RUWAIS FERTILIZER INDUSTRIES  
FERTIL & UREA CASALE SA

LARGE SCALE UREA PLANT REVAMPING:
AN APPLICATION OF CASALE SPLIT FLOW & FULL CONDENSER TECHNOLOGIES
In FERTIL’s UREA DEBOTTLENECKING PROJECT

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Abstract

Urea Casale’s industrially proven technologies are being applied for a large capacity increase in the Urea Plant of Ruwais Fertilizer Industries (FERTIL) in UAE.

The latest technologies developed by Urea Casale, namely the Full Condenser™ and Split Flow Loop™ designs, will upgrade Urea Plant Synthesis section from 1,830 up to 2,700 MTPD.

The Full Condenser™ design combines the mechanical advantages of the standard falling film configuration of the HPCC, with the very efficient bubble-flow condensation regime together with internal thermo siphon circulation.

The Split Flow Loop™ design takes advantages of the total condensation obtained in HPCC through Full Condenser™ design. These further increases the Reactor efficiency by splitting the vapours from HP Stripper so that the part that is required to be condensed is sent to HPCC while the rest to the Reactor. In this way only part of the inerts introduced in the plant reaches the Reactor, with a significant enhancement in the Reactor efficiency.

The paper will give an overview of the application of these two technologies to the specific revamping of the FERTIL urea plant and an overview of the project execution.
ABOUT FERTIL AND PROJECT BACKGROUND

Ruwais Fertilizer Industries (FERTIL) was established in October 1980 as a joint venture between Abu Dhabi National Oil Company (ADNOC) and TOTAL of France. Construction activities began in 1980 and production started in 1983. The prime objective behind establishing the company was to utilize lean associated gas supplied from onshore oil fields to produce Urea fertilizer and market it locally and internationally.

The plant facilities are located in Ruwais Industrial complex (RIC) which is about 250 km west of Abu Dhabi City.

The existing facility comprises of 1050 MTPD, Haldor Topsoe designed Ammonia plant and a 1500 MTPD Stamicarbon designed urea plant. The plants have fully integrated utility units with storage facilities. The company has been continuously improving its technology and productivity. Presently, Ammonia and Urea plants are operating at 130% and 120% respectively of their original name plate capacities.

FERTIL Shareholders contemplated to install a Melamine plant in Ruwais to which feedstock and utilities were to be provided by FERTIL. The returning Carbamate stream from the Melamine plant was also to be processed in the FERTIL Urea plant. Further, it was desired to convert all available surplus liquid ammonia (about 100,000 MTPY) in to Urea.

With the above mentioned Objectives in view, FERTIL engaged Urea Casale to conduct a Technical Study which formed the basis of the presently under implementation, Urea De-bottlenecking Project (UDP). The Urea De-bottlenecking project has three Components:

- Modifications to the Urea Plant to enhance its capacity from 1800 to 2700 MTPD (Synthesis section) enabling it to transform ammonia produced in excess in the ammonia plant into urea using the CO2 recovered from the flue gas of the reformer.
- Installation of a 400 MTPD CO2 Recovery plant utilizing Mitsubishi Heavy Industries (MHI)' proprietary KS-1 Chemical Absorption technology.
- Installation of 2500 MTPD Granulation unit using Uhde Fertilizer Technology (UFT)' license.

With processing of recycled Carbamate from Melamine plant, the revamped urea plant would have produced 2700 MTPD of Urea, out of which 800 MTPD would have been for the Melamine plant as raw material, while 1900 MTPD would have
been granulated. During Melamine plant shut down periods, the revamped urea plant would produce 2300 MTPD of granular Urea.

In March 2008 however, the plan to install the Melamine plant in Ruwais was changed and proposed at another location close to Abu Dhabi. Although, equipment related solely with the Melamine Project was deleted from the UDP scope, the main equipment modifications within the Urea Plant were retained. The Urea plant after UDP implementation shall now produce 2300 MTPD utilizing all excess ammonia presently available. There is also a plan to revamp the Ammonia Plant to increase production from 1300 presently to 1550 MTPD in future which shall enable FERTIL to utilize the surplus capacity in Urea Plant.

This paper describes the modifications in the Urea Plant originally designed with a name plate capacity of 1500 MTPD, presently operated at 1830 MTPD and revamped up to 2700 MTPD utilizing Urea Casale’s proprietary technologies of Split flow and Total Condenser.

Apart from providing the Process Design Package of Urea Plant Modifications for the FERTIL UDP, Urea Casale also performed the Front End Engineering Design (FEED) and Detail Engineering.

EPC contract was awarded to Descon Engineering of Pakistan in July 2007 and the Project completion is due in July 2009. The Engineering and Procurement activities have almost been completed and Construction is in progress. Overall Project Progress is around 70% completed.
UREA CASALE REVAMPING CONCEPT

The modifications implemented in the Urea Plant to comply with the increased capacity are described as follows:

- Implementation of the latest technologies developed by Urea Casale, namely the **Full Condenser™** and **Split Flow Loop™** designs, will upgrade Urea Plant Synthesis section from 1,830 up to 2,700 MTPD.

- Urea Reactor performance will be improved by adopting the **Casale-Dente high efficiency trays** which are the most efficient trays available in the market and are also an essential element to make **Split Flow Loop™** as efficient as possible.

- To debottleneck the synthesis loop a Decomposer operating in parallel to the existing Stripper has been provided (**MP Split Flow Section**). The urea solution from the Reactor will be split in two parts, one part to existing Stripper and other part to the new Decomposer. By condensing ammonia and CO₂ at medium pressure it is possible to recycle to synthesis section a carbamate solution more concentrated, increasing the performance of the Reactor, with respect to the recovery of un-reactants at low pressure.

- The last important element of the **Split Flow Loop™** process is the **High Efficiency Hydrolyser** that allows treating very efficiently the process condensate, eliminating all NH₃ and Urea, so that it can be discharged without any environmental effects or it can be used as boiler feed water.
Casale Split Flow Loop™ process for plant revamping

The Casale Split Flow Loop™ process, suited also for new plants construction, is an improved CO₂ stripping process.

The main concept of the Split Flow Loop™ process is to split the total amount of inerts present in the CO₂ feed so that only a minority portion is sent to the Reactor, which is operating with the lowest possible amount of inerts. In addition, high condensation efficiency is reached in the HP carbamate condensation using a submerged Condenser. This is achieved with the following steps:

- The vapours, containing NH₃, CO₂, H₂O and inerts, obtained from the HP Stripper are split so that a minority portion is sent directly to the Reactor while the majority portion is sent to the HP carbamate Condenser.
- The portion of vapour sent to the HP carbamate Condenser is totally condensed, in a submerged Condenser, obtaining a carbamate stream and an uncondensed stream of inerts.
- The stream of inerts leaving the HP carbamate Condenser is sent straight to the HP Scrubber, bypassing the Reactor.

The main steps of the Split Flow Loop™ process are the following (see Fig. 1):

- The solution from the Reactor is first treated in a Stripper, operating at the same pressure of the Reactor, where, using steam and CO₂ as stripping agent, most of the unreacted NH₃ and CO₂ are recovered.
- Part of the unreacted NH₃ and CO₂ recovered in the Stripper are sent directly to the Reactor, while the rest is recycled back to the Reactor through a HP Condenser.
- From the Stripper, the urea solution, still containing unreacted NH₃ and CO₂ in form of carbamate, is sent to a low-pressure single decomposition/condensation stage where practically all the remaining unreacted NH₃ and CO₂ is recovered in form of a carbamate solution.
- The urea-water solution, containing only small quantities of NH₃ and CO₂, is then further treated in a two-stage vacuum evaporation section to obtain a urea melt for the prilling tower or the granulator.
- The process condensate, obtained from the vacuum Condensers is purified with two columns and one hydrolyser in order to eliminate all NH₃, CO₂ and Urea.
- The carbamate solution obtained in the LP section is sent to the HP Scrubber where the inerts leaving the HP loop are washed.

In this way, the synthesis section operates with very low inerts content with the following advantages:

- High CO₂ conversion in the Reactor (up to 63-64%)
• High stripping efficiency
• High condensation efficiency.

For this reason, the Casale Split Flow Loop™ process is a process with high efficiency requiring, for a given capacity, equipment of smaller size with low investment costs.

As far as the operating costs are concerned, the Split Flow Loop™ process has values as low as the most advanced processes.

The Casale Split Flow Loop™ process is, therefore, suited for plants of very large capacity. The most critical equipment in fact, are smaller, for a given capacity, than in conventional processes.

The configuration of the HP loop of the Split Flow Loop™ process is shown in Fig. 2.

The solution leaving the Reactor is treated in the HP Stripper where the carbamate present in the solution and containing unreacted NH₃ and CO₂ is decomposed with the help of the CO₂ feed as stripping agent. The vapour stream generated by the carbamate decomposition and containing NH₃, CO₂ some water and all inerts present in the CO₂ feed, is split after leaving the HP Stripper. Only the portion of that vapour stream, which actually has to be condensed in this equipment, will go to the HP carbamate Condenser (HPCC).
In the Split Flow Loop™ configuration the rest of the vapours go directly to the Reactor bypassing the Condenser, which in a standard configuration of the CO2 stripping process would leave the HPCC un-condensed.

The HPCC is practically a total Condenser of the submerged type and the carbamate flow obtained in this equipment is sent to the Reactor.

Total condensation in the Condenser is not possible because of the presence of inerts, so that a small amount of uncondensed vapours leaves from the top of the Condenser and is sent directly to a HP Scrubber together with the inerts.

In this way, about 2/3 of the total amount of the inerts present in the CO₂ are not sent to the Reactor, and consequently the urea conversion is maximized.

The HP Scrubber recovers NH₃ and CO₂ from the inerts streams leaving the HPCC and the Reactor using the carbamate flow coming from the LP recovery section. The carbamate flow coming from the HP Scrubber is sent to the HPCC, to enhance the condensation, using an ejector driven by the ammonia feed, which is also sent to the HPCC.

In order to keep the correct ratio in the HPCC, part of the CO2 feed is bypassing the HPCC and is sent to the Reactor through a new ejector that enhances the driving force for the circulation sucking the carbamate leaving the HPCC.

![Diagram of Split Flow Loop™ configuration](image)

Fig. 2: Split Flow Loop™ configuration
Casale Split Flow Loop™ process – characterizing elements

The main elements characterizing the HP loop of the Split Flow Loop™ process are:

- **Casale Full Condenser™**
- **Casale-Dente high efficiency trays**
- **Casale High Efficiency Hydrolyser** used in the process condensate treatment unit

The **Casale Full Condenser™** is a submerged Condenser with a natural circulation replacing the standard falling film condensation regime.

A mixed two-phase flow flows up in most of the tubes with a very small amount of tubes, which are left without vapour phase, where liquid flows downward, thanks to the density gradient with the other tubes. This produces an internal natural circulation. Consequently, the new internal flow regime is a bubble flow inside a continuous liquid. In this way, the interfacial area between two phases (liquid and gas) is significantly increased, so that the transfer performance of the exchanger is highly improved. Moreover, the HPCC will be even better protected from corrosion in the new configuration, as all tubes surfaces will be better wetted.

The new flow pattern of the HPCC is shown in the sketch of Fig.3, and can be summarized as follow:

- Vapours coming from HP Stripper are fed through one of the bottom nozzle and distributed inside the continuous liquid phase by a distributor on the bottom of the HPCC.
- The two-phase flow, thanks to its lower density, flows upward and along the tubes the vapours condense.
- The two-phase flow exits the tubes from the top tube sheet and the inerts separates from the condensed liquid and exit the Condenser from the top nozzle.
- Fresh liquid (ammonia and carbamate mixture) enters the exchanger through the second nozzle in the bottom and is distributed in the tubes.
- A top weir defines the liquid level in the top part of the Condenser, the overflowing liquid exits the exchanger through the second top nozzle.

![Fig. 3 Full Condenser™ configuration](image-url)
The optimal circulation ratio is determined by Casale in order to achieve optimal condition for the heat transfer in the two-phase upward tubes.

The Full Condenser™ is a very efficient Condenser with 50% higher heat transfer efficiency than a standard falling film Condenser.

In addition being a submerged Condenser a significant amount of urea is formed in the Condenser itself reducing the load of the Reactor.

All the above features are obtained with a very simple, proven and reliable mechanical design used in many applications for the falling film configuration. With a very simple improvement in the internal part, the same design can work in a much more efficient configuration.

The Casale-Dente high efficiency trays are the most efficient trays available in the market and are also an essential element to make Split Flow Loop™ as efficient as possible.

The Casale-Dente design, in fact, improves the tray geometry realising a very efficient transfer of NH₃ and CO₂ from the vapours into the liquid phase where urea is formed.

The new trays (see Fig. 4) are, in fact, designed so that:

- Separate and distributed paths through the tray are provided. They guarantee a steady state flow of the two phases and better approach an even uniform flow of the two phases throughout the whole Reactor.
- These separated paths through the tray are chosen so that a very high mixing efficiency between vapour and liquid is obtained. Consequently a very high mass and heat transport within the liquid phase is realised.
- With an appropriate design, the diameter of the generated vapour bubbles is smaller than in any previous design. By consequence, the interfacial surface, for mass and heat transfer, is increased.
- A much larger surface of exchange between emulsion and clean liquid is created.
• The quite shorter path length of recirculation streamlines into the emulsion phase significantly decreases the transport resistances.

The trays are made up by several inverted U beams with large perforations for liquid passage on the bottom wings, and small perforations for gas passage on the sloping and top sections. With this unique design, very small bubbles are generated, and by consequence, very high specific surface for the mass and heat transfer is obtained. This advantage is combined with a very high efficiency in the mixing between vapours and liquid.

The last important element of the Split Flow Loop™ process is the High Efficiency Hydrolyser that allows treating very efficiently the process condensate, eliminating all NH₃ and Urea, so that it can be discharged without any environmental effects or it can be used as boiler feed water.

With the help of Urea Casale’s High Efficiency Hydrolyser (HEH - see Fig. 6), adding, if necessary, one or two stripping columns, it is possible to completely eliminate NH₃ and Urea from the process condensate reaching residual values lower than 3 ppm. This value meets the requirements for boiler feed water; the treated condensate can, therefore, be used as boiler feed with economical advantages.

The High Efficiency Casale Hydrolyser (see Fig. 5) makes efficient use of the stripping action of steam to remove the NH₃ and CO₂ from the treated urea plant waste water condensate in order to maximise the hydrolysis of the urea content.

The efficiency is enhanced by the fact that the hydrolyser is divided in two zones in order to keep the driving force for the NH₃ and CO₂ removal as high as possible. It is, in fact, very important to eliminate NH₃ and CO₂ from the liquid as much as possible as, since the NH₃ and CO₂ are products of the hydrolysis reaction, their presence tends to slow down the hydrolysis.

Both zones are provided with High Efficiency Casale Trays which divide them in compartments. In each compartment the liquid is separated from vapours (containing NH₃ and CO₂), creating a multiplicity of streams of vapours, which are injected again into the liquid in form of column of small bubbles maximising the mass and heat transfer.

The two zones have the following characteristics:

**First Zone**
The first zone, fed by the waste condensate to be treated, is...
operating in “co-current” with injection of steam in the bottom. At the top of the first zone the vapours are finally removed from the liquid which is then treated in the second zone.

**Second Zone**

The second zone, fed by the liquid coming from the first zone, operates in “counter-current” with liquid going downward and vapour going upward. Fresh steam is injected again in the bottom of this second zone. The driving force for the extraction of NH\textsubscript{3} and CO\textsubscript{2} is, in this way, increased, allowing reducing urea content to less than 3 ppm.

The vapours are separated from the liquid at the top of the zone and exit the hydrolyser together with the vapours coming from the first zone.

Steam at pressure lower than 25 bar can be conveniently used.
REVAMPING PROCESS DESCRIPTION

H.P. Section

Existing Reactor will be modified by replacing the existing trays with a set of new CASALE High Efficiency Trays.

After revamping, to cover the new demand of fresh ammonia both existing HP Ammonia Pumps should be put in operation. To have the necessary plant reliability, a new reciprocating pump identical to the existing ones will be added as spare.

Due to the increase in requirement of CO₂ flow an additional CO₂ compressor, reciprocating type, is installed, taking suction from CO₂ recovery unit and feeding to discharge of existing CO₂ compressor.

To cope with the new carbamate solution capacity for H.P. carbamate pumps new pumping capacity is being added.

Existing HP Stripper will be modified to fit the equipment to provide the new Split Flow configuration.

Existing HP Carbamate Condenser will be replaced since the existing one is at the end of its working life. The new Full Condenser has been designed for the new plant capacity.
MP Split Flow Section

In order to achieve the capacity increase up to 2'700 MTD a new decomposition section operating at 18-20 kg/cm² is installed in parallel to the existing Stripper.

The urea solution coming from the Reactor is split part to the existing Stripper and minor portion to the new Decomposer.

The vapors from Decomposer are condensed in the new Condenser with the help of carbamate solution coming from Level Tank for Carbamate Condenser through the new M.P. Carbamate pumps.

The solution coming from Decomposer joins the solution exiting the HP Stripper to feed a common new LP Flash vessel.
**L.P. Section**

Urea solution, both from the Stripper and the MP Decomposer, are fed into the new LP separator where the gas/liquid separation is achieved.

Therefore only the liquid phase is sent to the existing rectifying column, where the liquid distribution is improved by new internals of more efficient concept.

The vapors from the top of rectifying column, together with the vapors from new LP separator join a stream of CO2 from the compressor that is being added in order to guarantee optimum condensation into the existing and new LP Condensers. The liquid from new LP separator enters top of rectifying column which in turn enters into Recirculation heater for further decomposition.
**Vacuum Evaporation and Condensation Sections**

Due to the fact that this section has the same design capacity of the Granulation Unit (2500 MTPD) a new bigger evaporator is installed, which will be flanged to the existing separator. Inside this separator, special internals designed by CASALE will be installed, to avoid urea carry-over problems.

The urea solution 96% wt will be sent from separator to the new granulation section by means of new urea melt pumps.

**Hydrolysis / Desorption Section (Waste Water Treatment)**

The function of the revamped Waste Water Treatment section is to deeply treat the process water produced in the urea plant (recycle water plus formation water) in order to obtain water containing about 1 ppm of urea and NH$_3$ (suitable to be used as BFW) before it is discharged from the urea plant.

A new Distillation Column, is being introduced in order to achieve the process condensate quality to be suitable for BFW utilization.

This column is divided in two parts thanks to a chimney tray that split the column in the desorption section (upper part) and stripping section (lower part)

Upper part removes most part of NH$_3$ and CO$_2$ by means of vapors coming from the lower part through the chimney tray.

The water from the chimney tray of this column feeds the existing hydrolyser, which will be modified according to CASALE High Efficiency Hydrolizer technology thus reducing the urea content in the treated water down to about 1 ppm.
**Urea Debottlenecking Project (UDP) Process Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original capacity</td>
<td>1500 mtpd</td>
</tr>
<tr>
<td>Maximum achieved capacity</td>
<td>1800 mtpd</td>
</tr>
<tr>
<td>Capacity after revamp</td>
<td>2300 mtpd</td>
</tr>
<tr>
<td>MP Steam cons. after revamp</td>
<td>720 kg/ton</td>
</tr>
<tr>
<td>CW consumption (ΔT = 10 °C)</td>
<td>75 m³/ton</td>
</tr>
</tbody>
</table>
Project Implementation

The Urea Debottlenecking Project has been developed through the following main steps:

- Feasibility Study by UCSA
- FEED (Front End Engineering Design) by UCSA
- Detail Engineering of Urea Plant modification by UCSA and including:
  - Laser scanning of the existing plant (see figure below)
  - 3D modelling (see figure below)
- Supply of UCSA proprietary equipment (High Pressure Carbamate Condenser, HP Ejector, High Efficiency Trays, Split Parallel Section equipment)
- UCSA assistance to FERTIL for the procurement of Long Lead Item (CO₂ Compressor, High Pressure Ammonia and Carbamate Pumps)
- Construction, erection and installation with UCSA assistance
- Pre-Commissioning, Commissioning and Start-Up with UCSA assistance
3D model of Fertil Plant in Ruwais
The **Split Flow Loop™** process is operating in Ukraine in a plant that was originally designed according to the CO2 stripping technology and that was revamped by Casale in two steps, the last of which with the introduction of the **Split Flow Loop™** and **Full Condenser™** concepts.

The plant is operating since 2003 according to **Split Flow Loop™** process and is producing 1500 MTD of urea.

The plant is also incorporating the Casale High Efficiency Trays design for the Reactor and the **Full Condenser™** design for the HPCC, and this makes it a full reference for the Casale **Split Flow Loop™** process as described in this document.

The plant was originally designed according to the CO2 stripping technology with a design capacity of 1000 MTD of Urea.

In 1999 Casale installed the Casale-Dente High Efficiency Trays in order to debottleneck the HP synthesis section and a capacity of 1350 MTD was reached with some modification only in the low pressure section of the plant.

In 2003, thanks to the **Split Flow Loop™ / Full Condenser™** concept, Casale was able to reach the present capacity of 1500 MTD.

Just with the transformation of the HPCC to the **Full Condenser™** design and of the HP loop to the **Split Flow Loop™** configuration, the plant was able to reach a capacity of 1500 MTD with key items like the Reactor and the HPCC that were still the original ones.

It is important to note that the existing original falling film HPCC was just modified with new internals, and the same old Condenser can now operate in a much more efficient way. This is to stress the fact that the **Full Condenser™** design is a very simple design relying on proven and reliable mechanical concepts.

The CO2 conversion reached in the Reactor is much higher than the original design, reaching a value of 64%.

The Stripper efficiency has also increased compared to the original design value.

In conclusion, we can say that the **Split Flow Loop™** process is proven and, as it has demonstrated to be very suited to increase the capacity of existing plants keeping the same equipment, can be conveniently used to design new plants with minimum investment.
In addition to Fertil’s UDP, two more applications of the Split Flow Loop™ / Full Condenser™ concept are under implementation for revamping of urea plants to increase their capacity by 50%.

Casale has also recently designed, according to the Split Flow Loop™ process, a grass-root urea plant under construction in France.