UREA CASALE TECHNOLOGIES AND INDUSTRIAL EXPERIENCES IN UREA FIELD: AN OVERVIEW WITH LATEST DEVELOPMENTS

By
F. Zardi, A. Scotto

UREA CASALE S.A.
Lugano, Switzerland

For presentation at the
FAI International Technical Conference on Fertiliser Technology
12-13th April, 2007

UreaCasale

Abstract

Since the start of its activity, Urea Casale has developed several innovative technologies for the revamping of urea plants.

With the application of these technologies, Casale has been able to revamp more than 70 plants in the last 20 years achieving considerable increases in plant efficiencies and capacities, and gaining a leading position in urea plant revamping.

In this paper, an overview of the most important Casale technologies applied to urea plant revamping is given together with the main results obtained.

Particular emphasis is given to the latest technologies developed by Urea Casale, namely the Full-Condenser™ and Split-Flow-Loop™ designs.

These two technologies drastically increase the efficiency of CO_2 stripping plants introducing a new configuration for the HP Carbamate Condenser (HPCC), to obtain a more favourable condensation regime and improve its efficiency, and a new HP loop configuration, to reduce the amount of inerts present in the reactor.

In the second part, the paper gives an overview of the most recent projects involving the application of the Casale technologies applied to revamping.

Introduction

Urea Casale S.A., established in 1991 to carry on the urea technology activities initiated by Ammonia Casale S.A. in 1985, is the company of the Casale group active in the field of urea.

Since the beginning, efforts were mainly directed towards the revamping of existing plants, with almost 70 plants being revamped since 1985.
Through its revamping activities and thanks to its capability of developing innovative technologies, Urea Casale was able to become, in a very short time, a leader in urea plant revamping, having its own technologies to upgrade all types of urea plants and acquiring a considerable share of the market.

Capacity increase, energy consumption, corrosion control, pollution abatement and product quality are the key areas for upgrading plant performance.

Several urea plants have been successfully revamped by Urea Casale utilizing its proprietary technology.

Like the other companies of the Casale Group, the main strength of Urea Casale lies in licensing its technologies. Most of the technologies are, therefore, developed in-house by a team of very specialized and experienced people.
Following the trend set by Ammonia Casale, Urea Casale invested and is still significantly investing in technology development, putting also a lot of effort into developing the right process design tools.

Urea Casale Technical Services avail themselves of the right specialists and of advanced tools for investigating, analyzing and picturing complex phenomena, including such tools as computer-aided techniques with applications ranging from chemical process design to fluid dynamics evaluations.

Several of the technologies developed by Urea Casale, some of which are mentioned in this paper, are typical examples of how the combination of above mentioned tools and expertise can lead to the development of innovative concepts.

This is particularly true for the **Split-Flow-Loop™** and **Full-Condenser™** designs that are discussed in more detail in this paper.

In order to make plant revamping more and more efficient, there is a constant need to improve the efficiency of the key equipment of the plants.
Following this need, Casale looked at the possibility of improving the efficiency of vertical HP condensers typically used in CO_2 stripping plants. These condensers are one of the key items of the plant HP loop, that is the most important section of these types of urea plants.

As a result of its investigation, Casale found out a way to achieve the desired improvement with a simple transformation of the condenser from its original falling-film configuration into the more efficient submerged bubble-flow configuration.

With this transformation it is possible to increase the efficiency of the existing unit by at least 50%.
The possibility of transforming the HP condenser, as mentioned above, opened the way for improving also another key item in the HP loop.

Operating the HP condenser with a submerged bubble-flow configuration gives the opportunity to operate it as a total condenser and, with a simple piping modification, to reduce the amount of inerts present in the reactor.

Both changes result in an increase in the efficiency of another important piece of equipment in the HP loop, which is the reactor. The increase in efficiency corresponds to about 3 percentage points in the CO_2 conversion.

The development and successful design to transform an existing HP falling-film condenser into a submerged condenser was possible through a very accurate fluid dynamic simulation of the system combined with the modelling of the chemical-physical equilibriums and of the heat transfer phenomena.

The above was combined also with a process analysis, through simulation, of the HP loop, which made it possible to find out the way to even improve the reactor in combination with the transformation of the condenser.

Short Overview of Casale Technologies for Urea Plant Revamping

Since the start of its activity, Urea Casale has developed several technologies aimed at increasing the efficiency of various sections or pieces of equipment in urea plants.

For every revamping project, Urea Casale proposes one or a combination of these technologies in order to offer the most efficient revamping solution to the client.

In this chapter, most of the technologies developed by Urea Casale are shortly described, while the next section focuses on of the latest technologies developed by Urea Casale.

Casale-Dente High Efficiency Trays

The development of this technology was the first example, in Casale activity in the urea field, of how the investigation and analysis of complex phenomena, and the ability to picture it through the combination of process design and fluid dynamics tools, can lead to the development of the most advanced technologies.

In collaboration with Professor M. Dente, Urea Casale was able, through an accurate modelling, to identify all the parameters that influence the formation of urea inside a urea reactor. Through the modelling, it became clear that a good transfer of mass and heat within the phases of the heterogeneous reacting system of urea is of essence to reach a high conversion in the reactor. With the models, it was also possible to identify that the existing designs of internals (trays) used in urea reactors could be improved.

The Casale-Dente High Efficiency Trays design improves the tray geometry achieving a superior mixing with a much better mixing between the liquid and vapor phases.

The new trays 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 achieved.
- 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 superior mixing within the liquid phase is also obtained.

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.

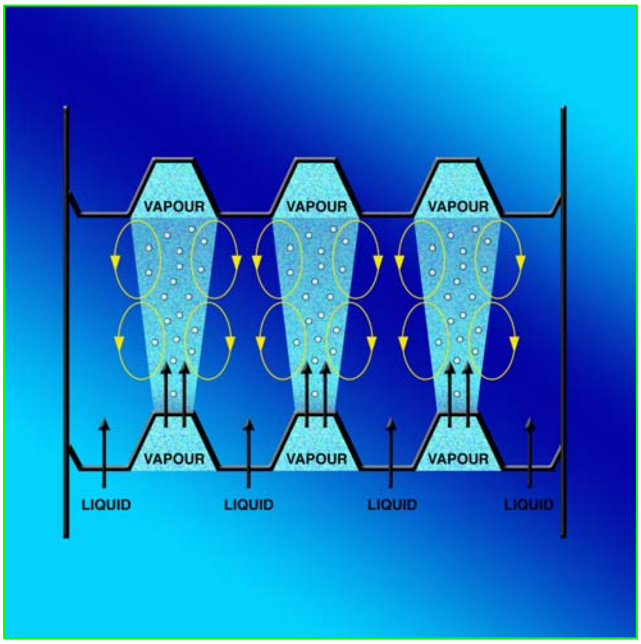

Fig. 1 - Casale-Dente High Efficiency trays

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 Casale-Dente High Efficiency Trays are used for any project aiming at reducing the steam consumption and/or at increasing the plant capacity.

So far the Casale-Dente High Efficiency Trays are operating in more than 50 urea plants.

Casale High Efficiency Hydrolyser
In order to reduce the liquid emissions, Casale has developed a new hydrolyser of increased efficiency, called High Efficiency Hydrolyser (HEH), which allows to completely eliminate Ur from the process condensate.

The Casale High Efficiency Hydrolyser (see Fig. 2) makes efficient use of the stripping action of steam to remove the NH_3 and CO_2 from the treated urea plant waste water condensate in order to maximize 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 NH_3 and CO_2 removal as high as possible. It is, in fact, very important to eliminate NH_3 and CO_2 from the liquid as much as possible as, since the NH_3 and CO_2 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 NH_3 and CO_2), creating a multiplicity of streams of vapours, which are injected again into the liquid in form of column of small bubbles maximizing the mass and heat transfer. The two zones have the following characteristics:

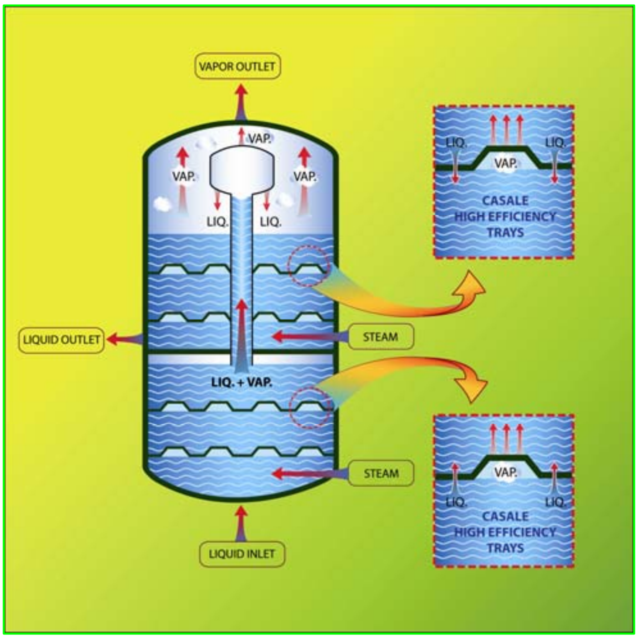

Fig. 2 - High Efficiency Hydrolyser

<u>First Zone</u>

The first zone, fed by the waste condensate to be treated, is operating in “co-current” with injection of 22-24 bar 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.

<u>Second Zone</u>

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 22-24 bar steam is injected again into the bottom of this second zone. The driving force for the extraction of NH_3 and CO_2 is, in this way, increased, reduces the 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.

With the help of the Casale High Efficiency Hydrolyser, and adding, if necessary, one or two stripping columns, it is possible to completely eliminate NH_3 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 Casale High Efficiency Hydrolyser is used when it is necessary to reduce the emission of Urea and NH_3 through the process condensate, or to increase the capacity of existing hydrolyser.

Existing hydrolysers of certain types can be also conveniently revamped by changing the internals with new ones designed according to the High Efficiency Hydrolyser technology.

So far the Casale High Efficiency Hydrolysers are operating in 5 urea plants.

HEC (High Efficiency Combined) Process
The development of this process opened the way to very large capacity increases, up to 50% or more, of conventional total recycle plants.

This process, based on the combination of a very efficient "once-through" reactor (primary reactor) and a conventional total recycle one (secondary reactor), presents the unique feature of having a very high average CO_2 conversion, 70% to 75%, and by consequence a low energy consumption.

Most of the urea is produced, in absence of any water, in the primary reactor with a high yield, generally 75%. This reactor has a carbamate condenser upstream, for controlling the heat balance, and a HP decomposer downstream to recycle most of the unreacted NH_3 and CO_2 directly into the secondary reactor, operating at lower pressure.

The urea solution from the HP decomposer joins the solution flowing out of the secondary reactor and together they feed a two-stage recycling section with NH_3 recovery column.

The capacity of conventional total recycle plants can be drastically increased by applying the HEC concept, and this with the addition of just few pieces of equipment.

In order to increase the capacity of conventional total recycle plants up to 50% or more, Casale proposes to install its HET in the existing reactor and to apply its HEC concept as follows:

- the existing reactor (fitted with Casale HET) is used as the primary reactor;
- a section consisting of the secondary reactor, an HP carbamate condenser and an HP decomposer is added (see Fig. 3).

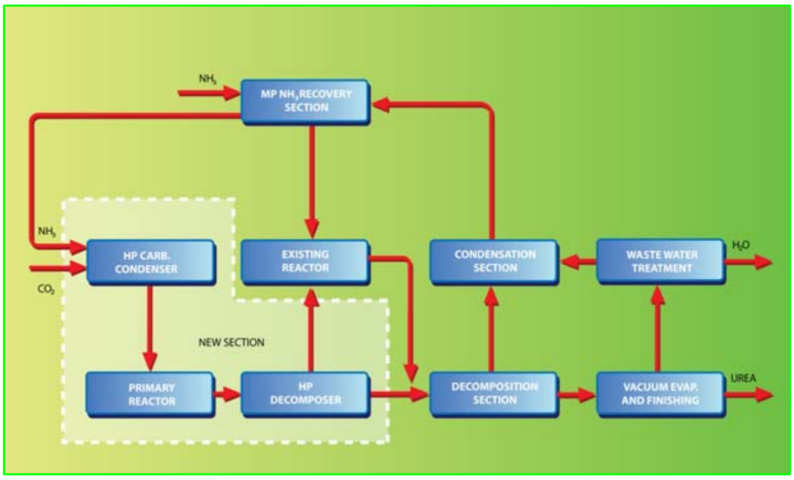

Fig. 3 - Conventional Total Recycle Plant revamped with the HEC Concept

The existing synthesis section will, therefore, be transformed in a HEC synthesis section and due to the much higher conversion obtained with the HEC synthesis section, the existing back-end of the plant can be re-utilized at higher capacity with only minor modification.

With this approach, the highest possible utilization of the existing equipment is reached, keeping the investment as low as possible.

For very large capacity increases, a primary reactor is added while the existing reactor will be used as secondary reactor.

After revamping, the following consumption's can be obtained:

- raw materials almost steichiometric
- MP steam ab. 900 kg/MT

VRS (Vapor Recycle System) Process
This technology has been developed for the revamping of stripping plants and is used in certain cases to drastically increase the capacity of said plants.

The VRS concept foresees a separate circulation of recycle water and recycle NH_3 and CO_2, i.e.:

- The carbamate solution obtained in the downstream process sections instead of being sent to the H.P. section, is distilled in an H.P. decomposer working in parallel to the existing stripper.
- The vapors thus obtained (containing NH_3, CO_2, and little water) are sent to the H.P. Section (H.P. Carbamate Condenser), while the distilled solution (enriched in water) is sent back to the back-end of the plant.

In this way, practically only the NH_3 and CO_2 contained in the carbamate are sent back to the synthesis section, while the water is almost totally sent back to the recycling and waste water treatment sections.

As a consequence, the H.P. synthesis loop will operate with very low water content with the following advantages:

- very high CO_2 conversion is obtained in the reactor (up to 70%).
- very high stripping efficiency.
- lower amount of water to be treated in the existing decomposition, vacuum evaporation and waste water treatment sections.

The existing plant (see Fig. 4) is modified according to the VRS concept adding a new decomposition section in parallel to the existing plant. The HP carbamate is sent to the new section where it is decomposed. The released vapors, rich in NH_3 and CO_2, are sent to the synthesis section, while the purified solution is sent back to the back-end of the plant.

As the existing reactor will be working with a low water content (H_2O/CO_2 molar ratio of 0.2 ÷ 0.25), a high CO_2 conversion is obtained (66 ÷ 70%).

Due to the fact that, in the existing plant, the new conversion is much higher and the water content much lower than the ones before the modification, the existing plant can, again, be re-utilized at higher capacity with only minor modifications.

With this approach, an increase in capacity up to 50% or higher can be achieved.

After revamping, the following consumptions can be obtained:

- raw materials almost steichiometric
- MP steam ab. 850 kg/MT.

One of the big advantages of the approach just described is that the required additional section can be installed while the plant is still running, and just a few tie-ins are necessary to interconnect them with the existing plant, minimizing in this way the shut down time for the modification.

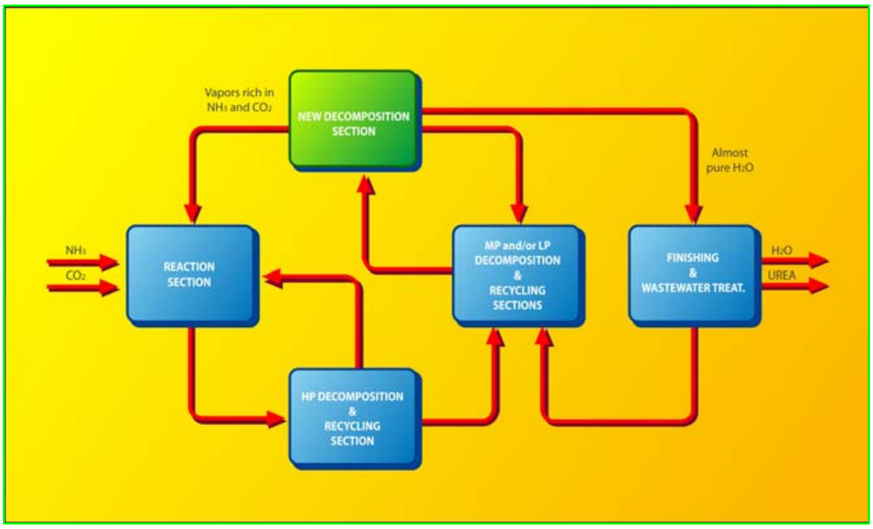

Fig. 4 - Stripping Plant Revamped according the VRS Concept

Furthermore, the solutions generated by plant upsets or shutdowns can be recovered very quickly.

<u>Latest Development of Casale Technologies: Split-Flow-Loop™ and Full-Condenser™ Concepts for CO_2 Stripping Plant Revamping</u>

The development of these two technologies is the result of Casale's constant research for new improvements in urea plants and the latest example of how, also in urea field, modelling is becoming more and more an essential tool for technical development.
These technologies are a powerful tool to increase the capacity of CO_2 stripping plants in a very efficient, and therefore, economical, way

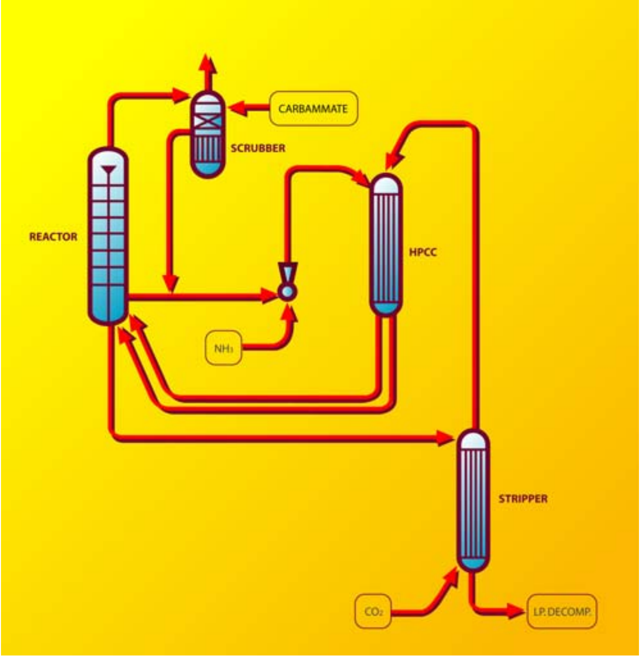

Fig. 5 - HP Loop of CO_2 Stripping Plants

State of the Art
Vertical HP condensers have been used in the HP loop of urea plants designed according the CO_2 stripping technologies for many years.

In such plants (see Fig. 5), the effluent of the reactor is stripped in the HP stripper using CO_2, together with heat, as stripping media. In this way it is possible to recycle a good quantity of unreacted NH_3 and CO_2 straight back to the reactor.
All the vapours leaving the stripper need to be partially condensed before they are sent to the reactor in order to keep heat balance of the latter.

In order to obtain this partial condensation, all the vapours from the HP stripper are sent to a falling-film condenser, namely the HP Carbamate Condenser (HPCC).

A certain quantity of inerts (including some air for passivation) is present in the CO_2 that is fed to the HP stripper.
All those inerts introduced into the HP loop of the plant reach the reactor through the HP stripper and the HPCC.

In its standard, and most used, configuration (see Fig. 6), the HPCC of a CO_2 stripping plant is a counter-current falling-film condenser with the following characteristics:

- The vapours to be condensed (coming from the stripper) enter the condenser from the top together with a liquid stream, consisting of the recycled carbamate, coming from the HP scrubber, and the ammonia feed.
- The liquid and the vapours are distributed in each tube. In the tubes a liquid film is formed from the condensing vapors and the entering liquid stream.
- In the bottom of the condenser the remaining vapours are separated from the liquid and both the liquid and vapours leave the condenser separately.

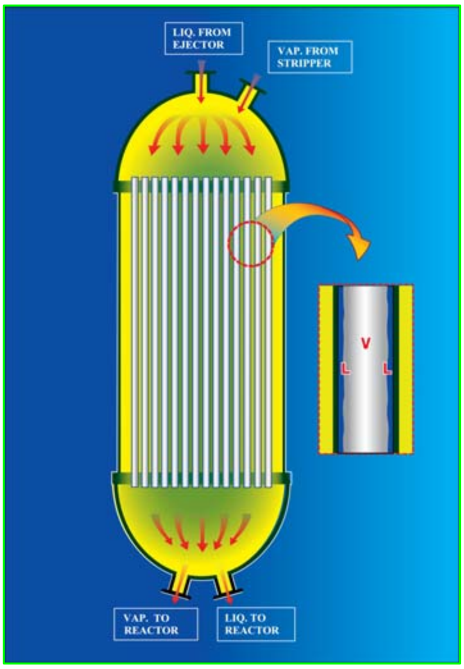

Fig. 6 - HPCC of CO_2 Stripping Plants
Most Used Configuration

Theoretical Considerations about Different Configuration for Condensation

In order to find a way to improve the performance of the HPCC, Casale examined, from a theoretical point of view, the performance of different types of condensation.

It is well known that the condensation using a falling-film configuration (see Fig.7) does not give the best condensation efficiency, and that the condensation efficiency could be improved if a bubble flow configuration (see Fig.8) is adopted.

The condensation of the vapours entering the HPCC, containing NH_3, CO_2 and water, requires the transfer of mass (and heat) from the vapour balk into the liquid phase, where NH_3 and CO_2 are condensed into carbamate. Even the overall heat transfer depends on this mass transfer.
In fact, if the mass transfer is not efficient the condensation rate will be low.

The lower efficiency in the mass transfer will, therefore, be reflected in a low value of the apparent heat transfer coefficient.

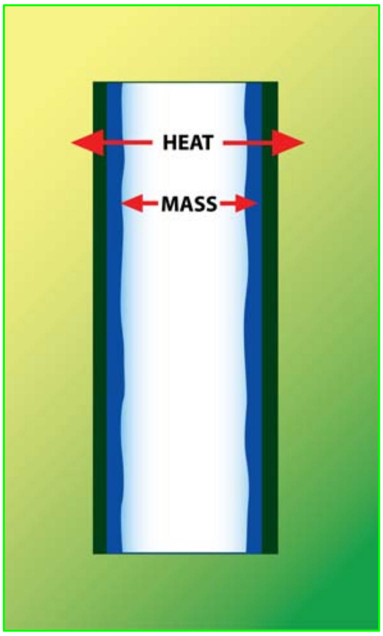

Fig. 7 – Falling-Film Configuration

In case of a falling-film type of condenser, this transfer of mass becomes a limitation as the surface at disposal for the transfer is limited by the external surface of the film.
In case of a bubble-flow configuration, on the contrary, the surface at disposal for the mass (and heat) transfer is much larger.
Furthermore, even if the heat transfer from the liquid film to the tube wall is pretty good with the falling-film configuration, it is lower than with the bubble-flow configuration due to the high turbulence generated by the bubble-flow and by the fact that the film can have laminar flow conditions.

The falling-film configuration is also sensitive to the distribution. An even distribution of liquid and vapour over all the tubes is not always easy to obtain and a non-optimal distribution also negatively influences the transfer efficiency.

Due to the above reasons, the tube side heat transfer coefficient can be, with the bubble-flow configuration, 4 to 5 times higher than with a falling-film configuration.

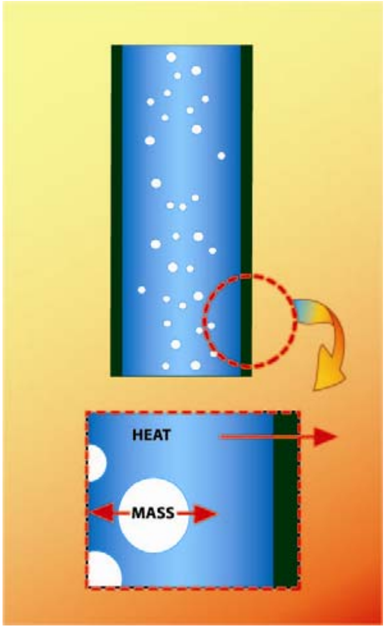

Fig. 8 – Bubble-Flow Configuration

Using a commercial package for the simulation of a heat exchanger combined with its physical-chemical equilibrium models for urea, Casale made rigorous simulations of the two configurations mentioned above.

From the modelling it became clear that with the falling-film configuration the tube side heat transfer coefficient is the limiting factor in the overall heat transfer coefficient, and, therefore, an improvement of the tube side coefficient would lead to an improvement in the overall coefficient.

The simulations also showed that changing the flow regime inside the tubes to the bubble flow regime could significantly increase the overall heat transfer coefficient.

Full-Condenser™ Concept

In order to improve the existing HPCC by changing the falling-film configuration to the more efficient bubble-flow configuration, Casale developed the **Full-Condenser™** concept according to which the condenser operates as a submerged condenser with a natural circulation replacing the standard falling-film condensation regime.

In order to fully develop the **Full-Condenser™** concept, Casale included in its model, mentioned in the previous section, also the fluid dynamic simulation. In this way, Casale could optimize the new design in all its aspects and all necessary tools to best design any further application of the new concept were then at its disposal.

According to the **Full-Condenser™** concept, an existing HPCC is modified so that a mixed two-phase flow rises up in most of the tubes.

A very small amount of the tubes are left without a vapour phase, and in those tubes 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.

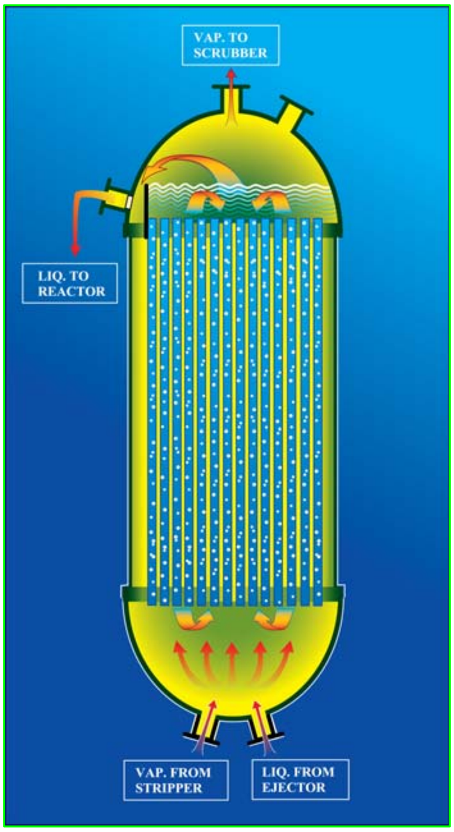

Fig. 9 - Full Condenser™ configuration

Moreover, the HPCC will be even better protected from corrosion in the new configuration, as all surfaces of the tubes will be better wetted.

The new flow pattern of the HPCC is shown in the sketch of Fig. 9, and can be summarized as follows:

- Vapours coming from HP stripper are fed through one of the bottom nozzles 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.
- A two-phase flow exits the tubes from the top tube sheet and the inerts separate from the condensed liquid and exit the condenser from the top nozzle.
- Fresh liquid (a ammonia and carbamate mixture) enters the exchanger through the second nozzle in the bottom and is distributed in all the tubes.
- A top weir defines the liquid level in the top part of the condenser, the overflowing liquid exits the condenser through a new nozzle.

The optimal circulation ratio is determined by Casale in order to achieve an optimal condition for the heat transfer in the two-phase upward tubes.

Once transformed to the **Full-Condenser™** configuration, the HPCC can easily operate as a total condenser with only inerts and a small amount of vapours leaving the condenser uncondensed. This opens the way to a further improvement in the HP loop, which is described in the next section.

Split-Flow-Loop™ Concept

Having the possibility to operate the HPCC in the **Full-Condenser™** configuration, it is possible, and also advisable, to operate it as a total condenser.

Casale has, therefore, studied a new configuration of the HP loop in order to best fit it with the new configuration of the condenser and to take the highest advantage from it by also obtaining an increase in the efficiency of the loop, and in particular, of the reactor.

In the new configuration of the HP loop that has been developed, called the **Split-Flow-Loop™** concept, the HPCC is practically a total condenser and only the amount of vapours that actually has to be condensed in this equipment will go to the condenser. This is about 2/3 of the total vapour coming from the stripper.
The rest of the vapours, which in the standard configuration would leave the HPCC un-condensed, bypasses the condenser and goes directly 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 the scrubber together with the inserts.

In this way, about 2/3 of the total amount of the inerts present in the CO_2 are not sent to the reactor, and consequently, the urea conversion increases.

Operating full of liquid, the **Full-Condenser™** is also, contrary to a falling-film HPCC, contributing to the formation of urea as the operating conditions and the hold-up are such to start forming urea.

The liquid from the total condenser is sent to the reactor through a new ejector that enhances the driving force for the circulation. The new ejector is driven by part of the NH_3 feed that is bypassing the condenser.
A sketch of the **Split-Flow-Loop™** configuration is enclosed in Fig.10.

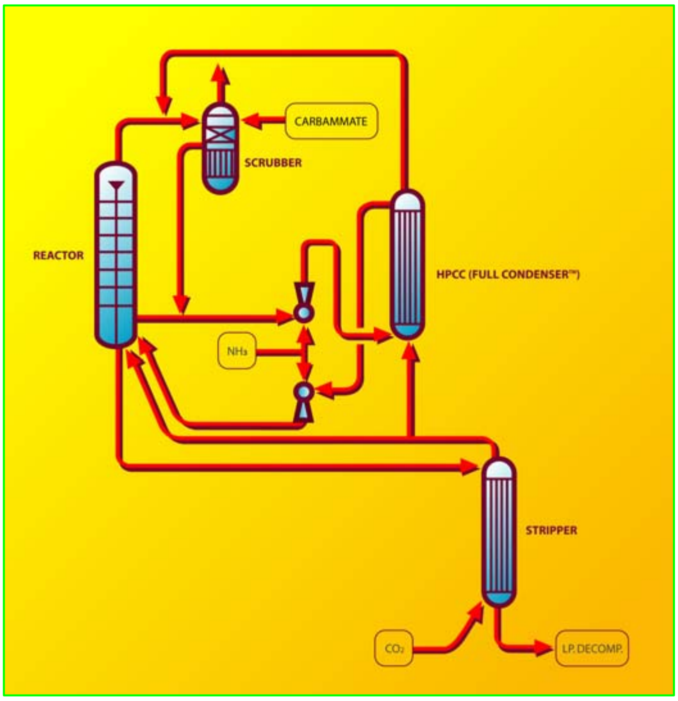

Fig. 10 - Split Flow Loop™ configuration

Even though only 1/3 of the inerts are reaching the reactor and, therefore, also only 1/3 of the passivation oxygen is reaching the reactor, this amount is more than enough to guarantee the passivation of the reactor.
The amount of oxygen fed to the CO_2 is, in fact, calculated to guarantee proper passivation of the stripper that is the most critical piece of equipment in terms of corrosion, and this amount is much more than the amount required for the passivation of the reactor.

Performances of the Full-Condenser™ and Split-Flow-Loop™

As said above, the **Full-Condenser™** concept has been developed to improve the efficiency of vertical HPCC used in CO_2 stripping processes.
The parameter that indicates the efficiency of such kind of equipment is the overall Heat Transfer coefficient (OHTC), and thanks to the **Full-Condenser™** concept, the OHTC of the vertical HPCC can be increased by at least 50%.

This means that the capacity of existing condensers can be drastically increased or new units for the same capacity can be made of a smaller size.

The **Split-Flow-Loop™** concept, on the other hand, increases the efficiency of the HP loop that is indicated by the CO_2 conversion in the reactor and by the NH_3 efficiency of the stripper. With the **Split-Flow-Loop™** concept it is possible to improve the efficiency of the HP loop while increasing the CO_2 conversion in the reactor by 2.5 ÷ 3 percentage points and also increasing the stripper efficiency.

The higher efficiency of the HP loop reduces the energy consumption of the urea plant and debottlenecks the plant for capacity increase.

It has to be mentioned that the **Full-Condenser™** concept also further contributes to increase the HP loop capacity as, contrarily to the falling-film design, urea is formed in the condenser boosting the capacity of the existing reactor.

Revamping of CO_2 Stripping Plants with the Full-Condenser™ and Split-Flow-Loop™ Concepts

Thanks to its performances, the combination of the **Full-Condenser™** concept with the **Split-Flow-Loop™** concept is a very powerful tool to debottleneck CO_2 stripping plants.

The plant can be easily transformed into the **Split-Flow-Loop™** / **Full-Condenser™** configuration by:

- Additional internal parts in the HPCC to transform it to the **Full-Condenser™** configuration.
- Some piping modification to re-route some lines according to the **Split-Flow-Loop™** concept.
- Addition of a new ejector.

In combination with other Casale technologies, such as the High Efficiency Trays, the **Split-Flow-Loop™** / **Full-Condenser™** configuration is applied to increase the capacity of CO_2 stripping plants with very low investment.

With the transformation of the HP loop to the **Split-Flow-Loop™** configuration, the transformation of the HPCC to the **Full-Condenser™** design and the introduction of the Casale High Efficiency reactor trays, the HP loop is drastically debottlenecked even for a large capacity increase (up to 50% over its original design).

Recent Projects involving Casale Technologies

In this section, we describe four recent projects that have been carried out or are under implementation by Casale using the technologies described in the previous section.

Revamping of a CO_2 Stripping Plant

In 1997, a Ukrainian company asked Urea Casale to study the revamping of its 1,000 MTD urea plant, originally designed according to the CO_2 stripping technology, to increase its capacity by 35%, decrease its energy consumption and increase its reliability.

The desired capacity increase could be achieved with the lowest investment by debottlenecking the HP synthesis section through the installation of Casale-Dente High Efficiency Trays thus avoiding any further modification to the existing equipment in the HP loop.

Modifications were, however, made to the HP pumps and CO_2 compressor, while additional heat exchange surfaces were required for the LP decomposer and condenser and for the vacuum evaporators and condensers, and some modifications were required in the desorbers in the wastewater treatment (WWT) section and in the prilling system.

All the revamp modifications were carried out in a normal shutdown and the plant has been operating successfully at the new capacity since 1999.

In 2001, the client asked Casale to further increase the capacity to 1500 MTD (50% of the original design capacity).

Taking advantage of spare capacity in the reactor resulting from the 1999 HET retrofit, and of a slightly larger stripper that had been installed in the meantime to substitute the existing one for maintenance purposes, Casale suggested to implement the **Split-Flow-Loop™ / Full-Condenser™** concept to reach the desired capacity increase of 1,500 MTD with a very low investment.

Thanks to the CO_2 conversion obtainable in the reactor, which is three percentage points higher than the value previously obtained with the High Efficiency Trays at 1,350 MTD, and to the corresponding increase in the stripper efficiency and of the pressure of the LP steam produced in the HPCC, the downstream sections of the plant could be debottlenecked without any alterations to the hardware.

The revamped plant is in operation since 2003 and the new capacity of 1500 MTD has been reached despite the fact that at the time of the modification, more than 10 % of the tubes in the HPCC, which was still the original size, had been plugged.
In spite of this consistent surface reduction of the carbamate condenser, the plant could reach the desired capacity of 1500 MTD equal to 1.5 times the design capacity.

Revamping of NH_3 Stripping Plant

Among the more recent applications of the High Efficiency trays we wish to mention the revamping of a 1500 MTD Russian plant, originally designed according to the NH_3 stripping technology.

In 2004 the client asked Casale to study the revamping of their plant to reduce the energy consumption.

In order to maintain a low investment cost, Casale suggested installing its High Efficiency trays in the reactor in combination with a better heat integration of the LP steam network.
The High Efficiency trays reduce not only the MP steam consumption, but also the LP steam production and, therefore, it is necessary to reduce the LP steam consumption through a better

heat integration. In this way, it is possible to obtain a net saving of MP steam, which was the goal of the client.
The original ten trays installed inside the urea reactor have been replaced with Casale High Efficiency trays plus five additional ones have been installed in the lower part of the urea reactor.
Thanks to the reactor conversion increase, due to the Casale trays' installation and to other minor interventions suggested by Casale to improve the plant efficiency and its reliability, a 24 bar steam consumption reduction have been obtained.

The LP steam saving has been achieved thanks to the installation of a new first vacuum concentrator based on a Casale design, which guarantees a proper heat recovery through a process double effect, obtaining an energy saving and a reduction of the pressure drop across the 1st vacuum concentrator.
The new 1st vacuum evaporator consists of two vertical shells and tube exchangers (without heads) that are flanged together directly to the separator. This type of arrangement minimizes the investment for this type of modification.
One of two exchangers is fed, shell side, by process vapours coming from the MP decomposition stage mixed with the carbonate solution coming from LP condensation stage, whereas the other one is fed by 4.5 bar steam.
The partial condensation of the process vapours, shell side, gives the heat for the concentration of the urea solution, tubes side, in counter-current with the condensing stream.
The rest of the heat required for the concentration of the urea solution is supplied by 4.5 bar steam.
Fig. 11 shows the arrangement just described.

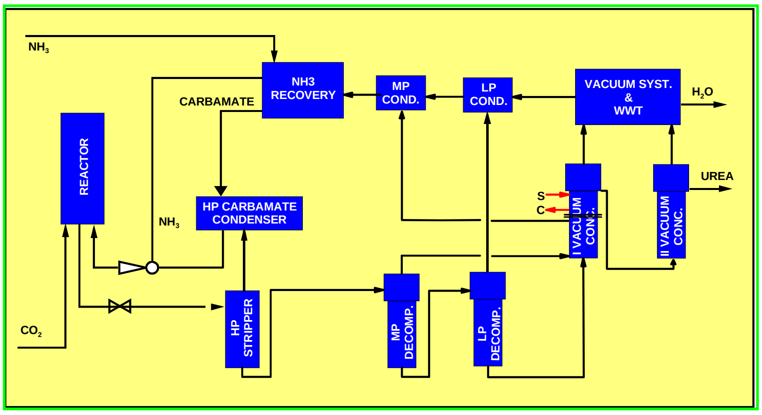

Fig. 11 – Heat integration

The new design of the evaporator guarantees also a reduction of the pressure drop. In fact the pressure drop in the original evaporator was caused by the fouling of the tubes, which had restricted the section at disposal for the flow.
The larger diameter of the tubes of the Casale equipment, guarantees to maintain a low pressure drop even with some fouling. Moreover, the larger diameter of the tubes guarantees there will be no temperature drop and an easier and effective cleaning of the tubes.

The main performances data obtained after revamping and compared with the previous ones are summarized in the Table1 reported below.

		Before revamping	**After revamping**	**Difference**
Plant Capacity	MTD	1500	1590	+90
24 bar steam stripper consumption	kg/t urea	929	789	-140
1st Evaporator LP steam consumption	kg/t urea	430	203	-227

Table 1: Plant Performances Data Before and After Revamping

After completion of the revamping in 2005, the client requested a new revamping to increase the capacity to 2000 MTD.

Thanks to the increase in efficiency of the HP loop resulting from the first revamping project, a potential spare capacity was created so that the new capacity could be reached without further modifications to the HP loop. Only limited modifications to the MP and LP decomposition sections are required.

In order to reduce emission, as requested by the client, modifications to the existing inerts washing unit are foreseen together with the addition of a new scrubber collecting all plant vent streams.

The project also foresees the installation of the Casale High Efficiency hydrolyser with a new stripping column to improve the quality of the process condensate to produce boiler feed water.

The new revamping step will be completed in 2008.

Revamping of a Conventional Total Recycle Plant with Integration with a Melamine plant
Casale has revamped a 1'000 MTD plant originally designed by Toyo according to the conventional total recycle technology and currently running at the capacity of about 1'300 MTD.

The client asked CASALE to integrate the existing urea plant with a 60,000 MTD melamine plant designed with Eurotecnica technology, and consequently increase its urea synthesis capacity by 25% up to 1625 MTD (60% over its original design capacity).

The integration with this type of melamine unit leads also to an increase of water recycled to the reactor of about 62% compared to the figures of a stand-alone plant. For this particular case of conventional total recycle plant, the impact of the increased water recycle has a higher negative effect than in case of stripping plants.

Analyzing the parameters of the project it was noted that the existing reactor was designed for a capacity of 1'000 MTD and after revamping it would be running at 1'610 MTD integrated with a melamine plant with increased carbamate flow.
It became clear then that the reactor efficiency would have decreased significantly due to reduced residence time and to the increased water content. The reduction of reactor efficiency would have had direct drawbacks on the downstream medium and low pressure recycling sections that are heavily overloaded.
A conventional approach of providing additional surfaces as well as pumping capacities, would not only become uneconomical but also hit the main constraints of the project, which are the limited space and the reduced shut-down time available to implement the new installations.

CASALE, then, selected to adopt a different approach aimed to improve the synthesis efficiency up to a level where the downstream section would not be significantly affected by the integration with the melamine plant. Moreover, the new melamine off-gas condensation unit is added with the objective of maximizing the utilization of the water already present in the process.

In order to improve the synthesis loop efficiency CASALE adopted its High Efficiency Combined (HEC) technology introducing a secondary reactor, with the relevant stripper used as reboiler and working the existing primary reactor with a once-through configuration together with the new carbamate condenser. The modification leads to the fundamental results of obtaining a higher conversion of the loop even if under a drastically worse H_2O/CO_2 ratio (due to the integration with melamine plant).
The reactor, in fact, before revamping was running with a 57 H_2O/CO_2 ratio and the conversion of 64%, while with melamine integration the H_2O/CO_2 ratio is rises to 0.93, but thanks to the installation of HEC, the conversion of the loop increased to 70%.

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

The CASALE HEC technology enables the increase of the HP loop capacity thanks to the improvement of the synthesis efficiency. Thanks to the higher efficiency the increase of the carbamate recycle flow is limited.

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

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

In addition to the above, a new off-gas condensation section was added consisting of L.P. carbamate pumps, off-gas condenser with relevant tempered cooling water system.

Besides the melamine integration, the project foresaw the replacement of crystallization with an evaporation section and the provision of a brand new waste-water section designed according to the Casale High Efficiency Hydrolyser technology.

The revamped plant is expected to be in operation at end of 2008.

Revamping of CO_2 Stripping Plant with Integration with a Melamine Plant
Casale has revamped a 1'500 MTD plant originally designed according to the CO_2 stripping technology and it is presently running at a capacity of 1'800 MTD.

The client asked CASALE to increase the urea capacity and to integrate it with an 80.000 T/y melamine plant designed with Agrolinz technology, reaching a final plant capacity of 2700 MTD (50% over its present capacity and 80% over its original design capacity).

Also in this case, the integration with this type of melamine unit would lead to an increase of water recycled to the loop of about 25% compared to the figures of a stand-alone plant.

Considering the high capacity increase and the amount of the off-gas, which is quite high, the existing equipment of the H.P. loop would not be in a position to handle the new output (i.e. 2'700 MTD) with the original scheme.

CASALE, thanks to its technologies, selected an approach that will save all the equipment of the H.P. loop.
The urea reactor is modified installing the CASALE High efficiency Trays, which enable an increase of conversion of about 1.5% even if the reactor is running with higher H_2O/CO_2 ratio (0.52 against 0.43 of stand alone plant).
In addition, CASALE has introduced its innovative **Split-Flow-Loop™** / **Full-Condenser™** technologies that drastically debottleneck the H.P. carbamate Condenser of CO_2 stripping plants, improving the reactor performances at the same time.
To overcome the limiting factor of the existing stripper, CASALE has foreseen a new section, equipped with a decomposer and a condenser, working at about 20 bar.

Due to the increased amount of process condensate, the existing WWT section has been revamped using the Casale High Efficiency Hydrolyser technology: the existing hydrolyser has been transformed to the Casale design by modifying its internal parts.

New installation/modification
In spite of the high capacity increase and of the integration with the melamine unit, the application of the **Split-Flow-Loop**™ / **Full-Condenser**™ technology, together with the High Efficiency Trays and High Efficiency Hydrolyser, minimized the required modifications, especially in the HP loop.

Some more details of the modifications are listed here below:
- High efficiency trays in the reactor.
- Introduction of **Full-Condenser**™ design in the H.P. Carbamate Condenser.
- New decomposition section, decomposer and condenser with relevant tempered water system and modifications to L.P. decomposition section.
- Addition to machinery sections (H.P. ammonia, Carbamate pumps and CO_2 compressor).
- Modification to WWT section (New distillation column, new Trays for urea hydrolyser and additional pumping capacity).
- Melamine integration unit and feed pumps.

The revamped plant is expected to be in operation in 2008.

Conclusion

Since the beginning of its history, Urea Casale has been able to develop various technologies and concepts that have brought a significant step ahead in the urea industry.

The recent development of the **Split-Flow-Loop™** / **Full-Condenser™** concepts was, again, a good example of how the combination of ideas/expertise with modelling capabilities can lead to the development of innovative technologies.

The capability of being able to properly model the various types of condensers with the correct chemical-physical relations was a key point to achieve the successful development of the **Split-Flow-Loop™** / **Full-Condenser™** concepts.

These new concepts have proven to be a very powerful tool to debottleneck the HP loop of CO_2 stripping plants, and offer to the owner of such plants a very convenient way to increase the capacity.

Moreover, the **Split-Flow-Loop™** process, based on the **Split-Flow-Loop™** concept with all Casale's most advanced technologies for equipment design, offers to the industry a very efficient process for the construction of new plants.

These last developments are the latest example of how Urea Casale has taken up the same spirit of commitment to excellence and achievement as Ammonia Casale and its founders, being in a position to offer the most advanced state-of-the-art technology and expertise to the world.

Lugano, March 2007