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Paper 444w

SAFUREX® : It was not a dream

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Reference list Safurex® items

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1. Abstract

This is the 3rd paper about Safurex®; this paper concludes the trilogy presentation about the material during the Stamicarbon world wide symposia.

The first ever presentation was made in year 2000. During that Stamicarbon symposium we announced the presence of Safurex and we also indicated the goals that we had in mind.

In 2004 we gave a follow up and it was obvious that Safurex was a success; several achievements were mentioned and highlighted. It was the fact that we has successful welded the (internal bore) tube to tubesheet connection in Safurex. From fabrication point of view all aspects were covered successful at that time.

This story called: Safurex®, it was not a dream, gives a follow up about the behaviour of Safurex or better, corrosion that not has occurred in Safurex equipment after being exposed to urea over a longer time.
We also deal with how both Stamicarbon and Sandvik handle Safurex, how to deal with spare material and even spare equipment.

2. Introduction

The name Safurex® does not need any further introduction in the urea world. It can be stated that this material can be listed as a development that has brought the design, maintenance and the operation of urea plants to a next generation.

During this Symposium a next generation of urea plants will be presented that will operate without the addition of oxygen; this is possible only due to Safurex®.

Due to the use of Safurex® as alloy protection, the investment of new plants became significantly lower, limitations with respect to operational aspects were widened and although the on stream times of Stamicarbon urea plants were already significant, with Safurex® we have realized on stream times that in the past never have been classified as being realistic. All this means that the efficiency and profitability of a urea plant is upgraded to a maximum level; one can easily talk about a maintenance free urea plant.

In the previous three papers about Safurex®, all presented during previous Stamicarbon worldwide symposia, information was mainly provided on laboratory results and the fabrication of equipment and materials. Now we are able to give a full picture of the behavior of Safurex® in operating urea plants.

In 1992 the development of Safurex® started. In 1996 we introduced Safurex® to the world. The developments did not stop at that time; in the meantime some adjustments have been made to the material, the design basis and the construction of urea equipment as a result of the experience gathered.

In the year 2004 during the 10th World Wide Stamicarbon Urea Symposium in Scheveningen, The Netherlands, we presented the successful results of three Safurex® heat exchanger tubes in the HP Stripper of the DSM urea plant in the Netherlands and also the successful results of two complete Safurex® HP Carbamate Condensers in Police, Poland and El Delta, Egypt.

Since that presentation numerous HP equipment items and HP Piping components have been fabricated in Safurex®, are in operation and have been inspected in the mean time. Several experiences have been gained in the fabrication of HP equipment and materials and also after several years of operation; all these experiences are shared in this paper. Amongst others, the results of the inspection of a complete Safurex® HP synthesis urea plant will be presented. This plant SAFCO IV located in Al Jubail, Saudi Arabia was also presented in the 9th World Wide Stamicarbon Urea Symposium in 2000 however in the mean time the first (guarantee) inspection has been performed.

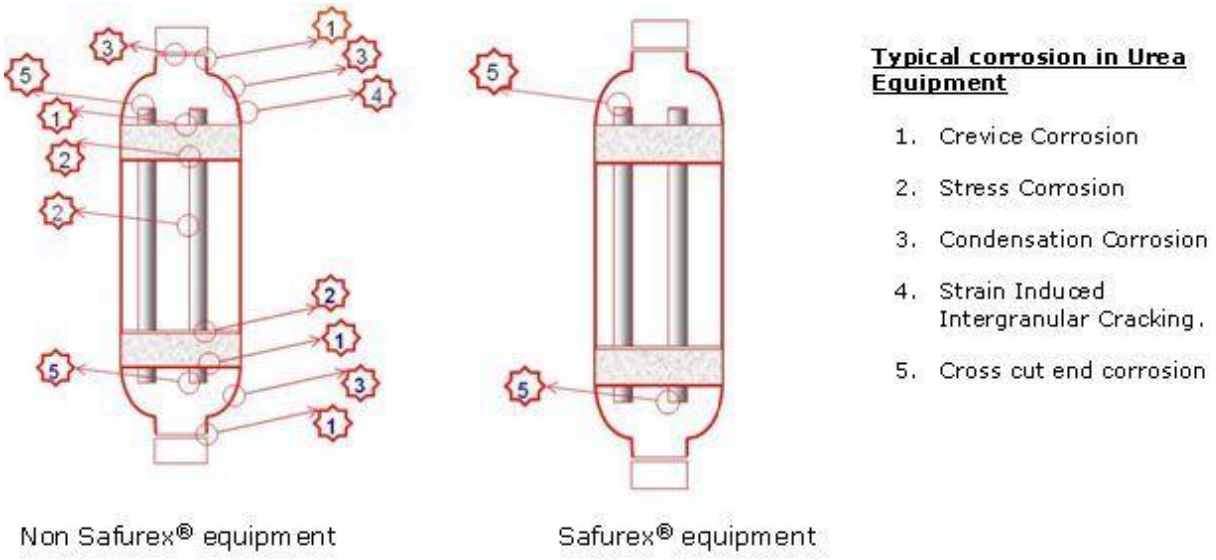
This paper deals also with the availability of Safurex®, a concern of the users and how to deal with the availability of Safurex® spares and materials.

3. Inspection results

As one can learn from the enclosed reference list many equipment items and materials have been fabricated in Safurex®. Several of these equipment items and even a complete HP synthesis have been inspected from corrosion point of view. Below briefly the results of these inspections are presented. The overall conclusion from these inspections is that Safurex® equipment is maintenance free.

Nearly all traditional corrosion phenomena that one typically finds in urea plants are history; the only two forms of corrosion that remain are a very low rate of overall corrosion and cross cut end corrosion at a very low rate and that only at higher temperatures.

Figure 1: Corrosion forms in Urea Plants



Below is a summary given of the inspection results of Safurex® HP Equipment.

3.1 Results Shiraz HP Stripper inspection

The first Safurex® Stripper ever installed in a Stamicarbon stripping plant was in the Shiraz Petrochemical Company Urea Plant in Shiraz, I.R. Iran. This is a plant with a design capacity of 1,500 mtd and was commissioned in 1984. In 2002 the existing HP Stripper was replaced by a new and larger Safurex® HP Stripper. The inspection took place after 1,097 days on stream.

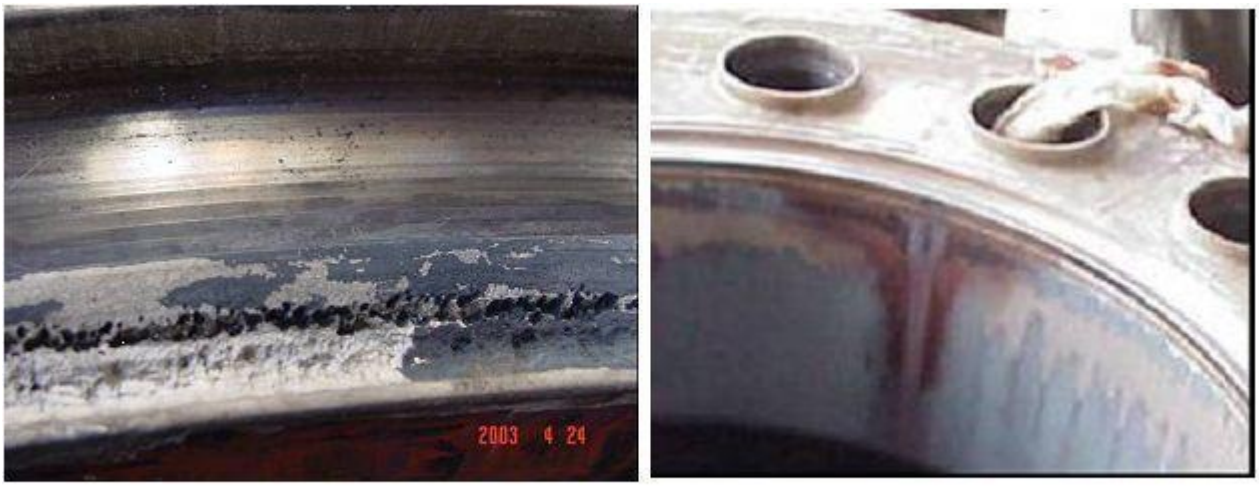
This inspection was executed immediately after an experiment was concluded to lower the oxygen level. Due to time limitations and because of the confidence Shiraz had gained in the performance of the HP Stripper from the Nickel readings, only an at random inspection was executed.

The visual inspection showed no sign of corrosion. This was confirmed by the eddy current inspection of the heat exchanger tubes; an average corrosion rate of some 0.05 mm per year on stream.

A remarkable event happened short after the start up of the Safurex ® HP Stripper; a gasket leak occurred in the top man way cover. Such a gasket leak leads typically to a devastating corrosion of the flange face and gaskets. The HP Stripper was opened and an inspection confirmed the leak. The findings showed following; the 316 stainless steel serrated gasket ring was corroded due to a damaged PTFE envelope.

However the Safurex® flange faces however did not show any sign of corrosion at all. Such leak occurred once more and again no corrosion of the Safurex® flange faces was found.

Photos 1 & 2: BC.05 (left) and Safurex® flange faces



BC.05 Safurex®

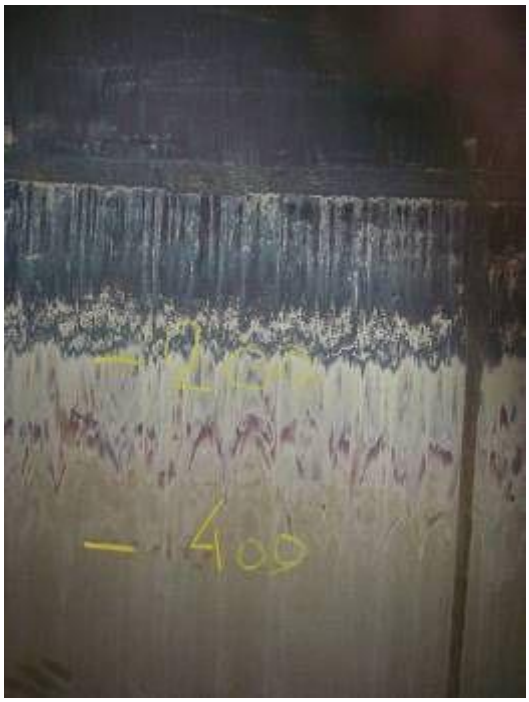
3.2 Results QAFCO-2 Reactor inspection

The Reactor in the QAFCO-2 plant was recently replaced by an identical size Reactor, only the alloy protection was changed from the usual BC.01 material to Safurex®. This Reactor has been equipped with Siphon Jet Pump Trays, all Safurex®.

In November 2007 after 851 days on stream the plant was shut down in order to revamp this plant completely with a Safurex® Pool Condenser. During these modifications a guarantee inspection was executed and of course with special attention to the behavior of the Safurex®.

Special attention was given to the Safurex® in the gas phase area and also to the transition between liquid and gas phase; No corrosion was found, also there was no overall corrosion.

Photo 3: Gas/liquid phase area Reactor



The cross cut ends of the tray support clips did also not show any corrosion, the marks from the fabrication were still clearly visible; the conclusion was that the Safurex® is in such a condition as it was never exposed to any carbamate solutions.

Photo 4. Tray support clip

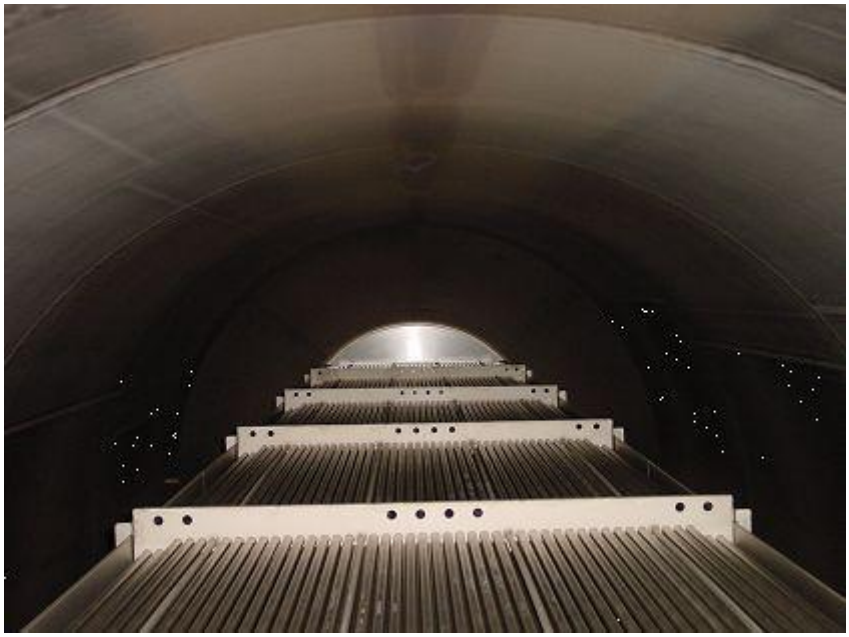
3.3 Results SAFCO-IV complete HP synthesis inspection

This is the first ever Urea plant with a complete Safurex® synthesis that has been put into operation. It is the largest operating urea plant in the world, recently producing 3740 mtd and is equipped with a Pool Condenser.

The plant was started up in June 2006 and after a smooth start up the plant recently shut down for the usual mechanical guarantee inspection; this was after 430 days on stream.
All the equipment was opened and a standard urea inspection was executed, visual and NDT inspections have been carried out.

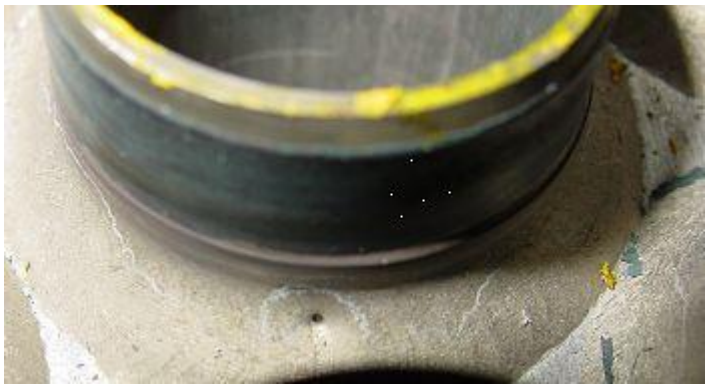
The results of this inspection was impressive and the inspectors advised to open the equipment for a next inspection after another 6 years on stream.

Photo 5: inside the Pool Condenser Safco IV



In the HP Stripper a pinhole in a tube-to-tubesheet welding was found in the top tubesheet. With different materials this would have led to active corrosion and even a leaking tube-to-tubesheet weld could not be excluded. This pinhole however did not show any active corrosion.

Photo 6: pinhole in a tube-to-tubesheet welding



The wall thickness of the heat exchanger tubes in the HP Stripper was measured. Since there was no base line measurements done it was not possible to determine a corrosion rate, however what can be concluded is that the wall thickness of the heat exchanger tubes is still within the tolerances of the new tubes.

In the urea Reactor, Pool Condenser and HP Scrubber no corrosion was found, only slight etching of the welds.

3.4 Results KAFCO Bangladesh HP Stripper inspection

The HP Stripper was replaced by a bigger Safurex® HP Stripper in January 2006. The on stream time at the time of the inspection was 677 days.
The visual inspection did not reveal any corrosion. With help of the base line wall thickness measurements an average corrosion rate of 0.06 mm for the hex-tubes per year on stream was established.
Also here it was advised to inspect the next time after six years on stream.

Photo 7: top channel Kafco HP Stripper

3.5 Results Police HP Carbamate Condenser inspection

This Polish urea plant has the oldest Safurex® HP equipment item in operation. The HP Carbamate Condenser was replaced in 1999 by a Safurex® one. Reason to replace the existing one was Chloride Stress Corrosion cracking. The old one was no longer reliable due to the presence of stress corrosion cracks in the top part. This HP Carbamate Condenser is now 9 years in operation and has been inspected yearly.

No stress corrosion cracking has occurred and the HP Carbamate Condenser is as new, corrosion rates are still within the fabrication tolerances and within the measuring tolerances.

3.6 Results Snamprogetti Profertil HP Stripper.

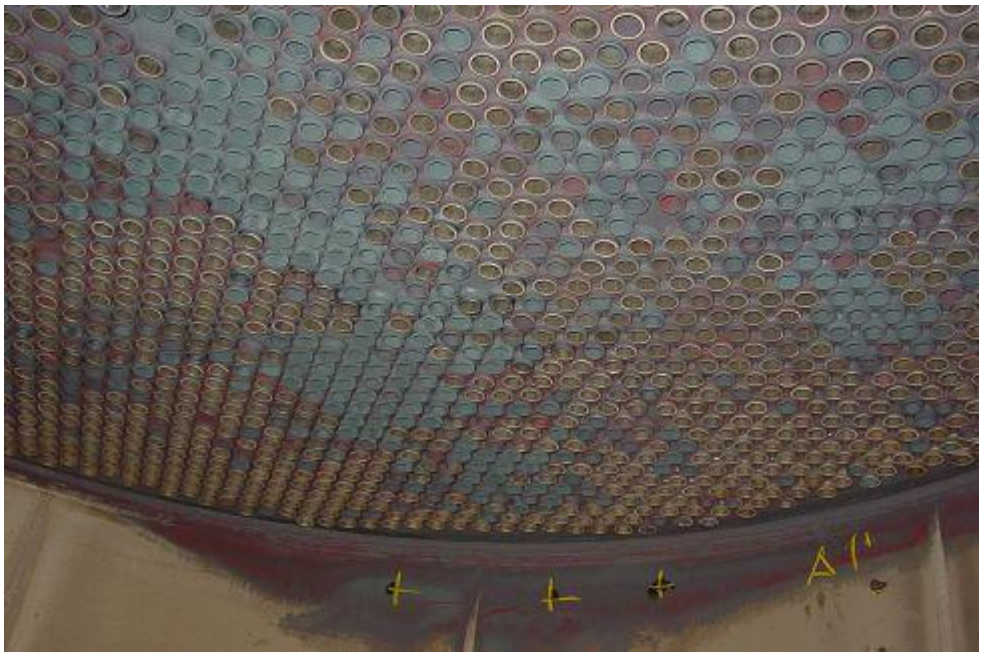
Many inspection results are available in Stamicarbon urea plant but the most impressive inspection result has been achieved in the Safurex® HP Stripper that was installed in the Profertil Urea Plant in Argentina.

Due to severe corrosion problems in the Snamprogetti Bimetallic HP ammonia Stripper the plant was no longer able to operate in an economical way and also from safety and environmental reasons precautions at short notice were unavoidable. The owners decided to install temporarily an existing and available Safurex® Stamicarbon HP Stripper. This HP Stripper was some four years in operation and Stamicarbon had the opportunity to inspect the Stripper three times in that period. Respecting the agreement between Snamprogetti and the plant owners, the conditions were not always optimal to perform these corrosion inspections.

We were able to determine in this HP Stripper the corrosion rates in the heat exchanger tubes with remote field eddy current technique. The third and last inspection was an extensive one and took place after 860 days on stream and allowed us to draw three conclusions:

- In the top section, where similar process conditions exist as in a Stamicarbon HP Stripper only here with reduced oxygen feed (0.25 vol.%), the average corrosion rate in the heat exchanger tubes in the top 3-meter amounts up to 0.05 mm per year on stream.
- In the bottom section of the HP Stripper, also with reduced oxygen content but in this part the operating temperature are at a far higher value than are reached in a Stamicarbon Urea Plant, namely 205°C, the average corrosion rate in the heat exchanger tubes in the bottom 3-meter amounts up to 0.08 mm per year on stream.
- The visual inspection revealed that the liquid/gas distribution is not optimal; the bad liquid distribution has no negative effect on the corrosion rates.

Photo 8: Bottom tubesheet after 860 days on stream shows a bad liquid distribution



In the meantime the HP Stripper has been moved to another Snamprogetti urea plant located in Canada. In this plant the HP Stripper has been revamped with a Stamicarbon liquid distribution system, designed for the conditions that are present in the top of such a Snamprogetti Stripper; This Stripper went into operation last October and performs very well.

Another nice observation we found in the top cover of this HP Stripper. The top cover had a lifting lug, which should be removed after installation to avoid condensation corrosion problems. As this HP Stripper was installed only temporarily, this was never done. Even after 860 days on stream still no condensation corrosion problems could be found, showing the excellent behavior of Safurex® under zero oxygen conditions.
When using Safurex®, crevice corrosion, pitting and condensation corrosion are history.

Photo 9: Top cover of a HP Stripper in with a Safurex® liner under condensing conditions

3.7 Conclusions from the plant inspections

The targets set when developing Safurex® has been clearly realized.
Safurex® in all its forms acts trouble free in urea/carbamate solutions and can be qualified as creating a maintenance free synthesis. Other than slight overall corrosion and some minor cross cut end corrosion at high temperatures no other forms of corrosion are found, even if exposed to severe conditions as there was for:

- the top cover of the Profertil Stripper (no condensation Corrosion)
- the high outlet temperature in combination with a low oxygen content as present in the bottom of the Profertil Stripper (no active overall corrosion)
- The Stress corrosion conditions in the Police HP Carbamate Condenser (no cracks)
- The leakage of the gasket in the top cover of the Shiraz HP Stripper (no crevice corrosion)
- The lower oxygen content test in the Shiraz HP Stripper (no higher overall corrosion)

It can be stated that Safurex® HP equipment will allow longer operating runs and simplifies maintenance in HP Urea Equipment and Piping systems.

3.8 Full Safurex® Urea Synthesis under construction

Several Urea Synthesis are fabricated or are under fabrication in full Safurex® , this counts for the HP Equipment as well as all Piping components.

Others modify their plants or increase the capacity of the plant by adding Safurex® components as shown in Photo 10, the Fosfertil Urea Plant adds a Safurex® Pool Condenser.

Photo 10: Pool Condenser installation in Fosfertil

The Erdos Project in China
This project is a retrofit of an old TEC plant. This plant was located in South Korea and has been relocated to Inner Mongolia in China. Stamicarbon has debottlenecked this plant from 2X1,000 mtd into a modern 3,520 mtd Pool Condenser plant.

The delivery of the HP Piping and its components was done by Stamicarbon. The delivery of the HP Synthesis parts has been concluded; the delivery of the HP Equipment of this 3,520 mtd Pool Condenser plant and all Safurex® components were delivered within the agreed period.
At this moment the plant is under construction and the target is to have the mechanical completion realized end of this year.

The Jiangfeng Project in China
This project is a grass root Pool Condenser Plant capacity 2,700 mtd. The plant will be located in Jiangfeng P.R. China. The whole HP Synthesis equipment including the Piping is supplied by Stamicarbon. Delivery is foreseen to take place end of this year.

The Sorfert Project in Algeria
This project is a grass root Pool Condenser Plant capacity 3,450 mtd. The plant will be located in Algeria.

The EAgrium project in Egypt
This project are two grass root Pool Condenser lines each with a capacity 2,000 mtd. The plant will be located in Egypt.

The Fatima project in Pakistan
This project is a grass root Pool Reactor plant with a capacity 1,500 mtd. The plant will be located in Pakistan.

4. Radar level measurements

A spin off of the availability of Safurex® is that new developments could be achieved in urea plants. One of them is the use of RADAR for level measurements in urea equipment. These level measurements are critical and with the presence of nuclear level measurements in both the HP Stripper and Urea Reactor these measurements became reliable. However, the use of nuclear devices becomes more and more difficult in the world as we live in today. Also are the presence of these nuclear devices in a urea plant a reason for concern from safety point of view.

Safurex® avoids that crevice corrosion will occur in the RADAR level measurement system between the ceramic transmitter/ receiver and its body.

At this moment several HP equipments in Stamicarbon urea plants and even in Snamprogetti urea plants RADAR is successful in operation.

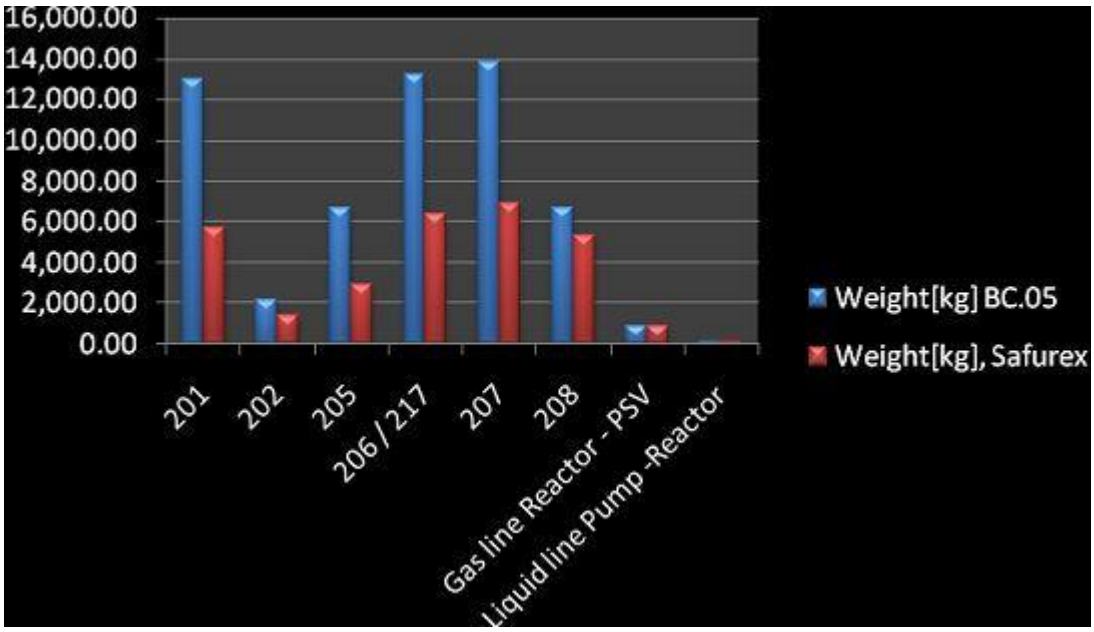
Photo 11. RADAR for a HP Stripper

5. HP Piping

A very successful development has taken place in the fabrication of the HP Synthesis Piping and all its accessories. By using Safurex® Piping advantages have been achieved in several ways.

The corrosion rates are low and the risk for selective corrosion is negligible. Special advantages exists in gas lines; here no condensation corrosion will occur anymore.
The wall thickness of HP Piping can be reduced quite impressive when using Safurex® Piping. In case of 316L Urea grade Piping one need a schedule 160, this wall thickness can be reduced in case of x2CrNiMoN 25.22.2 to schedule 120.

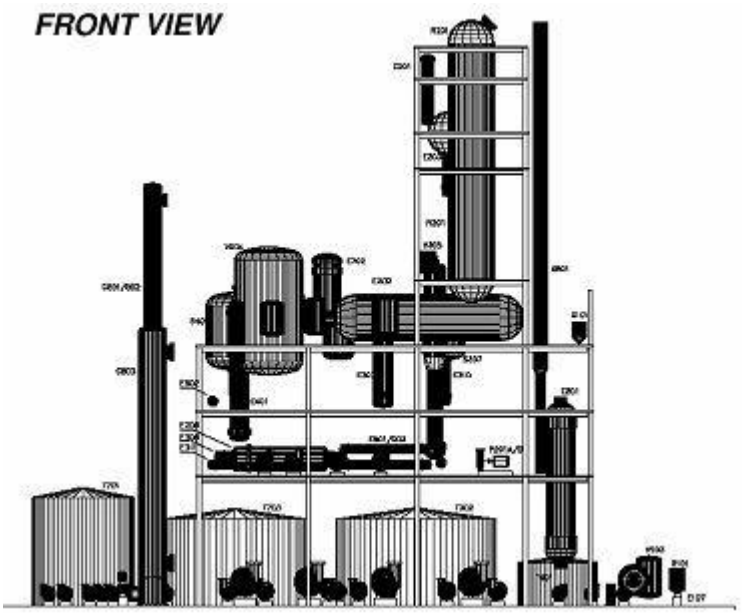
Figure 2: weight comparison between BC.05 and Safurex® HP Piping



This weight comparison is made for a typical Pool Condenser plant with a capacity of 3,250 mtd.

By using Safurex® Piping only a schedule 80 or 80S are used. This is the result of the high mechanical properties of Safurex®. The consequence of the reduction in schedule is that the large size pipes can be scaled down one size; this is valid for sizes of 10 inch and more, a one size smaller diameter Piping can be used while maintaining the inner diameter.

Figure 3: Typical Pool Condenser plant layout



Taking into account that pipe line sizes are one of the bottlenecks that might limit plant capacities the value of this advantage becomes more clear.

In the third place Safurex® has the same thermal expansion coefficient as Carbon Steel and thus significant lower than austenite steels. That means that one can shorten the lines since expansion loops are no longer needed to the extent as should be taken into account for the full austenite steels.

Safurex® Piping can be used in new plants but can of course also be used in operating plants for replacing Piping and its components.

We have also reviewed the economical consequences of the HP Piping and its components; we advise to use following Standards, which economically and design wise are the best options.

- Piping : as per ASME NS SCH.:
  * 80S up to size 10",
  * Dia 10" and more (18") Sch.80".
- Bends : ≥ 4D (induction bended)
- Flanges : as per IG 325*
- Lens rings : as per IG 325
- T-Pieces, Reducers & caps : as per ASME B16.9
- Weld o lets : as per MSSP 97
- Flanges : Threaded types in Carbon Steel.
- Bolts/nuts : C. Steel

Note: We have selected this flange face rating 325 bar because of the fact that this is an optimized design for the HP Synthesis; in that the flanges are stronger, less chance for deformation and its compact design.

6. Availability of materials

One of the first questions raised when discussing Safurex® equipment is the availability of Safurex® and the costs of said material.

Although Safurex® is a single source material we state that the obtainability of this material is better than of the other urea grade materials. With Sandvik the agreement has been made that Safurex® base materials are in stock and that the fabrication of Safurex® has priority within Sandvik mills.

Following parts can be delivered from stock;

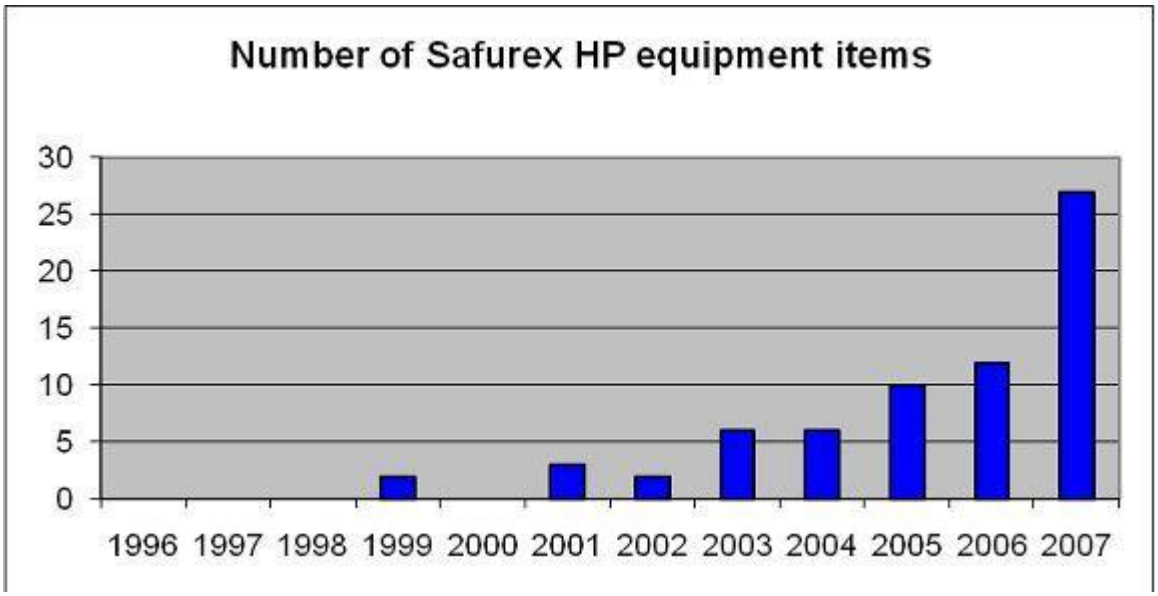
- Stripper tubes dia 31/26 mm are in stock to an extent that a Stripper with some 3,000 tubes could be retubed instantly.
- Plates thickness 5-mm are in stock to allow a relining of the Urea Reactor top section instantly.
- Weld consumables are on stock.
- Also Piping is on stock , dimensions varying from $^1/_2$ inch till 14 inch. The length of each size is chosen in such away to allow the fabrication of all bends needed in a large size urea plant. We have chosen for this philosophy in that bending takes some
  4 months in time; this is also the time that it takes to fabricate Piping.
- Forgings are also available from stock varying from dia 14 mm to dia 468 mm.

Today a short delivery time of material is essential in realizing the requested time to realize a project. The HP urea equipment and the CO_2 compressor are the long delivery items. In a recent project we are meeting the demand that the HP Synthesis equipment needed to be delivered 21 months after effectiveness of the agreement. We accepted this challenge, delivery is expected to take place in November this year; we are on schedule. We are now in discussion with a owner to have the synthesis delivered 16 months after signing the agreement.

The realization of the short delivery times can only be done in a special way of organizing the project and a high flexibility of licensor, owner/contractor and owner is a precondition. We can realize this short term deliveries as reselling projects; that means Stamicarbon delivers the HP Synthesis equipment and components.

<u>Suppliers of Safurex® equipment & materials</u>
Because of the spectacular increase in demand for Safurex® equipment and materials we had to review the list of propriety suppliers. A list of these companies is given in Stamicarbon vendor list for proprietary equipment.

Figure 4: Safurex® HP equipment items fabricated in time



In order to avoid that Safurex® gets into wrong hands it has been decided that Safurex® only can be purchased after permission of Stamicarbon. Sandvik and all other proprietary suppliers are aware of this rule. For you as users it means that one should order directly from these qualified vendors or from Sandvik Sweden directly. Please do not use trading companies when ordering as we will not give authorization to these organizations.

7. Fine tuning of Safurex®

In the course of the 16 years that Safurex® exists as a construction material for HP Urea Synthesis, several optimizations to the material have been made; the modifications and optimizations vary from small modifications in the alloying elements to for instance the change of the standard plate thickness.

7.1 Quality requirements of Safurex®

In general the evaluation of materials and procedures that are in use in Stamicarbon urea plants is a continuous process and is a result of findings during the fabrication of equipment, the operation of urea plants and the inspections executed in urea plants. The same process is valid for Safurex®.

The recognition of these practical experiences are evaluated on a continuous basis with the results of the quality tests executed in the Sandvik and Stamicarbon laboratories.

In the frame work of this process we recognized that the types of corrosion that can occur in Safurex® material and the risk of corrosion cannot be compared with the forms of corrosion that occur in the austenitic stainless steels as there are the BC.05 (x2CrNiMoN25.22.2) and the BC.01 (316L Urea grade) materials, see figure 1.

With Safurex® we observe a very low overall corrosion and we also recognize that there is a tendency for some cross cut end (stern face) corrosion; however only at elevated temperatures. All other corrosion phenomena, that can lead to the sometimes dangerous forms of selective corrosion, do not longer exist anymore.

When using Safurex®, crevice corrosion, pitting and condensation corrosion are history.
These observations allow us to relax the quality requirements of Safurex®.

We decided to reconsider the original requirements with respect its maximum allowable selective attack after the Streicher test.

Rejections based on this selective attack figure have no effect on the quality of Safurex® and are only increasing the Safurex® costs; for that reason the updated quality requirements for Safurex® are as follows:

- ✓ Streicher test, as per Stamicarbon specification 71112: ≤ 0.7 gr/m^2 hr
- ✓ Selective attack after Streicher test in all directions: ≤ 100 µm
- ✓ Ferrite content of base materials: 40 – 60% based on point counting
- ✓ Ferrite content for weld deposit and its heat affected zone: 30 – 70% based on point counting.

7.2 Doping tests

Since Safurex® is a single source material, the interests of both Sandvik and Stamicarbon, are identical. To make a material available that is resistant against the severe conditions that are present in the urea synthesis and a material that allows the operations of a urea plant in a safe way, all this in an economical way.

Counter checking as is specified for the austenite stainless steel makes no sense and is only increasing the cost of the Safurex® material. To verify the quality of the Safurex® base materials it has been agreed that Stamicarbon verifies the material quality in their laboratories on the basis of doping tests; four times per year Stamicarbon visits the Sandvik mill and take samples from the production as is ongoing.

7.3 Quality control of welded samples

Welded samples are still tested for each job. The combination of materials, weld process, weld consumables and weld position can have a detrimental effect on the quality. For that reason welding procedure qualifications and welders qualifications are still executed for each job. However the extent of this testing is less than we specify for the austenite stainless steels.

7.4 Electro Slag Overlay Welding (ESW)

For ESW overlay welding a special flux has been developed. This was needed to improve the quality of the overlay from mechanical point of view; once in a while pores showed up in this overlay affecting the integrity of the tube-to-tubesheet welding. The overlay on tubesheets must be defect free to ensure the quality of especially the inner bore welds present in Pool Condensers or Pool Reactors.

Photo 12: Internal Bore Welding in a Safurex® ESW overlay

7.5 Liner plate thickness

The liner thickness has been increased from 4 to 5 mm. Nor from design nor from corrosion point of view this increase was needed.

From strength point of view one needs only some 0.5 mm thick Safurex®. This is a result of its superior mechanical properties and also the fact that the thermal expansion coefficient is identical to that of carbon steel makes the liner thickness almost independent of the diameter of the equipment.

It was decided to increase the liner thickness due to the availability of the plates. 4 mm plates are made by cold rolling, this requires an additional fabrication step and moreover it may lead to a delay in delivery. So far the fabrication was to hot roll 6 mm plates and finish by cold rolling.

The costs for this extra step are relatively high and the mill who makes the Safurex® plates has only one cold rolling machine; This fact has led during the fabrication of the SAFCO-IV equipment to some delays in delivery of those plates.

An evaluation of this event made us decide to use 5 mm liner plates. Tests showed that 5 mm plates can be fabricated by hot rolling.

For trays and other internals 3 and 4 mm thick plates are still available.

7.6 HP Piping

HP Piping in Safurex® has been made right from the beginning but with complete Synthesis sections in Safurex® and considering the pipe sizes needed another challenge was presenting itself.

The fabrication of complete HP Piping systems in Safurex® appeared not to be difficult. 14 and even 18 inch Piping were produced without major trouble and were delivered in time. The biggest challenge appeared to be 8 inch Piping. The combination of diameter and wall thickness made it hard to fabricate this dimension by rolling.

Tests showed that this 8 inch Schedule 80 Piping should be made by trepanning (deep hole drilling) and proved to be the right solution. It should also be mentioned that this fine tuning was the lesson learned from the SAFCO-IV project but did not lead to a delay in the agreed delivery time.

Photo 13: Safurex® cap layer

Photo 14: Safurex® rootrun in HP Piping

7.7 Safurex® N/C meter

In order to allow the measurement of the N/C ratio under zero oxygen conditions we have together with the company SPIE, the Netherlands, modified the N/C meter in such away that this measurement can be done in all Safurex® and thus oxygen free carbamate solutions.

8. Welding

8.1 Welding guide lines

In the past 16 years a lot of experience has been gained in welding; right from the beginning welding was really not an issue and as per today we can confirm that there are no Safurex® welding problems. Important is to watch the interpass temperature when welding as this should be below a certain value. Also the heat input during welding should be controlled.

Also the inner bore welding of the tube-to-tubesheet connection in the Pool Condenser or Pool Reactor proceeds trouble free. The quality of these welds is comparable or even better to those made in the austenite materials; the risk for hot cracking or reheat cracking can be ignored.

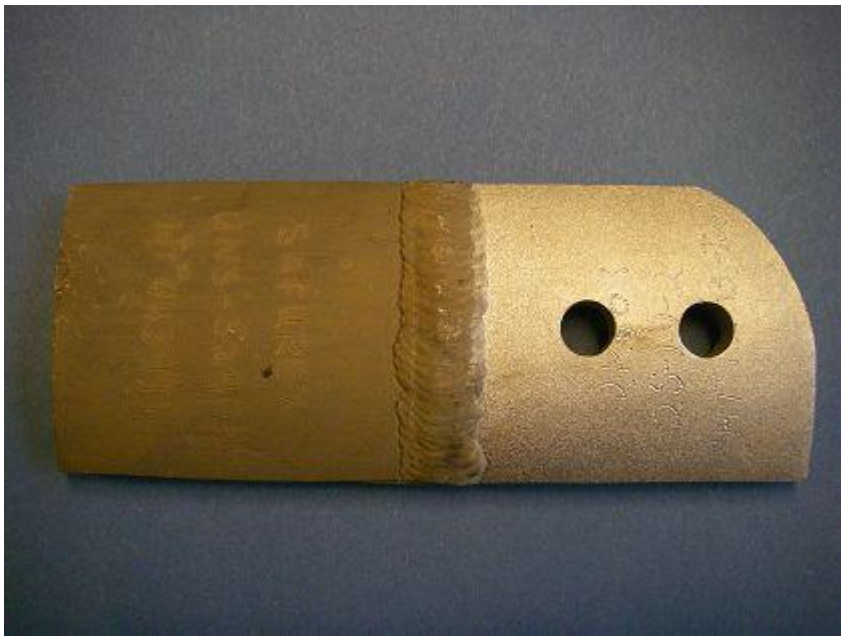
The requirements how to weld Safurex® are listed in a specification.

8.2 Dissimilar welding

One of the important items that we recognized when developing Safurex® was the fact that Safurex® had to be welded to the existing austenite stainless steels, since Safurex® was also developed to replace existing equipment and materials. From the beginning, investigations were done in the laboratory but also via in-Plant tests.

The conclusion is that welding of Safurex® to an austenite steel can be very well done and that the corrosion resistance is ensured if following rules are followed.

Photo 15: Dissimilar weld between Safurex® and BC.05 after long time exposure to Carbamate



8.3 Conclusions with respect to Safurex® welding

- ✓ Welding Safurex® to BC.05 material can be executed without any precaution, the weld consumable to be used can be either Safurex® or BC.05.
- ✓ Welding Safurex® to a BC.01 material is also possible but one has to buffer the BC.01 material first. It appeared that the difference in alloying elements between BC.01 (typical 17% Cr) and Safurex® (30% Cr) will lead to knife line attack. Buttering of the BC.01 face has to be done by BC.05; in case that has been done, welding can be executed in the same way as when welding BC.05 material to Safurex®, also in this case the weld consumable to be used can be either Safurex® or BC.05.

9. Lowering of the oxygen content

Although we have proven in laboratory test that Safurex® is resistant in oxygen free carbamate solutions, we were not able yet to do this test in a real Urea Plant. At this moment are we in discussion with SAFCO to achieve this in their Safco-IV plant.

We are convinced that in case the complete synthesis is made out of Safurex® the addition of oxygen is not needed anymore.

In case of an existing Stamicarbon urea plant with a Safurex® HP Stripper and a HP Carbamate Condenser with BC.05 (x2CrNiMoN 25.22.2) heat exchanger tubes the oxygen content can be lowered safely to 0.3 [vol.] percentage.

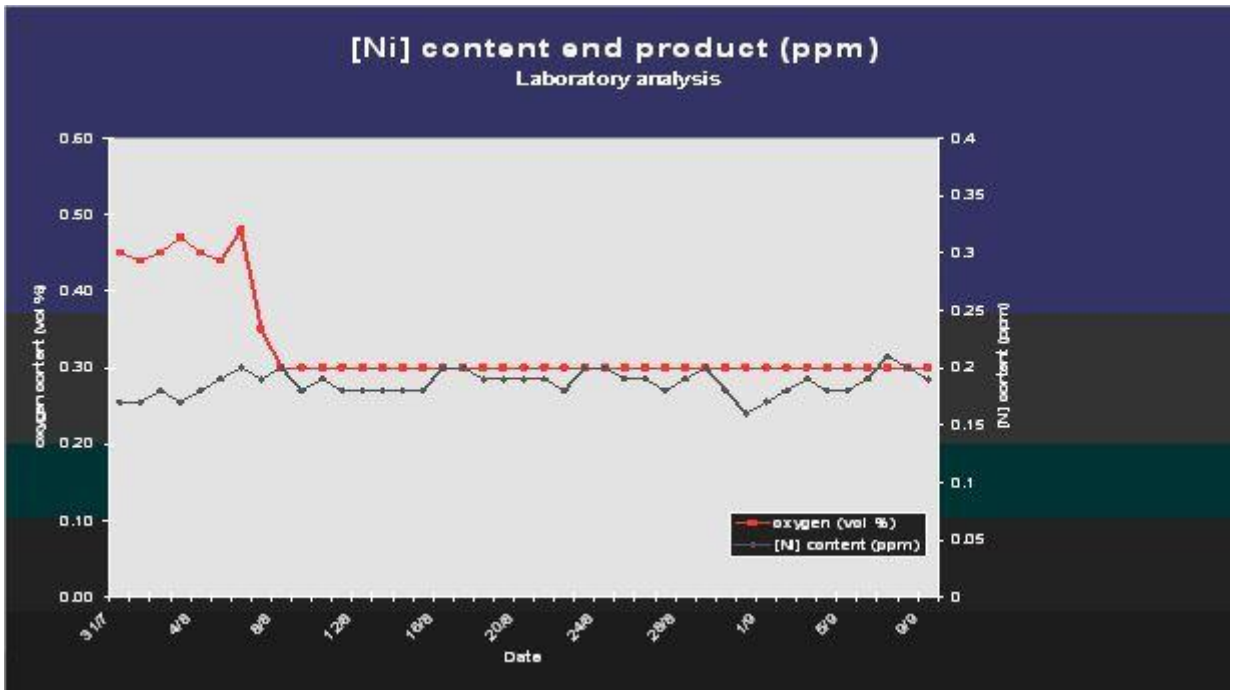
In the mean time there exists several results from real plants were it is proven that we can operate at lower oxygen concentrations.

In the Shiraz Iran Urea Plant we did an investigation with respect to the consequences when lowering the oxygen content. This plant, a Stamicarbon CO_2 stripping plant fulfills the afore mentioned conditions in that there is a Safurex® HP Stripper and a BC.05 HP Carbamate Condenser. This "normal" Stamicarbon HP Stripping plant operated with an oxygen concentration of 0.45 [vol] % oxygen content after installation of the Safurex® HP Stripper. It was agreed that the oxygen concentration would be lowered to 0.3 [vol]% one month before a planned turnaround and inspection.

This experiment was executed while monitoring the Nickel content in the final product on a daily basis. In order to have the possibility to review the effect of this lower oxygen content we at first had the determine the typical Nickel content of the plant under normal operating conditions as the nickel content of each plant varies. For that reason some six days before the experiment the Nickel content was measured under normal operating conditions daily; the oxygen content was then reduced to 0.3 vol % during one month. The observation made was that the Nickel content did not change at all and remained 0.2 ppm in the final product. Also, the next important parameter in discovering active overall corrosion in a urea plant, the color of the end product (prills) did not change.

An inspection was performed immediately after this test, both visual and with help of eddy current, and showed no abnormal findings.

Figure 5: Nickel content in end product (0.2 ppm). No change during Low Oxygen Test.



Another nice experience is the Safurex® Urea Reactor in PERM in Russia. This is a TEC urea Plant in which the Urea Reactor has been replaced by a by Stamicarbon designed Safurex® Reactor including Siphon Jet Pumps; this Reactor operates with an oxygen level of 0.2 vol%.

Also the HP Stripper in the Profertil plant operated with an oxygen content of 0.2 vol% for almost four years; the lecture of Mr. Don Timbres show the conclusion.

10. Conclusions

- Safurex® is not a dream.
- Safurex® has brought the design, maintenance and the operation of urea plants to a next generation.
- To operate a urea plant without the addition of oxygen and thus to realize an intrinsically safe urea plant is only possible thanks to Safurex®.
- The use of Safurex® lowers the investment cost of new plants.
- Limitations in operational flexibility have widened.
- All this means that the efficiency and profitability of a urea plant is upgraded to a maximum level; one can easily talk about a maintenance free urea plant.
- Safurex® is not a dream; it is a reality.

Appendices

Reference list Safurex® equipment

ITEM	CAPACITY MTPD	LOCATION	YEAR OF DELIVERY	CLIENT
Stripper		Novgorod, Russia		JSC Acron Novgorod, Russia
Control valves	3,450	Sofert, Algeria	2010	Uhde, Germany
Ejector	3,450	Sofert, Algeria	2010	Uhde, Germany
HP Piping	3,450	Sofert, Algeria	2010	Uhde, Germany
Stripper	3,450	Sofert, Algeria	2010	Uhde, Germany
Pool Condenser	3,450	Sofert, Algeria	2010	Uhde, Germany
Reactor	3,450	Sofert, Algeria	2010	Uhde, Germany
HP Stripper	3,500	Yara Sluiskil, Netherlands	2010	Uhde, Germany
HP Scrubber	3,500	Yara Sluiskil, Netherlands	2010	Uhde, Germany
Poolcondenser	3,500	Yara Sluiskil, Netherlands	2010	Uhde, Germany
Urea Reactor	3,500	Yara Sluiskil, Netherlands	2010	Uhde, Germany
HP Stripper	1,200	Sala, Slovakia	2010	Duslo Sala, Slovakia
HP Stripper	1,500	Kutina, Croatia	2010	Petrokemija Kutina, Croatia
HP Stripper	1,800	Piesteritz, Germany	2010	SKW Piesateritz, Germany
HP Stripper	1,800	Piesteritz, Germany	2010	SKW Piesateritz, Germany
HP Stripper	2,860	Hulunbeier, P.R. China	2009	Stamicarbon
HP Scrubber	2,860	Hulunbeier, P.R. China	2009	Stamicarbon
Poolcondenser	2,860	Hulunbeier, P.R. China	2009	Stamicarbon
Urea Reactor	2,860	Hulunbeier, P.R. China	2009	Stamicarbon
HP Condenser	1,150	Mangalore Karanataka, India	2009	MCF mangalore India
HP Stripper	700	Terra Verdigis, USA	2009	Stamicarbon
HP Stripper (2x)	1,950	Eagrium, Egypt	2009	Uhde, Germany
HP Condenser (2x)	1,950	Eagrium, Egypt	2009	Uhde, Germany
HP Scrubber (2x)	1,950	Eagrium, Egypt	2009	Uhde, Germany
Urea Reactor (2x)	1,950	Eagrium, Egypt	2009	Uhde, Germany
HP Stripper	3,500	Sorfert, Algeria	2009	Uhde, Germany
HP Scrubber	3,500	Sorfert, Algeria	2009	Uhde, Germany
Pool Condenser	3,500	Sorfert, Algeria	2009	Uhde, Germany
Urea Reactor	3,500	Sorfert, Algeria	2009	Uhde, Germany
Urea Reactor	1,500	Ruwais, U.A.E	2008	Stamicarbon
HP Condenser	2,300	Sala, Slovakia	2008	Duslo Salal, Slovakia
Liquid distribution system	1,000	PAK, pakistan	2008	Stamicarbon
Ejector	2,600	Jianfeng, P.R. China	2008	Stamicarbon
HP Synthesis piping (1"- 14")	2,600	Jianfeng, P.R. China	2008	Stamicarbon
Urea Reactor	2,600	Jianfeng, P.R. China	2008	Stamicarbon
Pool Condenser	2,600	Jianfeng, P.R. China	2008	Stamicarbon
HP Stripper	2,600	Jianfeng, P.R. China	2008	Stamicarbon
HP Scrubber	2,600	Jianfeng, P.R. China	2008	Stamicarbon
HP Condenser	2,800	Mesaieed, Qatar	2008	Qafco-III, Qatar
HP Control and block valves (1"- 14")	3,500	Erdosi, Inner Mongolia	2008	Stamicarbon
HP Synthesis piping (1"- 14")	3,500	Erdosi, Inner Mongolia	2008	Stamicarbon
HP Scrubber	2,300	Bintulu, Malaysia	2007	Asian Bintulu Fertilizer, Malaysia
HP Scrubber	1,500	Sadiqabad, Pakistan	2007	Kawasaki, Japan
HP Stripper	1,500	Sadiqabad, Pakistan	2007	Kawasaki, Japan
Pool Reactor	1,500	Sadiqabad, Pakistan	2007	Kawasaki, Japan

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Reference list Safurex® equipment

ITEM	CAPACITY MTPD	LOCATION	YEAR OF DELIVERY	CLIENT
Mixer		NEW Orleans, USA	2007	Cytec, USA
Reactor Trays (SJPT)		Medicine Hat, Canada	2006	CFL, Canada
Pool Condenser	3,500	Erdosi, Inner Mongolia	2007	Stamicarbon
HP Stripper	3,500	Erdosi, Inner Mongolia	2007	Stamicarbon
Urea Reactor	3,500	Erdosi, Inner Mongolia	2007	Stamicarbon
Reactor trays	3,500	Erdosi, Inner Mongolia	2007	Stamicarbon
HP Stripper	1,250	Fort Saskatchewan, Canada	2007	Agrium, canada
Pool Condenser	2,800	Curatiba, Brazil	2007	Fosfertil, Brasil
Pool Condenser	1,800	Mesaieed, Qatar	2006	Qafco-II, Qatar
HP Scrubber	1,800	Mesaieed, Qatar	2006	Qafco-II, Qatar
Angle valve 5"	1,800	Minudobrenia Perm, Russia	2006	Minudobrenia Perm, Russia
Urea Reactor	1,800	Minudobrenia Perm, Russia	2006	Minudobrenia Perm, Russia
Reactor Trays (SJPT)	1,800	Minudobrenia Perm, Russia	2006	Minudobrenia Perm, Russia
HP Condenser	1,200	Piesteritz, Germany	2006	SKW, Piesteritz, Germany
HP Condenser	700	Ahmadi, Kuwait	2006	PIC Kuwait
HP Stripper	2,610	Urumqi, P.R. China	2006	PetroChina, P.R. China
HP Stripper	700	Verdigris, USA	2006	Stamicarbon
HP Stripper	1,400	Mangalore, India	2006	Stamicarbon
HP Scrubber Bundle	1,500	Carseland, Canada	2005	Agrium Inc. Canada
HP Stripper	1,500	Odessa, Ukraine	2005	CEMAG f OPP, Ukraine
Reactor Down comer 10"		Chittagong, Bangladesh	2005	KAFCO, Bangladesh
Reactor trays (SJPT)		Chittagong, Bangladesh	2005	KAFCO, Bangladesh
HP Stripper	2,000	Chittagong, Bangladesh	2005	KAFCO, Bangladesh
Urea Reactor	1,800	Mesaieed, Qatar	2005	Qafco [2], Qatar
Reactor trays		Mesaieed, Qatar	2005	Qafco [2], Qatar
HP Stripper	2,610	Ningxia, P.R. China	2005	PetroChina, P.R. China
Urea reactor	3,250	Bandar Assaluyeh, [2], Iran	2005	Chiyoda Corp., japan
Pool Condenser	3,250	Bandar Assaluyeh, [2], Iran	2005	Chiyoda Corp., japan
HP Stripper	3,250	Bandar Assaluyeh, [2], Iran	2005	Chiyoda Corp., japan
HP Scrubber	3,250	Bandar Assaluyeh, [2], Iran	2005	Chiyoda Corp., japan
Pool Condenser	2,610	Ningxia, P.R. China	2005	PetroChina, P.R. China
HP Stripper	2,150	Al Jubail, Saudi Arabia	2005	Al-Bayroni, Saudi rabia
Pool Condenser	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
HP Stripper	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
HP Scrubber	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
Urea Reactor	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
HP Piping (1"-6")	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
Valves, control/block	3,200	Al Jubail, Saudi Arabia	2004	UHDE GmbH, Germany
HP Condenser	700	Ahmadi, Kuwait	2004	PIC Kuwait
Reactor Trays (SJPT)		Karachi, Pakistan	2004	FJFC, Pakistan
Relining HP Stripper, Partial		Bandar Imam, Iran	2004	Razi Petrochemical Co. Iran
Relining Reactor, partial		Shiraz, Iran	2004	Shiraz Petrochemical Co. Iran
HP Condenser	2,700	Bintulu, Malaysia	2003	ABF, Malaysia
HP Stripper	2,700	Bintulu, Malaysia	2003	ABF
Valve 10"	2,700	Bintulu, Malaysia	2003	ABF

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ITEM	CAPACITY MTPD	LOCATION	YEAR OF DELIVERY	CLIENT
Piping 10", 12"	2,700	Bintulu, Malaysia	2003	ABF
Reactor trays (SJPT)	2,700	Bintulu, Malaysia	2003	ABF
Reactor trays (SJPT)	1,200	Piesteritz, Germany	2003	SKW, Germany
Piping 8"		Carseland, Canada	2003	Agrium, Canada
HP Stripper	3,250	Bandar Assaluyeh, [1] Iran	2003	Chiyoda Corp., Japan
HP Scrubber	3,250	Bandar Assaluyeh, [1] Iran	2003	Chiyoda Corp., Japan
Pool Condenser	3,250	Bandar Assaluyeh, [1] Iran	2003	Chiyoda Corp., Japan
Urea Reactor	3,250	Bandar Assaluyeh, [1] Iran	2003	Chiyoda Corp., Japan
HP Condenser	850	Talkha, Egypt	2002	El Delta Fertilizer, Egypt
Valves, control		Carseland	2002	Agrium, Canada
HP Condenser	1,200	Dneprodzerzhinsk, Ukraine	2002	Dneprazot, Ukraine
Reactor trays (SJPT)	1,200	Piesteritz, Germany	2001	SKW, Germany
Reactor trays (SJPT)	1,200	Piesteritz, Germany	2001	SKW, Germany
HP Piping		Carseland, Canada	2001	Agrium, Canada
HP Condenser	1,500	Bandar Imam, Iran	2001	Razi Petrochemical Co. Iran
HP Stripper	1,500	Shiraz, Iran	2001	Shiraz Petrochemical Co. Iran
HP Condenser	600	Petfurdo, Hungary	2001	Nitrogenmuvek Rt. Hungary
Reactor Trays (HERT)	1,500	Shiraz, Iran	2001	Shiraz Petrochemical Co. Iran
HP Stripper	2,000	Red Water, Canada	2000	Agrium, Canada
HP Condenser	1,500	Police, Poland	1999	Zaklady Chemiezne Poland
HP Condenser	850	Talka, Egypt	1999	Semadco Talka, Egypt
HP Stripper (internals)		Curitiba, Brasil	1998	Ultrafertil, Brazil
HP Scrubber bundle	1,000	Geleen, The Netherlands	1997	DSM, The Nertherlands
HP Stripper (3 tubes)	1,000	Geleen, The Netherlands	1997	DSM, The Nertherlands

Update: March, 2009