reactor- Drum-Granulator-Dryer, combining the stages of ammoniation, granulation and drying (when producing ammonium phosphates) and granulation and drying (when producing superphosphate).

The product mix:

MAP - 12:52; DAP - 18:46, NPK, superphosphate - 42-46% P₂O₅.

A flexible process flow diagram for production of phosphate fertilizers using Drum-Granulator –Dryer (DGD)





– acid tank; **2** – high velocity ammoniator – evaporator; **3** – slurry tank; **4** – DGD; **5** – screen;

– cooler; **7** – absorber; **8** – cyclones; **9** – screen; **10** – conveyor;

– elevator; **12** – pipe reactor.



When manufacturing ammonium phosphates a wet phosphoric acid mixed with scrubber liquid is neutralized to mole ratio $NH_3:H_3PO_4=1-1,15$ (when manufacturing MAP) or to mole ratio $NH_3:H_3PO_4=1,65-1,75$ (when manufacturing DAP) in the pipe reactor, combined with Drum-Granulator-Dryer (DGD).

When manufacturing NPK a potassium-containing component (chloride or potassium sulphate) is fed to DGD together with recycle. When manufacturing superphosphate the phosphate rock is charged to the reactor and mixed with the acid fed for its decomposition. The slurry formed is sent to DGD for granulation and drying.



The advantages of this technology

The use of this technology offered and equipment allows the following:

- save capital costs
- decrease the production and energy costs
- reduce a specific consumption of materials
- increase a profitability and labor efficiency
- •obtain a high quality products
- obtain a high degree of purification of exhaust gases
- arrange the centralized system of gas emissions in one point

The process has been implemented at:

- ***JSC "Ammophos"**, Cherepovets 2004
- **❖JSC LLC "Mineral Fertilizer Plant", Balakovo 2008**



We can offer the whole package of services - from development of feasibility study to build mineral fertilizers plants to development of technologies and designing of plants, consulting services, licenses and "knowhow".

We can co-operate on mutually beneficial conditions.







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FSA Neutralization with Calcium Compounds

الإتحاد المربحي للأسمدة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

Mr. Salah Albustami Process Engineer - JACOBS

USA



FSA NEUTRALIZATION WITH CALCIUM COMPOUNDS

JACOBS Engineering SA

Submitted By: Salah F. Albustami, PE Stephen W. Hilakos

ABSTRACT

As environmental regulations continue to restrict chemical processing emissions, phosphate plant operators will eventually be required to neutralize fluoride waste materials. Most phosphate plants currently use direct contact barometric condensers with recirculating cooling pond water that is saturated with fluoride salts. Most of this fluoride is allowed to precipitate as the recirculating water cools in large cooling pond systems. When forced to treat fluoride contaminated water, phosphate producers typically use lime or limestone neutralization prior to discharging effluent. A better environmental alternative is to use scrubbers to remove fluorides as fluosilicic acid prior to condensing the vapors in barometric condensers. If a market cannot be found for the fluosilicic acid, it can then be neutralized with phosphate rock to produce a weak phosphoric acid. This technique is not currently used because it is not profitable. This paper discusses Fluosilicic Acid neutralization with several calcium compounds such as phosphate rock, lime and limestone.

Keywords: Fluoride, Fluosilicic acid, neutralization, phosphate rock, lime, limestone.

FLUORIDE DISTRIBUTION IN PHOSACID PLANTS

Fluoride is the major impurity in the rock feed to phosacid reactors. Pure fluoroapatite, $Ca_{10}F_2(PO_4)_6$, contains 3.8% fluorine by weight in the mineral lattice. Major deviations in fluoride concentration can occur due to lattice substitution of CI or OH for fluoride in the mineral and from entrained gangue materials such as $CaCO_3$ and CaF_2 .

During acidulation, fluorides form gaseous compounds (HF, SiF₄, H₂SiF₆), and depending on the composition of the rock feed as much as 70% of the total F may be present in a volatile form. The remaining portion is present as semi-soluble sodium and potassium silica fluoride salts and insoluble combinations of AlF₃ and CaF₂. Precipitation of the fluorine dissolved during acidulation is governed by the interaction of the impurities present and fluoride balances for phosacid complexes differ due to variations in the concentrations of Al, Si, Na, Mg, Ca and F in the rock. As many as twelve modes of fluoride precipitation were identified by Lehr. ⁽¹⁾ The stable forms are calcium compounds such as chukhrovite and CaF2, the focus of this paper.

The ultimate destination of fluoride entering the plant is either in the final products or as precipitated solids in the gypsum or the recirculating water system. As most of the plant process water streams remain close to saturation with sodium and potassium silica fluoride, these salts can either dissolve or precipitate with changes in temperature, concentration, or acidity, making the accounting for fluoride difficult. Only a minor fraction of the total fluoride entering the plant escape as volatile compounds, nevertheless, a small fraction of a large quantity can be a sizable amount. Depending on ambient conditions, nonpoint source fluorine emissions to the atmosphere can exceed one ton per day for plants with cooling ponds and wet gypsum stacks. In the U.S., only point sources are currently regulated.

Erickson's estimates for the distribution of fluorine from the manufacture of wet process Phosphoric acid are shown in the following table. (2)

Distribution of Fluorine during phosphoric acid processing

	% of Total F
1) The gypsum	10-20
2) Emissions from the reactor	10-25
3) Vapors produced during concentrations	40-60
4) The concentrated product acid	10-20

FLUORIDE SCRUBBUNG

The fluoride vapors generated during reaction and filtration are typically absorbed into pond water in order to limit the quantity of fluorides emitted from the process so as to conform to existing environmental standards. In the U.S., point sources for wet process phosphoric acid plants are limited to less than 0.020 lb of F per ton of equivalent P_2O_5 feed. (3)

The fluoride vapor evolved during concentration is either recovered as H₂SiF₆ (FSA) or is absorbed into the pond water used to condense the water vapor liberated during the evaporation process. Due to limited demand, the number of U.S. phosphoric acid plants

that currently recover FSA is small and the bulk of the FSA generated is absorbed into pond water and rejected to the cooling pond. To minimize precipitation problems, most producers of FSA only use scrubbers on evaporators dedicated to 54% acid production.

In the reaction, filtration, and first stage evaporation sections, the fluoride vapors generated are silica rich (ie. the mole ratio (MR) of F to Si < 6). Silicon tetrafluoride, SiF₄, has a higher vapor pressure than HF and is the main fluoride component in the vapor phase of the lower strength acids (<40% P₂O₅). As the silica content of the acid is depleted, the mole ratio of F to Si in both the liquid and the vapor increases and the vapor produced when evaporating acids at P₂O₅ strengths > 50% is usually rich in HF (MR>6). The following diagram, Figure 1, illustrates the changes in the vapor and liquid F to Si mole ratios as phosphoric acid is concentrated.

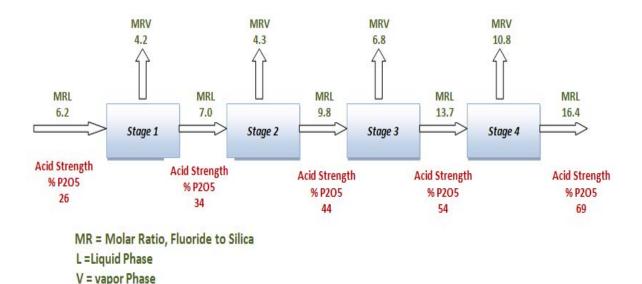


Figure 1: Fluoride to Silica Molar Ratio in Multistage Phosacid Concentration

The key to the successful operation of fluoride scrubbers is limiting the accumulation of SiO_2 scale. Scrubber recirculation liquors must be maintained at F to Si mole ratios > 5.5 to prevent SiO_2 gel formation. Solutions with lower mole ratios are marginally stable and can quickly turn milky white when SiO_2 precipitant begins to form. In the vapor phase H_2O and SiF_4 will co-exist, however when condensed, the combination will rearrange until enough HF has been formed to stabilize the solution (mole ratio = 5.0 to 5.5).

$$SiF_4 + 2 H_2O \Rightarrow 4 HF + SiO_2$$

2 HF + SiF₄ < = > H₂SiF₆

Low mole ratio vapor will generate SiO_2 as soon as liquid droplets are formed and will deposit scale on impact with any fixed solid surface. Typically this surface is the mist eliminator pads or other internal parts of the scrubber. This leads to high pressure drops across the demisting pads that either opens trap doors or rips the pads from their support structures.

Higher mole ratio recirculating liquors are required to prevent excessive scaling in scrubbers operating with low mole ratio vapor streams. This can be accomplished using counter-current flow schemes with the scrubber solutions generated by the higher strength evaporators being fed back to the first stage scrubbers.

The FSA concentrations of the scrubber liquor can vary and may range as high as 25% strength on units producing FSA for outside sales to as low as 3% to 4% on first stage evaporation units operating without demisting pads. Lower concentration scrubber liquors will absorb a higher percentage of the fluoride from the vapor phase and, due to the higher throughput of liquid, flush a portion of the SiO₂ solids from the scrubber prior to it forming permanent scale. Figure 2 depicts an FSA scrubber with a single stage evaporator.

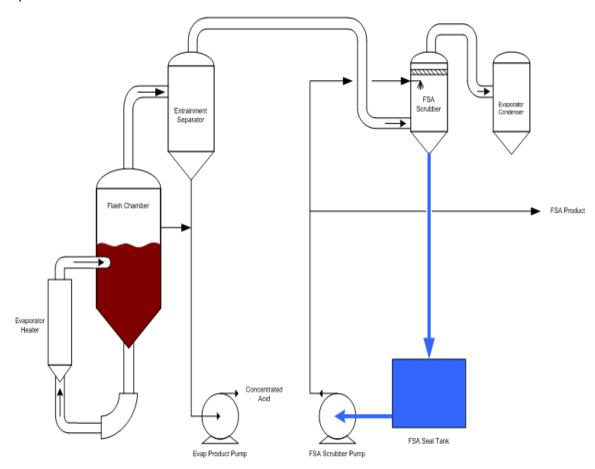


Figure 2: FSA Scrubber with Single Stage Evaporator

Due to the limited commercial demand for fluosilicic acid, many U.S. phosphate producers no longer capture FSA, and allow all the vapor generated during evaporation to condense directly into the cooling pond water. As the fluorides from the reaction and filtration sections are also reporting to the pond water system; as much as 70% of the incoming fluoride content is being sent to the cooling pond. Cooling pond fluoride concentrations, however, tend to remain constant, as the additional fluoride is precipitated.

POND WATER TREATMENT

Although most production facilities attempt to maintain a negative water balance, periodic imbalances frequently exceed available storage and facilities are forced to treat cooling pond water prior to discharge. Facilities with discontinued plant operations are also required to treat large amounts of residual cooling pond water.

Most U.S. facilities when faced with cooling pond water treatment employ a two stage liming process in order to meet U.S. EPA effluent guidelines.⁽⁴⁾ Two stage liming systems typically require large holding lagoons to consolidate slow settling solids and often the discharge effluent is only a fraction of the water treated.

Attempts to treat cooling pond water with R.O. units have been unsuccessful as the membranes are quickly fouled by the saturated solutions. Michalski, however, has presented a detailed three stage pretreatment process that allows both P_2O_5 recovery and water extraction from the saturated solutions. By employing a stepwise neutralization, the recommended process precipitates the fluoride components before activating, aging and separating the silica gels. Michalski recommends that an aging period of at least 2 hours and preferable 16 hours be allowed to complete the silica gel formation prior to clarification.

LIME AND LIMESTONE LABORATORY TESTING

When Jacobs' laboratory conducted neutralization tests with clean FSA solutions and calcium compounds such as calcium carbonate and calcium hydroxide, problems with silica gel formation occurred. FSA solutions that were neutralized at lower solution pHs were especially prone to gelling. It was suspected that the silica polymerization was initiated during periods with lower solution pH. Further experimentation revealed that gel formation could be avoided by maintaining the neutralizing solutions at pH values above 5.

FSA neutralizations performed with calcium carbonate were the most susceptible to gelling. Tests with calcium carbonate or ground limestone generated slurries that either became very viscous or solidified. The higher viscosity solutions experienced mixing problems and, as CO_2 was being liberated during the calcium carbonate neutralizations, problems with de-gassing.

Multiple continuous operation tests were performed neutralizing 15% FSA solution with 25% Ca(OH)₂ slurries without gel formation when higher reactor solution pHs were maintained. The solids generated in all the extended run tests quickly partitioned into 50/50 mixtures with free flowing slurry phases and clear liquids.

The continuous tests verified that the reactor discharge concentrations for soluble fluoride could be maintained at < 20 ppm and that the solids generated would remain stable after dilution with seawater or highly acidic gypsum slurry. Both the required residence time for the reaction, at approximately 30 minutes, and the calculated calcium dosage rate, at 1.5 times the expected stoichiometric requirements, were similar to values recommended by Patterson.⁽⁶⁾

NEUTRALIZATION OF FSA WITH PHOSPHATE ROCK

The total cost of fluoride neutralization and disposal can be offset by taking advantage of the acidity of the waste stream. Phosphate rock can be reacted with high strength FSA solutions to produce de-fluorinated phosphoric acid and neutralized fluoride compounds as Erickson has recommended.⁽²⁾ To completely convert all of the fluorine in the FSA to CaF₂ requires an excess of the stoichiometric amount of calcium be present in the rock. Typically the requirements are approximately 1.2 pounds of non-fluoride bearing calcium per pound of fluoride in the feed FSA solution.

Erickson specified 17% FSA solutions for processing dry phosphate rock and no lower than 20% FSA when operating with 70% wet rock slurry (PECO process). As demonstrated by Nagy, ⁽⁷⁾ the reaction can be accomplished with high rates of F conversion at lower strengths of FSA.

Nagy built and operated a 1/10th scale pilot plant based on the available FSA from a $400,000 \text{ t P}_2\text{O}_5$ / year phosphate facility. The pilot unit produced a weak phosphoric acid that was low in metal impuries when compared to typical wet process acid produced from the same rock feed. A comparison of the product acids is shown below:

		Concentrated	Conventional	PECO
	PECO Acid	PECO Acid	28% Acid	% of Conventional Acid
9 $P_{2}O_{5}$	6.55	28.41	25.72	
Al (ppm)	0.63	< 0.1	3224	< 1%
Ca (ppm)	5624	15900	1552	927%
Cr (ppm)	3.12	14.2	271	5%
F (ppm)	1580	1590	20800	7%
Fe (ppm)	98.8	341	1584	19%
Mg (ppm)	657	2400	3440	63%
Na (ppm)	859	3400	518	594%
Si (ppm)	429	289	4160	6%

The pilot plant employed a rather simple flow sheet as shown in Figure 3. The main processing units, a 500 gallon reactor and a 1000 gallon clarifier, were constructed from 316 SS. No process fume scrubbers were required.

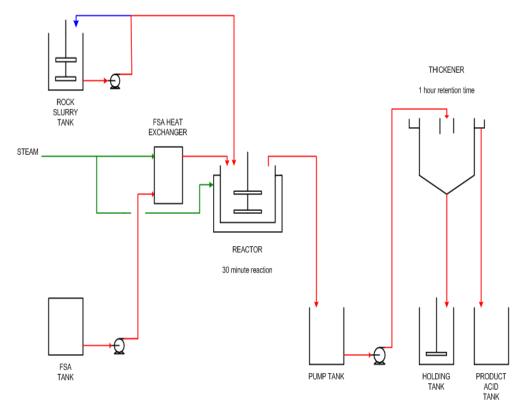


Figure 3: FSA Neutralization Process Utilizing Phosphate Rock

The acidulation of phosphate rock with H_2SiF_6 (-8.68 kcal/mole H_2SiF_6) is only slightly exothermic and requires an external source of heat to maintain the reaction temperature at 93°C (200°F) if feeding raw materials at ambient temperatures. Nagy maintained the reaction by introducing hot FSA (88°C) below the liquid level and steam jacketing the reactor.

Various FSA feed concentrations were tested with 68% to 70% rock slurries. FSA concentrations between 10% and 16% produced acid at 6% to 9% P_2O_5 strengths and fluoride conversion was maintained with FSA strengths as low as 5%. The CaF_2 solids produced remained stable in acidic pond water and when mixed with phosphogypsum being transported to the gyp stack.

The fluoride conversion and the P_2O_5 recovery were inversely related and could be shifted by changing the Ca to F feed ratio to the reactor. Lower Ca to F feeds (1.15-1.25) produced P_2O_5 recoveries of 75%-80% and 90%-95% fluoride conversion. Higher feed ratios (1.3-1.4) produced 99% fluoride conversion but with 70%-75% P_2O_5 recoveries.

CONCLUSION

Operating economics depend on being able to make good use of a very low strength, but high quality phosphoric acid. The major operating expenses are for the additional cost of evaporation and phosphate rock. The overall process is not profitable, but is much less expensive than treating similar quantities of fluoride with lime or limestone. Depending on the delivered cost of plant site raw materials, the PECO process may reduce the cost of fluoride neutralization by as much as 200/t H₂SiF₆.

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Topsøe Solutions for sulfuric acid and ammonia plants

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Arab Fertilizers Association

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Denmark



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Topsøe solutions for sulphuric acid and ammonia plants

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Haldor Topsøe A/S, Denmark

Founded in 1940 on the brink of the Second World War, Dr. Haldor Topsøe started the company based on a commitment to heterogeneous catalysis. This has placed the company in the frontier of developing tomorrow's catalysts for today.

The company is governed by the notion that only through fundamental science can we continue offering our clients the best; and the past 70 years an on-going tale of improving catalysis.

Topsøe has more than 70 years of experience in manufacturing VK catalysts, and today more than half of the world's ammonia is produced over Topsøe ammonia synthesis catalyst.

Topsøe has also contributed significantly to the development of efficient ammonia production technology. Today, approximately 50% of new ammonia plants use Topsøe ammonia technology. Topsøe's ammonia technology can be used for both the design of new plants and for revamps of existing plants.

This paper presents some of Topsøe's catalyst and technology solutions for the sulphuric acid and ammonia plants. The outline of this paper is as below:

- Part 1: Catalyst solutions for lower SO₂ emissions and reduced pressure drop build-up in sulphuric acid plants
- Part 2: Catalysts for improving ammonia production
- Part 3: Advanced Reforming Technology for Ammonia Plants



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Part 1: Catalyst solutions for lower SO₂ emissions and reduced pressure drop build-up in sulphuric acid plants

Marie Vognsen Haldor Topsøe A/S, Denmark

1.1. Introduction

In 1996 Topsøe introduced a caesium-promoted vanadium catalyst, VK69, designed for operation in the pass(es) after the intermediate absorption tower in double absorption plants. The high activity of VK69 opens opportunities for a more than 50% reduction in SO₂ emissions from existing double-absorption plants or, alternatively, the acid production rate can be boosted by 15-20% without increasing SO₂ emissions. Today, 15 years later, Topsøe has close to 100 installations with VK69.

However, still more stringent regulations are being placed on the sulphuric acid industry to lower SO₂ emissions. Topsøe has responded to these challenges by developing a new sulphuric acid catalyst designated VK-701 LEAP5™. This catalyst was introduced to the market in 2010. VK-701 LEAP5™ is based on a novel technology which circumvents the internal transport deficiencies of existing commercial sulphuric acid catalysts and thereby offers exceptionally high activity at low temperatures in strong gases.

For many sulphuric acid plants the bottleneck for prolonged operating time between plant shutdowns is the requirement for screening of bed 1 due to increased pressure drop caused by deposition of dust from the feed gas.

An improved protection against pressure drop build-up can be obtained by the use of a dust protection catalyst in the top of bed 1. In 2007 Topsøe introduced a new dust protection catalyst in the shape of a 25 mm Daisy. Installation of a 15 cm top layer of this unique VK38 dust protection catalyst results in a doubling of the operating time between screenings compared to the 12 mm Daisy.

1.2. Topsøe's sulphuric acid catalysts – the VK-series

VK38

VK38 is the classic all-round sulphuric acid catalyst. A high activity is provided in the entire range of operating conditions, and VK38 gives an excellent performance wherever placed in the converter. The VK38 will operate continuously from 400°C to 630°C and peak temperatures as high as 650°C will not harm the catalyst. At the other

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end, the VK38 features an ignition temperature as low as 360°C for fresh catalyst, which leaves the operator with ample operational flexibility.

VK48

VK48 is a high-vanadium version of the standard VK38 catalyst and is tailored for maximum activity in highly converted gasses, i.e. a high SO_3/SO_2 gas environment. Where the process gas contains large amounts of SO_3 , such as the last passes in a single absorption plant or the third pass of a 3+1 double absorption plant, VK48 has a 20-30% higher activity than VK38. The higher activity has been achieved not only by increasing the vanadium content, but also by changing the composition of the active phase.

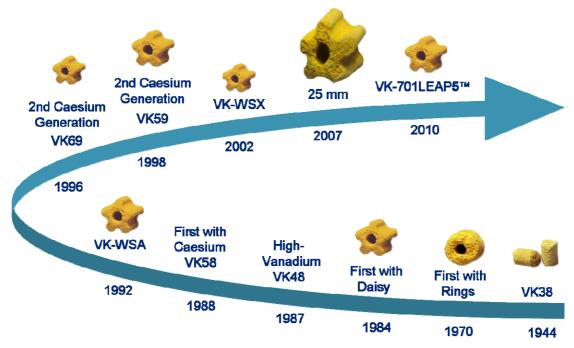


Figure 1: Topsøe's VK catalyst history in brief

VK59

VK59 is a caesium-promoted catalyst developed especially for operation in medium to high strength SO_2 gases at temperatures down to 370°C. This low temperature makes it possible to accommodate high SO_2 concentrations inlet the first pass without exceeding the maximum outlet temperature of 630°C.

In addition, the low ignition temperature of just 320-330°C makes VK59 very effective in accelerating plant start-up, meaning faster and cleaner start-ups. The ability to start



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from a very low temperature provides a significant extension of the period in which autothermal plant restart can occur after for instance an interruption of the feed gas supply.

VK69

VK69 is developed for operation under low SO₂ conditions following the inter-pass absorption tower in double absorption plants. It combines high vanadium content with a revised balance of its alkali-metal promoters.

VK69 is manufactured in a unique 9 mm Daisy shape. This provides a very high surface area, which is important for efficient SO₂ conversion in the passes following the intermediate absorption tower. The high void fraction of the 9 mm Daisy shape ensures that this occurs while maintaining a low pressure drop.

The extremely high activity of VK69 in the entire temperature range naturally provides a number of options for improved performance of existing double-absorption plants and in the design of new acid plants:

- More than a 50% reduction in SO₂ emission from existing double-absorption plants
- The possibility of a significantly increased production without increasing SO₂
- Possibility for SO₂ emissions from new or revamped plants of 50 ppm or less, eliminating the need for tail gas scrubbing

Today VK69 is installed in close to 100 converters worldwide, and feedback from the users has clearly verified its advantages. The purpose of the major part of the VK69 installations is reduced SO₂ emissions due to tightening of emission regulations and increased production rates while maintaining or improving the SO₂ emissions.

VK-701 LEAP5™

Haldor Topsøe's new sulphuric acid catalyst VK-701 LEAP5[™] is developed and optimised for operation in converted strong gasses. At these conditions VK-701 LEAP5[™] shows significant activity advantages compared to existing potassium- and caesium-promoted catalysts.

The major leap in activity for VK-701 LEAP5[™] is primarily due to high fraction of vanadium in the active oxidation state V5+. At operating conditions several vanadium species are present; but only oxidation state V5+ is active in the catalytic cycle. The



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high V5+ level in VK-701 LEAP**5**[™] has been brought about through physical as well as chemical changes compared to Topsøe's existing catalysts.

The increased content of vanadium in oxidation state V5+ results in a superior activity for VK-701 LEAP5[™] compared to VK48 and VK59 throughout the entire temperature range. The high activity offered by VK-701 LEAP5[™] presents new conversion opportunities for any single- and double-absorption plants:

Single absorption plants

- reduce SO₂ emissions by up to 40% by loading VK-701 LEAP5[™] in the final pass

Double absorption plants

- cut SO₂ emissions by up to 70% in 3+1 plants by replacing the third and fourth passes with VK-701 LEAP5[™] and VK69 respectively.
- cut SO₂ emissions by up to 40% in 3+1 plants operating with VK69 by replacing the third pass with VK-701 LEAP5[™]
- achieve as low as 50 ppm SO₂ emission from existing 3+1 plants
- design new plants with as little as 20-50 ppm SO₂ emission

For existing plants the reduced SO₂ emissions achievable with VK69 and VK-701 LEAP5[™] catalysts provide an attractive alternative to investing in a caustic or hydrogen peroxide scrubber. Even for plants equipped with tail-gas scrubbing, the use of VK-701 LEAP5[™] catalyst can be a cost-efficient way to reduce consumption of chemicals for the scrubbing.

Example: Reduced emissions from a double-absorption plant

The SO_2 emissions from an existing double-absorption plant can be reduced by 50% loading VK69 in the final pass and even further by also loading VK-701 LEAP $\mathbf{5}^{TM}$ in the third pass.

Layout: 3:1 double-absorption plant SO₂ source: Burning of elemental sulphur

Feed gas: 11% SO₂, 10% O₂ Catalysts in beds 1/2: VK38 / VK38

Conversion outlet bed 2: 88.5%

The performance of VK-701 LEAP5[™] and VK69 is compared to standard catalysts in Table 1. With standard potassium-promoted VK48 in bed 3 and VK38 in bed 4, the overall conversion of the plant is 99.85% corresponding to 200 ppm SO₂ in the stack gas. The feed gas to the fourth pass contains about 0.6% SO₂ in this case. If higher



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conversion is required, the first choice is to replace the VK38 in bed 4 with caesium-promoted VK69, which is optimised for the final pass of double-absorption plants, and reduce the inlet temperature to 395°C. This cuts the SO₂ emission to 100 ppm.

Bed 3 Catalyst Inlet temperature, °C Outlet temperature, °C Conversion outlet bed 3, %	VK48 440 461 95.45	VK48 440 461 95.45	VK-701 LEAP5 [™] 423 447 96.43
Bed 4 Catalyst Inlet temperature, °C Outlet temperature, °C	VK38 425 442	VK69 395 413	VK69 395 409
Overall conversion, % SO ₂ in the stack, ppm	99.85 200	99.92 100	99.95 64

Table 1. Performance of VK69 and VK-701 LEAP5™ in a 3:1 double-absorption plant

A further reduction in SO_2 emission can be accomplished by replacing the VK48 in bed 3 with an equal amount of VK-701 LEAP $\mathbf{5}^{\mathsf{TM}}$ and operating the bed at an inlet temperature of 423°C. Due to the higher activity of the VK-701LEAP $\mathbf{5}^{\mathsf{TM}}$, the SO_2 content in the feed gas to bed 4 is reduced to 0.47%, and the overall conversion is increased to 99.95%. The 64 ppm SO_2 in the stack achieved with a combined VK-701/VK69 loading corresponds to a 36% reduction compared to the VK48/VK69 loading and as much as 68% reduction compared to a loading of conventional VK48/VK38 catalyst in beds 3 and 4.

1.3. Industrial experience with VK69

Case story 1

In 1997, VK69 was installed in the fourth pass of a large 1460 MTPD sulphuric acid plant in Asia. The plant burns elemental sulphur and has a 3+1 layout. In the middle of 1997, the plant was met with a 100 ppm SO₂ emission limit. A number of options for improving the SO₂ conversion efficiency were studied including the installation of a caesium-promoted catalyst or the expansion of the plant with a fifth pass. It was calculated that through the high activity offered by Topsøe's VK69 catalyst, the emission limit could be met and the plant decided to choose this option.



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In the summer of 1997, the existing conventional catalyst in the fourth pass was replaced by 90.6 m 3 VK69 catalyst. The volume of VK69 loaded was slightly less than the volume of the previous catalyst. A test run performed after the start-up showed a more than 60% reduction in the SO_2 emission even though the plant load had been increased slightly and the catalyst volume had been reduced. With the installation of the high active VK69 catalyst in the fourth pass the conversion requirement of 99.92% corresponding to less than 100 ppm was met with an optimum inlet temperature to the fourth pass of 389°C.

Later in 1997, a full fourth pass loading of VK69 catalyst was installed in the identical sister plant.

Since the start-up in 1997 both plants have been shut down for catalyst screening several times. Also the VK69 catalyst in the fourth passes has been screened and new VK69 make-up catalyst added. In the autumn of 2009 the client still reported SO₂ emissions below 100 ppm from both plants.

	Before VK69	After VK69
Catalyst loading bed 4, litres	97,000	90,600
Production, MTPD	1460	1490
Conversion exit bed 3, %	94.7	94.4
Temperature inlet bed 4, °C	440	389
Overall conversion, %	99.79	99.92
SO ₂ exit bed 4, ppm	260	97

Table 2. Plant performance prior to and after installation of VK69 in the fourth pass

Case story 2

An Asian sulphuric acid producer operates a 2350 MTPD sulphuric acid plant based on off-gases from smelting of metals ores. The plant has a 3+2 layout (intermediate absorption located after the third pass). The catalyst loading was tailored to meet a conversion goal of 99.95% corresponding to less than 100 ppm SO_2 exit the last pass based on a feed gas composition of 14.2% SO_2 and 11.6% O_2 inlet the first pass. In July 2007 Topsøe's VK38/VK48 catalysts were loaded in the upper four passes including a top-layer of VK59 catalyst in the first pass. In the fifth pass 95 m³ of Topsøe's VK69 catalyst was loaded in order to meet the high conversion requirement.

Most sulphuric acid plants feeding on off-gases from metal ores experience fluctuations in the gas flow rate and composition. This is also the reality in the present plant and consequently variations in the conversion level are experienced. However, the trend in



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the operating data received from the plant shows stable performance of the Topsøe VK catalyst with SO_2 emissions in the range of 20-80 ppm and no deterioration of the catalyst performance is experienced during a 30 months period. In October 2010 a TOPGUN was performed at the plant showing SO_2 emissions of 20 ppm at more than 90% production capacity. No catalyst work has been carried out since the start-up in 2007, but it is scheduled to take place in the second quarter of 2011.

	Design	July 2008	TOPGUN 2008	July 2009	TOPGUN 2010
SO ₂ , mole %	16.3	15.96	14.0	15.6	14.4
Production, MTPD	2350	2300	2241	2340	2208
Overall conversion, %	99.95	99.95	99.98	99.98	99.99
SO ₂ emission, ppm	100	85	33	42	20

Table 3. Plant performance since the initial start-up in 2007

1.4. Dust protection

The alkali-metal promoted vanadium catalyst acts as a very effective dust filter due to the "fly-paper" effect of the pyrosulphate complex that is present as a liquid in the microscopic pores of the catalyst at operating temperatures. Observations from industrial applications have shown that part of the liquid melt migrates from the catalyst into the accumulated dust, making it sticky as well. The dust particles pass largely unhindered through the layer of inert rocks or ceramic bodies normally placed on top of the bed. Most of the dust is normally trapped in the upper 5-10 cm of the catalyst, eventually plugging the gas passage so that screening of the bed becomes necessary to relieve high pressure drop build-up.

The sensitivity to plugging and pressure drop build-up in a catalyst bed by dust-laden gas depends on the bed void fraction and how the dust is distributed. The penetration depth increases with the size of the catalyst particles because the relative surface area is lower.

Topsøe has developed an improved dust protection catalyst in the shape of a large 25 mm Daisy. This super Daisy catalyst combines the effect of a larger void fraction for higher dust capacity and the effect of a lower specific surface area for improved dust distribution.

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Installation of a 15 cm top layer in the first bed enables the plant to double the production time between catalyst screenings compared to the 12 mm Daisy.

With more than 80 installations, VK38 in the shape of 25 mm Daisy has proven to be an unmatched solution for plants suffering from rapid pressure drop build-up due to dust in the feed gas. Both metallurgical plants and plants based on sulphur burning have increased operating time between screenings and thereby, reduced the number of expensive shutdowns for catalyst screening.

1.5. Industrial experience with 25 mm Daisy for dust protection

Case story

A European sulphuric acid producer operates a 1330 MTPD sulphuric acid plant based on off-gases from smelting of metals ores. The plant has a 2+2 layout.

In October 2008, a 150 mm top layer of VK38, 25 mm Daisy was installed in the top of the first pass. The purpose of the dust protection layer was to extend the period between screenings.

Figure 2 shows the pressure drop development across bed 1 for the operations cycle prior to the installation of the dust protection layer as well as the operation cycle with the 25 mm Daisy installed in the top of the first bed.

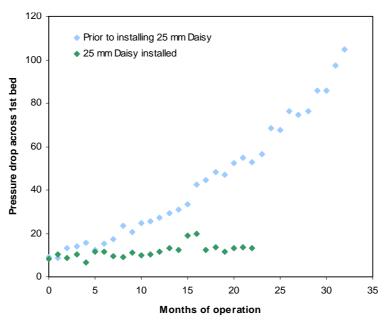


Figure 2. Actual pressure drop development for operation with and without the 25 mm Daisy



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The figure clearly illustrates that the installation of 25 mm Daisy has significantly reduced the rate of pressure drop build-up.

The 25 mm Daisy has been in operation for more than two years and for this period no pressure drop build-up has been observed. Without the 25 mm in the top of first bed the pressure drop had increased more than 5 times after two years of operation.

Consequently, the number of time-consuming and expensive shutdowns for catalyst screening is reduced and at the same time significant savings in blower energy result from the lower pressure drop.

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Part 2: Catalysts for improving ammonia production

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2.1. Introduction

The low temperature shift (LTS) catalyst is one of the most important catalysts in ammonia plants. Even small changes in its performance may have significant impact on operational costs. In this paper we will demonstrate some of these impacts.

The close cooperation between the industry, Topsøe's R&D Division and the catalyst manufacturing facility has resulted in the development of Topsøe's LK series of LTS catalysts. For more than three decades, Topsøe's LK series has acquired leading position due to features such as superior activity, rugged mechanical strength and unmatched resistance towards poisons. This is an outstanding combination which has made Topsøe LK series the most widely sold LTS catalysts on the market.

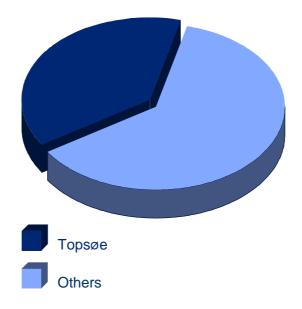


Figure 1. Global market share - Topsøe LTS catalyst

Topsøe LTS catalysts, LK-821-2 and LK-823, both possess the same high activity and unmatched resistance towards poisoning. As an added benefit, LK-823 is promoted in order to improve selectivity and this has resulted in significant reduction of methanol



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by-product formation. With the introduction of the low-methanol LTS catalyst, LK-823, Topsøe has provided the fertiliser industry with an effective and industrially proven technology, enabling achievement of even the most stringent reductions in methanol emissions.

2.2. Performance benefits with Topsøe LTS catalysts

The superior activity of Topsøe LTS catalysts makes it possible to operate the LTS reactor at a lower temperature level. Due to the exothermic character of the water gas shift reaction and the restrictions in the equilibrium, the CO leakage from the LTS will be lowered. A lower temperature level will also have a positive effect on the catalyst lifetime due to less sintering of the Cu crystals.

Case story 1

In order to quantify the benefits of having a more active LTS catalyst and thereby a lower CO concentration outlet the LTS converter, the following case story of performance benefits from operating with a lower CO leakage will be presented.

The case story illustrates the typical improvement in plant performance of having a Topsøe LTS catalyst. The case story is taken from a 1,000 MTPD Indian ammonia plant. The plant operated with a competitor catalyst for a period of 6 years. The charge was replaced with Topsøe LK-821-2 low temperature shift catalyst which today, 7 years later, is still in operation. From the development in the CO level illustrated in Figure 1, it can be seen that there are no signs indicating the need of replacing the catalyst in the near future. Actually, it is expected to last for at least another 2-3 years.

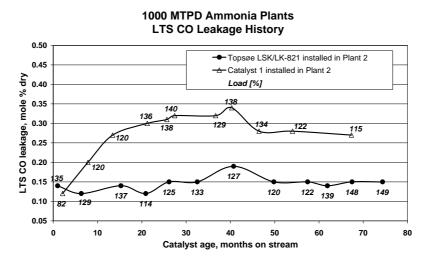


Figure 2: Development in CO leakage over time

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The lower CO leakage achieved with Topsøe LK-821-2 low shift catalyst in the Indian ammonia plant translates into a gain in production of an additional 21,000 MT of ammonia over a period of 6 years. Based on the current ammonia price this corresponds to an additional earning of USD 7 million.

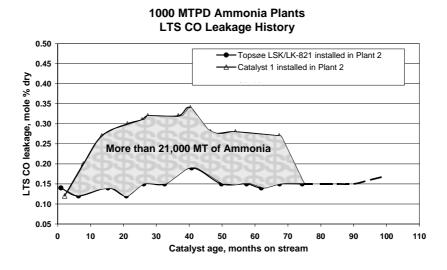


Figure 3: Difference in CO leakage and corresponding production gain

2.3. Benefits of reducing methanol-by-product-formation

The low-methanol LTS catalyst, LK-823, is today widely used in the industry as it is desirable to minimise methanol by-product formation for several reasons:

- Methanol emissions are being regulated to protect the environment
- Methanol by-product formation consumes valuable hydrogen
- Methanol may react to form amines causing odour problems
- Process condensate quality can be affected
- CO₂ quality can affect downstream processes

Case story 2

The undesired methanol by-product formed over the LTS catalyst has the adverse effect of valuable hydrogen being consumed to form the methanol.

By installing LK-823 the methanol by-product formation is greatly reduced as illustrated in figure 4.

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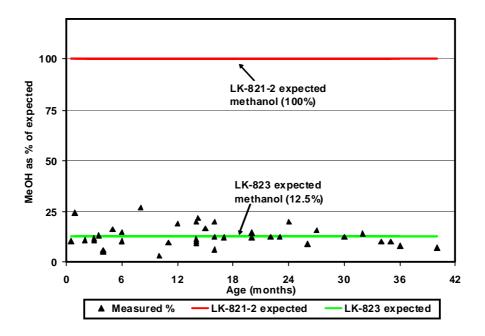


Figure 4: Reduction in methanol-by-product-formation

The methanol values in figure 4 are taken from actual industrial operation and are here benchmarked against our LK-821-2. The methanol formation across LK-823 is only about one eight of LK-821-2.

A very important aspect of LK-823 is that the low methanol by-product-formation has been achieved while maintaining the same high activity, poisoning resistance and stability as for LK-821-2. In other words, LK-823 will yield the same shift conversion and catalyst lifetime as LK-821-2.

The benefits of lowering the methanol by-product formation can be calculated and in this case story a standard 1500 MTPD ammonia plant is used as basis.

In order to evaluate the benefits of Topsøe LK-823 it is important to note that the methanol loss will greatly depend on the specific plant layout and the temperature in the separator.

However, the numbers in this case story is based on a plant layout where the condensate, including the methanol, will be recycled back to the reformer. Thus, the methanol loss is only depending on the temperature in the separator which thereby determines the fraction of methanol leaving the plant from the CO₂ absorber. For a



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temperature range in the separator of 70 degC to 120 degC the methanol loss through the CO_2 absorber would correspond to a loss of ammonia production of 0.6-3.0 MTPD. With current ammonia prices this translates into a value of 350,000-1,000,000 USD over a five year period.



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Part 3: Application of the Haldor Topsøe Exchange Reformer in Ammonia Plants

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Paper Abstract

Haldor Topsøe A/S (Topsøe) supplies a full range of reforming technologies which also includes heat exchange reforming technology. The Haldor Topsøe Exchange Reformer (HTER) technology is applicable to many technologies such as syngas, hydrogen, methanol, and ammonia.

This paper describes how this technology is adopted in an ammonia plant and what benefits can be offered to the ammonia industry. For a new ammonia plant, implementing the HTER reduces the size of the primary reformer and due to high reforming temperature still retains a low methane slippage, which is crucial for ammonia production.

Various options are available for a capacity increase in the front-end of an ammonia complex. Out of these, convective gas heated reforming stands out as an attractive option from both a technical as well as a cost effective perspective. The Haldor Topsøe Exchange Reformer (HTER) technology is a proven revamp option where a capacity increase of 20 - 25% can easily be achieved, while the methane leakage is retained at a low level.

The HTER technology has now been in successful commercial operation since early 2003. A full size industrial unit has been revamped with an HTER installed downstream of an Autothermal Reformer (ATR), this has resulted in a 33% increase in reforming capacity.

3.1. Introduction

Steam reforming is the dominant technology for producing hydrogen or hydrogen rich synthesis gas for example for ammonia production. Feedstock may range from natural gas to kerosene.

Topsøe supplies a full range of reforming technologies, all based on decades of intensive R&D in the relevant areas and evaluations of actual plant operation. Topsøe's most recent reforming technology is the Haldor Topsøe Exchange Reformer (HTER).



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HTER operates in series or parallel with another reformer(s) and draws the necessary heat of reaction from the effluent gas from this source. It has already been commercialised in combination with an autothermal reformer at Sasol's large facility in Secunda, South Africa, for conversion of coal to liquid fuels and other refined hydrocarbon products. The implementation of HTER at Sasol Synfuels is described in the paper [1], and shortly repeated here.

HTER in combination with a tubular reformer for a 206,000 Nm³/h Hydrogen plant is in the design phase and will become reality within a few years. Application of HTER in ammonia plants in combination with a tubular reformer and a secondary reformer is also very well suitable. This application will be described in more details in this paper. It is shown how HTER for ammonia plants can increase the reforming capacity in existing plants with up to 25% or for a given capacity for a new plant, how HTER reduces the size of the primary reformer.

The recent development of HTER for ammonia offers a very high reforming temperature resulting in low methane slippage without operating at high steam to carbon ratio (S/C). A low methane slippage is crucial for ammonia plants as the methane will otherwise end up in the ammonia synthesis affecting the rate of reaction. The overall S/C in the ammonia plant with both primary/secondary reformer and HTER is kept at the same level as for conventional plants with only primary/secondary reformer. The low methane slippage is obtained with HTER, without increasing the outlet temperature from primary reformer because the required process air is still introduced in the secondary reformer (which leads to a lower methane slip from the secondary reformer), whereas only part of the feedstock passes through primary and secondary reformer.

3.2. First Industrial Experience with HTER

Sasol Synfuels successfully operates a very large facility in Secunda, South Africa, for conversion of coal to liquid fuels and other refined hydrocarbon products. One of the important process steps on the way to the final products is the reforming section in which a methane rich gas is converted to syngas on the basis of autothermal reforming using Topsøe's burner technology. Sasol operates 16 parallel autothermal reformers (ATRs), each with a capacity equivalent to a syngas production for a 900 to 1025 MTPD ammonia plant.

Sasol Synfuels is actively pursuing opportunities for reforming capacity increase, in particular, opportunities that allows capacity increase without an increase in oxygen consumption. This is achieved with the Haldor Topsøe Exchange Reformer (HTER)

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technology, where the sensible heat from the ATR effluent is effectively utilised for steam reforming rather than for raising less valuable steam. In this way, a significant capacity increase can be achieved and at the same time the carbon and hydrogen efficiencies of the process are improved and, as a third and very important benefit, the hydrogen/CO/CO₂ ratio of the syngas can be controlled to match the stoichiometry of the downstream processes much better.

Figure 1 is a sketch of the reformer section of the Sasol Synfuels plant prior to the revamp.

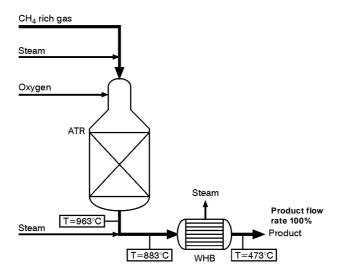


Figure 1: Layout of reforming section prior to revamp

The layout is quite conventional with the high level heat of syngas being cooled in a steam generating waste heat boiler placed downstream the oxygen fired ATR. One of the limitations to the process in the Sasol plant is the waste heat boiler inlet temperature as well as the duty. Both are stressed to or beyond the original design capacity and in order to protect the boiler, steam is used to quench the gas before the entrance to the boiler. This is obviously not optimal from an energy perspective.

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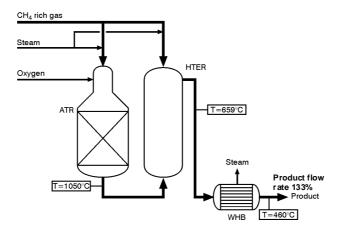


Figure 2: Layout of reforming section revamped with an HTER in parallel with the ATR

A more efficient process would be feed-effluent heat exchange at high temperatures reducing the oxygen required inside the reformer or, more attractively, increasing the total syngas product flow by driving additional endothermic reforming reaction with the high level heat. This process concept is depicted in Figure 2, where the HTER taking care of the additional reforming is installed in parallel with the ATR. This revamp scheme was chosen for the Sasol Synfuels project.

The revamped unit was started up early 2003 and an extensive full scale 22-month long demonstration run was performed at Sasol to prove the viability of the concept. The ATR/HTER pair has been in operation since and meets all expectations.

Since the initial start-up, there have been no unforeseen stops that were related to the HTER, and the HTER has been in continuous operation with the exception of planned shut-downs and the period of by-pass operation. This has led to a high availability factor (97%).

The HTER has been shut down at a number of predetermined occasions for inspection. The main purpose of these inspections has been to verify the mechanical integrity given the high material temperatures experienced in this piece of equipment and to examine for signs of corrosion, viz. metal dusting. It has been concluded from these inspections that the HTER is performing well and the projected life-time of the HTER internal has been confirmed. As an additional benefit, these inspections have served to confirm the maintainability of the HTER, and they have given valuable experience in shutting down and restarting the ATR/HTER pair.



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During the test run, it was shown that the predicted capacity increase and conversion of the revamped unit was reached – in fact, there was some additional capacity in the unit compared to the expected figures of a 33% capacity increase. Likewise, the pressure drops have been found to be stable and well within the anticipated values.

Since this new equipment was built into the plant as a full scale industrial unit with no prior pilot scale or side stream operating experience, the operators were anxious to learn how the reformer pair behaved under industrial conditions with whatever upstream and down-stream fluctuations that could be anticipated. It was found that the ATR/HTER pair was easily operable, however, slightly more sensitive to fast cut-back of the feed or the oxygen than the stand-alone ATRs.

Based on the successful experience with HTER, Sasol Synfuels plans to implement HTER in additional syngas lines. The HTER technology is not only suited for syngas preparation for Coal to Liquids or Gas to Liquids facilities, with minor adaptations it is equally suited to boost the capacity of a methanol or an ammonia producing facility. This option will be discussed further at the end of this paper.

3.3. HTCR Technology

Another reforming technology supplied by Topsøe is the Haldor Topsøe convection reformer (HTCR). HTCR is based on predominantly convective reforming and combines the functions of the radiant and waste heat sections of the conventional reformer in one relatively small piece of equipment [2].

The HTCR is available with capacities up to approximately 15,000 Nm³/h of hydrogen. With a special arrangement using two HTCR reactors operating in tandem, plants with capacities of 30,000 Nm³/h can be designed.

A first generation of the HTCR reformer was introduced to the industry in 1992. This design has since been used for 22 industrial applications. An updated design was introduced to the industry in 2003 and four units have been sold.

The design is based on the use of bayonet tubes, approximately 10 m long. Each bayonet tube is surrounded by a flue gas guiding tube. The HTCR reactor consists of a vertical, refractory lined vessel containing the tube bundle with several bayonet tubes.

Through the many HTCR applications, the bayonet tube principle for heat exchange reforming is now well established.

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3.4. Application of HTER in Ammonia Plants

In the above case for Sasol, the HTER is placed downstream of an ATR, but the HTER is equally well suited to be located after a secondary reformer or even downstream a stand-alone tubular reformer. The technology is thus interesting in many business areas such as hydrogen production, methanol production, GTL/CTL and ammonia production. In this section, we shall be looking specifically into the HTER option for ammonia plants – both as a revamp option or as an alternative to the classical layout for a grass-root plant.

Figure 3 is a sketch of a traditional ammonia plant front-end (reforming only) with a tubular primary reformer and an air fired secondary reformer followed by a Waste Heat Boiler (WHB). This unit can be revamped with an HTER in parallel (HTER-p) to the primary reformer as is shown in Figure 4.

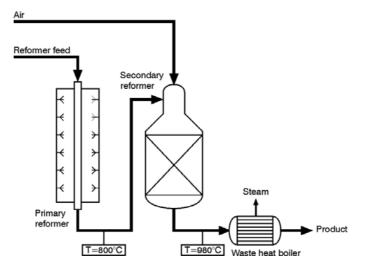


Figure 3: A traditional ammonia plant front-end

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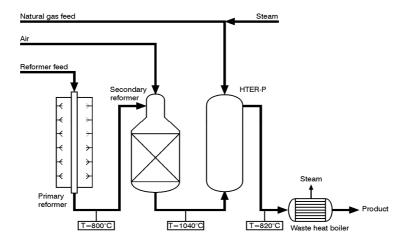


Figure 4: Ammonia plant front-end including an HTER-p

The parallel option can be executed in two ways: either the effluent from the secondary reformer (or ATR) is mixed with the reformed gas coming out of the HTER catalyst bed before cooling of the combined product gas takes place, or the two streams are cooled separately and mixed at the exit. Both ways have their advantages, and the selection of option depends on the circumstances. For the revamp case at Sasol Synfuels, the first option was chosen. In other cases where a low CH₄ leakage is crucial such as in syngas production for ammonia, the second option is the most attractive.

The HTER design can be made to accommodate both the above options and otherwise be optimised to suit the process requirements in the best possible way. The main features of the HTER will in all cases be the same as those demonstrated industrially at the Sasol Synfuels Gas Reforming Plant. The HTER suited for an ammonia plant will be made up of a number of double tubes that are furnished with a bayonet return tube. The heat transfer is laid out in such a way that only a very limited surface area will be subjected to metal dusting conditions, and consequently, the use of special resistant materials can be minimised.

Because of higher S/C in the process gas, there are less severe conditions with regards to metal dusting in HTER for ammonia compared to HTER for syngas. This will result in very long lifetime and again minimises use of special resistant material.

Process and design-wise Topsøe has many years of experience and more than 25 references with the design of bayonet tubes for reforming from our HTCR technology.

The obvious advantage of HTER for ammonia is besides the reduction in primary reforming duty that it offers a very high reforming temperature. A high reforming



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temperature results in a low methane slippage even with a S/C ratio at the same level as used in a traditional primary reformer for ammonia. The overall S/C ratio used in the front-end with HTER is the same as in the traditional front-end for ammonia.

In the case with HTER (Figure 4), it shall be noted that the outlet temperature from primary reformer is not higher than in the traditional case (Figure 3).

For a given capacity, HTER reduces the size of primary reformer for two reasons. Firstly, because part of the reforming duty is transferred to the HTER. Secondly, because the secondary reformer will perform better, as the total amount of process air, which is determined by the ammonia capacity, is fed to the secondary reformer and only part of the feedstock passes the secondary reformer. When the secondary reformer operates with a higher ratio of process air to process gas, the exit temperature will increase and the methane slip decrease.

To illustrate a revamp situation for an ammonia plant, a comparison between a base case and the revamp case is made in Table 1. As can be seen, a 25% increase in reforming capacity and equivalent ammonia production can be achieved by introduction of the HTER. It is noted that this capacity increase could equally well be translated into an unchanged capacity and a correspondingly smaller load on the primary reformer.

	Base Case	HTER Revamp Case	Change
Dry product flow, kNm ³ /hr	280	351	+25%
Equivalent NH ₃ production, MTPD	2225	2800	+25%
CH₄ leakage	0.44	0.38	
Steam production in syngas WHB	100%	90%	

Table 1: Key figures for the base case and the same ammonia plant revamped with an HTER.

The steam production in the syngas WHB is lowered by 10% only, but it should be emphasised that the total steam production in the plant (including the ammonia loop) is essentially unchanged. This means that it will not be necessary to upgrade the steam system in the plant, which will save both time and investment cost for the revamp. It can also be noted that the methane slip is kept around the original level in order to keep the inert level in the loop unchanged.

The above case clearly demonstrates that the HTER technology is attractive as a revamp option for an ammonia plant. The HTER is, however, also an attractive solution



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for a new grass-root plant. In Table 2, a comparison is made between the conventional based front-end and the HTER based front-end for the reforming section.

	Conventional	HTER
Primary reformer, No. of tubes	350	276
Secondary reformer diameter, mm 5	5000	4600
CH4 leakage, dry mole%	0.80	0.40
Total steam production, t/h 5	552	462

Table 2: Conventional vs. HTER based front-end for a new plant based on 3300 MTPD ammonia production.

As such, the benefit of introducing an HTER can either be harvested in terms of a significant capacity increase if an existing plant is revamped, or as an option to minimise the size of the primary reformer in a new plant and thereby save capital cost and improve operability of the plant. An additional benefit for a new ammonia plant is that the steam production and the steam consumption is partially balanced, i.e. virtually no steam import/export. This would be of particular interest for a stand-alone ammonia plant.

In the revamp option, the mechanical layout needs special consideration based on the actual available space in the plant. Often it is possible to locate the HTER next to the secondary reformer and re-route the exit transfer line to the bottom of the HTER. The combined exit gas from the HTER is led back to the existing WHB, preferably without moving any equipment in the front-end. It should be noted that there is no need for any special start-up system, because the HTER is easily heated up and put on-stream together with the primary and secondary reformers.

3.5. Conclusion

Topsøe has successfully demonstrated technologies within heat exchange reforming. Haldor Topsøe Exchange Reformer (HTER) has been in successful operation at the Sasol Synfuels plant in Secunda, South Africa, for more than 3 years. The HTER, which is a full scale plant, has been operating on a commercial basis for the entire period. Through more than 25 HTCR applications, the bayonet tube principle for heat exchange reforming is now well established.

HTER is a promising technology which is attractive not only in a synthetic fuels plant or hydrogen plant. The HTER is very well suited for ammonia and offers a very high



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reforming temperature. Even with an overall steam to carbon ratio kept at the same level as for new conventional ammonia plants, the HTER solution results in a reduced methane slippage which is crucial for ammonia production.

As the example in this paper has demonstrated, significant increases in ammonia production can be achieved if an ammonia plant with a traditional front-end layout is revamped with the HTER technology. Likewise, it has been shown that a new plant can be designed with a smaller and less costly primary reformer when an HTER is installed from the beginning.

3.6. References

- [1] Thomsen, S. G., Han, P. A., Loock, S., and Ernst W.: "The First Industrial Experience with the Haldor Topsøe Exchange Reformer" AIChE Ammonia Safety Symposium, Vancouver, 2006.
- [2] Dybkjær, I., Madsen, S. W.: "Compact Hydrogen Plants" Hydrocarbon Engineering, November 2004.

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IJC Experience on Revamping of Sulfuric Acid And Phosphoric Acid Plants

الإتحاد المربح للأسمدة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

Mr. AWINASH PESHWE PLANT HEAD - IJC

Jordan



IJC EXPERIENCES ON REVAMPING OF SULFURIC ACID AND PHOSPHORIC ACID PLANTS

Normally the process plants are designed to nameplate capacities. However, this may not be necessarily true. Usually plants have an inbuilt design margin, leading to incorrect operating constraints that cost a loss of production & in turn revenue. On the other hand, bottlenecks are often existing due to poor design and or poor control. These tend to result in having reduced throughputs. It was generally presumed that a new plant could produce at least 10% to 15% more than its nameplate capacity.

Today, however, we see plants being expanded to higher capacities due to a combination of new technology and improved operating techniques. Modernization and optimization are the key factors for long-term successful plant operation. Plant debottlenecking for incremental capacity or product quality changes costs less than a new plant. To plan the revamp the equipment needs to be analyzed, performance history checked and integrated with new equipment and desired process changes. Correctly identifying both limits and opportunities gives the lowest investment revamp. Processes include more than just equipment, operating conditions or using totally the out of box solutions. Correctly integrating equipment and process evaluation requires good field test data, an accurate analysis of the data. The revamp is not the same for all cases. Every plant is different. All equipment and every process have different limits and different capabilities.

Debottlenecking is like removing the weakest link in a chain, maximum production capacity of any process is limited by the lowest capacity steps in the process.



We, at INDO-JORDAN CHEMICALS CO LTD. (hereafter referred as IJC) are operating the 2000 TPD Sulfuric acid and 700 TPD Phosphoric acid plant. Some of our experiences are -

Bottleneck due to Waste Heat Boiler (WHB) pressure drop – Sulfuric acid plant

In the sulfuric acid plant, ash slippage through the sulfur was getting deposited in the waste heat boiler tubes, which limited the air flow and resulted in additional pressure drop. Root cause of ash slippage in the sulfur was identified as the pumping compartment in the filtered sulfur storage tank and filter outlet product to the storage tank were together on the same location. Then the filter outlet sulfur lines were rerouted / corrected in such a way that, the filtered sulfur storage tank will act as storage cum settling tank. This has resulted into following major advantages.

- Ash carry over in the furnace resulting into chokes in waste heat boiler tubes is minimized.
- The choke in the convertor first bed due to ash carry over is also minimized.

This reduction in pressure drop of the system has helped in smooth operation and saving in recurring energy.

Also, sometimes a fresh view of an operating facility can lead to debottlenecking ideas. Both revamp work and troubleshooting can be part of a plant debottlenecking effort.

Bottleneck due to limitation on sulfur flow to furnace - Sulfuric acid plant

Sulfur feed flow to the sulfuric acid plant furnace was observed as major bottleneck when the plant load was increased above 100 % due to sulfur feeding pumps pumping capacity. Though the pump can be replaced with higher capacity



pump, which can invariably have high replacement cost and high recurring cost due to higher rating of the pump and motor, this problem was attended in a reverse way that the back pressure in the discharge line was reduced by changing the size of the sulfur gun spray nozzles. Presently, these guns are capable of pumping up to a load of 125 % when other equipments in the system permit. This not only removed the bottleneck but also has resulted into saving of 6 kwh, which is indeed a great saving on annualized basis.

Bottleneck due to limitation on cooling water system – Phosphoric acid plant

Cooling water pumping to the process was considered as one of the major limitation factor for operating the plant at higher loads, while the other systems are adequate, i.e. key parameter of any phosphoric acid plant is the reaction temperature, which was not able to maintain due to inadequate cooling. Though the cooling water pumps are capable of pumping required flow of acidic water and pressure, it was not delivering its duty.

We worked out the total energy balance across the cooling system and studied the flow network.

Three pumps discharge lines were connected together in same header. Hence the discharge lines were corrected; this resulted into substantial improvement in the flow. Slurry cooling system network along with its cooling stages were also modified. This debottlenecking is helping us in maintaining the reaction temperature at the desired level and also in maintaining the P2O5 concentration in product acid.

The goal of a revamp is to improve some basic parameters such as capacity or processing efficiency. In contrast, troubleshooting merely aims to solve a problem that hampers current operation. Often, the problem exposes an opportunity for much greater gain in performance. Both revamp and



troubleshooting require open-minded thinking and proficiency with engineering tools. Both often rely on test runs to diagnose problems and uncover design errors or inaccuracies in equipment ratings.

The driving forces behind a revamp exercise may be a combination of the following items:

- 1. Understanding the process technology and available new ideas or technologies.
- 2. Knowing the mass and energy balance of the whole plant.
- 3. Using the available history of the plant with all relevant trends and creeps
- 4. Carrying out the simulation of all available data.
- 5. Taking trials in lab and on pilot plant scale.

Understand the process

A prerequisite for making a reasonable revamping effort or having any hope of a successful revamp is to have a thorough knowledge of the process.

Remember revamping in the traditional manner will get you whatever spare capacity the original designer left in the unit, at about the same yield and specific energy consumption. Tackling the same revamping with a creative approach could gain much more capacity and reduce operating cost at the same time.

Revamping on process efficiency and the capacity – Phosphoric acid plant

To enhance the efficiency and capacity, we had studied two different options viz.

- (a) Increasing the area of filtration
- (b) Converting the existing hemi hydrate process to hemi dihydrate



Increasing the area of filtration

After studying the down time analysis and various problems in the process, it was concluded that the efficiency of the filtration can be improved by providing the additional filter (third filter).

In hemihydrate process filter has very high choking tendencies resulting in loss of production and hence it requires periodical washing cycle. This drastically reduces the availability of filters.

If the area of filtration is increased by providing the third filter as additional one, the availability of filter goes up by 8–10 % with the improved filtration and resulting in better efficiency.

Conversion of Hemi Hydrate (HH) to Hemi Di Hydrate (HDH) process

Possibility of converting the existing HH process to HDH process was studied in laboratory, various trials were carried out. It clearly indicated that HDH process can result in to improvement of P2O5 recovery efficiency by at least $8-10\,\%$ with improved production.

IJC is seriously thinking to explore one of the two options.

We, at IJC are involving the people, suggestions are welcome. The ideas and bottlenecks are discussed; ownership is given. **This has been seen to make remarkable things to happen**;

We at IJC have found the success rate of debottlenecks are almost 100% due to team work and involvement at all level.



Authors -

- 1. Mr. Faisal Doudin, Managing Director
- 2. Mr. Awinash Peshwe, Plant Head
- 3. Mr. AL Subramanian, Process engineer

WELCOME TO DELEGATES EXPERIENCES ON REVAMPING OF SULFURIC ACID & PHOSPHORIC ACID PLANT FAISAL DOUDIN, MANAGING DIRECTOR AWINASH PESHWE, PLANT HEAD FROM INDO JORDAN CHEMICALS CO.LTD

ABOUT - INDO JORDAN CHEMICALS



- 2000 TPD Sulfuric Acid Plant based on DCDA process with technology from M/s. MONSANTO, U.K
- 700 TPD Phosphoric Acid Plant based on SINGLE STAGE HEMIHYDRATE process with technology from – HYDRO AGRI, BELGIUM
- 12 MW power plant
- · Export terminal at Aqaba port

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DEBOTTLENECKING - AN OVERVIEW



- Debottlenecking is like removing the weakest link in a chain.
- Key factors on debottlenecking:
 - (a) Understand the inbuilt design margin
 - (b) Identify the weak links
 - (c) Pinpoint the incorrect operating methods and correct the operating constraints
 - (d) Modernization & Optimization of all equipments and parameters

3

SULFURIC ACID PLANT



ASH SLIPPAGES

Issue : Ash slippage through sulfur and depositing

on waste heat boiler tubes / converter.

• Effect : Additional pressure drop and limiting the

air flow, increasing the energy requirement.

• Cause : Incorrect feed point and pumping location

in the filtered sulfur tank.

• Actions : Filter outlet pipe lines were relocated.

Benefits : Waste heat boiler chokes & Converter

I bed choke got minimized.

 This reduction in pressure drop of the system is helping in smooth operation & saving in recurring energy.

4

SULFURIC ACID PLANT



LIMITATION ON SULFUR FLOW

• Issue : Sulfur flow limitation for higher loads

• Effect : Loss of additional production though the

other systems permit.

Cause : Constraint in sulfur feeding network.Actions : Sulfur guns design was checked and

rectification carried out.

• Benefits : Weak link removed, Load can be

increased to 125 %.

This not only removed the bottleneck but also has resulted in saving of 6 KWHr, which is indeed a great saving on annualized basis.

5

PHOSPHORIC ACID PLANT



COOLING WATER SYSTEM - LIMITATION

Issue : Poor condenser efficiency and

insufficient flow of cooling water, for the

higher loads.

Effect : Constraint on controlling the reaction /

concentration temperature.

• Cause : Inadequate condenser stages and three

cooling water pumps on same header

Actions : Cooling water pump discharge lines were

corrected and condenser redesigned.

• Benefits : Maintaining the reactor / concentrator

temperature on desired level. This is helping

in maintaining the P2O5 concentration.

Ь

REVAMP – AN OVERVIEW



- The goal of a revamp is to improve some basic parameters such as capacity or processing efficiency.
- Driving forces behind a revamp may be a combination of the following:
 - (a) Understanding the process & new ideas
 - (b) Knowing the mass & energy balance
 - (c) Using the available history with all relevant trends
 - (d) Carrying out simulation of all available data
 - (e) Pilot plant scale trials

7

REVAMPING ON PHOSPHORIC ACID PLANT



To enhance the efficiency and the capacity, two options were studied.

- (a) Increasing the area of filtration
- (b) Converting the hemihydrate process to hemidihydrate
- Increasing of filtration area will increase the filter availability factor.
- Process conversion from HH to HDH will result in to efficiency improvement.

8



We, at IJC, are involving the people, suggestions are welcome. The ideas and bottlenecks are discussed, ownership is given.

This has been seen to make remarkable things to happen.



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Replacement of High Pressure Scrubber in SAFCO-II Urea Plant

الإتصاب الصربح للأسمدة هيئة عربية دولية Arab Int'l. Organization

Arab Fertilizers Association

Mr. Bellary Muhammad Usman Maintenance Superintendent - SAFCO

Saudi Arabia



REPLACEMENT OF HIGH PRESSURE SCRUBBER AT SAFCO UREA PLANT, JUBAIL, SAUDI ARABIA

SLIDES - 19 SABIC affiliate

CONTENTS

- **□** OBJECTIVE
- □ PROJECT CHALLENGES
- □ REPLACEMENT OF HIGH PRESSURE SCRUBBER
- □ SUCCESS STORY
- □ CONTRIBUTING FACTORS
- □ PROJECT PHOTOS & VIDEO





OBJECTIVE

To Share SAFCO experience in,

► Replacing old H.P. Scrubber with new one to Enhance SF-II Urea Plant Reliability.

Events captured during successful replacement of new High Pressure equipment is shared to the benefit of all SABIC Plants.



CHALLENGES IN HAND

- ► Manufacture and transport new H.P. Scrubber from Austria to SAFCO.
- ▶ Replace the old H.P Scrubber with new one at 80mtr elevation.
- ▶ Remove and restore Connected Piping and Structures to facilitate replacement of H.P. Scrubber.



REPLACEMENT OF H.P. SCRUBBER

- i. PROJECT TARGET
- ii. PROJECT MILESTONES
- iii. PRE-SHUT DOWN PHASE- PLANNING
- iv. SHUT DOWN PHASE EXECUTION

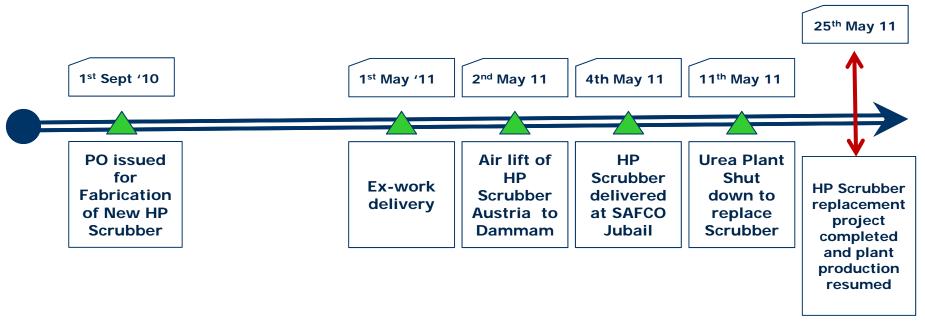


i. PROJECT TARGET

This Project is a sequence of unique, complex and connected activities having one goal and that must be completed within Planned duration, within budget

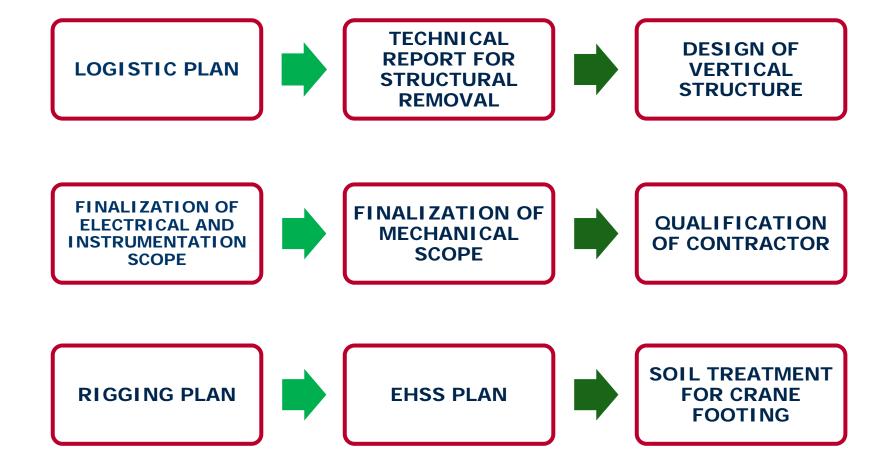


ii. PROJECT MILESTONE (NEW SCRUBBER)



	Project Status				
Activity	Contra	actual	Actual		
	Start	Completion	Start	Update	
Engineering	15/09/2010	07/01/2011	15/09/2010	07/01/2011	
Material Order & Delivery Status	11/10/2010	07/04/2011	11/10/2010	01/03/2011	
Fabrication & Testing	07/12/2010	01/05/2011	07/12/2010	01/03/2011	
Transportation	02/05/2011	02/05/2011	02.05.2011	02.05.2011	

iii. PRE-SHUTDOWN PHASE PLANNING





PRE-SHUTDOWN PHASE PLANNING

Contd · · ·

NEW SCRUBBER PREPARATION



HEAVY LIFT CRANE ASSEMBLY



WELDERS QUALIFICATION

CRANE AND RIGGING TOOLS CERTIFICATION



EXECUTION TEAM MEETINGS



QUALITY ASSURANCE PLAN APPROVAL



iv. SHUT DOWN PHASE- EXECUTION



SUCCES STORY

SF-II UREA PRODUCTION	Before Replacing HP Scrubber	1800 MTPD , Interrupted	Production increase
	After replacing HP Scrubber	1990 MTPD, Continuous	= 190 MTPD



CONTRIBUTION FACTORS: SABIC VALUES

Contributing factors for the successful story as below, but not limited to these



MOTIVATION AND ENCOURAGING THE EXECUTION TEAM AND CONTRACTORS.

UNDERSTANDING THEIR INDIVIDUAL CAPACITIES.



CREATED HEALTHY ENVIRONMENT AND ENSURED ENGAGEMENT OF EXECUTION TEAM AND CONTRACTOR THROUHOUT.





READY AVAILABILITY OF MANUFACTURING TEAM FOR SUPPORT AND APPROVING INITIATIVES OF EXECUTION TEAM.

Create



UNDERSTANDING OF SMT EXPECTATIONS TO DELIVER IN TIME AT OPTIMUM COST.

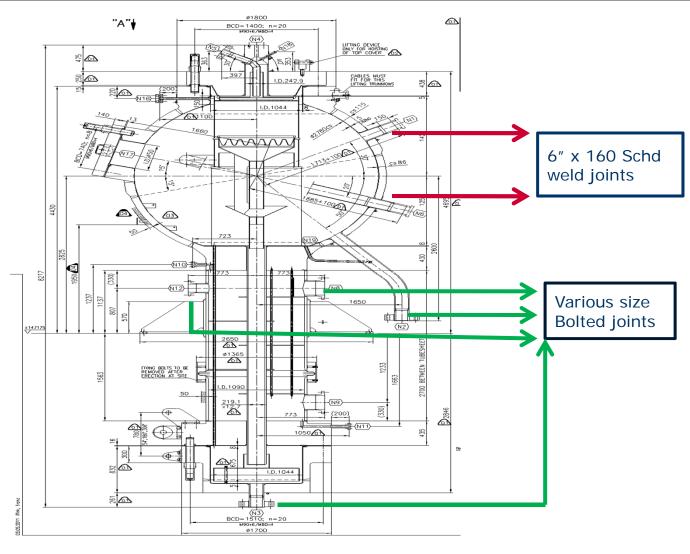
Deliver

11 of 19

All good performance starts with clear goals."



H.P SCRUBEBR CROSS SECTION VIEW





PHOTOGRAPHS - FABRICATION OF H.P.SCRUBBER







PHOTOGRAPHS - TRANSPORT FROM AUSTRIA TO SAUDI ARABIA











PHOTOGRAPHS - SOIL PREPARATION





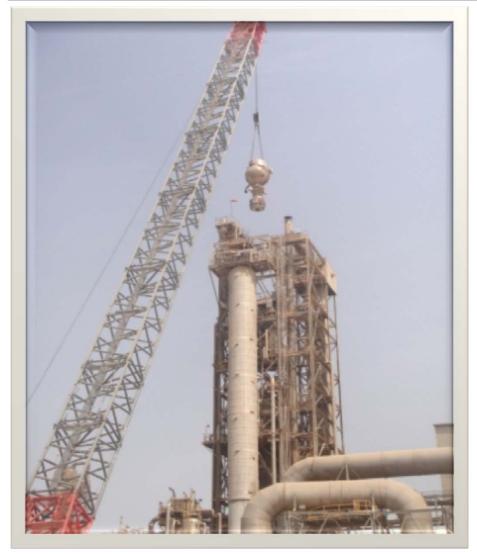




سافکو حمالہ

All good performance starts with clear goals."

PHOTOGRAPHS - OLD SCRUBBER REMOVAL

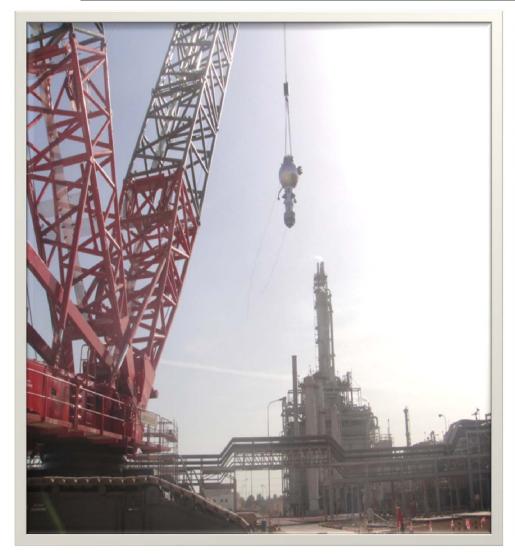






All good performance starts with clear goals."

PHOTOGRAPHS - NEW SCRUBBER INSTALLATION





سافکو معال*ہ*

All good performance starts with clear goals."



مکو

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Meeting environmental issues facing new and existing urea Fluid —bed Granulation with Plants

الإتصاف الصربح للأسمدة Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

Mr. Harald Franzrahe
Process Manager - Uhde Fertilizer Technology B. V.

Netherlands

Meeting environmental issues facing new and existing urea fluid-bed granulation plants

Dr. Harald Franzrahe, Process Manager Uhde Fertilizer Technology B.V.



Abstract: In recent years many environmental regulations have been amended by the regulatory bodies. This has led to a significant reductions in the permissible emission levels for ammonia and urea dust for new urea fluid-bed granulation plants. Existing plant operators are also faced with the demands from their environmental authorities to reduce their emissions to the environment as well.

While the reduction of dust emissions can be achieved by using scrubbing systems with a higher separation efficiency, reducing ammonia emissions in a urea granulation plant is more complicated. In principle significant ammonia reductions can be achieved by installing acidic scrubbing systems well known in the fertilizer industry.

In NPK or AN plants the resulting bleed stream from the acidic scrubber can be reintroduced into the process without any difficulty, as in these plants the bleed contains components which are already present in the plant and the product. For a urea fluid-bed granulation plant the situation is more complicated. In this case the bleed from the acidic scrubber contains components which cannot be processed in a standard urea synthesis and evaporation plant and which until now are usually not part of the product specification.

The bleed from the ammonia scrubber must be processed in some way. This processing can be done in various ways.

In accordance with UFT's commitment to improve the fluid-bed granulation process UFT has developed options for achieving ammonia emission reductions from fluid-bed urea granulation plants.

With UFT's Ammonia Convert Technology the acidic bleed from the ammonia scrubber has been successful integrated into the granulation process.

In this paper various available and industrially proven options for granulation plant operators are presented. In especially UFT's proprietary Ammonia Convert Technology, which combines minimized ammonia emissions with reduced production cost will be discussed.

1 The UFT Fluid Bed Urea Granulation Technology

Figure 1 shows the process flow diagram of the UFT Fluid Bed Urea Granulation process. Heart of the plant is the granulator, where urea solution with a concentration of 97% is atomized into fine droplets and sprayed onto the particles in the fluidized bed. Formaldehyde is added to the urea solution as granulation additive and to improve storage properties.

Crushed oversize and fines coming from the screens are utilized in the granulator as seed material and the particles continuously grow to their desired size by accretion. In the first cooler the product is cooled down and via bucket elevator lifted to the screens, which separate coarse, fine and on-size material. The on-size material is cooled down in the final cooler to the storage temperature and sent to storage.

The major advantage of the UFT fluid bed urea granulation process is the melt concentration of 97% urea. In this way the evaporating water is utilized in the granulator as additional coolant to remove the heat of crystallization. This leads to the following features:

- Single stage evaporation unit in urea synthesis section
- Low biuret concentration in final product
- Low quantities of fluidization air needed in granulator
- Lower investment cost due to smaller granulator, less fluidization air, smaller scrubbing unit and single stage evaporation unit
- Low steam consumption in evaporation and granulation
- Low electrical energy consumption due to low amount of air required

Figure 2 shows a typical plant concept for a world class granulation plant. In this concept it can easily be seen that the treatment of the off-gas from the granulation unit is a large section of the granulation plant. The scrubbing systems for the air from the granulator and the fluid bed coolers therefore contribute significantly to the investment and operating costs of the plant.

Their careful design and good operation are just as important as that of the granulation loop.

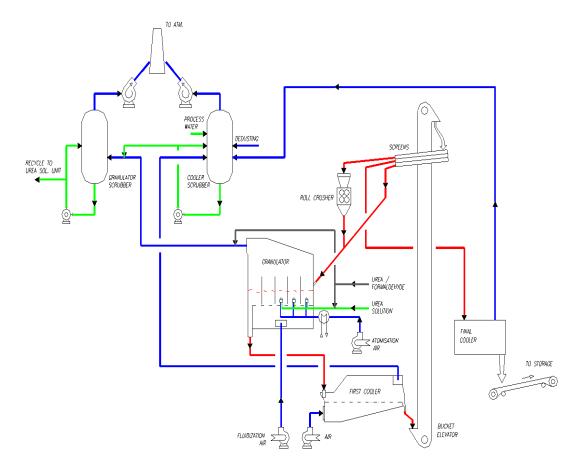


Figure 1 - Schematic of UFT granulation process

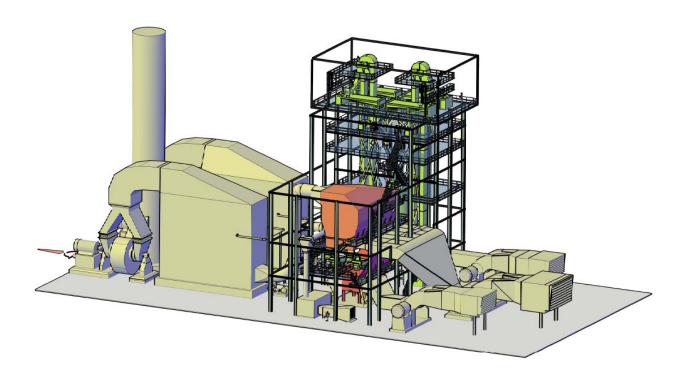


Figure 2 - World Scale Fluidized Bed Urea Granulation Plant

2 Emissions and emission limits from a fluidized bed granulation plant

There are three sources of emissions from a fluidized bed urea granulation plant

- dust or particulate matter
- ammonia
- water vapor (opacity)

Since the last decades emission limits have been a key focus of the environmental protection agencies. With the development of technology and increased public awareness the emission limits required by the regulatory authorities or recommended by leading institutions have been continually reduced. While the reduction of the permissible values primarily focuses on new plants and can be taken into account during the design.

However, with plant lifetimes of over 30 years, some older plants are now also required to achieve lower emission figures then was foreseen during their original design. Alternatively the new emission limits are imposed when the plant is debottlenecked. This poses additional challenges as the limitations of the existing facilities and the available space must be taken into account.

Source	Dust	NH ₃
PPAH (World Bank, 1998)	< 50 mg/Nm³	< 50 mg/Nm³
EFMA BAT Booklet (2001)	< 50 mg/Nm³ < 0.25 kg/to	< 50 mg/Nm³ < 0.25 kg/t
EU BREF LVIC (2007)	< 15 – 55 mg/Nm³	< 3 – 35 mg/Nm³
Saudi Arabia (RCER 2010)	< 0.25 kg/ t	< 50 mg/Nm ³
UAE (2011)	< 30 mg/Nm³	< 30 mg/Nm³
Malaysia (2011)	< 30 mg/Nm³	< 76 mg/Nm³

Table 1 : Development of the emission limits since 1998

While the World Bank or the International Financial Corporation (IFC) do not directly proscribe emission limits, their recommendations form the basis for the international financing organizations. These asses the financing of projects according to the so called "Equator Principles" . This is a financial industry benchmark for determining, assessing and managing social and environmental risk in project financing which is based on the Pollution Prevention and Abatement Handbook (PPAH) of the World Bank.

Currently the PPAH is being revised by the World Bank. From the drafts which have been published it is expected that the recommendations from the European Union BAT Reference document for Large Volume Inorganic Chemistry plants (BREF LVIC) will be the basis for the revised PPAH.

With increasing plant capacities the amount of emitted material from a single source has risen considerably. It is therefore worthwhile to invest in emission reduction systems which return the emitted material back to the process. However, particularly for ammonia emissions, only a few producers have taken up the challenge to reduce the emissions drastically. Available emission reduction technologies often being considered as unattractive or deemed only possible for plants serving a 'closed' market.

3 Dust emissions

The fluidized bed urea granulation plant is a solid-handling process. This means that solid material is transported and handled. In addition a melt is atomized into fine droplets and injected into the fluidized bed. All these actions can lead to dust formation and agglomeration. This is common to all granulation processes and entails that the plant must be cleaned at regular intervals.

Sources of dust:

- granulator (80 90%) mostly coarse dust but also some fine dust which is difficult to remove
- coolers (10 20%) mostly coarse dust, easy to remove
- material handling, in particularly from the crushers only traces

3.1 Dust emissions control

As shown above the operational possibilities to reduce dust emission are limited. Therefore dust scrubbing systems are standard for fluidized bed urea granulation plants. This is not only due to environmental reasons but also as a significant amount of product, which would otherwise be lost, is recovered and reintroduced into the process. A typical example for a dust scrubbing system is shown in Figure 3

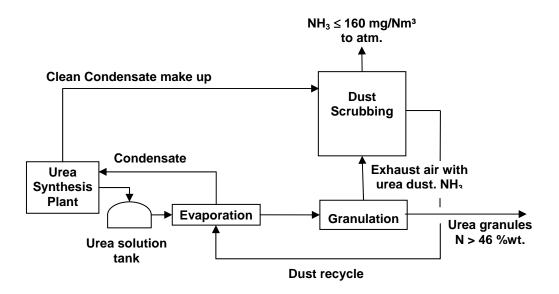


Figure 3: Conventional Urea Dust Scrubbing system

As urea is very hygroscopic wet scrubbing systems are preferred. These systems can utilize the following types of scrubbers :

Vertical scrubbers :

- Venturi type scrubbers
- Tray type types
- Packed bed types, usually with random packing

Horizontal scrubbers

- random packing
- structured packing

As the dust scrubbing systems are purely water based the reduction in ammonia emissions in such a system in minimal.

4 Ammonia Emissions

The ammonia emitted from the urea granulation plant is to a large extent not generated in the granulation plant, but enters the granulation plant with the urea solution. The amount of ammonia contained in the urea solution is the result of the conditions in the evaporation section. The ammonia is released from the urea solution during the spray of the urea solution into the fluidized bed.

If we assume a typical ammonia concentration in the urea solution of 600 ppm wt the ammonia concentration in the off gas is about 130 - 160 mg/Nm³, corresponding to a specific emission of 0.6 -0.7 kg ammonia per ton urea.

A much smaller amount of NH_3 is formed during the formation of biuret in the melt line between urea solution feed pump and the granulator spray nozzles. During the polymerization of urea to biuret ammonia is released, as shown in the reaction below.

$$2 (NH_2)_2CO \rightarrow NH_2C-NH-NH_2CO + NH_3$$

Free ammonia from evaporation section	≈ 500 to 600 ppm wt
Ammonia from biuret formation	≈ 90 ppm wt
Total free ammonia at granulator inlet	590 to 690 ppm wt
Free ammonia in final product	≈ 50 ppm wt
Free ammonia released (based on urea solution)	≈ 540 to 640 ppm wt

Table 2: Sources for ammonia emissions in a fluidized bed urea granulation plant

4.1 Process possibilities to reduce Ammonia emissions

- (1) The atomization and fluidization air to the granulator effectively 'strip' the NH₃ contained in the concentrated urea solution, the NH₃ content in the urea solution should therefore be as low as possible. This can only be done by the adjusting the operating conditions in the urea synthesis and evaporation units.
- (2) The polymerization of urea to biuret releases ammonia, therefore the biuret formation between evaporation and granulation units must be minimized.
 - Do not overheat the urea solution to the granulator e.g. high steam pressure on tracing or jacketing
 - Reduce residence time of urea solution at elevated temperatures (> 120°C)
 - Residence time and biuret content Increase when the capacity of the granulation plant is reduced
 - Do not recycle urea solution unnecessarily.
- (3) The process water from the melt plant often contains NH₃. This water as make-up water for the scrubbing system of the granulation plant. Any NH₃ in the process water will be stripped in the dust scrubbers and increase the NH₃ emissions.

5 Ammonia Emission control

With a purely water based scrubbing system the gaseous ammonia released cannot be removed effectively. The reason is the low solubility of ammonia in water under the prevailing temperature in the atmospheric scrubber (~ 45°C). As the operational options for the reduction of ammonia emissions are limited, additional ammonia reduction systems are required to meet the new environmental legislation.

5.1 Ammonia Abatement System

The ammonia abatement system is based on the reversible gas phase reaction off ammonia with formaldehyde. The formaldehyde is injected into the exhaust air duct from the granulator to the granulator scrubber and in the finely dispersed droplets formaldehyde reacts with the gaseous ammonia to form hexamethylenetetramine.

$$6 \text{ HCHO} + 4 \text{ NH}_3$$
 → $C_6 \text{H}_{12} \text{N}_4 + 6 \text{ H}_2 \text{O}$
Formaldehyde + Ammonia → Hexamethylenetetramine + Water

The hexamethylenetetramine is returned with the urea solution recycle to the evaporation section in the melt plant. Under the prevailing conditions of pressure and temperature in the evaporation unit the hexamethylenetetramine complex decomposes into formaldehyde and ammonia. The ammonia leaves the evaporation section with the vapors and is recovered in the urea synthesis, while the formaldehyde is absorbed in the urea solution and sent to the granulator.

$$C_6H_{12}N_4 + 6H_2O \rightarrow 6HCHO + 4NH_3$$
Hexamethylenetetramine + Water \rightarrow Formaldehyde + Ammonia

In total formaldehyde balance no additional formaldehyde is required to operate the ammonia abatement system. This system was developed and patented by Hydro Agri, the predecessor company of UFT. A number of ammonia abatement systems are in operation. A more detailed description can be found in the literature.

The ammonia abatement system, such as shown in Figure 4, will only reduce the amount of ammonia in the off-gas by approximately 25 - 40%. Unfortunately this is often not sufficient to achieve modern emission levels.

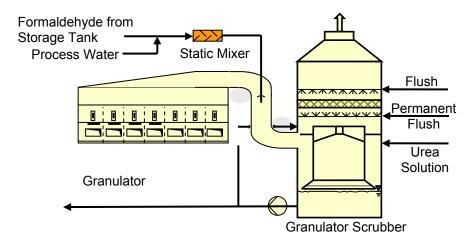


Figure 4 Typical Ammonia Abatement System

As can be seen in figure 4 the ammonia abatement system only requires the installation of a small amount of additional equipment - an additional UF line with a static mixer and a spraying system in the duct between granulator and dust scrubber. The total amount of formaldehyde does not increase! The formaldehyde required according to the product specification is split between the feed to the urea solution and the scrubber.

5.2 Acidic Scrubbing

While such systems are long established in other fertilizer plants e.g. AN/CAN or DAP/NPK, for urea plants these systems produce a fundamental problem. The bleed streams from the ammonia reduction systems introduce foreign components which cannot easily be processed in the NH₃ / Urea complex. These 'new' components, mainly ammonia salts, would cause serious corrosion and other problems for the urea synthesis unit.

With an acidic scrubbing system as shown in Figure 5 the ammonia emissions from a UFT granulation plant can be reduced to less then 0.2 kg/ton of product, corresponding to about 30 mg/Nm³.

Many different acids could be used, in practice only two mineral acids are used. The most common systems use sulfuric acid. This is readily available and the resulting salt solution – ammonium sulfate – is easily handled. The sulfuric acid is added to the dilute circulating ammonium sulfate solution. The slightly acidic and dilute ammonium sulfate solution then fed to an separate acidic scrubbing stage installed downstream the dust scrubbing section. In the acidic scrubbing stage the gaseous ammonia the ammonia reacts with the acid to form ammonium sulfate. The resulting ammonium sulfate solution must be drained off continuously to keep the salt concentration in the acidic scrubbing loop constant.

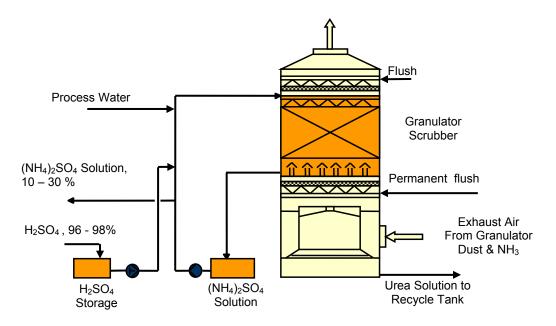


Figure 5 - Typical Acidic Scrubbing System

An alternative to sulfuric acid is nitric acid. The efficiency and the process is the same, but there is a safety issue. Apart from dealing with dilute ammonium nitrate solution there is the danger that at low pH the nitric acid and urea react to form urea nitrate. Urea nitrate is highly explosive. Therefore special attention must be given to control the pH of the acidic scrubbing section. In addition great care must be taken to prevent dead – spots in the equipment and piping where nitrate containing material could crystallize and accumulate.

Basically the same safety requirements as are required for the handling of dilute ammonium nitrate solutions must be implemented. These require special pump designs, additional instrumentation and washing facilities that ensure that all traces of nitrate containing material are flushed from the scrubbing system thereby preventing any accumulation of nitrate material, e.g. in areas of the scrubber system which are not wetted continuously.

Ammonium sulfate can be used as a liquid fertilizer, as a feed stock in a NPK plant or crystallized. The nitric acid option is usually only feasible for sites which have a nitric acid / ammonium nitrate facilities. In this case the ammonium nitrate solution can be sent to the ammonium nitrate plant, e.g. for producing UAN solution.

While conventional acidic scrubbing (Figure 6) systems are very efficient and well proven, they require a number of additional measures:

- precise separation of the dust and ammonia removal sections.
 This requires separate scrubber stages and separate scrubber circulations systems
- they produce a salt solution which is not easily integrated into the existing facility.
 As the salt solution cannot be disposed to a waste water treatment facility, it requires additional units, e.g. a crystallization unit or a UAN plant.

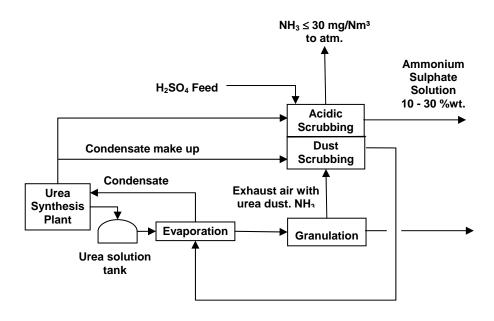


Figure 6 Conventional Acidic Scrubbing System

5.3 Ammonia Convert Technology

The objectives for the development of the UFT proprietary Ammonia Convert Technology were:

- Reduction of ammonia emission by at least 80%
- System to be simple and reliable
- No side stream of scrubbing solution of acidic scrubber
- No contamination of the urea synthesis with ammonia salts
- Overall economics to be feasible

Based on these objectives and the experience gained from acidic scrubbing systems, the scheme shown in Figure 7 has been developed.

In the granulation plant in additional acidic scrubber stage is installed downstream of the dust scrubber. This is to ensure that only a nearly dust free gas flow enters the acidic scrubbing stage. Otherwise the urea would be decomposed by the acid. The ammonia is absorbed in the acidic scrubbing system and is converted into ammonium sulfate.

The bleed of the combined scrubbing system is sent to a small evaporation unit, consisting of a single stage vacuum evaporator. In this small evaporation unit the urea solution containing the ammonium salt is concentrated up to the urea content required for granulation and is subsequently mixed with the 'fresh' urea solution coming from the vacuum evaporation unit of the urea synthesis plant.

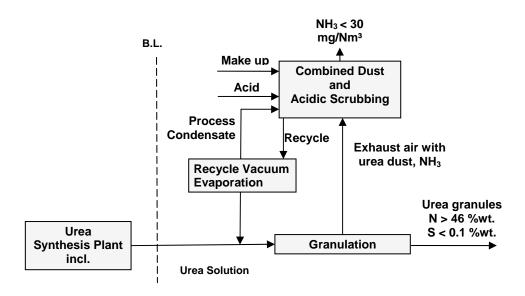


Figure 7 - UFT proprietary Ammonia Convert Technology (ACT)

To avoid entrainment of sulfur and/or sulfuric acid into the urea synthesis plant, the vacuum section of the small evaporation stage and the process condensate from the vacuum condenser are separated from the urea synthesis plant. The vapors of the small evaporation unit are condensed and used as make up for the combined acidic and dust scrubbing system. Depending on the composition of the incoming urea solution from the urea synthesis plant additional condensate make-up with clean condensate might be required.

The process vapors of the vacuum evaporation in the urea synthesis plant are returned to the desorption and hydrolysis section of the urea synthesis plant.

The result is an ammonia concentration in the off gas from the granulation of less than 30 mg/Nm³ of air.

The separation of the recycle flow from the urea synthesis plant has some interesting aspects:

Evaporation section:

- Same total evaporation load, but split over a big and a small evaporation unit
- In total same steam and cooling water consumption

Desorption & Hydrolysis:

- Reduced load on desorption / hydrolysis section, means
- Lower investment cost (smaller equipment)
- Less steam consumption

For existing plants the proposed scheme makes spare capacities available in the existing evaporation section as well as in the desorption and hydrolysis section, because there is less condensate to be

treated. The spare capacity gained is about 15% of the total plant capacity. So the ammonia convert technology is an excellent revamp option.

What about the product?

Urea granules consist of urea incl. biuret, formaldehyde and moisture. The market requirement is for 46 %wt Nitrogen minimum, which corresponds to 98.57 weight % urea. The remaining 1.43 %wt are additional urea, formaldehyde and moisture and typically contains 0.45% formaldehyde, 0.2 % moisture and 0.78 % urea incl. biuret.

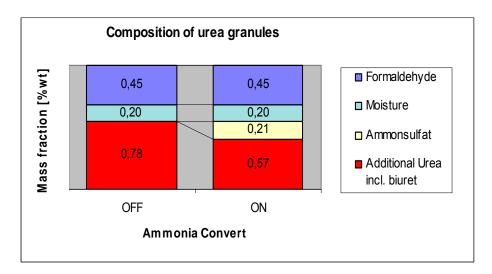


Figure 8 – Comparison of product composition

If the Ammonia Convert Technology is applied, a part of the urea is replaced by ammonium sulphate. The resulting sulfur content in the final product is than roughly one quarter of the ammonium sulphate content. Under typical operating conditions the sulphur content in the product will be about 0.05 wt. %.

5.4 Comparison of Ammonia emission reduction systems

In Table 3 the various NH3 emission reduction systems are compared. To completely meet current and expected emission regulations for NH3 an acidic scrubbing system must be installed. Acidic scrubbing systems deliver a bleed stream containing an ammonium salt. This bleed can be processed externally or integrated into the urea production. The latter option is implemented in UFT Ammonia Convert Technology, which as a consequence has the lowest operating costs of all options

Reduction system	Ammonia Abatement	Acidic Scrubbing	Ammonia Convert Technology (ACT)
Emission reduction by	25 to 40 %	> 80 %	> 80 %
Waste stream	None	Approx. 2 kg AS/mt urea as 30 - 40% solution	None
Operations	Easy	Easy	Easy
Additional investment	Low	Moderate	Cost efficient
Operating cost	Low	Moderate	Minimum

Table 3 – NH₃ emission reduction systems

When the Ammonia Convert Technology is implemented there is, beside the positive impact on emission reduction, a remarkable economical impact as well. The market pays for 46 %wt nitrogen in (granular) urea, but the actual nitrogen content is higher and reaches usually close to 46.3 %wt. This means there is a surplus of urea added to the product, which the producer does not get paid for. By adding ammonium sulfate part of the surplus urea is replaced by the ammonium sulfate. The production cost for the ammonium sulfate produced in the Ammonia Convert process is much lower than for urea.

The additional investment required for the Ammonia Convert Technology is an additional acidic scrubbing stage, a sulfuric acid dosing system and some modifications in the evaporation and condensation / vacuum section. This is easy to consider for the design of a new grass root plant and is possible to be implemented in an existing plant as well.

The financial pay-off time of the system is a few years only and from then onwards there is a positive cash flow. The return of investment with respect to image and acknowledgement by the customer and in the community is for the lifetime of the plant.

6 Options during Revamp or Debottlenecking

Frequently when plants are revamped or modernized the existing scrubbing system is a bottleneck.

Apart from the desired capacity increases which entail higher air flows, new emissions limits must also be considered. Such a situation was faced by one of UFT's clients recently

Objective

- Nameplate capacity to be increased by 20%
- Usage of existing equipment to maximum extent
- Minimum of shut down time for modifications
- Minimum investment costs for new / modified equipment

- No compromise on product quality and environmental aspects

Problems:

- Layout restrictions for new / exchanged equipment
- Steel and concrete structure restrictions
- Increased pressure drop of scrubbers due to requirement of higher fluidization air flows
- Limited spare capacity of major rotating equipment, especially scrubber exhaust fans

Approach:

- Enlargement of static equipment to the optimum usage of available space inside the building considering refined distribution of cooling duties
- Replacing the internals of the existing high pressure drop Venturi-type scrubbers with two stages of low pressure drop structured packing type.

The use of the structured packing reduced the pressure drop of the existing scrubber to about 1/3 of the original value. In this case the new increased air flow can be handled by the existing scrubber and the existing scrubber exhaust fan.

The new internals are arranged in two stages, therefore one stage could be used for a acidic scrubbing if required at a latter stage.

7 Summary

The ammonia emission reduction technologies available have all one or another draw back. Either the achievable reduction is limited (ammonia abatement system) or a waste stream is generated, which can not be treated economically in a stand alone ammonia/urea complex

The proposed Ammonia Convert Technology is based on an acidic scrubbing stage and a recycle of the obtained ammonium salt into the final product. This allows reduction of ammonia emission to very low levels, while at the same time avoiding an unwanted liquid waste stream.

The Ammonia Convert Technology is beneficial to the environment as it reduces ammonia emissions drastically. At the same time production cost for granular urea can be reduced. Finally a urea fertilizer as produced, which gives added value to the consumers due to the content of micro nutrients while still supplying a nitrogen content of min. 46 %wt.

8 Reference List of UFT Fluid Bed Urea Granulation Plants with Ammonia Emission Reduction Systems

Date of Order	Client	Location	Capacity (MTPD)	Ammonia emission reduction scheme applied
2011	OLAM	Port Gentil, Gabon	3,850	Ammonia Convert Technology
2011	SAMUR	Malaysia	3,850	Prepared for Acidic Scrubbing
2010	Petrobras	Tres Lagoas, Brazil	3,600	Ammonia Convert Technology
2009	Qatar Fertilizer Co. (Qafco VI)	Mesaieed, Qatar	3,850	Ammonia Abatement System
2009	Ruwais Fertilizer Industries (Fertil II)	Abu Dhabi U.A.E.	3,500	(Acidic Scrubbing – under discussion)
2009	CF Industries	San Juan de Marcona, Peru	3,850	Acidic Scrubbing
2009	Hengam Petrochemicals	Bandar Assaluyeh, Iran	3,250	Acidic Scrubbing
2008	Algeria Oman Fertilizer Company (AOFP)	Arzew, Algeria	2 x 3,850	Acidic Scrubbing
2008	Qatar Fertilizer Co. (Qafco V)	Mesaieed, Qatar	3,850	Ammonia Abatement System
2006	Ruwais Fertilizer Industries (Fertil I)	Abu Dhabi U.A.E.	2,500	Ammonia Abatement System (Acidic Scrubbing – under discussion)
2005	Sohar International Urea & Chemical Industries S.A.O.C. (SIUCI)	Sohar, Oman	2 x 1,750	Ammonia Abatement System
2003	Saudi Arabian Fertilizer Co. (Safco IV)	Al Jubail, Saudi Arabia	3,600	Prepared for Acidic Scrubbing
2002	OMIFCO	Sur, Oman	2 x 2,530	Ammonia Abatement System
2001	Saudi Arabian Fertilizer Co. (Safco III)	Al Jubail, Saudi Arabia	1,800	Acidic scrubbing, by owner
2001	China National Off Shore Oil Corp.	Basuo (Hainan), P.R. China	2,700	Ammonia Abatement System
2001	Qatar Fertilizer Co. (Qafco IV)	Mesaieed, Qatar	3,500	Ammonia Abatement System
2000	Petrochemical Industries Company (K.S.C.)	Shuaiba, Kuwait	1,750	Ammonia Abatement System
1999	NamHae Chemical Co.	Yochon, (Yosu) South Korea	1,500	Acidic Scrubbing
1998	FertiNitro S.A.	Jose, Venezuela	2 x 2,200	Ammonia Abatement System
1998	Incitec Ltd.	Gibson Island Australia	950	Ammonia Abatement System

Date of Order	Client	Location	Capacity (MTPD)	Ammonia emission reduction scheme applied
1998	Petrochemical Industries Company (K.S.C.) (PIC)	Shuaiba, Kuwait	1,750	Ammonia Abatement System
1997	Saudi Arabian Fertilizer Co. (Safco II)	Al Jubail, Saudi Arabia	1,800	Acidic scrubbing, by owner
1996	Petronas Fertilizer Sdn. Bhd. (PFK)	Kedah, Malaysia	2,000	Ammonia Abatement System
1996	Yara Belle Plaine (formerly Saskferco Inc.)	Belle Plaine, Saskatchewan, Canada	Revamp to 2,850	Acidic Scrubbing (by owner, with Nitric Acid)
1996	Yara Sluiskil B.V.	Sluiskil, The Netherlands	Revamp to 1,050	Acidic Scrubbing
1978	Yara Sluiskil B.V.	Sluiskil, The Netherlands	800	Ammonia Abatement System
1975	Yara Sluiskil B.V.	Sluiskil, The Netherlands	150	Acidic Scrubbing

9 Literature

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Best Available Technology in Fertilizer Industry :
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Revamping of a Conventional Total Recycle Urea Plant

الإتحاد العربك للأسمدة

هیئة عربیة دولیة Arab Int'l. Organization

Arab Fertilizers Association

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Oatar



Revamping of a Conventional Total Recycle Plant

by N. Selvaraj, **QAFCO, Mesaieed, Qatar**

Prepared for Presentation at **24**th **AFA Int'l Technical Fertilizers Conference** 22-24th November 2011, Amman, Jordan



Recently Qatar Fertilizer Company, Urea Casale and Qatar Constructions Company (QCon) have successfully carried out major Urea revamp project by applying Urea Casales's technologies.

This paper gives an overview of a project recently completed, which involved the application of the above mentioned technologies.



FOREWORD

A significant and recently accomplished example of urea revamping project aimed at fulfilling large capacity increase with Melamine off gases integration is:

- The Toyo Total Recycle Urea plant revamping of Mesaieed (Qatar) plant (start up June 09) in connection with the installation of the new Eurotecnica Melamine plant.

This project represents a very important example of innovative technology for large scale revamping project applied to urea plants originally designed with a total recycle technology largely utilized in the world.

INTRODUCTION

In July 2007 UREA CASALE (UCSA) and Qatar Fertilizer Company (QAFCO) signed a Contract for the revamping of the Total Recycle urea plant (Toyo technology) located in Mesaieed (Qatar).

The original capacity of QAFCO Urea plant No1 was 1,000 MTD; the plant used to run, before revamping, at the overall capacity of about 1,320 MTD.

The scope of the project was to integrate the existing urea plant with a 60,000 T/y melamine plant designed with Eurotecnica technology. The revamping was aimed at increasing the urea synthesis capacity up to 1,610 MTD (about +30%). The increase in plant capacity was achieved by utilizing the recycle Carbamate from the Melamine plant.

Beside the Melamine integration, the other major objective of the Urea-1 revamp project was environmental improvement to eliminate the ammonia and urea emissions from the Urea-1 plant to the sea.

Proposed Technical Solution

From process point of view, the main disadvantage of urea-melamine plant integration is the surplus of Carbamate flow recycled back to the urea synthesis loop (about +50% compared to the figures of a stand-alone plant), which has a detrimental impact on the reactor conversion.

CASALE opted for revamping the synthesis unit with its High Efficiency Combined (HEC) process, thus providing a technology able to improve the overall CO₂ conversion and minimize the modifications in the downstream sections.

In addition the project provided the implementation of a new process condensate treatment unit, designed according to CASALE HEH (High Efficiency Hydrolyser) technology, in order to produce BFW quality treated condensate

A process block diagram of the overall urea plant is illustrated in figure 1.



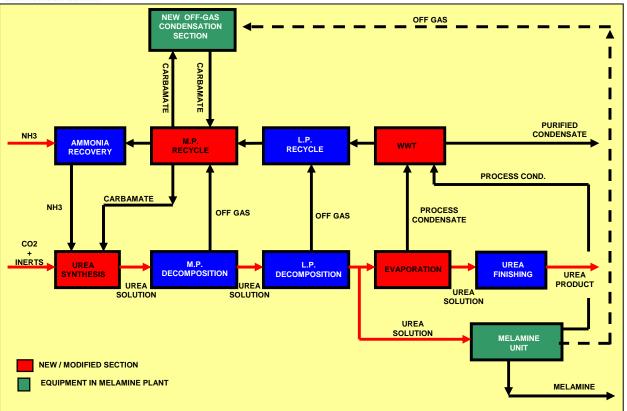


Fig. 1 - Urea Total Recycle Plant integrated with Eurotecnica Melamine

The main modifications were the ones relevant to the synthesis loop:

- New secondary reactor equipped with high efficiency trays
- New stripper
- New Carbamate condenser
- New Centrifugal Carbamate pumps (replacement of existing Reciprocating pumps)

Apart from the pure process aspect of providing additional surfaces, additional reaction volume in synthesis as well as pumping capacities, the main constrains of the project were the limited space and the reduced shut-down time available to implement the new installations.

CASALE selected to adopt a different approach aimed at improving the synthesis efficiency up to a level where the downstream section would not be significantly affected by the integration with the Melamine plant.



The modification of the synthesis loop is shown in figure 2. In figure 2a is shown a picture for the new HEC loop.

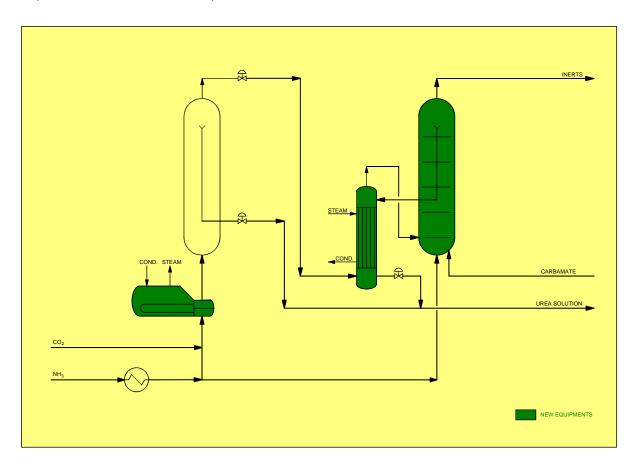


Fig. 2 - New HEC Loop of Total Recycle Urea Plant

In order to improve the synthesis loop efficiency CASALE adopted the HEC technology introducing a Secondary Reactor, with the relevant Stripper used as reboiler and using the existing primary reactor with once through configuration together with the new Carbamate condenser. The modification led to the fundamental results of obtaining a higher conversion of the loop even if under a drastically worst H_2O/CO_2 ratio. In fact the loop before revamp was running with 0.57 H_2O/CO_2 ratio (as per original material balance) and the conversion of 64% while with melamine integration the H_2O/CO_2 ratio has raised to 0.93, but thanks to the installation of HEC the conversion of the loop has increased to more than 70%.

The result of this modification is that the medium and low pressure sections do not include significant modifications and the new added HP section can be easily and quickly tied in, thus limiting to the maximum extent the shut down period.



In fact the plant was started up in June 2009 after a shut-down of <u>only</u> 26 days urea to urea. The Urea plant has been operated without Melamine integration up to May 2010 since the Melamine project was ready only at that time. At present the plant is running full capacity integrated with Melamine unit running at full load from middle December 2010.



Fig. 2a - New HEC Loop picture



In addition to the HEC Loop, a new off-gas condensation section was added consisting of L.P. Carbamate pumps (located in the Urea plant), Off-gas condenser with relevant tempered cooling water system and Carbamate recovery tank (located in Melamine plant).

For this section UC supplied the Basic Engineering Design package. Detailed Engineering and procurement for this section was done by Eurotecnica.

The scheme of off-gas condensation is illustrated in figure 3.

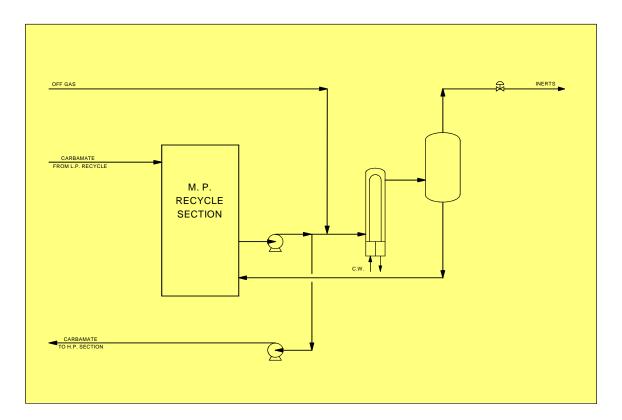


Fig. 3 - New Off-gas Condensation Section



Besides the Melamine integration the project foresaw the replacement of crystallization with evaporation section and the provision of a brand new Waste Water Treatment (WWT) section of capacity 65 MT/h, to eliminate Ammonia and Urea going to the sea.

In the enclosed figure 4 we show a process flow diagram of the new Waste Water Treatment sections. In figure 5 we show a picture for the new Desorber / Hydrolizer columns.

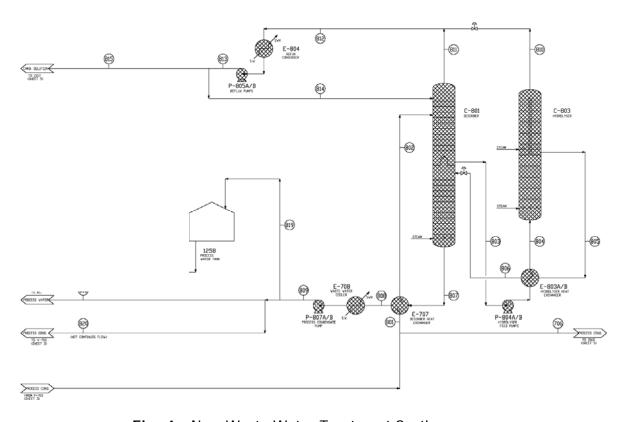


Fig. 4 - New Waste Water Treatment Section

The WWT design is based on CASALE HEH (High Efficiency Hydrolyser) technology; the operating pressure of the hydrolyser (using MP steam) is about 20 bar. Since the first operation, the new WWT section has demonstrated to be to produce treated condensate suitable for BFW use (after passing through a polishing unit). In fact the ammonia content in the treated condensate has been detected to be approximately 2 ppm while urea is less than 1 ppm.



Installation of the unit completely eliminated the ammonia and urea emissions to the sea from Urea-1 plant, thus meeting the commitment given to the environmental authorities.



Fig. 5 - New Desorber / Hydroliser Columns picture



Plant Operation

For your reference, please find in the attached table some operating data of the plant before and after melamine integration.

Parameters	Unit	Before revamping	Current with Melamine off gas	Remarks
Synthesis capacity	[MTD]	1,320	1,680	
NH ₃ consumption	[kg/ton of U]	580	568	
CO ₂ consumption	[kg/ton of U]	752	740	
Steam consumption	[[Gcal/ton of U]	-	0.88	
Sea Water consumption (dT=7°C)	[m³/ton of U]	-	135	
Electrical consumption	[KWh]	-	-	
Carbamate recycle	[kg/h]	67,000	105,000	
Specific carbamate recycle	[kg/ton of U]	1,237	1,509	
Total Off-Gas flow	[ton/h]	-	About 30	
NH₃ in Off-Gas	[ton/h]		About 13.5	
CO ₂ in Off-Gas	[ton/h]		About 10	
H ₂ O in Off-Gas	[ton/h]		Balance	
NH ₃ /CO ₂ loop ratio	-	3.48	3.58	
H ₂ O/CO ₂ loop ratio	-	0.57	0.93	
Overall loop conversion	[%]	64	72	

As it is clear from the above table, the introduction of the HEC CASALE technology enables the increase of HP loop capacity thanks to the improvement of the synthesis efficiency.

The specific Carbamate recycle flow has increased by 20% only despite the Carbamate flow increased of about +50%, which is a further confirmation of the improved efficiency of the system.



Project Execution

After a feasibility study, QAFCO and Urea Casale agreed to enter in a Contract for the execution of the project.

Urea Casale's scope of work covered:

- Basic Engineering
- Detail Engineering
- Supply of all Equipment and Materials
- Site Assistance during construction
- Site Supervision during commissioning, start-up and test-run.

Construction was performed by a local company (Qatar Construction Company) directly hired by QAFCO.

Since the initial phase of the project, QACFO nominated a project team to follow the project, which, during the engineering phase, was located in Urea Casale offices. This approach gave the advantage to simplify and speed-up communications and contingency plans implementation.

The engineering activities performed by Urea Casale covered also the complete HSE – Health, Safety and Environment analysis (HAZOP, SIL, Risk and Noise analysis, etc.) of the revamped plant during Engineering phase of the project, which are required to satisfy the very stringent local norms and standards.

Project Main Milestones

- Effective Date of Contract: 1st September 2006
- Shutdown of Urea-1 for final revamp activities: 24th May 2009
- Restart of Urea-1 after shutdown: 19th June 2009 (total plant shut-down <u>only</u> 26 days urea to urea)
- Urea-1 & Melamine integration: from May 2010 (Melamine plant was ready only at that time).
- Performance Test of Evaporation section: 14-15th April 2010
- Urea-1 at 100% capacity, integrated with melamine plant: mid Dec 2010 (Melamine plant reached 100% load only at that time)
- Urea-1 Plant performance test, integrated with Melamine plant at 100% load: June 2011.



Project Execution Challenges

The execution of the project posed many challenges to the Company and the contractors, some of which are listed below:

- The contract strategy of Engineering and Procurement with Urea Casale and Construction with Qcon, led to many coordination challenges to the Company, due to lack of experience with such contract strategy.
- The project required nearly 450 tie ins. To execute such large number of Tie ins, majority of which were done in a running plant or during unplanned short stops were difficult to execute.
- Major part (around 80%) of the construction was done in a running plant. This
 required the presence of large number of construction workers presence in the
 plant, which posed safety challenges.
- While routing the new pipelines, there were many clashes with existing pipelines, both with above ground and underground pipelines.
- Making new pilings for installing new equipment/structure very close to existing equipments in a crowded, running plant was a difficult task.
- Training of the operators, to adapt to the new process, was difficult. Training has to be done while the plant is online and the change from old process to new process happens too quickly after the final shutdown.

Conclusion

The Urea-1 revamp was a successful project, having met all its project objectives, without any safety or environmental incidents. This was achieved through the dedicated team work of all involved personnel from QAFCO, CASALE and QCon.

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Best Available Technology in Fertilizer Industry :
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Best-practice on RBI driven Integrity Assurance from Concept to Implementation

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Best-practice on RBI driven Integrity Assurance from Concept to Implementation

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In recent years, the applicable Legislation in a number of countries permits greater flexibility in the setting of inspection strategies (inspection intervals, methods and coverage) for pressure equipment and other static plant items, through the use of RBI (Risk Based Inspection) technology. It is a technology process which, when correctly applied, is used to formally optimize inspection efforts for each static equipment items of plant, whilst minimizing equipment failure risks caused by the relevant deterioration mechanisms.

This paper outlines a reliable and proven RBI driven equipment integrity assurance process best-practice in RBI technology application and. The paper also describes the challenges faced by GPIC during the implementation and actual integration of the same into the existing systems, together with the RBI benefits which have been achieved to date. When this technology is implemented at any plant site, it has been shown to deliver

- **&** Enhanced integrity
- ***** More focused inspection strategies
- **❖** Maintenance control strategies to reduce equipment failure risks
- **❖** Improved 'working together culture'
- **Capture technical corporate memory**

1. TRADITIONAL INSPECTION PRACTICE - BACKGROUND

It is widely accepted that traditional inspection methods employed at prescribed fixed intervals for managing integrity of pressure equipment in service are not necessarily conducive to ensure safety and can contribute to high operational costs. Experience shows that a lack of adequate knowledge of applicable damage mechanisms, their causes and where they occur in each equipment item together with a lack of understanding of their risk profiles have led to:-

- In some cases, failures of plant items with unacceptable consequences, because inspections were not targeted to match all active and potential damage mechanisms applicable to an item.
- In most cases, unduly restrictive plant run-length times and/or costly individual item inspection plans (particularly unnecessarily frequent inspection of many items). It may be worth noting that unnecessarily frequent inspections do not necessarily improve safety.

The traditional inspection process is generally regarded now as reactive rather than proactive.

2. LEGISLATION AND RBI ASSURANCE STRATEGY - BACKGROUND

In many countries, the legislative process is effectively self-regulating with the 'in-house' inspection/integrity department at a plant site or an external 3rd Party inspection body defining appropriate levels of inspection. This has resulted in an industry move in recent years towards basing the integrity assurance and inspection of pressure equipment on a technically reviewed risk assessment process, since there are significant safety, reliability and economic gains to be achieved.

As a result of legislative changes, Risk Based Inspection (RBI) strategies and assessment methods have been developed in many forms to maximise benefits.

3. Summary of RBI Assessment Methods

RBI assessment methods can be broadly divided into three categories

- That which relies primarily on expert judgment, known as 'qualitative'. It is a 'screening level' assessment usually used for identifying areas of plant at most risk but considered unsuitable for developing detailed risk based inspection plan on an item basis.
- That which incorporates statistical / probabilistic analysis and engineering calculations known as 'quantitative'. The procedure is complex and time consuming. For these reasons, it is generally regarded as very costly and little practical value to plant inspection engineers who are responsible for managing integrity assurance.
- That which incorporates informed team judgement and some engineering calculations known as 'semi-quantitative'. The 'semi-quantitative' approach is now widely regarded as part of the best practice RBI Assurance process [refs. 1- 5]. It is driven by a competent multi-discipline team study approach, similar to a 'Hazop' study.

The RBI assurance process described in this paper is based on 'semi-quantitative' approach.

4. RBI DRIVEN INTEGRITY ASSURANCE PROCESS – WHAT IS IT?

Risk based integrity assurance is a proactive process used to understand the equipment risk profile at any particular time during its lifecycle and put in place strategies to manage, and reduce potential risks. Risk Based Inspection (RBI) forms a major part of this assurance process as applied to static equipment items of plant. It is an optimized inspection plan with other mitigating strategies derived from a detailed integrity risk assessment of each equipment item. In a typical chemical plant, the static equipment items referred may include reactors, distillation columns, heat exchangers, various other types of pressure vessels, reformers, boilers, fired heaters, piping, storage tanks, etc.

The assessment is carried out using a competent multi-discipline team study process and particularly focuses attention on all active and potential damage mechanisms, which could affect an item. This is followed by an evaluation of integrity risk profiles for each of the identified damage mechanisms for the item. Optimised inspection plan (inspection interval,

method & scope) is then set up, which addresses each of the damage mechanisms applicable to the item, whilst ensuring the effectiveness / capability of the selected NDT methods match the identified damage mechanisms. Through this process the identified risks associated with each item are managed within defined acceptance levels, thus providing integrity assurance & reliability at optimum costs to plant owner.

The dynamics of the whole RBI process is shown in Fig.1. Procedures and responsibilities therefore must be set up to successfully manage the whole process at a plant site.

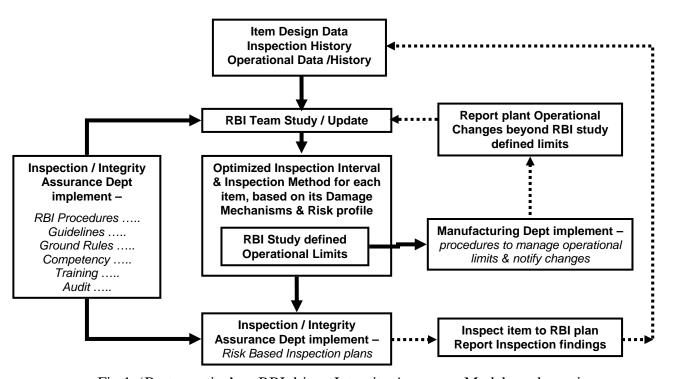


Fig.1 'Best-practice' on RBI driven Integrity Assurance Model – a dynamic process

4.1 Implementing RBI Assurance process – 'best practice'

Based on the foregoing, the implementation of 'best practice' RBI driven integrity assurance process for pressure equipment assets at a typical chemical plant site therefore requires:-

- An RBI technology process and methodology, which would provide the required selfassurance to plant inspection, mechanical and plant operation chemical engineers at site.
- Inclusion of best practice guidance for RBI technology application. In particular, the methodology must ensure reliable assessment of the risk profile for each of the 'active' and 'potential' damage mechanisms identified for an item. This must also be

supported by appropriate 'ground rules' to develop reliably optimised inspection interval for <u>each</u> equipment item (i.e. to ensure equipment item integrity assurance is not compromised).

- An experienced multi-discipline team to carry out the RBI study following the methodology. The team study process for each item needs to be thorough, transparent and auditable.
- Procedures set up for reporting and managing any changes to equipment operational limits identified by the RBI team study. Identify affected items to assess effect of such changes on the inspection plans in place before such changes are implemented. Procedures set up for updating RBI study records & risk based inspection plans.
- Similarly, procedures set up for feed back of inspection results or new information on damage mechanisms / rates to assess effect on RBI plans in place. Procedures set up for updating RBI study records & risk based inspection plans as necessary.
- The software system must have adequate functionality and details to facilitate and support <u>all</u> of the above. The following are minimum
 - Needs to support the RBI assurance technology and the multi-discipline team study process
 - o For <u>each</u> item, facility for recording team discussions, judgement and decisions
 - o Needs to be transparent on how the damage mechanisms (DMs) integrity risk profiles for an item are reliably assessed.
 - Needs to be transparent on how the optimised inspection inspection interval for an item is reliably derived, based on identified damage mechanisms and the risk profile of each DM.
 - All of the above records needs to be fully auditable, including RBI study data used, the initial RBI study and output, team members, subsequent Reviews and Updates.

5. RBI ASSURANCE METHODOLOGY – OUTLINE

This process covers the application of Risk Based Inspection (RBI) strategies to reliably and economically manage equipment integrity at chemical plant sites, which have pro-active commitment for the process from top level management.

The assessment process relies on the availability of historical operating data and previous inspection history and is therefore best suited to plant where this data can be reliably obtained. The technique is still considered of value for application to new plant, in terms of inspecting for the identified damage mechanisms and areas of vulnerability, whilst the inspection intervals developed must take account of greatly reduced availability of actual condition and reliable operational data.

The following section summarises the key elements of an RBI team study. It should be noted that RBI is a methodology to optimise inspection activities based on integrity risk assessment. As such, it is a critical process itself, which must be performed comprehensively and competently. The relevant managers at plant site must therefore be committed to providing the required resources.

Additionally, the **RBI technology used** to carry out the RBI team study **must be able to reliably assess equipment item risk profile** based on identified damage mechanisms. This is essential to the whole process **because the evaluation of optimised inspection interval for an item mainly depends on its risk profile**. Satisfying these requirements would help provide the required self-assurance to plant inspection, mechanical and operations chemical engineers.

It is also important that throughout the organisation RBI is not perceived as a one-off exercise to modify inspection periods and inspection scope but as a comprehensive risk based integrity assurance process for the lifetime of a plant. This involves responsibilities for plant operations chemical engineers to manage identified RBI dependent operational parameters within the agreed band. The initial RBI study and developed RBI plans also require reviews and updates accordingly, due to feedback of inspection results or due to operational changes. Procedures must be put in place to accommodate these tasks.

5.1 <u>Best -Practice Aspects of RBI driven Integrity Assurance Pr</u>ocess

The following points list the various mandatory elements, in order to provide an overview to what are considered the best-practice aspects within a reliable RBI Assurance process:-

- The RBI study must be carried out by a competent multi-discipline team the members of which each have suitable qualifications and experience. Normally team membership would be covered by five core team members:
 - o RBI team study Facilitator
 - o Plant Inspection Engineer
 - o Plant Mechanical (or Maintenance) Engineer
 - o Plant Operations & Process Engineer
 - o Metallurgist (or Corrosion) Engineer

For audit reasons, team member names should be recorded in the study for each item.

- Training must be given to all personnel involved in the implementation of the RBI process.
- The RBI methodology used must be thorough, clearly defined and transparent. The application of the methodology and resulting documentation must be recorded in such a way that the study process, key discussions and decisions made are fully auditable and future reviews / updates are carried out easily and efficiently with minimum resource commitment.
- The RBI study data for each item (including design conditions, operating loads / fluid streams data and historical changes, inspection history) must be accurate.
- The methodology and the team study process must be thorough enough to provide high confidence in determining all 'active' & 'potential' damage mechanisms applicable to an item.
- The failure mode for each of the identified damage mechanisms should be determined in order to evaluate realistic consequence of failure.
- The consequence and in particular the probability of failure for each of the identified damage mechanisms applicable to an item must be reliably assessed by the team. From the assessment of the risk profile, the optimised inspection interval for the item must also

be reliably evaluated against an acceptable risk profile for each of the damage mechanisms.

- The operational limits of key process parameters and maintenance issues (e.g. external paint coatings, fire-cladding & insulation) must be defined and the implementation audited.
- The study must consider confidence levels the team has in the assessment, which may be reduced, for e.g. owing to limited availability of data. The output must be adjusted accordingly.
- The process must include for the development of an inspection plan derived from the RBI assessment with consideration and specification of reliable NDT methods linked to the damage mechanisms. This inspection plan must consider the capabilities and effectiveness of NDT and the need for speculative and sample inspections to ensure that any unexpected deterioration is covered, particularly for high consequence items.
- The process must manage the transfer from current inspection plan to RBI driven inspection plan with consideration of the requirements of governing local legislations.
- The whole RBI process must be internally audited within the QA system.
- The site Inspection Dept shall retain full responsibility for RBI implementation.
- Specific ground rules to suit site must be identified and implemented in the RBI team study process to ensure consistent application and to avoid misuse of RBI technology.
- Procedure must be put in place at plant site to ensure that the RBI study output is embedded into the site practices and procedures including the management of future reviews & updates.
- A supporting software system should be installed at plant site to facilitate and reflect the RBI technology assurance and implementation process described above.

Based on experience, the foregoing process has been proven to provide improved reliability, safety and a reliably optimised inspection interval and inspection requirements for each item of plant.

5.2 The role of NDT in RBI driven Integrity Assurance Process

When the RBI technology process is used to justify extended inspection intervals, in particular for high consequence items, or extended plant run-length times between turnarounds, the role of NDT and the accuracy required of the inspection results in this process cannot be underestimated.

NDT plan - Need to match the Damage Mechanism (DM)

- Define purpose of NDT [to detect DM or to assess DM rates or both]
- Define how to inspect, which components of the item, what methods and what coverage.
- Optimise balance between risk, effectiveness & cost. Depends on consequence & complexity.
- Invasive or Non-Invasive inspection?
 - o Consider feasibility and benefits.
 - o Need a structured decision process.
- Capability & Effectiveness of the technique and Reliability of results is key.
- More responsibility is placed on the NDT Engineers
 - o Expected to be more proactive
 - o Qualification and experience relevant to DMs
 - Accuracy of results need to check calibration and question the findings at the time of inspection. If in doubt ASK. (It is too late when the plant is back online)
 - Better reporting of results to help update RBI study output and future inspection plans.
 - o Need clearly defined procedures to narrow reliability gap between NDT engineers' performance to improve confidence in results and repeatability.
- Non-invasive Inspection [NII]
 - o Decide in accordance with recommended practice
 - o NII methods targeted and tailored need data on degradation types / locations

6. FINANCIAL ANALYSIS OF POTENTIAL BENEFITS TO PLANT OWNER

To analyse whether RBI implementation is successful at a plant site, the plant site needs to define the short, medium and long term RBI objectives. Common objectives usually considered are:

- ❖ Improvement to equipment integrity assurance [enhanced reliability and safety] through better understanding of equipment vulnerabilities and resulting inspection strategies.
- ❖ Improvement to equipment availability & reliability and reduction in unexpected failures.
- ❖ Increased plant run-length time between turnarounds and reliably optimised (or extended) inspection interval and inspection activities for each equipment item.
- ❖ Replacement of intrusive inspections with non-intrusive techniques for relevant items and reduction in scheduled turnaround inspection scope for items which are over inspected.

Key Performance Indicators [KPI] should be defined within the RBI Assurance process for each of the selected objectives to monitor progress and the implementation must be managed as a project.

7. IMPLEMENTING RBI TECHNOLOGY AT GPIC – A SUCCESS STORY

The venture into new technology or improvement to any system has to be part of the corporate objectives of the organization for it to succeed and flourish. The decision for GPIC to implement RBI technology is part of the overall vision of the company to adopt state of the art, proven technology to enhance its asset reliability and safety. The main pillars that the company vision and mission are built on, formulated the main criteria for selecting, planning, and implementing the right RBI technology process in GPIC. The overall plan for the RBI technology process selection and implementation is shown in fig.2.

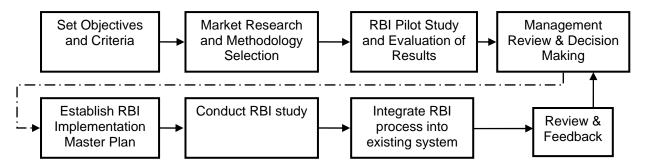


Fig.2. RBI Implementation plan of GPIC

The main objective of GPIC's venture into the adoption of RBI technology was to enhance and reliably optimise the overall inspection activities at site whilst improving each equipment item reliability and safety in a structured, scientific, and transparent way to meet the internal and external stakeholder requirements and expectations. In order to select the appropriate methodology from the many that were in the market, a number of criteria were set to evaluate the different options. The main criteria can be classified into Reliability & Robustness of the RBI technology process, Methodology for successful implementation, the Structure, thoroughness & Transparency of the RBI team study process, Simplicity of use, Flexibility, and Technical support.

After many presentations by RBI service providers and feedback from end users, the project was awarded to PP SIMTECH to provide the RBI technology process and support for implementation. Importantly, this RBI methodology included a proven technology breakthrough, which provides a process to easily and reliably assess the risk profile for each of the identified damage mechanisms applicable to an item. This in turn ensures that the resulting inspection interval is reliably optimized, thus providing the required confidence and self assurance to plant site staff responsible for equipment integrity and reliability assurance.

It was concluded that an open and transparent RBI study conducted in-house with the available experience and facilitated by PP SIMTECH would be more beneficial for the company for both short and long term. In order to ensure that the selected methodology would deliver the expected benefits and to get a feel for requirements of such methodology, a pilot study was initially carried out on a specific unit of the plant, before embarking on RBI full implementation.

The RBI pilot study was designed to include various types of equipment in the plant, to identify any shortcomings of the selected RBI methodology, to assess duration of the study

and resource commitment and quality of the final outputs. Table –1 summarizes the outcome of the pilot study.

Table −1: RBI Pilot Study Summary

Equipment Type	No. of Items	No. of Identified	No. of Days	
		Damage Mechanisms	(time taken for RBI team study)	
Heat exchangers	31	137	15.5	
Tanks	3	18	1.5	
vessels	17	66	8.5	
Columns	2	10	1.5	
Total	53	285	27.0	

The points below outline the findings of the RBI pilot study:-

- 21 items required ultrasonic thickness scanning at specific locations
- The study uncovered many potential damage mechanisms in areas where they had not previously been considered active. These damage mechanisms include various types of corrosion, fretting damage, caustic & chloride stress corrosion cracking and fatigue.
- Inspection intervals of 44 items could be safely and reliably extended.
- Non intrusive on-line NDT inspection techniques were included for some equipment items at an intermediate inspection period to cater for any uncertainty and improve confidence.

During the management review of the pilot study outcome, it was very clear that the selected RBI methodology fully satisfied the set objectives and criteria. Furthermore it was able to provide many other tangible benefits to the company, such as capturing process modifications, enhancing wider experience of the RBI study team members through knowledge sharing, and training of graduate engineers in plant operational influence on equipment integrity, failure analysis and troubleshooting.

After approving the methodology & allocating the necessary resources for full implementation of this RBI technology process at site, a master plan was established highlighting the number of items to be assessed every year, bearing in mind the other commitments of the RBI team members from the site. Table –2 highlights the master plan of the RBI study for full implementation.

Table – 2: Overall Project plan for RBI full Implementation

RBI Master Plan								
Year	Ammonia	Methanol	Urea	Utilities	Offsite			
2003	10	55	0	0	0			
2004	0	29	0	0	0			
2005	0	63	0	0	0			
2006	45	5	11	0	0			
2007	13	0	41	4	0			
2008	32	0	0	0	0			
2009	14	0	18	22	0			
2010	0	0	0	0	0			
2011	12	0	21	12	25			
2012	0	0	14	44	12			
Total	126	152	105	82	37			
Completed (end 2010)	114	152	91	26	0			
Overall Progress			76%					

^{*} Actual completed up to Jun 2011.

The **above plan is very flexible** with respect to core team availability & actual plant requirements.

7.1 The key stages of the RBI team study process at GPIC for each item included

In order to assist the facilitation of the RBI team study process, future reviews of the studies carried out and help to ensure transparency, auditability and consistency, the supporting software system rbiAsystTM is being used. Additionally, for this purpose, full advantage is taken of the facilities provided in rbiAsystTM to record data used, key discussions, judgments & decisions made.

As a background note, after reviewing many of the RBI softwares available in the market place against the best practices in developing RBI technology, the software system rbiAsyst™ was originally developed jointly by PP SIMTECH & BP Chemicals in 2002 to successfully support the implementation of best-practice technology process as described in Sections 4 and 5.

The key stages of our RBI team study included the following

- 1. Familiarization with item purpose, design, construction, materials & environment.
- 2. Detailed review of item inspection history & any repairs, modification and cause.
- 3. Detailed review of actual operational loads/duty and operational process fluids data and historical changes and excursions.
- 4. Focused discussion on the item by review against a standard list of questions in the RBI software rbiAsystTM.
- 5. Identification of all damage mechanisms (active & potential) based on stages 1 to 4, their causes & affected locations and other potential locations for damage occurring.
- 6. Team confidence assessment with respect to the item.
- 7. Reliable assessment of integrity risk profiles for each of the identified damage mechanisms leading to evaluation of latest inspection date for each damage mechanism applicable to item.
- 8. Development of risk based inspection plan for the item based on results of stages 5 to 7. It comprises reliably optimised inspection interval, inspection type, inspection method and inspection coverage for the Major and any Intermediate [usually non-intrusive] examinations. Specification of appropriate NDT as applicable to match the identified damage mechanisms for the item. The chosen NDT method(s) must have the required effectiveness and capability.
- 9. Checks to ensure the agreed RBI Ground Rules are adhered to when finalising inspection intervals for each item.
- 10. Identification of any critical operational boundaries, maintenance & NDT issues which may have a direct influence on the identified damage mechanisms applicable to the item and reliability of the inspection results. These are key parameters which if not adhered to can adversely affect the risk based inspection plans and the inspection results.

The team study for full RBI implementation at site started early in 2005. The relevant team members ensured that the required inspection and operational data was accurate and was populated in the RBI software rbiAsyst™ in advance of RBI team study meetings. The study was facilitated by PP SIMTECH and the complete team study is recorded in this software system for each item.

On average, approximately 2 - 3 items are completed per working day depending on the complexity of the item and the availability of the required data.

The initial periods of the study faced many challenges which were addressed during and after each set of study period. Corrective actions and management controls were implemented to

ensure full commitment and smooth execution of the project. Below are some of the main challenges:-

- Availability of appropriate team members
- Quality of available historic (operational and inspection) data of plant
- Repetitive training of members to the RBI team

The benefit of the RBI study in terms of existing systems improvement was realised by GPIC from the pilot study phase and these are currently being addressed.

Any recommendations and actions resulting from RBI team study meetings including details of the team member assigned to follow-up the action and the closeout response are recorded in rbiAsyst™. This and other facilities catered for in rbiAsyst™ ensure transparency, auditability and reliable implementation of the RBI technology process. The existing inspection reporting system is utilized to report the follow-up work carried out as a result of these actions and recommendations.

A management review meeting is held to discuss the outcome of the study on a monthly basis and to improve on the overall process in terms of achieving the set objectives. One of the most significant outcomes of these review meetings was to adopt this RBI methodology to assess the integrity of piping systems and enhance the existing piping inspection program.

7.2 Benefits to GPIC

The main strategy adopted by GPIC to implement the RBI technology process is outlined in the foregoing sections. To date many benefits have been gained. These benefits, some of which are interlinked, can be broadly classified into the following four sections:

1) Enhancing plant equipment integrity & reliability through:

- **a.** Identification of several new potential damage mechanisms ranging from various corrosion mechanisms, fretting, metal dusting, various H₂ & H₂S induced mechanisms, creep, stress relaxation cracking to various types of fatigue damage and many stress corrosion cracking damage mechanisms.
- **b.** Identification of vulnerable locations for these damage mechanisms and specification of inspection methods to reliably assess condition of each equipment item.
- **c.** Establishing a reliable and optimised inspection plan for each item. The optimised inspection interval, inspection method and scope of inspection are matched to

- identified damage mechanisms and vulnerable locations, whilst ensuring the risk profile for the item is acceptable within the optimised inspection interval set by the RBI Resource optimization.
- **d.** As anticipated, for almost 80% of the items studied, the previous internal inspection interval can be safely and reliably extended to at least double the existing frequency. This has a direct benefit on resource allocation requirements for routine and turnaround inspection activities. Additionally plant turnaround time can be improved.

2) Strategic planning:

- a. There may be a few items in a plant which can be a barrier to achieve one or more of the set objectives. In this respect, this RBI technology combined with the supporting team study process has been found to be an excellent tool to identify and resolve complex item technical issues (e.g. reactors, reformers, strippers, furnaces, etc.). Accordingly, work has been identified to investigate and resolve any technical barriers in order to help achieve the required benefits for GPIC without compromising reliability or safety. It also provided the core information for a 10 year CAPEX equipment replacement strategy at plant site.
- **b.** The RBI team study, carried out by a competent multi-discipline team, provided a formal technical justification with recorded evidence for extending statutory examination of 36 items. This was one of the main factors restricting the desired uninterrupted plant run-length time between the turnarounds.

3) Knowledge sharing & learning:

- **a.** As part of the RBI technology process, an extensive damage mechanisms document was developed by a team of metallurgists from both PP SIMTECH and their clients including input from GPIC. This document has captured in simple form the distilled information from four international standards and various codes of practice. It is now used at GPIC as a reference for all engineers and in conducting other studies such as HAZOP and Root Cause analysis at site.
- **b.** On average 2 graduate engineers participate in every RBI study session, thus enabling them to capture a wealth of wider experience of the multi-discipline team & history of the plant.

- **c.** Fiveway exposure of knowledge and experience sharing is acquired during the RBI team study between mechanical integrity/materials technology support, the inspection & reliability group and the operations & process engineering group.
- **d.** During the RBI team meetings, full advantage is taken of the facility available in the supporting software rbiAsyst[™] to capture valuable knowledge of 'informed resources' at site to benefit corporate memory & facilitate effective transfer of technology to junior engineers.

8. CONCLUSION

The leap from traditional inspection practices to RBI driven equipment integrity assurance process represents a cultural change in terms of improving reliability and plant safety. This paper described the successful implementation at GPIC an RBI technology process, which is believed to be at the leading edge of RBI best-practice. It highlights the benefits which can be gained by properly adopting and integrating it in the overall culture of the Company. The many benefits that can be reliably achieved from adopting such a methodology as highlighted in the paper can range from enhancing the Company's overall strategic planning and achieving the set site objectives to multi-discipline knowledge training of junior engineers at site.

It is clear that there is no short cut to implementing RBI successfully. For any plant site wishing to successfully embark on RBI implementation, the chosen technology and the team study process must be robust and reliable and the process must be managed as a project. The success equally depends on fully understanding the implications of the methodology and the resulting benefits and most importantly recognising the role it will play in achieving the overall company objectives.

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Best Available Technology in Fertilizer Industry :
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Health, Safety and Environment in Fertilizer Industry Story behind APC Success in achieving 4000000 MHW Free of LTI-s

الإتصاف الصربحة للأسمدة Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

Mr. Sami Amarneh QES Manager- APC

Jordan

Highlights of Arab Potash Safety Process

Story behind APC Success in achieving 4000000 PHW Free of LTI-s

Issue Date: Nov-02-2011

Introduction: As quality experts say, "Success is a Journey". In 1981, when we started our operations at Arab Potash Company, safety was a real challenge. We went through a series of ups and downs, but the good part about it is that over time our incident rates have reflected a clear descendent character year by year until the glorious success which was achieved in 2011 by surpassing 4000000 PHW free of LTI-s during the period from Feb-02-2011 till September-08. Our year to date LTI Frequency Rate is (0.18) Accidents per 200000 PHW while our YTD Frequency Severity Indicator (FSI) is (0.04). These rates are obviously within the same rates' achieved at PSC/Potash and DSW as illustrated in the graphs. During this presentation, we will highlight some of the factors that we believe were the most significant drivers in this success.

- 1. Applying a safety management system according to the best and recent international safety standard-(OHSAS-18001:2007).
- 2.Exemplary commitment, involvement and dedication
 to safety by Top Management:

Our top management looks at safety as the main pillar of our operations sustainability. There is nothing more important than the safety of our employees. Production is an objective, but it will never ever be at the expense of safety. What our management is driving for is "Maximizing Safe Production" as our constant objective.

3. Instilling, growing and sustaining a vibrant safety culture that engages all APC employees in a continuous proactive safety dynamic by applying the concept of "Council Driven Safety Management" through conducting "so far" 6 safety forums out of 8 scheduled for 2011. These forums are attended by 200 employees at each forum including management employees and non-management employees. The GM, DGM-s and the departments' managers attend these forums and they are heavily involved in them through presentations that enhance the safety culture in the company. The presentations from each forum are

published in a booklet and a copy is distributed to each employee after each forum.

- 4. Integrating the safety culture in Islam with the safety culture in the company by preparing and presenting a speech at each forum by the Company Religious Guidance Head. This practice is unprecedented and it is exclusively applied by APC. These presentations have addressed the following topics: Safety Culture in Islam; the Culture of Change from an Islamic Perspective; Importance of time and impermissibility of wasting it; Prohibition of Inflicting Harm from a Religious Perspective; Honesty and Its Impact on Life and finally "Strength and Honesty are the Most Important Inducements for Progress and Success". Integrating local culture with our organization's safety culture has not been restricted to Islamic culture only; we hosted also at our safety forums the patron of the Roman Orthodox Church who gave the APC employees a lecture entitled "The Earth and Man".
- 5. Applying the concept of "Incident Recall Technique" at the safety forums designed for our Trucking drivers (3 out of 4 have already been conducted in 2011). At these forums we ask those drivers who encountered dangerous driving situations, in which they have something to control the risk and accordingly succeeded to prevent possible incident, to present these situations in front of others' drivers (about 200 attendees). Through this practice the unsafe conditions, hazards and at risk behaviors are effectively communicated to other drivers as well as the effective ways of controlling them, and consequently preventing possible incidents.
- 6. Enforcement of SMART Objectives Development by Managers and Superintendents for Safety, Quality and Environment. These objectives need to be Specific, Measurable, Attainable, Reasonable and Time Bond. We apply the randomness principle in selecting the superintendents that we safety presentations ask them to present superintendents' safety forums (3 out of 4 have already been in 2011). This practice creates motivation in each superintendent to be up his to responsibilities, as each of them will expect that possibly

will be one of those selected to give the presentation. The superintendent presentation addresses the YTD actual performance on his annual safety objectives and the actions he/she took (or is in the process of implementation) to eliminate the gap between the actual performance and the set objectives.

7. Developing and implementing an effective safety procedure to monitor, control and improve the safety performance of our service providers:

Intensive efforts were exercised for developing this proved effective. procedure which to be very implementation early in 2011, only one minor LTI has occurred This procedure addresses service provider worker. thoroughly and explicitly the safety duties of all involved parties as follows:

7.1. The Hired Service Provider by APC:

Two appendices that address Administrative control requirements and technical control requirements have to be strictly followed and complied with by the hired service provider.

- 7.2. Service Requester Department responsibilities.
- 7.3. The awarding Department Responsibilities.
- 7.4. Supervising Department Responsibilities.
- 7.5. Work Incubating Department Responsibilities.
- 7.6. HR/Training Responsibilities.
- 7.6. QES/Safety Department Responsibilities: All the service providers' workers are subjected to initial safety training by the APC QES Department before allowing them to enter our facility and commence their work. They have to pass a test designed by the instructor for each category of workers based on their literacy and overall competence. Those who don't pass the test and are found to be un-trainable are not allowed to enter our facility. Moreover, at the end of each month, the safety performance of each hired service provider is assessed in figures by a team of 3 members (QES Internal Audit Superintendent, Safety Superintendent and the engineer from the supervising department of the contracted service. The results of this safety performance assessment are communicated to all concerned departments including the service provider.

8.Applying Safety Incentives Scheme:

All APC field workers have been grouped with about 5 to 10 individuals in each group. The members of each group must have common exposure to the same hazards and have interdependent safety duties amongst them to control these hazards. If a month passes without any member of the group being subjected to an incident, all the group members will receive at the end of this month 5 JD each. In addition, if a year passes (12 months successively) without any member of the group being subjected to an incident, all the group members will receive at the end of this year 50 JD each. Furthermore, for every one million PHW achieved free of LTI-s, each employee will receive a present of about 50-80 JD and lunch meal as well for each employee including our 14-Days laborers. Also, a crucial element in the employee annual appraisal is his/ her safety performance; the higher the employee seniority, the higher is the weight given for the safety element in the appraisal. Moreover the bonus to all employees at the end of the year is dependent on the achievement of the safety objectives: zero fatality or life altering injury and the LTI frequency rate not to exceed 0.75 Accidents per 200000 MHW.

9. Improved safety inspections and audits programs:

Safety inspections and audits are carried out on daily basis both by supervisors, superintendents and managers at each department, by QES auditors and inspectors DGM/Technical and QES Manager. DGMT and QES Manager Safety inspections are done jointly on a weekly basis without prior notification, each time at a different location. inspections and audits address our service providers' workers and workplaces at the same rate as for APC workers workplaces. If an unsafe condition is observed during the safety inspection or the audit, a safety work order document must associate the safety inspection report.

10. Quality, Environment and Safety management Systems' Integration:

The unification of Quality, Environment, Safety, Housekeeping and Emergency Services in one department provided the needed platform for the integration of all Quality, Environment and Safety Management Systems. Many procedures have been unified including: Internal audit procedures, Management Meetings, Training and awareness and others. The culture that continually pump to our workforce is that Environment and Safety do constitute the main pillars of our operations. The interaction among these functions reflects itself on the integrates QES objectives; like reducing fuel water consumption is а quality and environmental objective, while reducing fires, leaks, wastes, exposures and emissions is a safety, quality and environmental objective.

11. Effective Management Review Meetings:

A management review meeting headed by our GM and administered by QES Manager is held quarterly. During these meetings all departmental QES objectives are presented by department managers, illustrating the actual performance versus the set objectives. Other subjects include corporate, financial, HR and Marketing. The number one focus at these meeting is Safety.

12. Effective Safety Committee meetings:

A safety committee composed of 8 management members and 8 first line workers meets once a month under the chairmanship of DGMT. The efficacy of this committee meeting is continually improving as it opens the door for workers and the labor union representative to express their safety thoughts and proposals. An average of 10 safety decisions is taken at each meeting targeting the continuous improvement of our safety performance by eliminating unsafe conditions and at-risk behaviors. The implementation progress of decisions taken at previous meeting is addressed and tracked at each meeting.

13. Effective Emergency-(Fire, First Aid and Rescue Services:

About one year and a half ago, APC developed and signed an agreement with Jordan Civil Defense, in which a civil defense center was built to mainly provide Fire, First Aid and Rescue services to Arab potash. The center is located near our plants; the building, equipment and emergency vehicles were provided by APC while the operating manpower is provided by Civil Defense. The civil defense crew works in an integrative manner with the existing APC emergency crew which takes care of the inspection of plants' fire alarm and fighting systems, manual fire extinguishers inspection and maintenance, hot work permit services, planning, coordination and co-supervision of emergency drills with civil defense, and supporting the civil Defense team in case of a real emergency.

14. Improved Safety Training for regular work and for emergencies:

On-the-job safety training is being carried out on daily basis and several scheduled safety training courses are carried out, both at our training center as well as externally. Since 2005; about 45 safety training course have been conducted with total attendance of 4760 employees. Periodic emergency evacuation drills are also performed at all APC sites.

15. Improved Housekeeping Performance Monitoring and Control Procedure Using the 5S criteria-(developed by Hiroyuki Hirano) which are:

Sort, Straighten, Sweep, Standardize and Sustain. Our environmental section performs weekly housekeeping inspections and issues a weekly report showing the housekeeping performance score for each department. 10 recognition trophies were granted so far to the departments with top housekeeping performance.

16. Lessons learned From PCS Incidents:

All TapRoot Incident reports received from PCS are being analyzed, reproduced in an easy way to read, focusing on the similarity of the unsafe condition, or the at-risk behavior between PCS and APC that contributed to the incident. The reports are then distributed to all department managers asking them to have them addressed at their next safety meeting and to take action to prevent the occurrence of similar accidents at APC. The targeted groups for sharing these TapRoot incident reports with them are mostly: superintendents, supervisors, safety committee members, TapRoot investigators and service providers working under the supervision of APC various departments. To avoid doubling of these PCS incidents reports; it is worth mentioning that only the TapRoot reports are distributed, while the flash reports are not as the reason of reporting is to give the recipient the needed message to develop the preventive action for the recurrence of similar incident at APC.

17. Development of an effective safety work order procedure:

A robust safety work order procedure has been developed early on 2011, whereby all supervisors are authorized to issue these safety work orders. If urgent, it has to be acted upon immediately, if it can wait, then the Planning Department will schedule the implementation time. A monthly review and follow-up meeting chaired by DGMT is carried out for the review of the implementation status of these orders.

18. Effective TapRoot investigations and corrective actions:

In the first years of TapRoot implementations; our TapRoot corrective actions were not as efficient and timely as they are now. The performance of our taproot investigations has been improved significantly. The final review of these corrective actions, before approving them and implementing them, is being done jointly to ensure the simplicity, practicality and hitting the target according to the hierarchy of control pyramid. Eliminating the risk is the first level of consideration when developing a corrective action. An example of our TapRoot corrective actions which we eliminated the risk of contact between our trucks and 33 KV OHL at 4 crossings was implemented by raising the OHL from a height of 6-7 meters to

about 11 meters and by insulating that part of the cable with which a possible contact with the passing truck under it may occur.

19. Implementation of New Management System for Food Preparation, Service and Distribution according to ISO-22000:

Potash has 3 main food preparation, Arab service distribution centers at the Township, Hussein Housing and Agaba Housing, which provide a hot meal for each employee daily. Due to high temperature and the long distances between most of these centers and the targeted groups for service, there is an obvious need to ensure that all our workers receive a healthy meal which is of high quality. The ISO-22000 addresses the standard infrastructure for these food centers, some lab test for inputs and out puts and a standard procedure ensure a high quality meal of zero risk contamination, degradation or food poisoning. The system documentation will be ready by the end of 2011, while the needed upgrading of infrastructure will be completed within about 6 months from now.

20. APC Quarterly Magazine:

APC issues on quarterly basis a magazine that addresses a variety of subjects; the main focus is on safety, our GM and DGMT have a standard article in each issue addressing a new directional safety topic. Other managers and active employees have their contributions as well. Each employee in our organization receives a copy of each new issue of this magazine.

Prepared by:
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Arab Potash Company
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24° AFA Int'l. Technical Fertilizers Conference & Exhibition 22 – 24 November 2011, Amman, Jordan

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10 Years of Safurex Experiences in Stamicarbon Urea Plants

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Arab Fertilizers Association

Mr. Joost Roes

Acqisition Manager Mechanical Engineer - Stamicarbon

Netherlands

Ten Years Safurex® in Stamicarbon Urea Plants

AFA, Amman Jordan Nov. 2011

Joost Roes, Stamicarbon The Netherlands

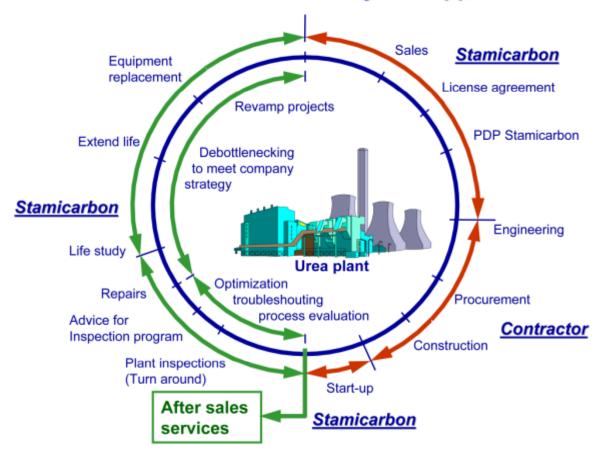




10 Years Safurex® inspection experience

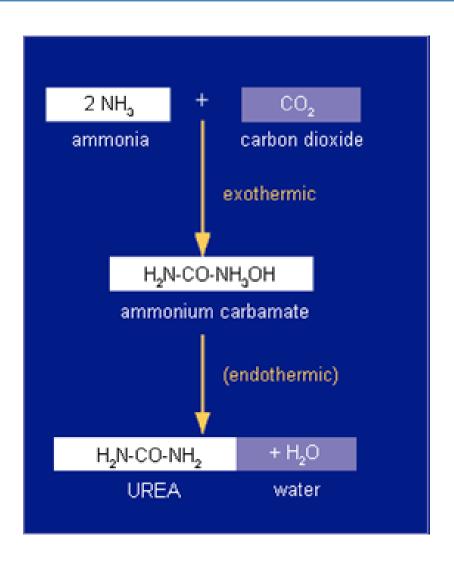


Stamicarbon Full Life Cycle Support



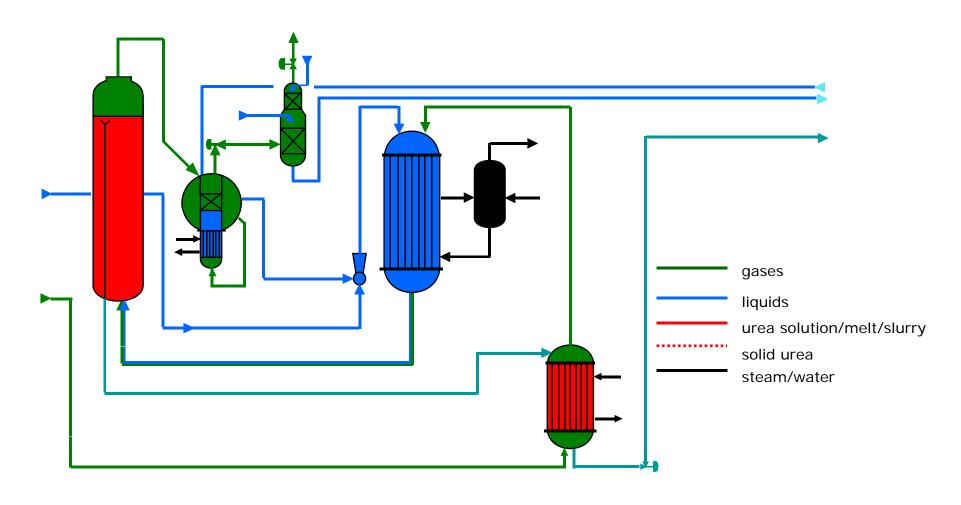
10 Years Safurex® inspection experience





Stamicarbon Urea Synthesis







Forms of corrosion found in Urea Synthesis using fully austenitic stainless steels:

- 1. Overall attack (passive or active)
- 2. Crevice corrosion
- 3. Condensation corrosion
- 4. Stress corrosion cracking
- 5. Strain induced intergranular cracking
- 6. Stern face attack
- 7. Under deposit corrosion

All vessels

All vessels

All vessels

Typically HPCC

Typically Urea Reactor

Typically HPCC & Scrubber

Typically HP Stripper

Initial goals set for Safurex®:



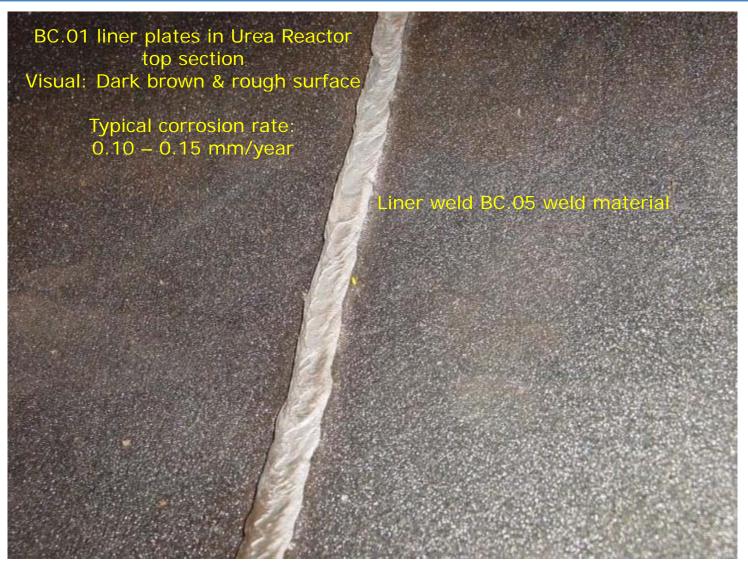
- Improved corrosion resistance in carbamate solution without the risk for active corrosion
 - Passive corrosion rates comparable or better compared to BC.01/BC.05
 - Improved corrosion resistance to stress corrosion cracking
 - Improved mechanical properties
 - Improved weld-ability



HP Vessel	Vessels total	Vessels in Operation	Number of vessels inspected	Number of inspections	Inspection performed after on-stream years Min. / Max	Remarks
Urea Reactor	17	9	5	6	2 y / 6 y	1 reactor (2x)
Poolreactor / Poolcondenser	24	9	5	5	2 y / 4 y	
HP Stripper	44	24	10	16	1 y / 10 y	1 Stripper (4x) 2 Strippers (2x)
HP Carbamate Condenser	16	12	6	9	1 y / 7 y	3 HPCC's (2x)
HP Scrubber	27	10	5	5	2 y / 3 y	
HP Piping/ Internals	67	44	4	4	2 y / 3 y	

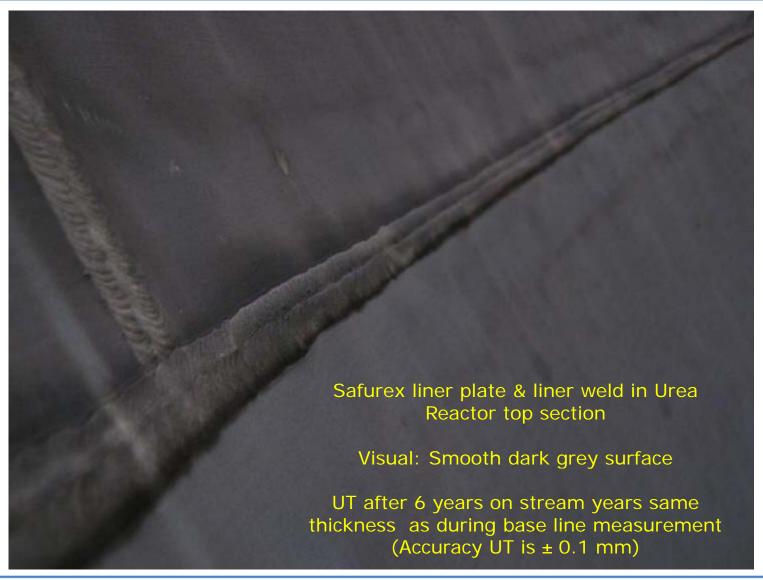
Overall Attack (BC.01) material





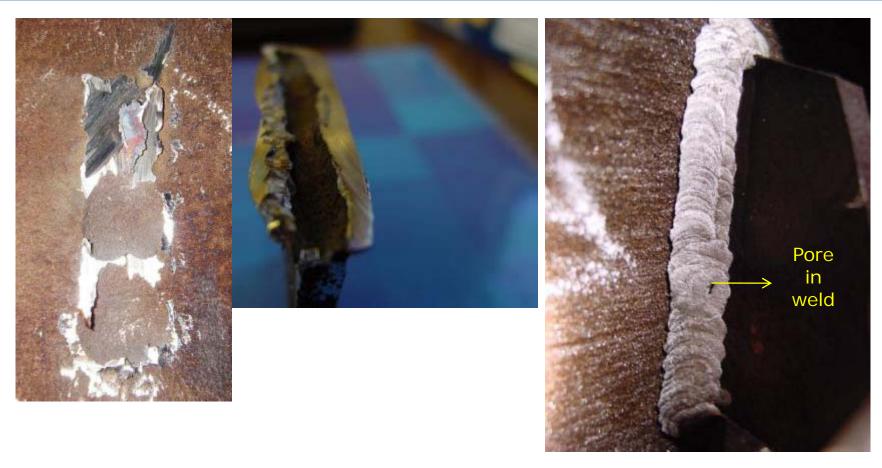
Overall Attack (Safurex®)





Corrosion under weld defects BC.01 material

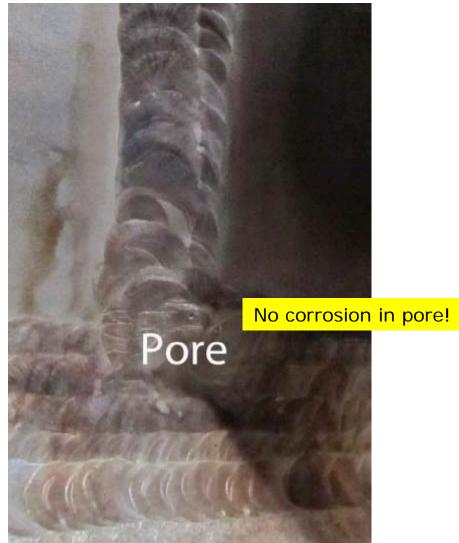




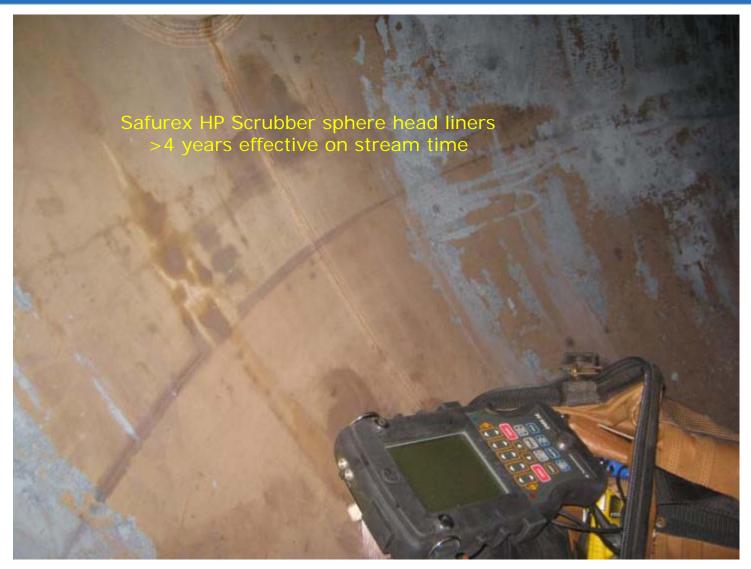
Typical corrosion problem using BC01/BC05 materials, crevice corrosion due to weld defect (porosity)









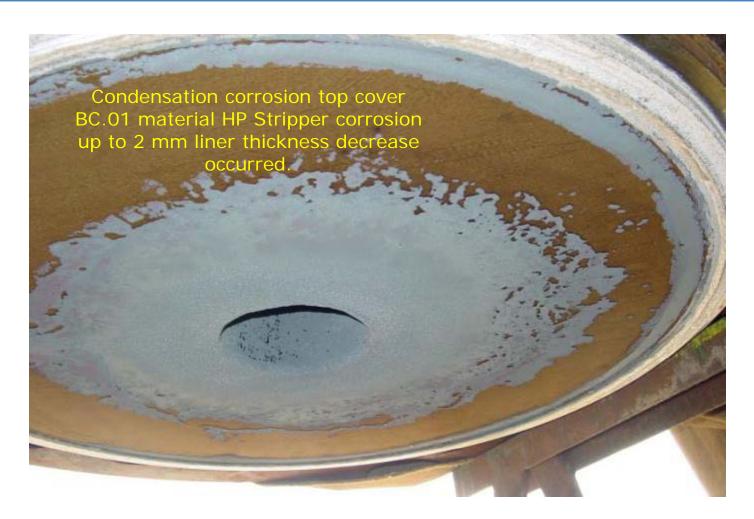






Top Cover liner BC.01 with condensation corrosion





Safurex[®] inspection experience



Huge cold spot created by lifting lug (lifting cover only ?)

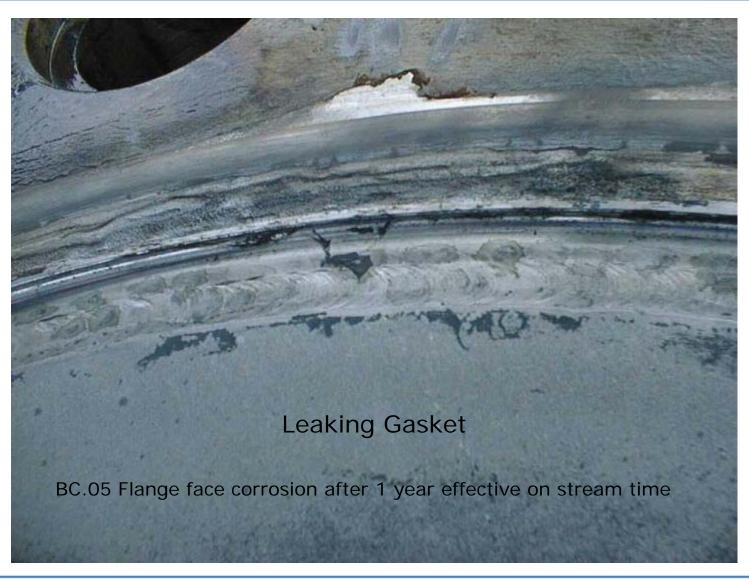




No gasphase and no condensation corrosion

Corrosion on flange face BC.05









S.C.C. in BC.01 heat exchanger tube (HPCC)

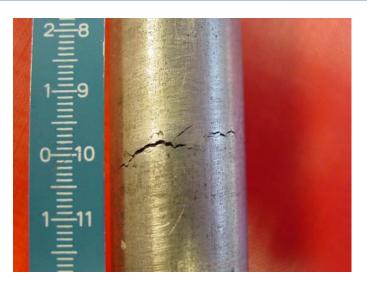




O.D.

SCC:

- Chlorides
- Temperature > 60 °C
- Stress
- Oxygen
- pH (< 9.5)



Stress corrosion cracking of urea grade AISI 316L (BC.01) heat exchanger tube

I.D.

Many HP Carbamate Condensers have been replaced due to S.C.C. due to chloride contamination.

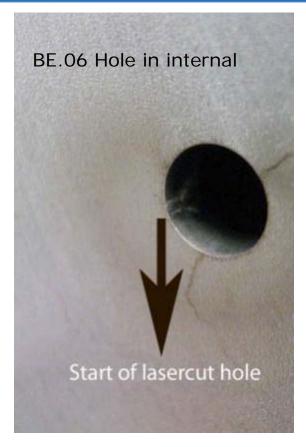
No Safurex HP Carbamate Condensers have suffered S.C.C. even despite higher chloride levels

Safurex[®] inspection experience





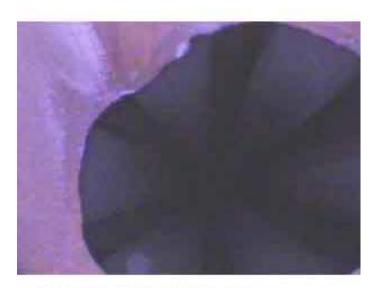
Overall attack BC.01



BE.06 (6 years on stream Safurex®)

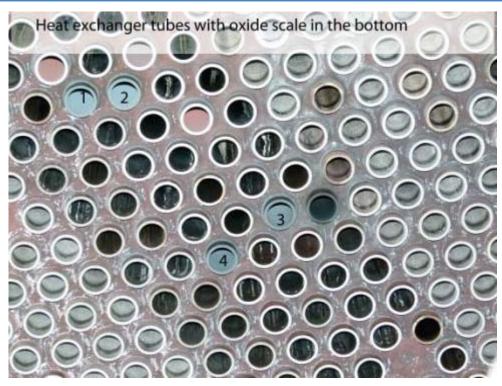
Active corrosion HP Stripper tubes BC.05





Tube #2,282 from top side

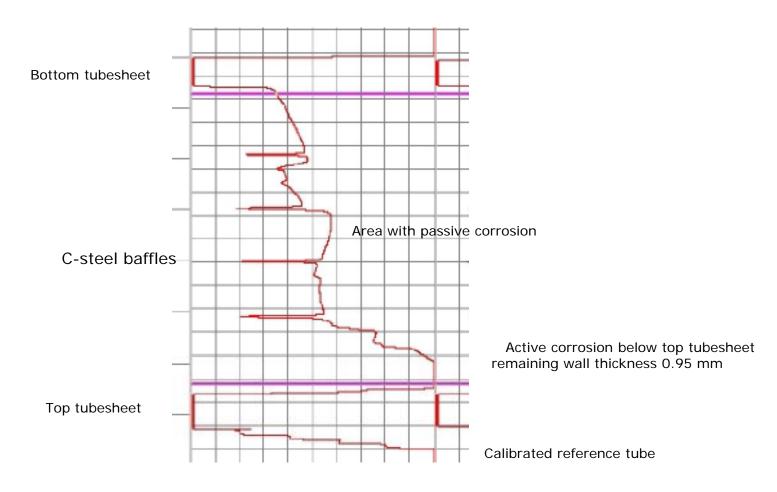
Tube rupture 8 days after scheduled TA active corrosion in HEX tubes due to lack of passivation



Tubes 1-4 show pronounced gas-phase indicating disturbed liquid flow

Active corrosion HP Stripper tubes BC.05

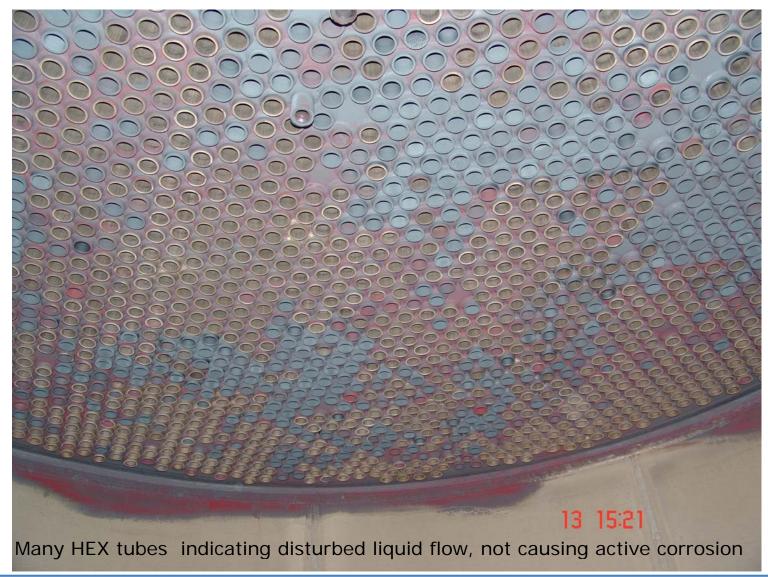




Eddy current graph indicating corrosion in BC.05 Stripper tube

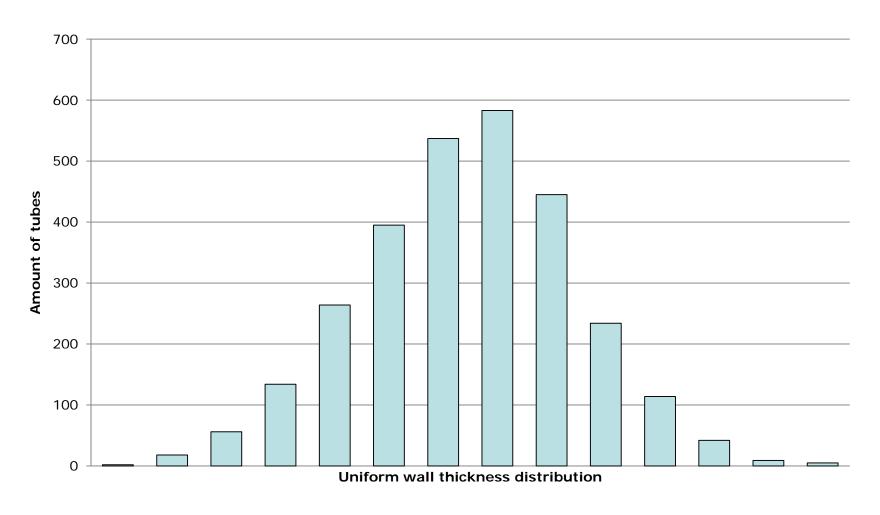
Disturbed liquid flow in Safurex® HP Stripper





Safurex[®] inspection experience





Uniform distribution of wall thicknesses indicates no HEX tubes with active corrosion



HP Stripper heat exchanger tubes:

BC.05 (X2CrNiMoN25.22.2)

Nominal thickness 3.0 mm Plugging adviced at 1.45 mm

ACTIVE CORROSION: 30 - 60 mm/year

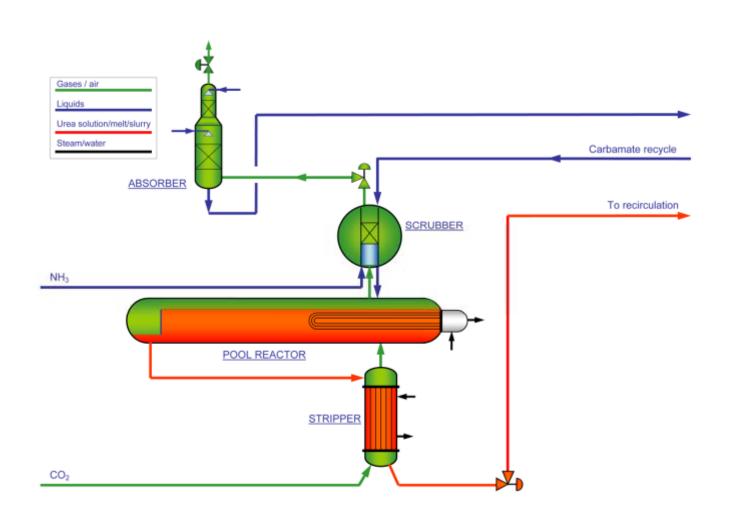
BE.06 (Safurex®)

Nominal thickness 2.5 mm Plugging adviced at 0.9 mm

ACTIVE CORROSION: NOT FOUND

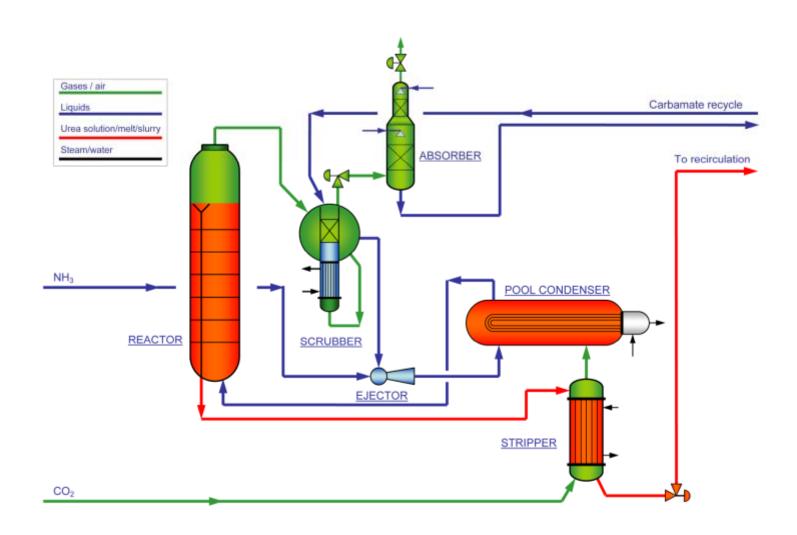
Process flow synthesis Pool reactor plant



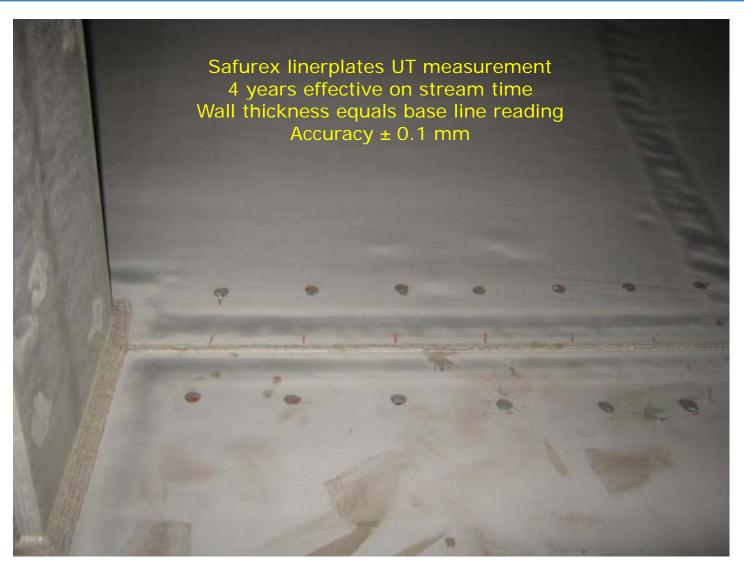


Process flow synthesis Pool condenser plant













Safurex[®] inspection experience



Conclusions:

- 1) Up to date no active corrosion is found on Safurex® material.
- 2) Up to date no repairs were necessary on Safurex[®] in Stamicarbon Urea plants.
- 3) Passive corrosion on liners and overlay welds for all Safurex® parts in Urea Reactor, HPCC, HP Scrubber, HP Stripper, Poolreactor en Poolcondenser cannot be measured after max. of 7 years effective on stream time.

 Corrosion resistance has improved compared to BC.01 / BC.05 material quality.
- 4) No Safurex® HP Carbamate condensers have been found with S.C.C.
- 5) Passive corrosion in Safurex® HP Stripper heat exchanger tubes is normal and comparable with the corrosion rate found in BC.05 heat exchanger tubes in HP Strippers.
- 6) Lower OPEX costs resulting from less inspections and/or increased inspection intervals. Also less repairs are expected, so far even none.
- 7) Safurex® did meet al the goals set for this material quality!



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Arab Fertilizers Association

Mr. Thomas Krawczyk Senior Process Engineer - Uhde GmbH

Germany



Capacity Increase of Urea Plants

24th AFA Int'l. Technical Fertilizers Conference & Exhibition 22 – 24 November 2011, Amman, Jordan

Authors:

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ThyssenKrupp Uhde GmbH, Germany

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1 Revamping in General

Starting with an explanation, why a revamp is not just an enhancement of the capacity of a urea plant, two revamps conducted by Uhde are presented. Furthermore two examples showing Uhde's optimization gained through the experience in engineering and construction of urea plants is discussed. Since the restrictions of a capacity increase might be the upstream ammonia plant, ways and opportunities are visualized in order to provide necessary ammonia and carbon dioxide feed in the desired ratio.

1.1 Targets and Requirements

Before going deeper into topics like opportunities of increasing the capacity of a urea plant, it first should be stated that a revamp does not only mean increasing the amount of product. Revamping rather has the meaning of renovating since the term "Revamp" etymologically originates from replacing the upper front part of a shoe.

The target of a revamp in terms of a capacity increase shall always use the existing margins to get a maximum possible additional product with the lowest effort necessary. Consequently this target asks inherently for finding the bottlenecks to achieve a certain capacity. Depending on these bottlenecks it sometimes makes sense to think in terms of a step model since each elimination of a bottleneck refers to a certain investment. For instance there is maybe a sharp border at a certain capacity which results in the necessity of an additional piece of HP equipment, if exceeded.

A target may also be the reduction of the energy consumption by heat integration for instance. Reducing the operating costs in a considerable extent will also be a benefit for the plant's owner. Due to experiences gained in the past and due to improvements of technologies, materials and others a target might also be the increase of the reliability and availability of the plant. Environmental improvements might also be a target of a revamp, hence reducing emissions in order to comply with new laws and international standards for instance.

An inherent requirement of such a revamp is to utilize a well proven and reliable technical concept. In addition, one of the most important requirements is to realize a short as possible implementation downtime for modifications and new equipment.



1.2 Uhde's Recent Expierences

In the recent past Uhde carried out the basic and detailed engineering for the revamp of two Egyptian urea plants, which have basically the same starting point with a capacity of 1925 MTPD each. The capacities of these plants, which where commissioned by Uhde in the years 2000 and 2006 will be increased by about 17% to a new capacity of 2250 MTPD. Furthermore those two plants mainly differ in their finishing sections since one uses UFT technology for the granulation and the other uses the granulation technology of Stamicarbon.

By finding the general revamp concept only part of the work is done. In order to fulfill all individual requirements of the client a precise investigation of all existing equipment has to be carried out in addition to the newly installed items.

In general for a capacity increase of a urea plant additional reaction volume, stripping, evaporation and condensation capacity needs to be installed depending on how much the capacity will be increased, where the plants bottlenecks are and what the requirements of the clients are, which ends in each small part of the plant. All these factors will always lead up to a very unique revamp concept.

Decisive for the extent of the capacity increase of a urea plant is at first the investigation of opportunities to provide the necessary raw materials and utilities. Remains to point out that for the aforementioned revamp projects which will be discussed in the following chapter more in detail, extra ammonia and carbon dioxide are available through a standalone NH₃ plant located near to the revamped urea plants.

2 Revamp concept

2.1 Basis and Desired Capacities

As already mentioned before both urea plants originally designed for a urea capacity of 1925 metric tons per day (MTPD). They are both using the conventional CO₂ stripping process technology of Stamicarbon for the melt part. The capacity is increased to 2250 MTPD, which is an enhancement of 17%. The granulation section of the first plant using the technology of UFT was originally designed for 2000 MTPD which refers to an increase of 12.5% to achieve an additional production of 250 tons per day.



The granulation section of the second plant uses the technology of Stamicarbon and was their first grass root granulation plant. It was also designed for 2000 metric and will be increased by the same amount.

The figures 1 and 2 show the synthesis sections of these urea plants before and after the revamp. The high pressure synthesis loop of the conventional CO₂ stripping process of Stamicarbon consists of a HP stripper decomposing the carbamate contained in the liquid reactor outlet by means of high pressure carbon dioxide and high pressure steam for the purpose of keeping the raw materials NH₃ and CO₂ in the synthesis loop.

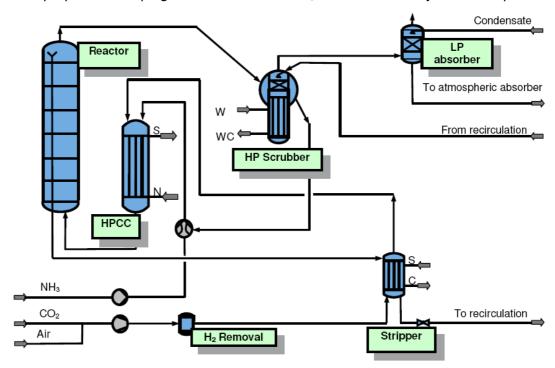


Figure: 1 Conventional Stamicarbon CO₂ stripping process

These strip gases are subsequently condensed together with recycled carbamate and fresh ammonia in the high pressure carbamate condenser (HPCC), while generating LP steam due to the first fast and exothermic reaction to carbamate. The outlet of the HPCC enters the reactor where the second slow and endothermic reaction from carbamate to urea by splitting off a water molecule takes place. Finally the liquid phase is leaving the reactor via the overflow pipe and entering the aforementioned stripper, where the reactor outlet is stripped and routed to the LP recirculation section for further downstream processing. The major bottleneck of this urea synthesis loop is the high pressure stripper since the load of urea solution to the stripper tubes is limited. Exceeding a specific flow will lead to flooding and hence lowering significantly the stripping efficiency.



The only revamp measure for the two Egyptian urea plants in the high pressure section as indicated in figure 2 is the installation of an after reactor, which is basically just like an enlargement of the existing reactor gaining more reaction volume. Furthermore figure 2 shows that the bottleneck of the HP stripper is circumvented by splitting the urea solution coming from the after reactor and sending it partially to a new medium pressure add-on section.

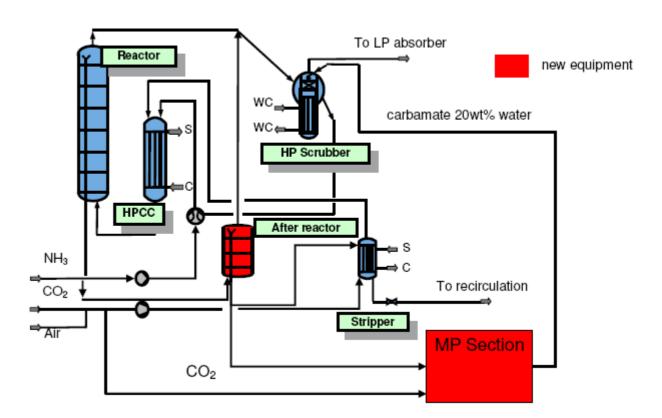


Figure: 2 MP add-on concept applied to conventional CO₂ stripping process

2.2 The MP Add-on Concept

The block diagram in figure 3 shows the revamp measures by highlighting the main new units added to the existing plant in light green and gives a general overview of the MP add-on concept applied to both revamps licensed by Stamicarbon and engineered by UHDE. As it is visualized in the block diagram apart from the urea solution, also carbon dioxide and LP carbamate are fed to the medium pressure add-on section.

Two main process streams leave the newly installed MP section. On one hand there is a carbamate stream which replaces the carbamate from the low pressure recirculation section by combining the carbamate streams from the LP and MP section. On the other



hand there is a urea solution stream with a composition comparable to the urea solution leaving the HP synthesis. Furthermore the block diagram in figure 3 shows also that waste heat is exchanged between the medium and the low pressure stages.

According to the aspired capacity a parallel low pressure recirculation part and a parallel desorption section are added to the existing plant.

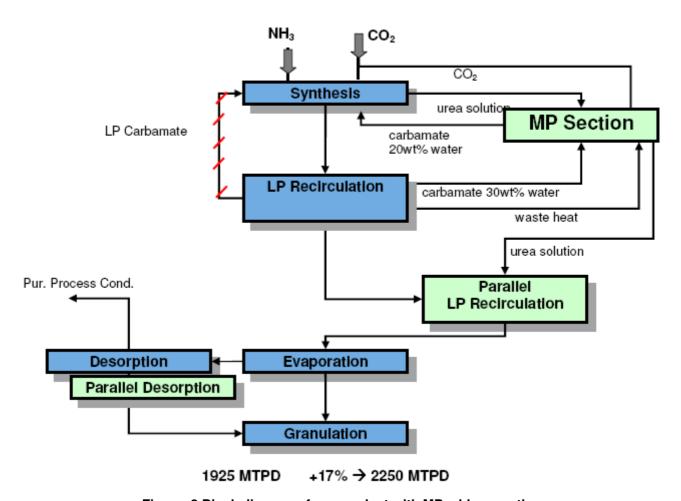


Figure: 3 Block diagram of a urea plant with MP add-on section

As shown in the flow diagram in figure 4 the MP add-on section basically consists of equipments comparable to equipments known from the LP recirculation. The urea solution originating from the urea reactor is first fed to the MP Rectifying Column via a let down valve, enabling the separation of the flashing gas and liquid. Subsequently this liquid is counter currently rectified by means of carbamate gases, which are generated through heating with steam in the lower part.

This rectified urea solution is further sent to the MP Stripper, where it is adiabatically stripped with MP CO₂ which is provided via a dedicated MP CO₂ compressor. The urea solution leaves the MP stripper to the LP Recirculation and is processed as usual. The



composition of the urea solution is almost the same as the one coming from the high pressure stripper and sums up to approx. 20% of the total amount of urea solution further processed in the downstream sections.

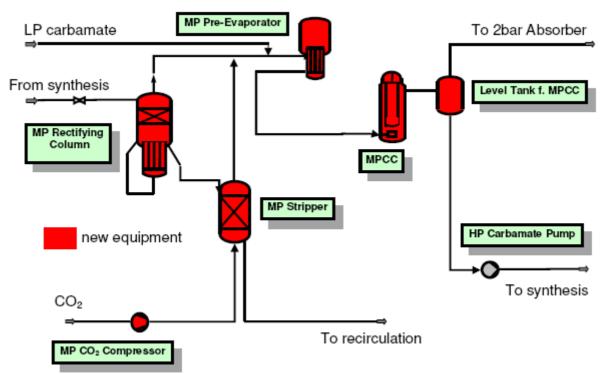


Figure: 4 flow diagram MP section (red box in fig. 2)

The off-gases of both the MP Rectifying column and the adiabatic MP CO₂ strip column are sent to the shell side of the MP Pre-Evaporator, where the MP carbamate gases are pre-condensed together with LP carbamate, which serves as absorption medium for the NH₃ and CO₂ gases since the reaction to carbamate subsequently takes place in the liquid phase. The condensation heat is exchanged with urea solution on the tube side for the purpose of concentrating the solution from 70% to about 79% prior to the evaporation section.

The partially condensed MP carbamate gases are then finally condensed in the MP carbamate condenser by means of conditioned cooling water and afterwards pumped via the existing HP carbamate pumps back to the urea synthesis. Due to the elevated pressure in the medium pressure section the carbamate contains about 20% water. This is 10% less water than the LP carbamate with about 30%. In general the carbamate flow back to the synthesis will increase to such an extent, that two HP carbamate pumps will be operated in parallel.



Although the medium pressure section is an integrative part between the low pressure recirculation and the high pressure synthesis, provisions are made to run the plant almost with the same configuration as compared to the situation before the revamp.

2.3 Revamp Measures of Downstream Sections

Further downstream processing with respect to the melt plant will not be discussed since it is basically straight forward. Moreover the necessity of parallel or additional equipment in these sections may differ from each and every plant due to the client's requirements, the existing design margins and the sought capacity increase.

For the finishing sections, the granulation part of both urea plants generally require to balance the additional heat input originating from the crystallization heat introduced by the increased load to the granulator. This can be realized in different manners. In order to compensate the additional heat input, the air flow to the fluid beds can be increased, the temperature of the fluidization air may be lowered by means of either evaporating water or by means of chilling with ammonia. For the sake of keeping efforts as low as possible the task for the conceptual engineering is to minimize the modifications to the existing plant, while maximizing the effects on the heat balance, which is finally also unique for each plant.

3 More than just the Enhancement of Capacity

With the completion of the licensor's process design package just a small part of the engineering is done. Especially for a revamp the input and involvement of the contractor might have a severe influence on the success of a revamp project in terms of providing the client a tailor-made solution. In the following two issues are presented exemplarily which show Uhde's input to optimize a revamp concept.

3.1 Stand-by Pump Philosophy

As mentioned in chapter 2 two high pressure carbamate pumps will run in parallel as illustrated on the right-hand side in figure 5. This requirement also applies for the high

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pressure ammonia pumps. Consequently if the prevailing philosophy of redundancy for pumps shall be kept, a third high pressure pump suggests itself.

But due to the fact that the stand-by pumps, on one hand the HP ammonia pump and on the other hand the HP carbamate pump are only needed if the new MP add-on section is in operation, the fall back position will be a capacity of 1925 metric tons per day in case of malfunction or maintenance of one pump. Hence the scenario is no longer comparable to the situation before the revamp and a risk-benefit analysis may have completely new results.

Although the high pressure pumps in such a revamp might have a higher cost and time impact compared to other equipment, it is also reasonable discussing the necessity of other items. Uhde is able to assist in solving tasks of this kind for the sake of finding the optimal solution for the benefit of the client. For this specific example two additional high pressure pumps for ammonia and carbamate will be installed based on client's decision.

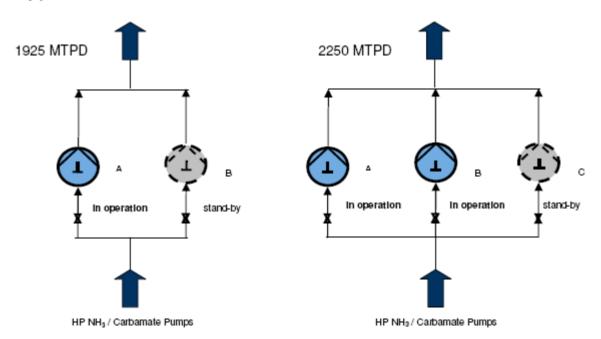


Figure: 5 Redundancy of high pressure pumps

3.2 Closed Cooling Water Loops

Figure 6 illustrates the conditioned cooling water loop for medium pressure carbamate condenser (MPCC), which has the same configuration as it is the case for high pressure scrubber and the low pressure carbamate condenser.

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In this special case for these plants the client faced a fouling problem for the plate heat exchanger tempering the closed cooling water loop according to the correlated carbamate condensation temperature, which lies in the range of the temperature of the HP scrubber.

Due to these high cooling water temperatures and the therefore resulting high wall temperature in the plate heat exchanger the tendency to fouling is increased specially where certain circumstances like an open cooling water loop are present.

Uhde improved this set up by adding an additional pump, which generates a secondary loop circulating around the plate heat exchanger, and reducing the inlet temperature through mixing the hot return water with already tempered water from the outlet of the heat exchanger. Scaling the ratio between both flow rates by choosing the size of the additional pump leads to a certain mixing temperature which will be reduced to such an extent that fouling tendency will be significantly lowered.

Furthermore Uhde applied the concept of a secondary cooling water loop to the existing closed loops of the HP scrubber and the low pressure carbamate condenser and thus gaining a better performance and more availability of the whole plant.

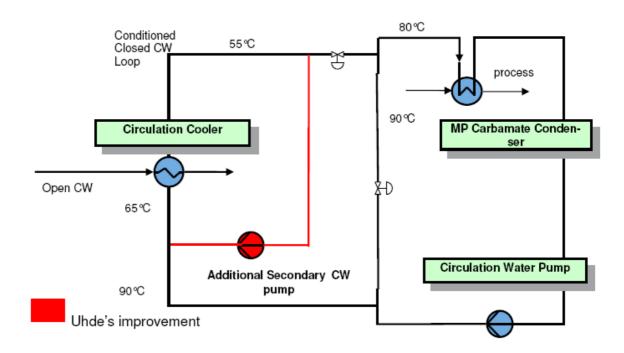


Figure: 6 Closed cooling water loop



4 CO₂ Generation

4.1 Situation

When a capacity increase of a urea plant is discussed, it is a natural question to ask for the source of the additional ammonia and CO₂ needed. A natural-gas based ammonia plant is producing both feedstocks for the urea plant, NH₃ and CO₂. In an existing ammonia / urea complex, there is often the situation that there is a surplus of ammonia which can not be converted into urea due to a lack of CO₂. This is due to the fact that normally the production rates of ammonia and CO₂ are not independent of each other. In an idealised process of production of ammonia from pure methane (CH₄), air and water, the ratio of products CO₂ and NH₃ is 1.14 t/t. In the real process, it can be lower or higher, for example depending on the natural gas composition and losses in the process.

In contrasts to that, the urea plant consumes CO_2 and NH_3 in a higher ratio of approx. 1.29 t/t (0.733 t CO_2 / t urea and 0.566 t NH_3 / t urea). Thus, the first bottleneck is the lack of CO_2 . In order to utilise all available ammonia for urea production, extra CO_2 must be sourced as shown in figure 7.

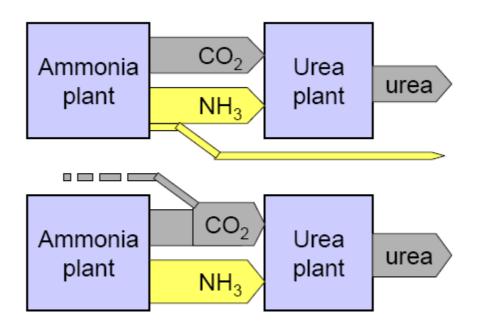


Figure: 7 NH₃/CO₂ ratio in an ammonia / urea complex



4.2 Generation of Extra CO₂

For the urea plant revamp discussed in the previous sections, there is an ammonia plant located nearby, which can provide additional CO₂. Not every producer is in such a comfortable position, and thus must take care of its own extra CO₂ production.

Several possibilities exist for the generation of this extra CO₂. One is an increased production in the CO₂ removal unit of the ammonia plant, the normal source of all CO₂ consumed by the urea plant. The other is to use a separate unit for collection of CO₂ from other CO₂ containing streams like flue gas.

4.3 CO₂ from the CO₂ Recovery Unit in the Ammonia Plant

CO₂ for urea production is normally generated by separation from synthesis gas in the CO₂ removal unit. The amount of CO₂ can be increased by passing more synthesis gas through this unit. Downstream of the CO₂ removal unit, the excess synthesis gas not needed for ammonia production is withdrawn and is sent to the reformer where it is used as fuel gas. This scheme increases the feed gas consumption of the plant and leads to a higher throughput and consequently higher duties in the front end units of desulphurisation, reforming, waste heat recovery, CO shift and CO₂ removal. On the other hand, the synthesis gas which is returned to the reformer as fuel reduces the natural gas used as fuel. However, there is of course a net increase of natural gas consumption. This is illustrated in figure 8.

If the additionally needed amount of CO₂ is small, and there is still margin in the front end units, the modifications are really small and of low cost as only a let-down for a small syngas stream to the reformer fuel gas system is needed, as shown in Figure 8. For higher amounts of CO₂, additional modifications must be made in a revamp of the plant to allow for the higher duties of the said process units.

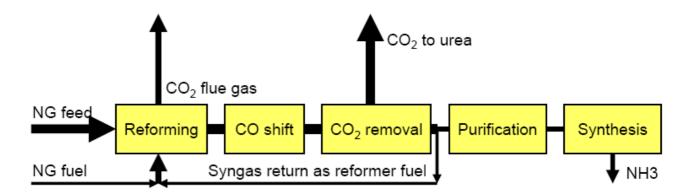


Figure: 8 Increased CO₂ production by increased front end flow



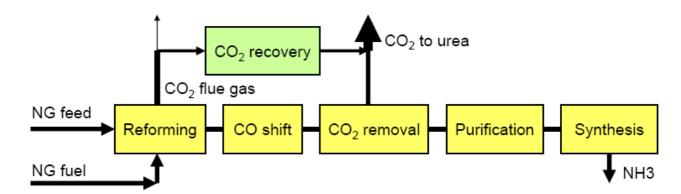


Figure: 9 Increased CO₂ production by recovery of CO₂ from flue gas

4.4 Recovery of CO₂ from Flue Gas

High amounts of CO_2 are present in the flue gas from the reformer and the package boiler which make them another possible source of CO_2 for urea production. Several technologies exist to recover it from the flue gas stream. Same as the CO_2 removal from synthesis gas, also the processes applied to flue gas are based on the same principle of absorption and desorption. The recovered CO_2 is of good quality (no hydrogen content) and is mixed to the existing CO_2 stream upstream of the CO_2 compressor. Often amines are used as solvents here as well, but they are different in order to cope with challenges by the side components O_2 , NO_x and SO_2 in the flue gas. These processes are also under investigation for separation of CO_2 from fossil power stations for later sequestration.

A CO₂ recovery unit is a separate and additional unit. It is connected to the flue gas outlet of the reformer or boiler, as shown in figure 9, but does not have many other interconnections with the rest of the plant. That makes installation of such a unit as a revamp an easy task.

On the other hand, the investment cost is the relatively high. Operating cost occur for steam for solvent regeneration and electric power for pumps and flue gas fans. In addition to that, there is a constant need to balance the solvent losses by addition of fresh chemicals.



	Increased ammonia plant front end	CO₂ recovery from flue gas
Revamp scope	Higher throughput through front end up to outlet of CO₂ removal unit, relatively simple plant modifications	Additional unit connected to flue gas outlet of reformer or boiler
Investment	Relatively low	Relatively high
Operation	High load in front end might bring the plant to its capacity limit	No change in existing units
Operating cost	Increase due to higher natural gas consumption	Increase due to consumption of steam, electrical power and chemicals

Table: 1: Comparison of the two CO₂ generation schemes

Table 1 lists the main characteristics of the two CO₂ generation processes. Both ways of CO₂ production have their advantages and disadvantages. The economical optimum mostly depends on the amount of CO₂ needed and the cost of energy, namely natural gas. For a high amount of CO₂ or for a site with high gas cost, the solution with the CO₂ recovery from flue gas is the better choice. If only a small amount of CO₂ is needed, or the energy price is not so critical (as it is typically the case in Arabian countries), the increased production of the front end might be favoured. Another factor which can be taken into account for the decision can be the CO₂ emission to the atmosphere, the "carbon footprint". The overall CO₂ emission of the plant per ton of urea produced is less for the version with CO₂ recovery from flue gas. While this paper is on revamps of plants, it should however be noted that for a new plant also an ammonia process using autothermal reforming (ATR) is an interesting option as its syngas usually contains more CO₂ which is separated from it in the standard CO₂ removal unit, being available for urea production.

5 Conclusion

Concluding it can be stated that there are a lot of ways to conduct a revamp for a urea plant. An often chosen strategy for revamping is the selection of a determined process concept like the above presented MP section, which is capable to gain a certain extra capacity. This results finally in defined demands on raw materials, upstream plants and utilities such as boiler or the cooling water system.

Considering the fact that changes in one place always lead to changes in another place, makes it important to select a competent contractor, who is familiar with the up-

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stream ammonia plant, is living the cooperation with the urea licensor Stamicarbon and is very experienced in issues concerning offsites and utilities, like Uhde.

Moreover it is essential that plant owner and contractor work together in good partnership. Different from a new plant for a revamp there are many constraints set by the existing periphery.

Finally it is the contractor's obligation to complete and optimize the process design package of the licensor, which is just a part of the whole in order to provide the client a tailor-made solution.

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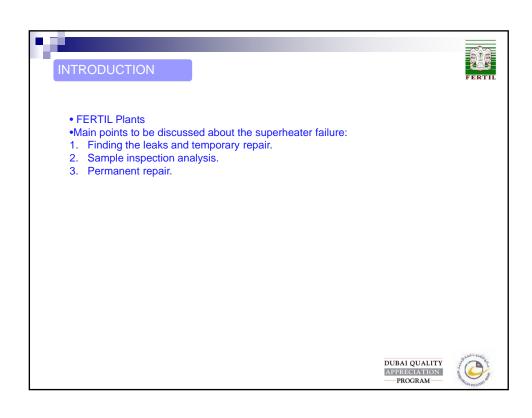
M.P. Boiler Super Heater Coil Failure and Replacement

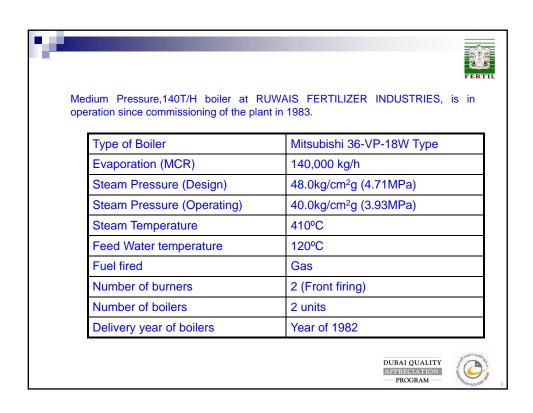
الإتصاف الصربح للأسمدة Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

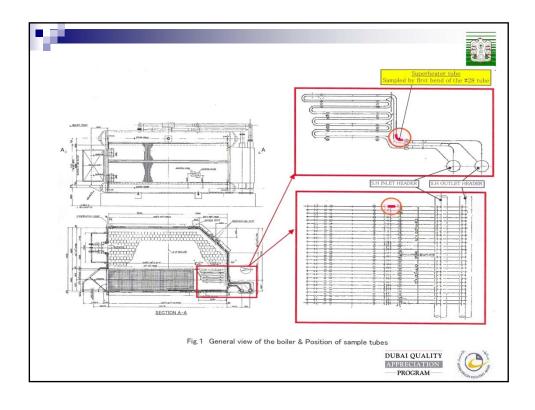
Mr. Adel Mohammad Al Wahedi Mechanical Engineer - FERTIL

UAE









M.P. Boiler - Super heater Coil Leaks



Finding the leaks and temporary repair:

On internal inspection of the boiler during plant shut-down in April 2008, water seepage was observed on the refractory wall of the super heater coil tubes.

On closer inspection after erecting scaffolding, the seepage of water was found from a hole 3.0 mm diameter in the super heater coil tube at the 28th row (top most) from the first inner bend exiting the wall refractory.



Additional tube leaks confirmed on pressurization and opening of the refractory. (27th & 26 row)







External photo of inner bend with holes

M.P. Boiler – Super heater Coil Leaks

On test slight leak was noticed from two more tubes

3 leaky coils were cut and removed, plugging the nozzles at the super heater inlet & outlet headers.

The remaining 25 rows of super heater coil tubes were pneumatically tested at 3.0 Kg/cm2G. No further leaks or drop in pressure was observed.









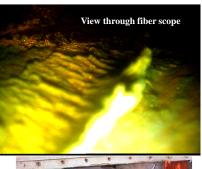
M.P. Boiler - Super heater Coil Leaks



To check the integrity of the remaining 25 rows of super heater coil tubes, further inspection methods were adopted.

UT scanning was limited to accessibility and was only partially done at the inner bends. The results were inconclusive.

Fiberscope inspection was possible for the 25th and 3rd row of inlet super heater coil tubes, after drilling holes at the super heater header inspection nozzles.





insertion for viewing the tubes

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M.P. Boiler - Super heater Coil Leaks



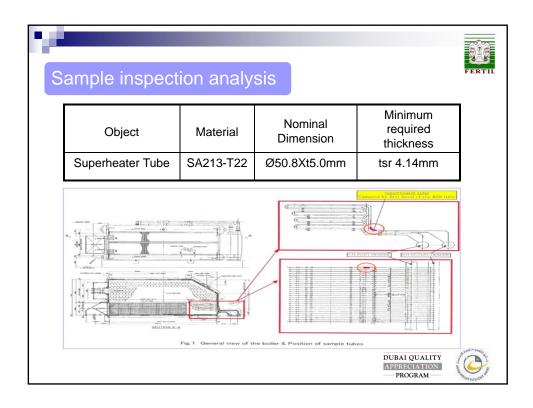
Temporary Repair done and boiler 'A' was put in service on low load.

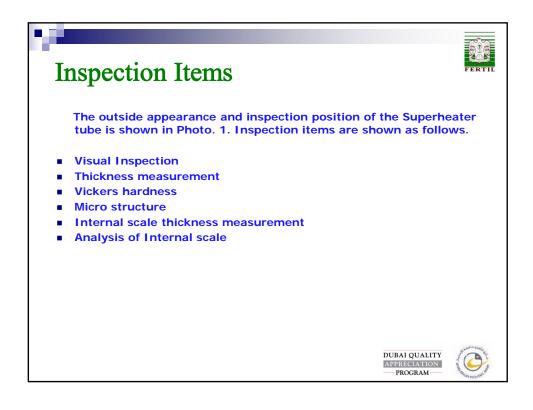
Considering the nature of failure and aging of the coils two sets of new coils were ordered to MHI, (OEM) Japan.

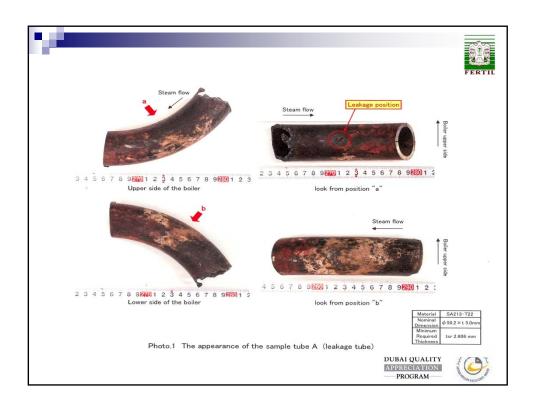
Boiler A coil was replaced during March 2009 followed by 'B' during May 2009.

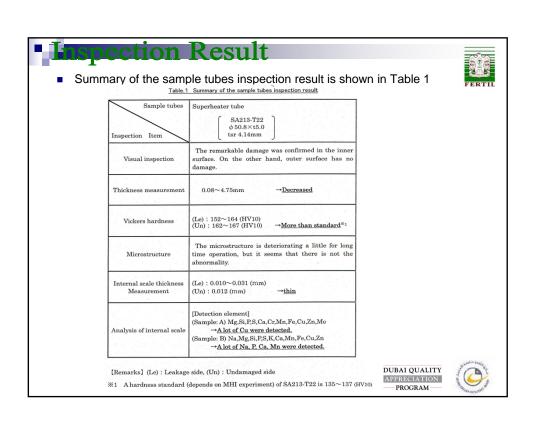
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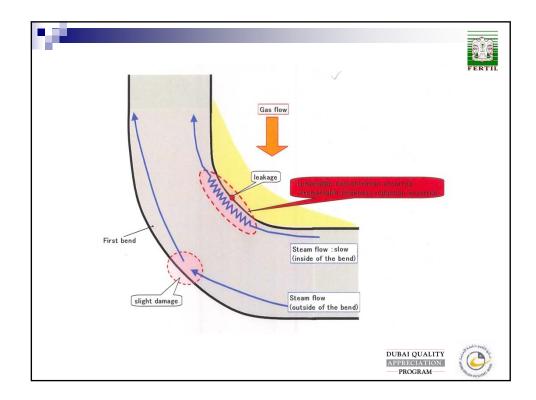
FINDINGS

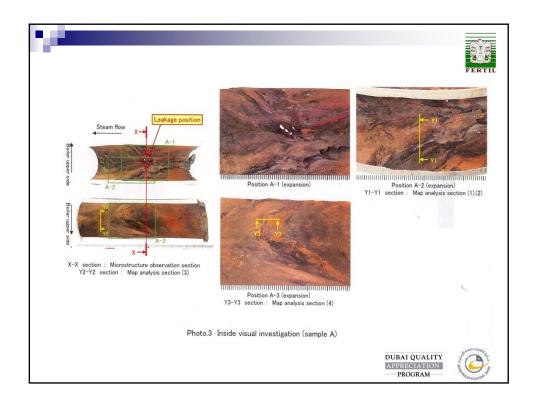


- When visually inspected, sample A found with holes in the inner side of the bend. On the other hand, the outer side had a slight damage too. It was also observed that brown internal scale existed on the sample. The scale colour is similar to that of the evaporation tubes scales.
- As a result of thickness measurement, the thickness was found less than the nominal dimension at many positions. [MIN found thickness: 0.08 mm]
- As a result of Vickers hardness measurement and microstructure inspection, it was confirmed that materials did not deteriorate. (hardness was found increased to 167 HV10 but didn't result in the failure).
- The scales thickness was measured and found from 0.010~0.031mm thickness inside the tube.
- The scales were chemically analyzed and found with large quantities of alkali (for example, Na, P, Cu).
- Internal scales are available in the boiler feed water (for example, Na, P, Cu) in large quantities. Usually, these scales shouldn't be available in the steam going to the superheater but were observed on the bend inner surface. Therefore, the possibility that carry-over occurred was considered. It is possible that the carried over water had relatively high concentration of alkali.
- The first bend (row 28) is the position where the carry over have the highest concentration of corrosive scales occurs.
- That lead to a caustic attack which in turn lead to the thickness reduction and the tube leak eventually.
- The major damaged part was the inner side of the bend while the outer side of the bend was slightly damaged. That's because the inner side of the bend has more exposure to the flue gas and also because the steam flow is slower in the inner side than the outer side.

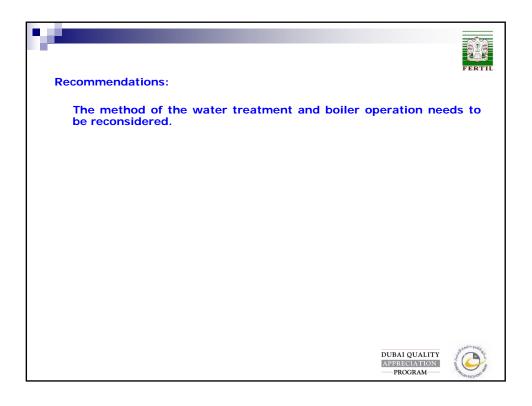




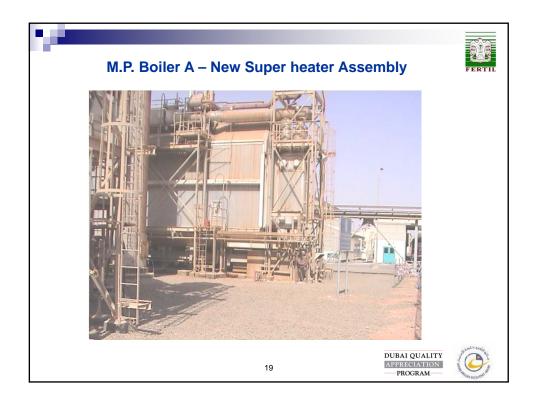












M.P. Boiler A - New Super heater Assembly



Mitsubishi Heavy Industries (MHI), the original equipment manufacturer for the MP Boilers, have been awarded the contract for materials supply & fabrication of new replacement Super Heater assemblies including the sacrificial bank & rear wall tubes. Fabrication, Inspection & hydrostatic test of the shop fabricated components carried out at MHI Yokohama works, were witnessed by Lloyds Register (Third Party inspectors) & FERTIL. Site assembly of the new super heater coils & bank rear wall tubes was completed in about 30 days from tentative boiler shut-down on 12-03-2009.



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M.P. Boiler A – New Super heater Assembly



Tentative Schedule

Tentative Schedule (24 hour work basis)	Target Dates
Receive at site Fabricated Materials from MHI	25-02-2009
Site Preparation by Fertil (Tools & equipment)	10-03-2009
Boiler A shut-down	12-03-2009
Open access doors / Gas test / Scaffolding	14-03-2009
MHI manpower arrival on site	14-03-2009
Remove outer casing, insulation & refractory. Provide temporary structural supports, remove obstructing structure, cables & cable trays, remove thermocouples.	17-03-2009
Install track / trolley beam / remove drums internals / cut & remove rear wall tubes, super heater coils & headers.	22-03-2009

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M.P. Boiler A - New Super heater Assembly



Tentative Schedule

Tentative Schedule (24 hour work basis)	Target Dates
Complete installation, welding & Inspection for SH new headers & coils	27-03-2009
Replace bank rear wall tubes, welding / inspection	29-03-2009
Hydrotest SH coil assembly & rear wall tubes	31-03-2009
Restore insulation, refractory & casing	04-04-2009
Gas test	05-04-2009
Restore structure, remove scaffolding, clean up	08-04-2009
Restore connections / Start up	10-04-2009

Note:

MHI simultaneously carried out the integrity assessment of the boiler tubes, economizer & drums, during the above assembly work, which took approx. 10 days.

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M.P. Boiler A - New Super heater Assembly

Sequence of site erection works:

- Disconnect & remove thermocouples.
- Remove drum internals partially. Remove seal box.
- Cut & remove sacrificial bank rear wall tubes & their fin plates, make cut between steam & water drums.
- Pull out expanded tube ends from drums inner side. (Shrinkage method for tubes to be adopted (heat by gas torch & cool by water) Note: 2 x tubes samples to be sent for analysis to MHI Japan.
- Provide temporary supports for inlet & outlet steam headers.
- Cut all super heater nozzles by gas torch. Cut seal plate.
- Disconnect all inlet / outlet flanged connections to SH headers.
- * Remove inlet / outlet super heater headers by track crane.
- Pull out super heater coil tubes from top to bottom.





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Sequence of site erection works:

- Super heater supports & lugs to be inspected visually & by random PT.
- * Air blow new super heater tube coils. Polish & inspect bevels by PT.

Measure the ID. (No longitudinal scratch marks are allowed)

- Polish & PT inspect, bevels of tube nozzles on inlet / outlet headers.
 (No longitudinal scratch marks are allowed)
- Pull in super heater coils carefully, avoiding deformation or damage to tubes
- & supports.
- Position super heater headers in place by track crane. Air blow to remove dust particles. Connect flanged connections to the headers.
- Carefully align super heater tubes & nozzles according to the drawing.







M.P. Boiler A - New Super heater Assembly



Sequence of site erection works:

- Weld by GTAW process. (WPS 866-FS01 for welds connected to inlet header nozzles & WPS 866 FS02 for welds connected to outlet header nozzles.) Weld the seal plate.
- PT after root & final pass to be done. 100% RT examination for all welds.
- Inspect tube holes in the drums by visual & PT examination.
- Insert the bank rear wall tubes, polish the ends. Measure ID & OD accurately.
- Expand / flare the bank rear wall tubes using tube expander. Expansion ratio to be controlled strictly by MHI inspector.
- Weld all fin & tube fittings before final expansion is done.
- Weld rear wall tube RW1 to WPS 866 FT01, PT of root & final passes & RT of completed welds. (Dwg. B-D103619)
- Inspect super heater headers through the inspection nozzles. Air blow if required.
- Weld inspection nozzles (WPS 866 FS04 for inlet headers & WPS 866 FS06 for outlet headers.)

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M.P. Boiler A - New Super heater Assembly

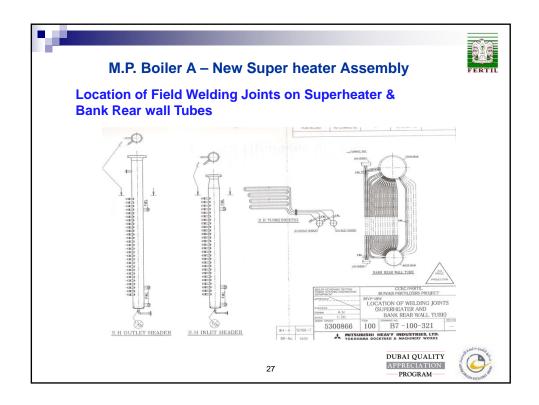


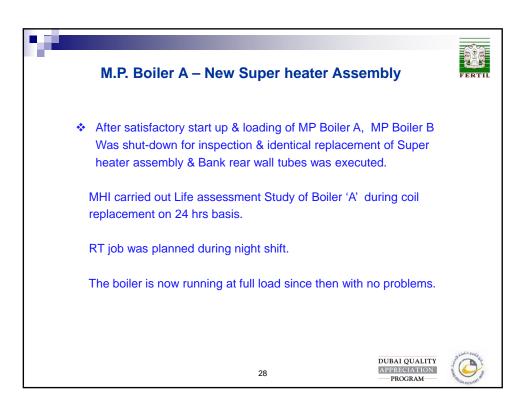
Sequence of site erection works:

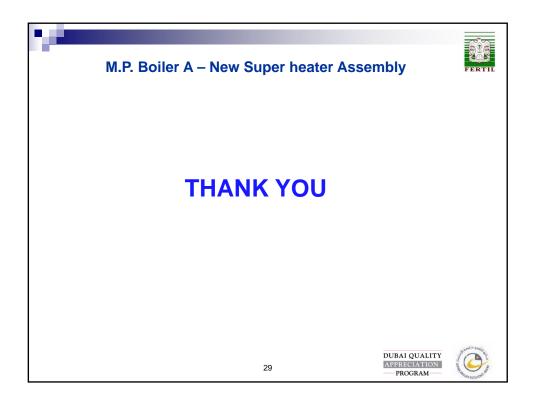
- ❖ PT after root & final pass to be done. 100% RT examination for the welds.
- Socket weld drains to nozzles on inlet & outlet headers. (Refer WPS 866 FS03 & WPS 866 FS05)
- * PT of root & completed welds required.
- Connect thermocouples.
- * Restore drum internals & close manholes.
- Carry out hydrostatic pressure test of all pressure parts at maximum working pressure (48 Kg/cm2G), using boiler feed water & pump.
- Carry out Gas leak test after completion of all fin welding, seal box welding, seal plate to seal plate welding & skin casing & castable refractory. Use FDF operation pressure & check by using soap suds on the welds. Alternately check welds by PT.
- Remove scaffolding, Restore structure & cables to original.











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The Challenge of Adding Cooling Capacity to an Existing Fertilizer Plant

الإتصاف الصربح للأسمدة Arab Int'l Organization هيئة عربية دولية Arab Fertilizers Association

Ms. Marietta Mansvelt
Solex Thermal Science Inc.

Canada

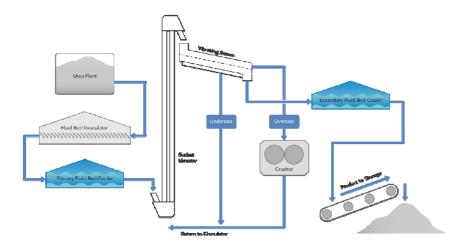
The Challenge of Adding Cooling Capacity to an Existing Fertilizer Plant

Many fertilizer facilities in the course of their lifecycle will require expansion for the purpose of increasing capacity. Increasing total capacity to a facility requires adding additional cooling capacity to cool the fertilizer in the final stages of production.

Ensuring sufficient cooling capacity is important because it reduces the likelihood of caking and lumping of the fertilizer.

Increasing cooling capacity can be a significant challenge for two reasons. Older facilities have typically been built using fluid bed coolers for the final stage of fertilizer cooling. In order to increase cooling capacity, another fluid bed cooler must be added. The first obstacle to adding another cooler is the physical size of the cooler itself. The second challenge is the increase in air emissions created by the added cooler.

Solving these two problems is not easy since the existing facility has two constraints that compound the problem. Firstly, existing facilities are limited in physical space (see figure 1) in which to add an additional fluid bed cooler. Fluid bed coolers are designed to be installed horizontally and therefore require a very large installation footprint. A typical fluid bed cooler footprint in a 100 t/h plant is 3m wide x 8m long. Accommodating the additional equipment is not only a challenge, but any possible solution will be costly. Secondly, fluid bed coolers rely on massive amounts of air in order to achieve the required cooling. A fluid bed cooler in a typical 100 t/h fertilizer plant will require approximately 350 – 400,000 Nm3/hr of chilled air. This additional air capacity must somehow be treated; however, existing scrubbers, filters and bag houses are unlikely to be sized to accommodate such additional volumes of air. As a result, additional scrubber capacity must be added to the facility to enable the installation of the added fluid bed cooler. Adding such additional filters, ducting, and scrubbers to an existing facility is difficult, expensive and can also require the added burden of dealing with emissions permits.



The Real Challenge

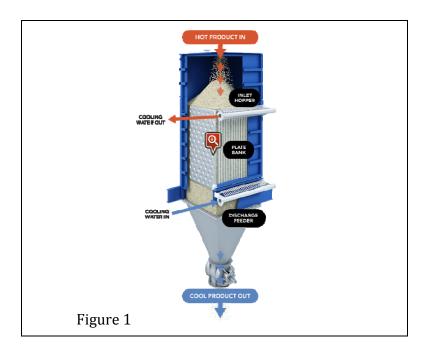
Until now, there have been few technology options available that work well for cooling fertilizer. As a result, the industry settled on fluid bed coolers as the standard. But clearly, in the case of capacity increases, a better option is needed. The ideal solution that would enable additional cooling capacity to an existing fertilizer plant would be a technology with a small footprint that does not rely on additional air volume for the cooling process.

The Benefits of Indirect Plate Cooling Technology

Advancements in indirect plate cooling technology and experiences from many successful installations are proving that the benefits of this technology for fertilizer cooling applications are too important to ignore. The main benefits for fertilizer plant expansions are the fact that this technology completely eliminates the footprint and air emissions issues experienced with fluid bed coolers. As a result, this technology is being quickly adopted as the logical solution in such applications.

About Indirect Plate Cooling Technology - How It Works

The heart of the indirect plate cooling technology is the bank of exchanger plates, installed vertically inside the heat exchanger housing. The product to be cooled flows slowly downward between the plates. Cooling water flows through the plates in counter flow and the product is cooled by conduction. Mass flow of the product is achieved by means of a Discharge Feeder mounted as an integral part of the exchanger below the plate bank. The Discharge Feeder also regulates the flow of product through the exchanger to keep it full at all times. A 3D view of a Bulk Solids Cooler is shown in Figure 1.

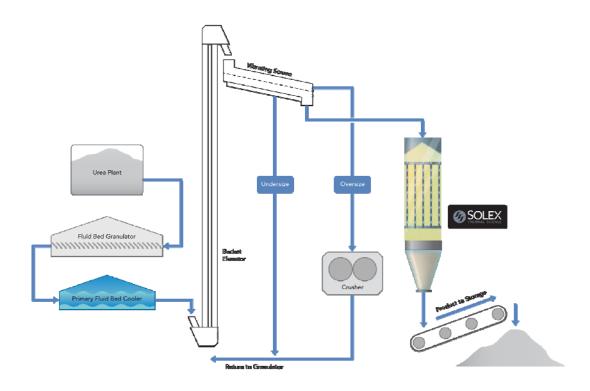


The indirect cooling technology cools the fertilizer indirectly with water. The unique advantage of this technology is the indirect method of cooling and the fact that air is not used in the cooling process.

What Are the Implications of Cooling Without Air?

With indirect cooling, the cooling fluid is plant cooling tower water. This has the big advantage that the thermal cooling duty is "free," except for the cooling water pumps. In comparison, a fluid bed cooler requires large volumes of chilled air. Chilling the air is very energy inefficient because the heat load includes the heat to condense the water out of the air to the dew point. Furthermore the air has to be "over-cooled" and then reheated so that it is not saturated when it enters the cooler.

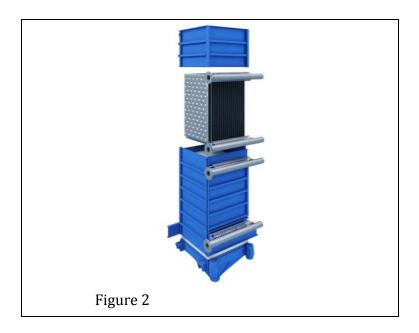
With indirect cooling, the cooling media does not come into direct contact with the product, which means no dust or emissions are created. This eliminates the problem of having to add more pollution control equipment associated with fluid bed coolers. The amount of work and the cost of the installation of the additional cooling equipment are thereby greatly reduced. It also means that the addition of cooling capacity does not add to emissions permitting concerns.



The Benefits of a Vertical and Modular Design

The nature of the indirect plate cooling technology is the vertical configuration. This design means that the installation footprint of the indirect plate cooler is approximately 85% less than that of a fluid bed cooler. The installation footprint of a typical fluid bed cooler in a 100 t/h facility is $3m \times 8m$. The equivalent indirect plate cooler is only $1.6m \times 2.4m$ —a fraction of the size. The compact installation footprint means that the space required to add additional cooling capacity to an existing facility is greatly reduced. Not only is adding cooling capacity now feasible, the costs are greatly minimized and the time required for installation significantly reduced.

There is one more important benefit of the vertical design that is unique to this indirect plate cooling technology. Since the plate banks are installed vertically inside the heat exchanger housing, it is possible to add more heat exchanger plate banks in the future if more cooling capacity is required. See figure 2. Capacity increases with the indirect plate cooling technology are a manageable task compared to the addition of an entire new fluid bed cooler. In fact, new facilities that start out with indirect plate cooling technology find that adding more cooling capacity does not present any of the common issues associated with attempting to add capacity using fluid bed coolers.



What About Efficiency?

The indirect plate cooling technology offers significant benefits that enable the addition of cooling capacity in fertilizer expansions and helps reduce the costs and workload in doing so. However, once installed, what are the operating costs of the indirect plate cooling technology compared to fluid bed technology? The question of efficiency is important.

The premise behind fluid bed cooling technology is that large volumes of chilled air are used to both fluidize the material (required to enable the product to flow) and to act as the heat exchange medium—adding or removing heat from the process.

With this technology, ambient air is taken in using large fans and, in most climates, the air must be chilled before blown across the product using large horsepower fans. The air leaving the fluid bed cooler is then discharged through an emissions stack. Both the chilling process and the circulating fans have high energy requirements.

By comparison, indirect plate cooling technology works by cooling bulk solids indirectly using water. No air is used in the cooling process. With this technology,

cooling water is pumped through a vertical bank of hollow stainless steel plates while the bulk solid passes between the plates with sufficient residence time to achieve the required cooling.

The inherent problem with using air to directly cool fertilizer is the large quantity of air required and the expense involved in chilling, processing and cleaning that air.

Below is an energy comparison between a fluid bed cooler and the indirect plate cooling technology. As can be seen, the indirect plate cooling technology uses up to 90% less energy than fluid bed technology.

Indirect Plate Cooling Technology Uses up to 90% Less Energy

	Fluid Bed Cooler	Solex Cooler
Electrical Fan Power	500 kW	-
Electrical Pump Power	_	25 kW
Bucket Elevator Power	_	25 kW
Air Chiller Power	550 kW	-
Cooling Tower Fans	_	40 kW
Total Power Consumption	1050 kW	90 kW
Operating Hours / Year	8000 hrs	8000 hrs
Total Energy Cost / Year (\$0.05/kW)	USD \$420,000 / Yr	USD \$36,000 / Yr

Conclusion

Advancements in indirect plate cooling technology make it an ideal solution for fertilizer expansions and debottlenecking projects because of its compact installation footprint, ability to cool without air and its ultra high efficiencies. The modular design makes it possible to add more cooling capacity with relative ease and will make it a logical choice not just for expansions but also for new facilities in the future.

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Analysis of Safety Performance of Indian Fertilizers Plants

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Analysis of Safety Performance of Indian Fertilizer Plants

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Abstract

FAI has been conducting safety survey of fertiliser plants for the past several years to assess the status of the safety performance of the industry as a whole and to help fertiliser plants improve their performance to establish a safe and healthy working environment. The present survey was carried out for 31 ammoniaurea and NP/NPK complex fertiliser plants for a period of five years for the years 2005-2010. The paper provides the results of analysis of accident data with respect to various safety parameters viz. incidence rate, severity rate and fatality rate. The analysis also identifies the causes of incidents and fatalities and plant areas prone to incidents so that plant management can address the issues to minimize the occurrence of incidents.

1. Introduction

India is the third largest producer of fertilizers in the world. There was a production of 38.5 million tonnes of various fertilizer products in the year 2010 – 11. It involved production of large quantities of intermediate chemicals like ammonia, sulphuric acid, phosphoric acid and nitric acid. These chemicals along with the wide range of finished products involve application of complex process technologies. There are extreme operating conditions in terms of temperature, pressure and hazardous chemical environment. The safety of personnel and plants remains a top priority for any plant management. Extreme care is taken in design, operation and maintenance of fertilizer plants. The safety performance of fertilizer industry in India has been quite satisfactory. A number of units have received international safety performance awards.

The Fertilizer Association of India (FAI) has always been active in promotion of the cause of safety in the industry. A systematic collection and analysis of safety related incidents was started in 1990s. FAI also instituted an award for Excellence in Safety in the year 2001. The present paper presents the analysis of data on reportable accidents during the five year period of 2005 – 10. The data concerns with the human injuries and loss of life in fertilizer industry. The data includes 15 integrated ammonia-urea plants, 7 ammonia urea plants integrated with NP/NPK fertilizer plants, and 9 NP/NPK complex fertilizer plants including five acid plants. These plants accounted for 97 per cent of total nitrogen and 88 per cent of total P₂O₅ during the period. The average regular and contractual manpower of about 52.4 thousand was employed by 31 fertilizer plants in almost equal share.

2. Safety Indices

An injury which requires minimum 24 hours absence from work is defined as a reportable accident. The data was analyzed w. r. t. frequency and severity of accidents and their causes. Various indices have been worked out to indicate the frequency of accidents and their impact on human life.

2.1. Incident Rate

Only the data for reportable accidents are included in the analysis including fatal accidents. An injury which required a minimum of 24 hrs of absence from work after an accident is defined as reportable accident.

The incidence rate i.e. the number of accidents per million man hours indicates a gradual decline during the survey period of (2005-2010). The lowest incidence rate of 0.47 was reported in 2009-10 and highest incidence of 0.75 was reported in 2005-06. The average of five year period was 0.59 as shown in **Table 1**

Table 1: Incidence Rate (based on million man hours worked)

Year	Million man	Total no. of reportable accidents	Incident Rate*
	114.44		
2005-06		86	0.75
2006-07	121.39	89	0.73
2007-08	126.16	66	0.52
2008-09	126.89	62	0.48
2009-10	125.4	59	0.47
Average			0.59

*Incidence Rate = No. of reportable accidents
Million man hours worked

Figure 1 depicts quartiles for incident rate for five year period for Indian fertilizer plants. It can be seen that the best 25% plants showed an average incident rate of 0.07 while the last 25% reported an average incident rate of 1.22. The fertilizer plants reported incident rate from 0.0 to 1.59.

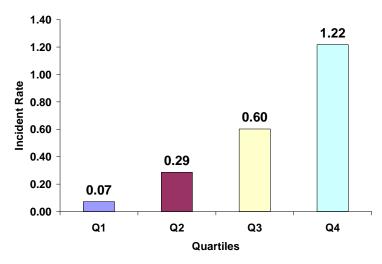


Figure 1: Quartiles of Incident Rate (2005-10)

2.2. Severity Rate:

The severity rate is calculated to examine the impact of accidents on human health. Severity rate is the lost time due to injury preventing an employee from working in his assigned work shift. Thus severity is calculated as million man hours lost due to accidents as a percentage of total direct man hours worked, as shown in Table - 2.

Table: 2 Severity Rate of Indian Fertiliser Plants

	Million- Man	Million-Man	Severity
Year	hours worked	hours lost	Rate@
2005-06	114.44	0.446	0.39
2006-07	121.39	0.546	0.45
2007-08	126.16	0.405	0.32
2008-09	126.89	0.499	0.39
2009-10	125.40	0.451	0.36
Average			0.38

@ Severity Rate = No. of man-hour lost due to reportable accidents * 100 No. of man -hours worked

From Table 2 it can be observed that less than half a percent of time was lost due to injuries in accidents in plants. The severity of accidents increases due to fatal accidents.

2.3. Fatal Accident Frequency Rate (FAFR)

There was increase in number of fatalities from 38 in 2000-05 to 47 in 2005-10. The Fatal Accident Frequency Rate (FAFR), i.e. the number of deaths from industrial injury expected in a group of 1000 persons during their working life (1000x 40 years x 52 weeks x 48 hours) is equivalent to 99.840 million man-hours worked. FAFR for the period of 2005-10 (five years) has been worked out in **Table 3.**

Table-3 Fatal Accident Frequency Rate (FAFR)

Year	Fatal Accident Frequency Rate (FAFR)	No. of Casualties
2005-06	7.85	9
2006-07	9.05	11
2007-08	6.33	8
2008-09	7.87	10
2009-10	7.18	9
Average	7.65	

The FAFR was the highest in 2006-07. The average FAFR for the period of current survey is 7.65 which is much higher than that of 5.63 for the period 2000-05.

2.4. Accident Free Period:

It can be seen in **Table 4 that** accident free period is becoming longer from the past 15 years. This indicates that on an average, number of accidents is decreasing from each survey of 5 years consistently.

Table: 4 Comparison of Longest Accident free Period

	2005-10	2000-05	1995-00
Average of Accident free period (days)	929	657	459

3. Causes of Reportable Accidents:

Detailed analysis of major reportable accidents is tabulated in Table 5 which shows that maximum accidents have occurred due to Slip & fall (78) followed up by those due to Hot Condensate/Chemical burn (42). Fall from Height (27), falling objects (28) and entanglement with moving equipments like conveyors (31) also caused a significant number of accidents in plant. Accidents due to movements of vehicles (30) in the battery limit of the plant are noteworthy. Total number of reportable accidents in this period has reduced to 361 from 719 in 1995-2000 and 857 in 2000-05.

Table 5: Causes of Reportable Accidents

Sl. No	Causes	2005-06	2006-07	2007-08	2008-09	2009-10	2005-10
1	Slip and Fall	18	16	7	22	15	78
2	Hot Condensate / Steam / Chemical Burn / Hot water	8	16	7	6	5	42
3	Entanglement with Moving Equipment	9	8	5	5	4	31

18	Subtotal	85	89	66	63	58	361
17	Miscellaneous	6	2	4	5	5	22
16	Collapse of Material/Goods	0	1	4	0	0	5
15	Construction	2	1	0	3	1	7
14	Asphyxia/Drawning	1	2	1	1	2	7
13	Entanglement with Static Equipment	2	2	1	3	1	9
12	Fire	2	0	0	5	2	9
11	Equipment/Vessel /Line Failure	1	3	4	1	3	12
10	Explosion	0	7	0	0	5	12
9	Electric Burn / electrocution	3	3	4	1	1	12
8	Ammonia Cold Burn /Inhalation	11	1	0	1	1	14
7	Improper Tools, Tackles and Procedures	4	4	6	1	1	16
6	Fall from Height	7	3	7	5	5	27
5	Falling Objects	5	9	5	4	5	28
4	Road/Rail/Moving Vehicle	6	11	11	0	2	30

4. Accident analysis Area wise:

Accidents were classified according to location of the incidents occurred for identify areas which are more prone to accidents. Area wise accidents are given in Table -6.

Table 6: Area wise accidents analysis

Sl.	Areas	2005-06	2006-07	2007-08	2008-09	2009-10	2005-10
NO. 1	NP/NPK complex	13	14	16	9	13	65
2	Ammonia	15	10	9	8	9	51
3	Material handling/Bagging	11	11	6	15	6	49
4	Utilities/offsites/ETP	12	5	13	6	7	43
5	Roads/rail track	3	9	10	2	6	30
6	Urea	12	8	1	4	2	27
7	Sulphuric acid	3	8	4	2	3	20
8	Workshop	2	8	0	0	1	11
9	Phosphoric acid	3	1	2	2	2	10
10	Stores/yard	2	2	1	4	1	10
11	Godown/warehouse/silo	1	3	2	0	3	9
12	Electrical area	0	3	1	4	0	8
13	Laboratory	1	2	0	0	0	3
14	Garage/locmotive shed	0	1	0	0	0	1

	Subtotal	85	89	66	63	58	361
16	Miscellaneous	7	4	1	6	5	23
15	Nitric acid	0	0	0	1	0	1

This analysis shows that maximum number of accidents have been reported from the plants that involve large manpower for process and material handling. NP/NPK Complex fertilizer plants accounted for maximum 65 accidents followed by Ammonia plant (51). Ammonia plants are highly automated and large number of accidents in ammonia plants need to be investigated further. Material handling and bagging areas accounted for large number (49) of accidents perhaps due to large number of persons employed in these operations. A significant part of employees in these areas are contract labours. Again a high number of accidents (30) are road and rail track bring out need for precautions during driving on road or shunting of rail wagons.

5. Fatal Accidents:

Causes of fatal accidents are listed in **Table 7**, it can be seen that most of the fatal accidents were due to slip and fall/fall from height and rail. Significant fatal accidents were due to road accidents and moving vehicles in the factory. There was a major accident due to process related explosion which caused collapse of prill tower which resulted in two workers death and injuring three workers. Another fire and explosion accident in CO shift converter resulted in 3 casualties. A total of 47 fatal accidents were reported from 31 fertiliser units.

Table 7 Cause of fatal Accidents

Sl. No.	Cause of fatal Accidents	No. of fatal Accidents
1	Slip and Fall / Fall from Height	14
2	Rail/Road Accident in Factory	10
3	Explosion	7
4	Fire	4
5	Electrocution	3
6	Entangle with rotating equipment	2
7	Equipment/vessel/line failure	1
8	Asphyxia/ Drowning	2
9	Collapse of Material / Goods	2
10	Miscellaneous	2
	Total	47

Brief description of some major accidents which caused fatalities:

(i) Explosion in Nitro phosphate plant :

An explosion occurred in nitro phosphate plant in 2006-07. Decomposition of ammonium nitrate took place due to high temperature in NP melt tank and its piping resulting in an explosion. Control Room underneath the tank and the surrounding structure on the top of prill tower collapsed and the victims got trapped/ buried under the debris resulting in the death of two workers and injuring three workers.

Causes: High temperature leading to decomposition of Ammonium Nitrate.

Remedial Action: Prilling technology was changed to granulation technology where temperature requirement is quite low.

(ii) Fall of scaffold from height:

This accident happened in urea plant during painting of internal shaft of urea prilling tower, julla fell down from height of about 30 feet due to shearing of pinion of electrical winch, in which 3 persons were badly injured and 2 fatalities was reported.

Causes: Shearing of pinion of electrical winch machine.

Remedial Action: Second holding of the julla to be made foolproof.

(iii) Minor Flash Fire:

This accident occurred inside DM plant, when repair job for application of FRP coating inside vessel was done. Minor flash fire took place resulting in 3 fatalities.

Causes: Sparking in the chemical used for FRP coating.

Remedial Action: Proper rescue equipments have been procured by the company for vessel entry and chemicals used for FRP coating were reviewed. Permit system was initiated before the start up of any process and it is made mandatory to conduct gas test in each shift by competent person of E & QC department.

6. Area of Concern:

Any of the accidents reported did not cause shut down of the plants. Majority of accidents were not due to process hazards. The detailed analysis of fatal accidents reveals that most of the accidents could have been avoided if proper procedures/techniques were followed with proper training to the labours especially contractual. A large number of accidents in fertiliser plant have occurred due to improper housekeeping, inadequate safety procedures, equipment inspection and lack of supervision. A Road accident within the battery limits is an example of completely avoidable incidents. Safety is the result of control of recognized hazards with a good policy, programme and proper organizational structure with clearly assigned responsibilities.

7. Hazard Evaluation:

The ability to ensure safety in a plant is influenced by many things, for example employing appropriate technology in design and construction, anticipating the effects of external circumstances, understanding and dealing with human behavior and having effective management systems. However all these efforts depend on a successful hazard evaluation programme, without these evaluations, the company will not know what layers of protection are needed. Every fertiliser plant carries out safety audit every year and recommendations from the auditors are to be implemented in the prescribed time frame. Numbers of plants carry hazard evaluation with assistance of experts especially for the accident prone areas of the plant. Many plants have taken safety initiatives like OHSAS 18001, PSMS and have earned prestigious safety awards. HAZOP studies are frequently done by the process experts for periodic hazards reviews of existing equipments or review of new equipment before its start-up. Proper training programmes and good housekeeping system should remain top priorities. Committee comprising of multidisciplinary team drawn from operation, maintenance, fire and safety should be entitled for surprise visits to any area of plant and hefty fines should be imposed for violation of any safety rules.

8. Conclusion:

The safety survey of five years for fertiliser industry shows that today the biggest challenge before any chemical industry is the safety of their plant personnel. It was observed that most of the accidents occurred during this survey period was due to human error, adopting unsafe working practices and lack of supervision. For adoption of safe work practices safety of chemical plants requires full commitment of management, interaction of plant personnel with various departments. Only two major accidents occurred due to process hazard leading to some fatalities. The analysis of data clearly brings out the need for focus on behavioral safety.

There should be frequent training sessions to sensitize the employees of hazards of each work process and task. Special attention need to be paid to use of personnel protective equipments, cleanliness of area, safe entry into vessels and avoid any shortcuts.

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Commissioning and Revamping Fertilizer Plants Through an Objective Oriented Approach

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24th AFA Int'l. Technical Fertilizers Conference & Exhibition 22 – 24 November 2011, Amman, Jordan

Commissioning And Revamping Fertilizer Plants Through An Objective Oriented Approach

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The paper brings out how the strategy and road map have to be developed to complete the very challenging world class projects along with the implementation of the revamping ones.

Theoretical aspects and the straight implementation of the principles are focused and highlighted in order to provide tools to accomplish the different expectations that all the involved Entities have in mind to make business and to fulfil commitments.

The framework, into which activities are confined, is considered the base for getting results and its dynamic structure the main tool for preparing action plans and corrective ones.

Leadership's attitude and capability to carve out strategies and to provide a sure focal point for the Project success are considered.

Examples are made available to make the issue more understandable and familiar.

INTRODUCTION

The development in the recent years of fertilizer industry towards the application of economy of scale to new plants through the technology improvements for high capacity, has urged Owners to improve their economics by increasing the production efficiency and/or outputs.

In this endeavour to maintain a production cost within limits acceptable to the market, notwithstanding the sharp increase of gas cost in many areas of the world, Owners find good allies among those technology Licensors who have a long experience in commissioning and revamping Plants and have developed throughout the years schemes and strategies suitable for new challenges.

OBJECTIVES TO BE MATCHED

While elaborating the various scenarios applicable to a fertilizer plant, it is very important to focalize on the objectives, whose identification can be planned according upon the desired improvements.

In case the objective is to improve the plant economics, the applicable scheme will be defined in order to minimize the production cost and to maximize the production output (the latter is related to the availability of the associated raw materials and utilities).

The production cost reduction can be accomplished through modifications aiming at decreasing the variable cost (energy saving) as well as decreasing the fixed cost (schemes that minimize the maintenance and labour costs).

Maximize the production output is the goal of capacity increase, but may also be the increase of reliability of the plant in terms of on-stream performance throughout the operating year.

While the first is the key objective of new tendency towards jumbo plants, the improvement of reliability also depends on other factors like maintenance, quality of material, availability of external sources, etc. etc.

Among the objectives to be matched, product quality and emission control are very important.

Product quality can be affected by bringing the plant production beyond its nameplate capacity, so that independently on the necessity to increase plant output, it is always necessary to take it into consideration, often in connection with the variability of performances through the year linked to the seasonal changes of ambient conditions.

Emission control is a mandatory requirement in the new plant generation.

Licensors have developed the "zero tolerance" approach to attain total control of emissions under any operating conditions.

REVAMP PHILOSOPHY

The approach philosophy applied to the revamp is of utmost importance to obtain the desired technical and economical viability of the project.

In this regard, the first consideration is that the plant, to be revamped, has to be in continuous production so that the shut down time required to implement the revamp will be minimized.

Moreover the utility additional consumption has to be inside the capacity of the existing facilities, otherwise a further request from the process unit may turn out to imply a huge investment cost for the associated utility plants.

Similarly, also the increase of consumption of raw materials must be in accordance with the planned increase of the upstream process plant (ammonia).

In any case the revamp has to maintain the specific raw material consumption within the actual one or to improve it.

The same concept is applicable to the product quality since no worsening is ever acceptable.

A central concept in a revamping Project is to maintain the plant operability and flexibility.

The plant is originally designed to perform its task under certain design conditions and within reasonable variability of process parameters.

This is obtained by introducing appropriate design margins in the plant, so that it can withstand the variation of operating conditions that may take place: the achievable flexibility and operability are characteristics of the applied process technology.

The revamp philosophy should be based on maintaining as much as possible the plant flexibility and operability and , when these have already been trade off for a capacity increase, on restoring them.

All the above goes along with the minimization of the investment cost.

However all the schemes have to be scrutinized considering that the prevailing factor for selection has to be based on cost-benefit analysis.

COMMISSIONING PHILOSOPHY

Commissioning a huge fertilizer Complex it means to apply an integration of Entities that have to be full aware that only a smooth, comprehensive and proactive links can bring to the expected results.

Coordination and planning are two main key elements that have to be clearly kept in mind and used as driving forces.

The strategy to be adopted has not to be confined only to the execution phase but starts from the very beginning and it easy to say that new philosophy has to be applied to execute the projects.

The recent fertilizer Projects have shown a tendency to create a merger in between the main Contractors to tackle drawbacks based on the magnitude of the economics linked to the actual execution of the Projects.

The Client's expectations and the risks that can derive from the complexities of the fertilizer Complex, in terms of material supply, financial package, market crisis, waves of unstable political issue, have led to reconsider the capability limited to the single Contractor and bring on the table the option of searching for partnership approach.

The globalisation has created waves that sometimes are not under rational control and this situation is confined mainly in Countries where the concept of "make system" has displaced the single Contractor's capability in favour of other issues that not always are technically and economically understandable but can find justification when confined in social corners.

Few Projects can be mentioned to highlight the new trend:

PROFERTIL Project – Argentina
 OMIFCO Project – Oman
 ENGRO Project – Pakistan
 QAFCO Project – Pakistan
 Contractors: Snamprogetti / Techint
 Contractors: Snamprogetti / Descon
 Contractors: Snamprogetti / Hyundai

The synergic approach in between the main Contractors could not be enough if no link is established with the Client's and Shareholder's capabilities.

It has to be said that the fertilizer Industry is a well mature one as well as the technologies to be applied.

In this contest, the Fertilizer Community is a very small Entity and the principal actors are well experienced technicians with solid knowledge and know-how that have been the result of years of deep involvement.

It should be a no proactive approach to limit or not to consider the opportunity to share opinions, to carve out mutual solutions, to make each other a very successful team with the same goal.

Beside this vision, there is a fundamental issue that has to be taken in serious consideration and tested on a day by day scrutiny and analysis: the mission has common ground even if the shores are opposite; the only professor is the Complex to be built and the involved Entities are at its service.

It is well understood at the beginning of the project implementation that the success of completion of the project would mainly lie with "the first time right" approach for commissioning and very little margin there is for errors and corrections.

Hence the project has to be termed as "COMMISSIONING ORIENTED PROJECT".

The definition is not confined only to the early phase of commissioning strategy and to the sequence of activities, but this concept has to be thought during the design phase of the Project.

The early identification of the Commissioning Manager and his involvement in the process design stage has the great advantage to allow to design the plant to be "tailor-made" to the needs of the commissioning activities, foreseeing details and systems that should speed up the starting up of the plant.

The more the possibility to envisage the commissioning activities, the more the positive outcome in terms of earlier production.

The overview of the needs allows to assure a complete scenario of the different systems and units that form the entire Complex and this will forecast the sequence of activities that will dictate the steps during the construction phase.

Details, new systems and sequences of construction are the root of success and all these are to be identified at the earlier stage of the Project and have to be implemented at proper time.

As an example, specific mention is made to the new opportunities available on the market for steam blowing activities and cleaning of the auxiliary boiler.

The Commissioning Manager has to be prepared to switch his attention from the usual procedures to the new ones available on the market and his knowledge will influence positively the sequence of the activities.

It is no more acceptable that the procedures to be adopted were old, not updated, and, above all, time consuming.

Efforts are to be put into action in order to have available the recent achievement in the field and technological breakthroughs have to be considered so that the Commissioning Manager can coordinate, implement and make all these issues familiar in between his structural organisation.

What makes the figure of the Commissioning Manager so important and so demanding is the fact that there is no allowance on his doing and so his performance is always under deep scrutiny and his outcome are well in front of everybody.

Commissioning a plant it is a very demanding task and more and more ,in the future, other commitments will be on his shoulders and under his umbrella.

Few additional tasks are mentioned herebelow:

- Prepare detailed programs, procedures and sequences of start up to be reflected in the preparation of the design package.
- Implement lesson- learned policy to make it an added value to the project.

- Create positive and professional approach with the process team to develop a mutual understanding and confidence on the recognition of specific roles and responsibility.
- Apply strategy for material selection to improve reliability.
- Review safety issue on giving recommendation to be implemented during design, engineering, construction and start-up phases.

The more the complexity of the job, the more effort and unity has to be established in between different Entities.

Common understanding, similar vision and mission are to be part of the duty that each pivotal figure has to nourish.

The Project Manager and the Technical Manager are to be an integrated team with the Site Manager and the Commissioning Manager.

Each of them has to understand that the positive result is not based on the single capability but mainly in the process to integrate the attitude, the knowledge and the experience.

The team's performance is not the sum of the single capability but the result of integration and understanding.

Getting good players together is easy: getting them to play together is the hard part.

PM, SM, TM and CM represent the team that the Clients has to identify as a group where all the members focus on a collective target.

A team does not pull together well when each individual member focus on their own target.

The Commissioning Manager, being the ultimate chain of the Project, has to look at team dynamics for getting all the efforts under his control, notwithstanding that he himself has to be dynamic.

There is a critical point in the execution of the Project where the importance of the commissioning activities becomes so huge and impelled that the Commissioning Manager has to put the strike to become the leader as decision-maker.

To identify this crucial moment, sometimes, is a question of success or not for the outcome of the Project.

The time to switch from construction responsibility to the commissioning one has to be careful selected and the sooner the better.

Normally this stage implies a radical change in the organization and the switch requires identification of the pros and cons with the relevant consequences.

The number of activities for the Commissioning Manager will increase, proper segregation of areas will be considered when the construction phase does not allow smooth change-over, policy of "work permit" will be shifted to the commissioning team, priority of the activities will be dictated by commissioning team as well as the responsibility.

Proper commissioning activities will be scheduled on two weeks time to focus on the relevant outstanding construction systems to be finished to move on; overlap between adjacent stages and homogeneous systems have to be evaluated and implemented in order to allow the sequence of the start-up activities.

STRATEGIC MANAGEMENT

Strategic Management refers to the managerial process of forming a strong mission-based vision, setting objectives, crafting strategy, implementing and executing that strategy and initiating corrective adjustments to the vision, objectives, strategy and implementation that are found necessary.

Strategic management has assumed a critical dimension in recent years due to the increased competition resulting from globalization, technology improvements, availability of resources, merger and acquisitions among major Companies and the rapid changes in the business environment.

For transformational change to be effective, a strategy must be executed with the full participation and involvement of the workforce.

The key to this transformation is awareness of the strategy at the centre of the management process.

The commissioning phase is the result of activities that have to be performed in such a way not to create any negative impact at the crucial moment represented by starting-up the Plant.

Do not cut corners and do not compromise on services and commitments represent the right approach to avoid waste of time and waste of energy.

All the activities, and the Management play a very crucial role, are to be beneficial to the objectives that day by day have to be achieved.

Strategy has to be formulated and implemented.

Key principles are required for building sound strategies:

- Translate strategy to operational terms
- Make strategy everyone's everyday job
- Make strategy a continual process
- Mobilise change through strong effective leadership
- Align the organisation to the strategy

Implementation is what is executed on a daily- weekly-quarterly basis, over time, to move ahead with the chosen strategy and realise the objectives.

This task is best performed by devising action plans to implement the strategy.

Now the critical points:

- How can the strategy be accepted, without any compromise by the Client and Contractor together?
- Is the strategy belonging to the Client's basket or, vice versa, represents a tool in the hands of the sole Contractor?
- What makes the strategy a common tool to be shared by Client and Contractor?

The foundation of all the accomplishment is RELATIONSHIP.

The more the importance of the matters to be dealt with, the more the urgency to create a collaboration feeling in order to expand the opportunity for accomplishments.

This is the case where the common understanding is dictating the pace for achievements.

Trust, appreciation, respect are factors that have to be characteristics of the behaviour to be nourished.

The coordinate action is the driving-force that makes the hurdles flat and easy to overcome for getting results.

The Commissioning phase nowadays has to be thought as a time to act positively, proactively, refusing to make business as usual; everyday has to mark a breakthrough in the business affair in order to remain competitive as top class player.

By the way, these approaches require perfect knowledge of the complexity of the Fertilizer Plants.

It is well understood that the Fertilizer Plants, in this case Ammonia and Urea Plants, are basically the sum of Units that are correlated, linked and started- up following a well defined sequence.

Nevertheless, the single activity for each Unit can be forecasted in such a way to save time and to speed- up the starting of the Complex.

Generally speaking, the framework of action plans should be set over two different time frames: short term and long term.

The approaches have to be marked by elements of intuition, imagination and creativity.

This process ensures that a proper structure has to exist to keep pace with the strategy.

This structure complies with the issues by relationship, skills, staff and their competencies, culture, motivation, communication, logistic resources to share the same vision to attain the goals.

While the implementation is in progress, decisions need to be taken in the context of closely monitored budgets and time schedules.

The task of reviewing the actual performances, to evaluate the implementation of the strategic plan is of critical importance.

The review exercise includes assessment of each process and plan to ensure that the actual situation complies with the requirements, the performance has not been affected by new developments and that the results are in line with those expected.

In terms of time frame, it is essential that the progress is in keeping with the time schedule and milestones established.

If any area examined indicates that there is a deviation from the original plan or there is a slip in time, the necessary corrective action needs to be initiated.

In actual practice the difficult task is all the more compounded by difficulties and problems that could not have been originally envisaged in the initial scheme.

This requires a workforce to be adequately skilled and trained, to be alert to the problems as they arise, or, if possible before they arise or assume dangerous proportions.

The same workforce needs to be creative to tackle these problems in the most innovative and effective manner.

Only a workforce that is constantly motivated can achieve such results.

The other side of the coin, imply that the review has to be limited to the critical path of the Project and that, at certain time, it is necessary to manage and tackle the uncertainties by personal experience and to leave apart any preselected tool of analysis.

What has to be avoided it is the series of meetings that deal with all the matters and great attention has to be paid to the very critical issues that require really brainstorming session.

The commissioning phase is very demanding and very crucial.

No postponement is acceptable and every day lost for rectification brings the certainty that the production will be delayed accordingly.

CONCLUSION

To be part of the challenging moment of commissioning a fertilizer plant, put all the associated Entities in a situation that covers all the story of the plant itself along with all the demanding activities that are prerequisite for getting the final product.

Proper timing, commitments, action plans and relationship are the fundamental factors that make the commissioning phase a successful one.

The leadership of the Commissioning Manager is of outstanding importance in order to cope with the needs that day by day arise.

The organisational aspects are of vital importance and great efforts are always requested for making all the technical departments working at the top of the expectation.

The performances are always the result of good management and to create a collaborative spirit with the Clients leads to overcome misunderstanding, misjudgements and wrong doing.

None can say to be the captain without trust from colleagues, vendors, manufacturers and Clients.

It is the role of the Commissioning Manager that has to be underlined to get results.

24" AFA Int'l. Technical Fertilizers Conference & Exhibition 22 – 24 November 2011, Amman, Jordan

Best Available Technology in Fertilizer Industry :
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Environmental friendly way of spent catalyst recycling

الإتصاد العربك للأسمدة

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Arab Fertilizers Association

Mr. Clemens Kuhnert

Area Manager Middle East & Africa - Nickelhutte Aue GmbH

Germany

Nickelhütte Aue GmbH

Spent Catalyst Recycling

A complete service from the cradle to the grave

Topics

- **▶** Introduction NHA
- Why recycling is important
- Catalyst/Basemetal demand
- ▶ Recycling loop NHA
- Way of material
- Pyrometallurgy
- Hydrometallurgy
- **▶** Environmental responsibility
- Service

Where we come from

- ▶ 1635 founded as "blue dye work"
- ▶ 1849 first nickel cubes
- **▶** 20th Century secondary

metal works

Certified as

Today

- Catalyst recycling
- Sludge recycling
- ▶ Nickel, copper, cobalt and vanadium production
- **▶** Recycling of corrosive solutions
- **▶** Alloy smelting

- Metal trade
- Energy generation
- Dismantling of transformers

Why it is important to recycle metal

Recycling Saves the Earth metals are precious natural resources of the Earth. Metal deposits are non-renewable resources that will run out if exploited at the present rate. Example: NHA recycled 3300 t of nickel instead of the deep impact in the environment to explore 230 000 t of ore. (average Ni 1,45%)

Recycling Saves Energy It takes less energy to melt down waste metal and recycle it than it does to produce new metal (save 85 % by Cu recycling instead of using ore)

- Recycling Helps Mitigate Global Warming and Reduce Pollution Using recycled metal reduces CO2 emissions and air pollution. By saving energy in industrial production through recycling, the greenhouse gas emissions from factories and industrial plants are lessened.
- Recycling Reduces Waste Products in Landfills By recycling, we can lessen the waste materials that are placed into landfills and we are able to make the most out of these materials Reduces the amount of metal going to landfill as despite a growing awareness of the value in recycling metal,
- Recycling Helps you Save Money Recycling provides ways to save money. With selling spent catalyst you will benefit on the recycling system and the actually marked prices.

Ni/Cu prices

base metal catalyst demand worldwide

average metal demand in non-PGM catalyst in Germany

Production

▶ 20 – 30 % Recycling rate

Contribute to the Environment

The Recycling Loop

Process diagram

The way of the material

Pyrometallurgy roasting department

feed materials

•

Desulfurisation / Purification / Steam-Reforming / Methanation / Hydrocracking / Hydrotreating / Hydrogenation / Refining

- Ni
- Cu
- Co
- PGM
- V
- Mo
- W
- Zn

Pyrometallurgy melting department

feed materials electroplating and wastewater sludges, filter cakes, dusts, ashes

- Nickel
- Copper
- Cobalt
- **▶** PGM

Specification

Nickelmatte

Ni 20% - 30%

Fe 25%

Pb, Zn & Cr < 2%

Chemical production Ni/Co Extraction

Specification

Nickelsulphate /

Nickelchloride /

Nickelnitrate

Cu, Fe, & Cr < 10 ppm

Zn < 10 ppm

Copper Sulphate Production

-corrosive solution from Circuit Board

-extracted copper from concentrates

Specification

HCl min 30 %

Ca, Mg, & Na < 20 ppm

Pb, Zn & Fe < 1 ppm

Chemical production

Vanadium

Specification

PGM Recycling

Waste Gas Utilization

Air quality

Water purification

Preparation of disposal documentation

accompanying documents notification documents financial guarantees

Supply of Dangerous Goods Labels

Provision of drums, big bags, IBC's

Organisation of transport &

transport documents

Analysis of samples

We work for

NHA Activities Worldwide

Thank you for your attention

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A new approach for Urea Plant Optimization Using Advanced Process Control

الإتصاد العربج للأسمدة هيئة عربية دولية Arab Int'l. Organization

Arab Fertilizers Association

Mr. Christiaan Moons - Sales Director Mr. Luc Dieltjens - Process Engineer IPCOS-Stamicarbon Belgium

Sirius@Max: A new approach for Urea Plant Optimization using Advanced Process Control

Model predictive control (MPC, also known as Advanced Process Control or APC) has been widely accepted industrially during the last decade, mainly because of its ability to handle constraints explicitly and the natural way in which it can be applied to multivariable processes. For processes with strong interaction between the different parameters, MPC can offer substantial performance improvements compared with the traditional single-input single-output PID-control strategies. The dense interaction matrix of urea processes, combined with its extreme slow dynamics make these processes ideally suited for MPC technology.

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Stamicarbon and IPCOS

n the 23rd of February, Stamicarbon and IPCOS announced the signing of a agreement aimed cooperation providing urea producers with IPCOS' high-end Advanced Process Control and Optimization solutions. The cooperation agreement will facilitate the combination of Stamicarbon's leading process knowledge and IPCOS' innovative Advanced Process Control (APC) solutions. By bringing together the experience of Stamicarbon, market leader in Urea process licensing, and the experience of IPCOS, market leader in Advanced Process Control solutions for Fertilizer producers, a next generation Urea Optimization solution is made available to the market.

Sirius@Max

Several years ago, IPCOS launched its Urea@Max solution, a generalized APC solution for all types of Urea plants. The Urea@Max solution is part of the solution suite

that IPCOS offers to the Fertilizer industry, including process-specific solutions Ammonia@Max, NitricAcid@Max, Steam@Max, Granulation@Max and many more. Each of these solutions in the suite optimizes plant operation by making small changes to key operating parameters, ensuring optimal operation whilst keeping key process parameters within operator- and engineerspecified limits. These low-cost solutions allow fertilizer producers to significantly improve their production rates (1-5% increase is typical) and operating efficiency without the need to undertake major plant equipment investments. Following the successful launch of Urea@Max, Stamicarbon and IPCOS decided to bring together Stamicarbon's leading Urea process knowledge and IPCOS' state-of-the-art APC technology called INCA, and develop an APC solution which is specifically designed for Stamicarbon Urea plants. The new solution is called Sirius@Max. It optimizes the operation of the Urea plant minute by minute, every minute of the hour, every hour of the day. The Sirius@Max solution provides Urea producers with improved reliability in operation, by ensuring continuous, consistent best practice operation. The variability in key process parameters is significantly reduced (typically by a factor 2 to 5), and production rates and energy efficiency are increased from conventional, operator-driven operation. Downstream units such as granulation or prilling sections benefit tremendously from the improved consistency of the quality of the Urea melt.

Sirius@Max is normally implemented by a combined team of experts from IPCOS and Stamicarbon. Typical payback times of 3 months to one year are achieved, and guarantees can be provided for the benefits that the solution will generate.

Optimizing urea plants

Optimizing urea plants often means maximizing the production capacity and/or minimizing the energy consumption. In order to optimize a urea plant, some basic understanding on thermodynamics of a system containing urea, water, ammonia and carbon dioxide is required. In all commercial processes, the production of urea proceeds by a two-stage reaction according to the Basaroff reactions:

$$\begin{split} 2NH_3 + CO_2 &\Leftrightarrow NH_2COONH_4 \\ \Delta H &= -117 \frac{kJ}{kmol} \\ NH_2COONH_4 &\Leftrightarrow NH_2CONH_2 + H_2O \\ \Delta H &= +15.5 \frac{kJ}{kmol} \end{split}$$

The formation of ammonium carbamate out of ammonia and carbon dioxide is strongly exothermic and reaches very rapidly chemical equilibrium. In comparison to the first reaction, dehydratation of ammonium carbamate to urea and water is slow and endothermic.

A prerequisite for every urea plant to maximize production and minimize the energy consumption is obtaining a maximum yield in the reactor. It is obvious that the formation of urea only takes place in the reactor. The equilibrium reaction dictates that the formation

of urea does not go to completion, and hence non-converted ammonia and carbon dioxide need to be recovered and recycled back to the synthesis.

Such carbamate recovery often involves an evaporation and condensation step, not only consuming energy, but also reducing retention time in the reactor.

Optimizing reactor yield is a key element in the new advanced process control system. Among other tailor designed control objectives, it always contains optimal reactor yield control by:

- -Azeotropic control in the reactor and recycle carbamate.
- -Water management control.

Dynamics and control characteristics of urea plants

All urea stripping plants are characterized by a "high degree of interaction" among the process variables. Any change at the backend will affect the synthesis and vice versa. These are typical control characteristics for plants containing multiple recycles. It's however beyond the scope of this article to detail the degree of interactions among those parameters.

As mentioned before, the dehydration of ammonium carbamate to urea and water is slow, which requires large retention times in the reactor (typically some 60 minutes). This reactor hold-up is characterized as a "pure dead time" in the process.

As the name implies, dead time is the property of a physical system by which the effect of a disturbance is delayed.

A simple PID feedback controller would provide a quite unsatisfactory closed-loop response on N/C-control, for the following reasons:

- A disturbance entering the process will not be detected until after a significant period of time.
- The control action that will be taken on the basis of the last measurement will be

inadequate because it attempts to regulate a situation (eliminate the difference between set point and process value) that originated a while back in time.

 The control action will also take some time to make its effect felt by the process.

As a result of all the factors noted above, significant dead time is a significant source of instability and oscillations for closed-loop responses.

Further, some unit operations contain transfer functions with "non-minimum phase" behavior (popularly known as "inverse response"). Those processes initially respond in opposite direction to where it eventually ends up.

Single loop PID-controls are in general not compatible to control processes with control characteristics as described above without introducing plant oscillations.

What's in the name...

Advanced Process Control (APC) and Modelbased Predictive Control (MPC) are terms that are widely used throughout process industries for a variety of control solutions. It is important to note however that true APC is a multivariable solution, capable of tackling the control challenges described in the previous section. Some companies refer to APC as a (complex) cascade of PID loops, calculation blocks and sometimes even logic blocks. This is not APC, but Advanced Regulatory Control or ARC. Application of ARC can help stabilizing the plant operation, but will not give the same order of benefits that APC will bring, since only APC is capable of handling the complex interactions in the process.

Sirius@Max, like all @Max solutions in the solution suite of IPCOS, is based on multivariable APC technology, and is therefore capable of optimizing the entire Urea plant operation, taking into account all complex interactions in the process.

What does it take?

Whether or not a Urea plant is ready to have an Sirius@Max solution installed depends on several factors. A critical factor in determining whether or not a Urea plant is APC-ready is that the critical instrumentation required for APC is present and functioning reliably and accurately. This requirement is however very often misunderstood to mean that "all possible equipment needs to be available and all possible equipment needs to function correctly". This is not correct. APC critical instrumentation is just a rather small subset of the equipment available on site. Sure enough, there are occasions where for instance temperature indications are not located at the right tray in a column, or an online analyzer is not available for a stream property that cannot otherwise be calculated. But in most cases a plant is "more ready than people think". Remember that operators are currently running the plant. So one way or another there seems to be sufficient information available to allow them to run the plant. This makes the likelihood of the plant being APCready quite high.

In order to assess the feasibility of applying Sirius@Max to a plant, IPCOS and Stamicarbon offer a plant assessment which will report on the technical and techno-economical feasibility of implementing the Sirius@Max solution, and which will contain the recommended next steps to the implementation of Sirius@Max on the Urea plant.

For more information, contact the authors or go to www.ipcos.com or www.stamicarbon.com

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	Egypt	Egypt Ibrahim EL ABIAD Egypt Mohamed FALLAH Egypt Zeyad EL MOLLA Egypt Walid EI-GANINY Egypt Mohamed Abdel Aal YOUSSEF Egypt Mohamed Adel EL DANAF Egypt Ahmed EL-Said AL-SAID Egypt Gamil HABIB Egypt Nefissa Mohamed AWAD Egypt Shaker MORIES Egypt Mohamed EL HADY Egypt Mohamed Ahmed EL REFAAY Egypt Mamdouh Mohamed SABRY	CountryNameRegst. #EgyptIbrahim EL ABIAD2nd-Ev.2011-Ord-1085-550EgyptMohamed FALLAH2nd-Ev.2011-Ord-1085-560EgyptZeyad EL MOLLA2nd-Ev.2011-Ord-1085-570EgyptWalid El-GANINY2nd-Ev.2011-Ord-1085-580EgyptMohamed Abdel Aal YOUSSEF2nd-Ev.2011-Ord-1085-590EgyptMohamed Adel EL DANAF2nd-Ev.2011-Ord-1209-400EgyptAhmed EL-Said AL-SAID2nd-Ev.2011-Ord-1209-410EgyptGamil HABIB2nd-Ev.2011-Ord-1209-420EgyptNefissa Mohamed AWAD2nd-Ev.2011-Ord-1209-430EgyptShaker MORIES2nd-Ev.2011-Ord-1209-440EgyptMohamed EL HADY2nd-Ev.2011-Ord-1209-450EgyptMohamed Ahmed EL REFAAY2nd-Ev.2011-Ord-1209-460EgyptMamdouh Mohamed SABRY2nd-Ev.2011-Ord-1209-470	Country Name Regst. # Position / Company Egypt Ibrahim EL ABIAD 2nd-Ev.2011-Ord-1085-550 Chemist ALEXFERT Egypt Mohamed FALLAH 2nd-Ev.2011-Ord-1085-560 Ammonia Process Supervisor ALEXFERT Egypt Zeyad EL MOLLA 2nd-Ev.2011-Ord-1085-570 Ammonia Process Supervisor ALEXFERT Egypt Walid El-GANINY 2nd-Ev.2011-Ord-1085-580 Urea Process Supervisor ALEXFERT Egypt Mohamed Abdel Aal YOUSSEF 2nd-Ev.2011-Ord-1085-590 Urea Process Supervisor ALEXFERT Egypt Mohamed Adel EL DANAF 2nd-Ev.2011-Ord-1209-400 Chairman & Managing Director Helwan Fertilizers Co. Egypt Ahmed EL-Said AL-SAID 2nd-Ev.2011-Ord-1209-410 Production Manager Helwan Fertilizers Co. Egypt Mefissa Mohamed AWAD 2nd-Ev.2011-Ord-1209-420 Finance Manager Helwan Fertilizers Co. Egypt Shaker MORIES 2nd-Ev.2011-Ord-1209-430 Planning & Follow up manager Helwan Fertilizers Co. Egypt Mohamed EL HADY 2nd-Ev.2011-Ord-1209-440 Mechnical Maintenance Manager Helwan Fertilizers Co. Egypt Mohamed Ahmed EL REFAAY 2nd-Ev.2011-Ord-1209-460 Night Super Intendent Helwan Fer	Country Name Regst. # Position / Company Telephone Fax Egypt Ibrahim EL ABIAD 2nd-Ev.2011-Ord-1085-550 Chemist ALEXFERT +203 5603775 Egypt Mohamed FALLAH 2nd-Ev.2011-Ord-1085-560 Ammonia Process Supervisor ALEXFERT +203 5603024 Egypt Zeyad EL MOLLA 2nd-Ev.2011-Ord-1085-570 Ammonia Process Supervisor ALEXFERT +203 5603024 Egypt Walid El-GANINY 2nd-Ev.2011-Ord-1085-580 Urea Process Supervisor ALEXFERT +203 5603024 Egypt Mohamed Abdel Aal YOUSSEF 2nd-Ev.2011-Ord-1085-590 Urea Process Supervisor ALEXFERT +203 5603024 Egypt Mohamed Abdel EL DANAF 2nd-Ev.2011-Ord-1208-400 Chairman & Managing Director Helwan Fertilizers Co. +20104616177 Egypt Ahmed EL-Said AL-SAID 2nd-Ev.2011-Ord-1209-410 Production Manager Helwan Fertilizers Co. +20105149832 Egypt Nefissa Mohamed AWAD 2nd-Ev.2011-Ord-1209-420 Finance Manager Helwan Fertilizers Co. +20101405919 Egypt Mohamed EL HADY 2nd-Ev.2011-Ord-1209-430 Mechnical Maintenance Manager Helwan Fertilizers Co. +20105769060 Egypt <

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Country					
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371			Production Manager Suez Co. for Fertilizer Production	+2062 3710210 +2062 3710212	sfie02@sfie.com.eg
371			Wadi Holdings S.A.E.	+201000066812	mohamed.mahgoub@wadigroub.com.eg
Egypt	Hend EL-HADAD	2nd-Ev.2011-Ass-1909-1040	Projects Research Coordinator Wadi Holdings S.A.E.	+201000049884	hend.elhadad@wadigroup.com.eg
France	Abdelhak MAOUI	2nd-Ev.2011-Oth-1119-1010	Regional Sales Manager RPA Process SAS	+33 689453596 +33 156838301	abdel.maoui@rpaprocess.fr
France	Eric DUCREUX		Sales & Marketing Director RPA Process SAS	+33 689453596 +33 156838301	eric.ducreux@rpaprocess.fr
Germany	Thomas KRAWCZYK	2nd-Ev.2011-Ass-4-320	Senior Process Eng. / Ammonia & Urea Division Uhde GmbH	+49 1728954639	thomas.krawczyk@thyssenkrupp.com
Germany	Clemens KUHNERT	2nd-Ev.2011-Oth-1481-230	Area Manager ME/Affrica Nickelhuette Aue GmbH	+49 1733589851 +49 3771505209	kuhnert@nickelhuette-aue.de S
Germany	Stephanie WINKHOFF	2nd-Ev.2011-Oth-1805-970	Sales Manager Umicore AG & Co. KG	+49 6181595285 +49 6181597528!	stephanie.winkhoff@eu.umicore.com
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Germany	Christop SCHOLZ	2nd-Ev.2011-Oth-1906-480	Sales Manager Aumund Holding	+49 174 3436490	scholz@aumund.de
Germany	Peter SACHS		Business Developing Manager MP		
	Egypt Egypt Egypt Egypt Egypt Egypt France France Germany Germany Germany Germany	Egypt Mohamed ABD EL RAZIQ Egypt Nabih AMER Egypt Ahmed MAHMOUD Egypt Mohamed MAHGOUB Egypt Hend EL-HADAD France Abdelhak MAOUI	Egypt Amr HAMDY 2nd-Ev.2011-Sup-1768-150 Egypt Mohamed ABD EL RAZIQ 2nd-Ev.2011-Ord-1808-600 Egypt Nabih AMER 2nd-Ev.2011-Ord-1808-610 Egypt Ahmed MAHMOUD 2nd-Ev.2011-Ord-1808-620 Egypt Mohamed MAHGOUB 2nd-Ev.2011-Ass-1909-1030 Egypt Hend EL-HADAD 2nd-Ev.2011-Ass-1909-1040 Erance Abdelhak MAOUI 2nd-Ev.2011-Oth-1119-1010 Erance Eric DUCREUX 2nd-Ev.2011-Oth-1119-1020 Egermany Thomas KRAWCZYK 2nd-Ev.2011-Oth-1481-230 Egermany Stephanie WINKHOFF 2nd-Ev.2011-Oth-1805-970 Egermany Norbert KLINKER 2nd-Ev.2011-Oth-1902-210 Egermany Christop SCHOLZ 2nd-Ev.2011-Oth-1906-480	Amr HAMDY 2nd-Ev.2011-Sup-1768-150 Product Support Executive Middle East Star Plant Manager Suez Co. for Fertilizer Production Technical Affairs Manager Suez Co. for Fertilizer Production Projects Manager Wadi Holdings S.A.E. Tennee Hend EL-HADAD 2nd-Ev.2011-Ass-1909-1030 Projects Research Coordinator Wadi Holdings S.A.E. Tennee Abdelhak MAOUI 2nd-Ev.2011-Oth-1119-1010 Regional Sales Manager RPA Process SAS Tennee Eric DUCREUX 2nd-Ev.2011-Oth-1119-1020 Sales & Marketing Director RPA Process SAS Tennemany Thomas KRAWCZYK 2nd-Ev.2011-Oth-1191-1020 Sermany Clemens KUHNERT 2nd-Ev.2011-Oth-1481-230 Sermany Stephanie WINKHOFF 2nd-Ev.2011-Oth-1481-230 Sermany Norbert KLINKER 2nd-Ev.2011-Oth-1902-210 KOEPPERN Sales Manager Umicore AG & Co. KG Coerpean Christop SCHOLZ 2nd-Ev.2011-Oth-1906-480 Sales Manager Aumund Holding Susiness Developing Manager	Fax

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail
71	Germany	Thibaut LENORMANT	2nd-Ev.2011-Oth-1916-1650	Business Development Evonik Industries AG	Tax	
72	Germany	Schulz WOLFGANG	2nd-Ev.2011-Oth-1920-1940	General Manager WAGU International GmbH	+49 290297390 +49 2902973979	wolfgang.schulz@wagu-international.com
73	Germany	Juergen CREMER	2nd-Ev.2011-Oth-1920-1950	General Manager WAGU International GmbH	+49 290297390 +49 2902973979	juergen.cremer@wagu-international.com
74	Germany	Aidil Izzat HASHIM	2nd-Ev.2011-Oth-1923-2120	Technical Sales Manager UNIDENSE Technology GmbH	+49 3575294781 +49 35752947289	logistic@unidense.com
75	Germany	Rizal Mohammad SALIM	2nd-Ev.2011-Oth-1923-2130	Operations Manager UNIDENSE Technology GmbH	+49 3575294781 +49 35752947289	logistic@unidense.com
76	Germany	Bernd RICHTER	2nd-Ev.2011-Oth-1923-2140	Director UNIDENSE Technology GmbH	+49 3575294781 +49 35752947289	logistic@unidense.com
77	India	Manish GOSWAMI	2nd-Ev.2011-Oth-679-350	Dy Chief (Technical) FAI - The Fertilizer Assoc. of India	+91 11 46005200 +91 11 26960052	tech@faidelhi.org
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80		Mohamed Abdallah MOHAMED	2nd-Ev.2011-Ord-1784-870	Deputy Minister Ministry of Industry & Minerals	+964 790191101	mdalanii@yahoo.com
81	Iraq	Mohammed OBAID	2nd-Ev.2011-Ord-1143-260	State Co. of Fertilizers Industry/South Region	+964 7705696833	mam2000@yahoo.com
82	Iraq	Atheer Jihad AL AWAN	2nd-Ev.2011-Ord-1143-270	Maintenance State Co. of Fertilizers Industry/South Region	+964 7709041247	
83	Iraq	Saadoun AL KNANI	2nd-Ev.2011-Ord-1143-280	State Co. of Fertilizers Industry/South Region	+964 7712508072	
84	Iraq	Nael SHAEQANE	2nd-Ev.2011-Ord-1143-290	Chief Engineer State Co. of Fertilizers Industry/South Region	+964 770568609!	nalshakhani@yahoo.com

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail	
85	Iraq	Arif Yousif ALAMSAILIH	2nd-Ev.2011-Ord-1143-300	Technical Manager State Co. of Fertilizers Industry/South Region	+964 7705675774	arif.yousif@yahoo.com	
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87	Jordan	Mohamed S. BADERKHAN	2nd-Ev.2011-Ord-404-830	Vice Chairman / CEO - Finance & Admin. JPMC	+962 6 5607010 +962 6 5682270	m.baderkhan@gmail.com	
88	Jordan	Jafar SALEM	2nd-Ev.2011-Ord-822-1350	Deputy G. M. Marketing Arab Potash Company	+962 6 5200520 +962 6 5673105	jafar.s@arabpotash.com	
89	Jordan	Mohammad ABU GHEYAB	2nd-Ev.2011-Ord-822-700	Production Arab Potash Company			
90	Jordan	Mohammad SHARAF	2nd-Ev.2011-Ord-822-710	Production Arab Potash Company			
91	Jordan	Jamil ERMAN	2nd-Ev.2011-Ord-822-720	Production Arab Potash Company			
92	Jordan	Heyam ADAYLEH	2nd-Ev.2011-Ord-822-730	Marketing Arab Potash Company			
93	Jordan	Ayman GHALAYENI	2nd-Ev.2011-Ord-822-740	Trucking & Garages Arab Potash Company			
94	Jordan	Mohammad ABDULLAT	2nd-Ev.2011-Ord-822-750	Maintenance Arab Potash Company			
95	Jordan	Ala OMARI	2nd-Ev.2011-Ord-822-760	Technical Arab Potash Company			
96	Jordan	Zaid HALASA	2nd-Ev.2011-Ord-822-770	Technical Arab Potash Company		S	
97	Jordan	Mohammad MA'AYTAH	2nd-Ev.2011-Ord-822-780	Aqaba Site Arab Potash Company			
98	Jordan	Hussein SHORMAN	2nd-Ev.2011-Ord-822-790	Energy & Water Arab Potash Company			

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail
99	Jordan	Khalid NAWAYSEH	2nd-Ev.2011-Ord-822-800	Technical Arab Potash Company		
100	Jordan	M Maawyeh SAMHOURI	2nd-Ev.2011-Ord-822-810	Maintenance Arab Potash Company		
101	Jordan	Sami AMARNEH	2nd-Ev.2011-Ord-822-980	QES Manager Arab Potash Company	+962 777111148	sami.amarneh@arabpotash.com
102	Jordan	Jamal AMIRA	2nd-Ev.2011-Ord-822-990	Technical Det. Manager Arab Potash Company	+962 777111152	jamal.amira@arabpotash.com
103	Jordan	Yousef MA'AYTAH	2nd-Ev.2011-Ord-822-1000	QES Arab Potash Company		
104	Jordan	Awinash PESHWE	2nd-Ev.2011-Ord-424-1330	Plant Head Indo-Jordan Chemicals Company	+962 799092814	awinash@ijcltd.com S
105	Jordan	Hamdallah HUSBAN	2nd-Ev.2011-Ord-424-2270	Manager (Procurement) Indo-Jordan Chemicals Company	+962 65512874 +962 65512871	mdoffice@ijcltd.com
106	Jordan	Issam Hussain AL-JUNDI	2nd-Ev.2011-Ord-424-2280	Sr. Plant Engineer Indo-Jordan Chemicals Company	+962 65512874 +962 65512871	mdoffice@ijcltd.com
107	Jordan	A. L. SUBRAMANIAN	2nd-Ev.2011-Ord-424-2290	Process Engineer Indo-Jordan Chemicals Company	+962 65512874 +962 65512871	mdoffice@ijcltd.com
108	Jordan	Qais Muneer Furhan HADDAD	2nd-Ev.2011-Ord-424-2300	Engineer (Mechanical) Indo-Jordan Chemicals Company	+962 65512874 +962 65512871	mdoffice@ijcltd.com
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110	Jordan	Ibrahem JAAFREH	2nd-Ev.2011-Ord-937-1060	Shift Section Head KEMAPCO	+962 6 4601993 +962 6 4601995	ibrahem.jaafreh@kemapco.com.jo
111	Jordan	Ayman SHREITEH	2nd-Ev.2011-Ord-937-1070	Process Engineer KEMAPCO	+962 6 4601993 +962 6 4601995	shreiteha@yahoo.com
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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail
113	Jordan	Ruba ALREFAI	2nd-Ev.2011-Ord-937-1090	Sales & Delivery Planning Specialist KEMAPCO	+962 6 4601993 +962 6 4601995	ruba.alrefai@kemapco.com.jo
114	Jordan	Murad DAKHKAN	2nd-Ev.2011-Sup-720-1680	Jordan International Chartering Co. (JICC)		
115	Jordan	Hani AL TRAWNEH	2nd-Ev.2011-Sup-720-1720	Jordan International Chartering Co. (JICC)		
116	Jordan	Samer AL ROUSAN	2nd-Ev.2011-Sup-720-1730	Jordan International Chartering Co. (JICC)		
117	Jordan	Munir RUSAN	2nd-Ev.2011-Oth-1267-1760	Soil Fertility & Fertilizers Jordan University of Science & Technology		
118	Jordan	Mousa ABU ARABI	2nd-Ev.2011-Oth-1267-1780	Chemical Engineering Jordan University of Science & Technology		
119	Jordan	Anna AL RASHDAN	2nd-Ev.2011-Oth-1267-1800	Faculty of Agriculture Jordan University of Science & Technology		
120	Jordan	Reham Al-FASED	2nd-Ev.2011-Oth-1267-2150	Chemistry, Lab Supervisor Jordan University of Science & Technology		
121	Jordan	Sultan ABU ORABI	2nd-Ev.2011-Oth-1918-1770	President Arab Universities Organization		
122	Jordan	Yousef MUBARAK	2nd-Ev.2011-Oth-1924-2160	Chemical Engineering University of Jordan		
123	Jordan	Ali Khalaf AL MATAR	2nd-Ev.2011-Oth-1924-2170	Chemical Engineering University of Jordan		
124	Jordan	Ibrahim JEBREEL	2nd-Ev.2011-Oth-1925-2180	Chemical Engineering Yarmouk University		
125	Jordan	Diya AL ROUSAN	2nd-Ev.2011-Oth-1919-1790	Chemical Engineering Hashemite University		
126	Jordan	Amjad JABRI	2nd-Ev.2011-Oth-719-1670	General Manager Jordan Group For Shipping Agencies (JGSA)		

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail
127	Jordan	Basil MASARWEH	2nd-Ev.2011-Oth-821-2200	Section Head/ Investment Evaluation & Follow Up Arab Mining Company	+962 6 5663146 +962 6 5684114	leis@go.com.jo
128	Jordan	Abdullah ZWEIRI	2nd-Ev.2011-Oth-821-2210	Information Head Department Arab Mining Company		azweiri@armico.com
129	Jordan	Osama NOFAL	2nd-Ev.2011-Oth-821-2220		+962 799967620 +962 65684114	osama.nofal@yahoo.com
130	Jordan	Khalil JABBARIN	2nd-Ev.2011-Sup-1319-1380		+962 79 5647111 +962 6 5522412	ajetco@batelco.jo
131	Jordan	Samir MASRI	2nd-Ev.2011-Sup-1319-1540		+962 6 5522820 +962 6 5522412	ajetco@batelco.jo
132	Jordan	Easa OWAIS	2nd-Ev.2011-Sup-1319-1550		+962 6 5522820 +962 6 5522412	ajetco@batelco.jo
133	Jordan	Nabil BATA	2nd-Ev.2011-Sup-1319-1560		+962 6 5522820 +962 6 5522412	ajetco@batelco.jo
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135	Jordan	Abdul Fattah ABU HASSAN	2nd-Ev.2011-Sup-1319-1810	Jabarin Engineering & Trading Co.		
136	Jordan	Ahmad MUBAIDEEN	2nd-Ev.2011-Sup-1319-1820	Jabarin Engineering & Trading Co.		
137	Jordan	Ahmed TARAWNEH	2nd-Ev.2011-Sup-1319-1830	Jabarin Engineering & Trading Co.		
138	Jordan	Suhaib ABDULLAH AL-ANI	2nd-Ev.2011-Sup-1726-60		+962 65515451 +962 65515459	ceo@dallah-group.com
139	Jordan	Jamal ABUSALEM	2nd-Ev.2011-Oth-1826-2240	GUEST		
140	Jordan	Issa Awad HASAN	2nd-Ev.2011-Sup-1903-1660	Business Development Manager Jordan National Shipping lines (JNSL)		

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail
141	Jordan	JNSL 1	2nd-Ev.2011-Sup-1903-1740	Jordan National Shipping lines (JNSL)		
142	Jordan	JNSL 2	2nd-Ev.2011-Sup-1903-1750	Jordan National Shipping lines (JNSL)		
143	Jordan	Farid ABDEL JABAR	2nd-Ev.2011-Oth-1917-1690	General Manager Jordan National Lines for Ship Operation		
144	Jordan	Amjad MASWADEH	2nd-Ev.2011-Oth-1917-1700	Commercial Manager Jordan National Lines for Ship Operation		
145	Jordan	Fuad AGHA	2nd-Ev.2011-Oth-1917-1710	Chartering Manager Jordan National Lines for Ship Operation		
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147	Kuwait	Salah RASHED JASEM	2nd-Ev.2011-Ord-410-1160	Analysis & Business Planning Team Leader PIC	+965 23211510 +965 23211588	salah_rashed@pic.com.kw
148	Kuwait	Mejbel AL-SHAMMERY	2nd-Ev.2011-Ord-410-1920	Manager - HSE Dept. PIC	+965 23260073 +965 23262002	mejbel_alshammeri@pic.com.kw
149	Kuwait	Salem AL-AZMI	2nd-Ev.2011-Ord-410-1930	Operation Manager PIC	+965 23261009 +965 23260651	salem_alazmi@pic.com.kw
150	Libya	Khalifa YAHMED	2nd-Ev.2011-Ord-1744-950	Chairman LIFECO		
151	Morocco	Jamal Eddine BENSARI	2nd-Ev.2011-Ord-408-920	Director Raw Material Procurements & Freight OCP	+212 661 145765 +212 522 998305	je.bensari@ocpgroup.ma
152	Morocco	Mohammed BENZEKRI	2nd-Ev.2011-Ord-408-2050	Director Market Research & Communication OCP	+212 661442234	M.BENZEKRI@ocpgroup.ma
153	Morocco	Abdelhak KABBABI	2nd-Ev.2011-Ord-408-2060	OCP		
154	Morocco	Abdelaali KOSSIR	2nd-Ev.2011-Ord-408-2070	ОСР		

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Ser.	Country	Name	Regst.#	Position / Company	Telephone Fax	E-mail	
155	Morocco	Mehdi KHOULOUD	2nd-Ev.2011-Ord-408-2080	Ingenieur de Recherche, Engrais et Fertilisation OCP			
156	Morocco	Driss DHIBA	2nd-Ev.2011-Ord-408-2090	New Product Development Director OCP			
157	Morocco	Esber BITAR	2nd-Ev.2011-Oth-1914-1440	Deputy General Manager JACOBS Engineering S.A.	+212 661637021 +212 522877234	esber.bitar@jacobs.com	
158	Morocco	Abdelaziz EL MALLAH	2nd-Ev.2011-Oth-1914-1450	Deputy General Manager JACOBS Engineering S.A.	+212 660214242 +212 522877234	abdelaziz.elmallah@jacobs-esa.com	
159	Morocco	Ryad MOULINE	2nd-Ev.2011-Oth-1914-1460	Deputy Business Development Director JACOBS Engineering S.A.	+212 661236015 +212 522877234	ryad.mouline@jacobs-esa.com	
160	Netherlai	Joost ROES	2nd-Ev.2011-Ass-17-1470	Acquisition Manager Mechanical Engineer Stamicarbon BV	+31 464237080 +31 464237001	joost.roes@stamicarbon.com	S
161	Netherlai	Jo van de POEL	2nd-Ev.2011-Ass-17-1480	Senior Plant Engineer Stamicarbon BV	+31 464237080 +31 464237001	jo.poel-van-de@stamicarbon.com	
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163	Netherlai	Stephen ZWART	2nd-Ev.2011-Ass-17-1500	Vice President Licensing Management Stamicarbon BV	+31 464237080 +31 464237001	stephen.zwart@stamicarbon.com	
164	Netherlai	Emiel MEHLKOP	2nd-Ev.2011-Ass-17-1510	Mechanical Service & Solution Manager Stamicarbon BV	+31 464237080 +31 464237001	emiel.mehlkop@stamicarbon.com	
165	Netherlai	Jeroen VISSER	2nd-Ev.2011-Ass-17-1520	Licensing Manager Stamicarbon BV	+31 464237080 +31 464237001	jeroen.visser@stamicarbon.com	
166	Netherlai	Harald FRANZRAHE	2nd-Ev.2011-Oth-1213-340	Chief Process Manager Uhde Fertilizer Technology	+49 1721510377 +49 2315473515	harald.franzrahe@thyssenkrupp.com	S
167	Netherlai	Mark BROUWER	2nd-Ev.2011-Sup-1900-50	Director Urea KnowHow.com B.v.	+31(6)29576845 +31(43)3256288	mark.brouwer@ureaknowhow.com	
168	Oman	Ahmed AL AWFI	2nd-Ev.2011-Ord-1141-940	Acting CEO OMIFCO	+968 11 2553201 +968 11 2556284	alawfi@omifco.com	

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Ser.	Country	Name	Regst. #	Position / Company	Telephone Fax	E-mail	
169	Pakistan	Armaghan YUSUF	2nd-Ev.2011-Oth-1911-1190	Business Manager Engergy Management Solutions AVANCEON	+92 4211194094(+92 4237515128	armaghanyusuf@gmail.com	S
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195	Tunisia	Omar ABEDI	2nd-Ev.2011-Ord-1506-2020	GCT		
196	Tunisia	Jalal SHERIF	2nd-Ev.2011-Ord-1506-2030	GCT		

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