Urea Casale Technologies
for
Urea Plant Revamping

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CONTENT

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 almost 90 plants in the last 20 years achieving considerable increase in plant efficiencies and capacities, and gaining a leading position in urea plant revamping.

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

Directly derived from the two above technologies, the Split Flow Loop™ process can be used to design advanced grass-root urea plants.

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

1. INTRODUCTION

Urea Casale S.A., established in 1991 to carry on the urea technology activities started 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 to the revamping of existing plants, with almost 90 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.

Energy consumption, capacity increase, 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 a typical example of how the combination of above mentioned tools and expertise could 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. Those condensers are one of the key items of the plant HP loop that is the most important section of such type of urea plant.

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, increasing its efficiency by at least 50%.

This gives the opportunity to operate it as a total condenser and opened the way for improving also the reactor, by providing additional reaction volume and reducing the amount of inerts present in it. The increase in efficiency corresponds to ab 3%age points in the CO_2 conversion.

The above development, as well as others done by Casale, was possible through a very accurate fluid dynamic simulation of the system combined with the modeling of the chemical-physical equilibriums and of the heat transfer phenomena and with a process analysis, through simulation, of the HP loop.

Using the above mentioned Split Flow Loop™ process and the very advanced design of critical equipment, like reactor, HP condenser etc, Casale is in a position to design very efficient grass root urea plants, as demonstrated by the plant completely designed by Casale which is currently under construction in Europe.

2. CASALE TECHNOLOGIES AND THEIR APPLICATION TO UREA PLANT REVAMPING

2.1 General Considerations on Urea Plant Revamping

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

The general revamping philosophy of Casale has, in fact, always been based on upgrading the plant with new technologies, on maximizing the efficiency the most important plant sections and on minimising modification to the existing plant

A urea plant revamp, can touch different areas and is, generally, aimed to improve the performance of an existing plant.
Every urea plant revamping project can be different from previous ones. The plant owner can have different goals to reach and the plant, even if designed with the same technology, may have different bottlenecks.

The starting point for each project is the identifications of client's goals and of the actual plant bottlenecks. A plant survey is organised in order to collect actual plant data and plant information. A base case material and energy balance is developed reflecting actual operating condition.

After this first phase, Casale proposes a tailor-made technical solution that is considered to reach the required goals with the best return. Casale generally proposes the best combination of its technologies and of third parties technologies available to it.

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.

One can identify the following main typologies of urea plant revamping projects on which Casale has worked and developed various technologies:

- energy saving
- capacity increase
- pollution control
- product quality enhancement
- integration between melamine and urea plants

Often revamping projects may involve combinations of the above typologies.

In the next sections, the Casale approach for the above typologies and the related Casale technologies will be described.

2.2 Energy Saving

The projects aiming at reducing the energy consumption are generally characterized by the need of improving the efficiency of the plant with low investments. The returns generated by a project aiming at just reducing the energy consumption do not, in fact, justify very large investments.

One can improve the efficiency of the various components or sections of the plant or the energy integration. In order to improve the efficiency of one of the most important component of a urea plant, Casale has developed some times ago an innovative design for the urea reactor trays, which is described here below, and achieve an improvement of the plant efficiency with low investment.

Whenever possible, Casale also proposes to improve the energy integration within the plant by improving the energy recovery. A good example is the recovery of part of the condensation heat contained in process vapor streams by supplying it to other process streams that need to be heated, as described here below.

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, could lead to the development of most advanced technologies.

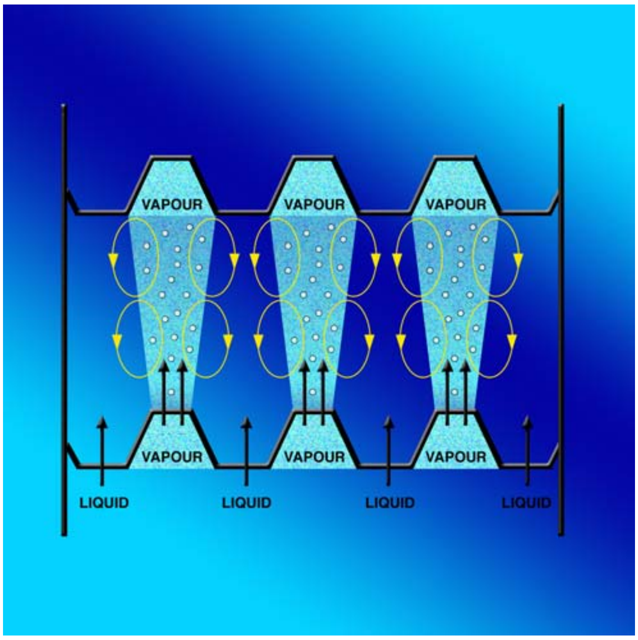

Fig. 1 - Casale-Dente High Efficiency Trays

In collaboration with Professor Dente, Urea Casale was able, through an accurate modeling, to identify all the parameters that are influencing the formation of urea inside a urea reactor. Through the modeling 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, its 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 realizing a higher 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 vapor and liquid is obtained. Consequently a very high mass and heat transport within the liquid phase is realized.
- With an appropriate design, the diameter of the generated vapor bubbles is smaller than in any previous design. By consequence, the interfacial surface, for mass and heat transfer, is increased.
- A much higher 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.
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 vapors 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.

Energy Integration Scheme

In order to reduce the energy consumption in those plants, typically ammonia stripping plants, having a MP decomposition stage and a vacuum evaporation section fed by LP steam, it is possible to utilize part of the condensation heat of the vapors from the MP decomposer to replace part of the LP steam used in the 1^{st} vacuum evaporator, according to a well known techniques.
With the Casale particular design, it is possible to achieve the LP steam saving according to this technique in a very convenient way.

Thanks to the substitution of the existing first vacuum concentrator with one designed by Casale according to the process double effect technique, it is possible to obtain a proper heat recovery with minimal investment. In addition to the energy saving a reduction of the pressure drop of the 1^{st} vacuum concentrator can also be obtained.
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 is minimizing 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.

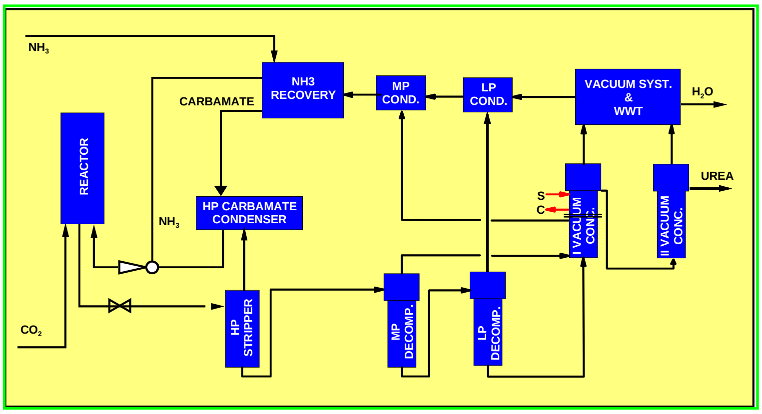

Fig. 2 – Heat Integration

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. 2 shows the arrangement just described.

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 no temperature drop and an easier and effective cleaning of the tubes.
The saved amount of LP steam can be utilized for some other uses in the plant or can be upgraded to MP steam saving through the installation of the High Efficiency Trays.
Two applications of this scheme are already in operation in India.

2.3 Pollution Abatement

The emissions of a urea plant to the environment are either the excess process condensate, which has to be discharged to keep the water balance, or the vent where the inerts are discharged to avoid accumulation. Both these emissions are contaminated with compounds involved in the urea synthesis and have to be purified to the most possible extent in order to satisfy environmental regulations, which are becoming more and more severe.

The process condensate stream generally contains NH_3, CO_2, and Urea. The majority of plants treat the condensate to recover CO_2 and most of the NH_3 in order to minimise raw material losses. Many plants, however, do not have the capability of either completely eliminating NH_3 and Urea or reducing their content below the accepted values.

In order to reduce the liquid emissions, Casale disposes of a proprietary hydrolyser of increased efficiency, called High Efficiency Hydrolyser (HEH), which is described here below and allows to completely eliminating Ur from the process condensate.
Utilizing appropriate more efficient scrubbing designs, which are proposed according to its know-how and experience, Casale can reduce the emissions from the vents down to very low values complying to most stringent regulation.

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 eliminating Ur from the process condensate.

The Casale High Efficiency Hydrolyser (see Fig. 3) 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.

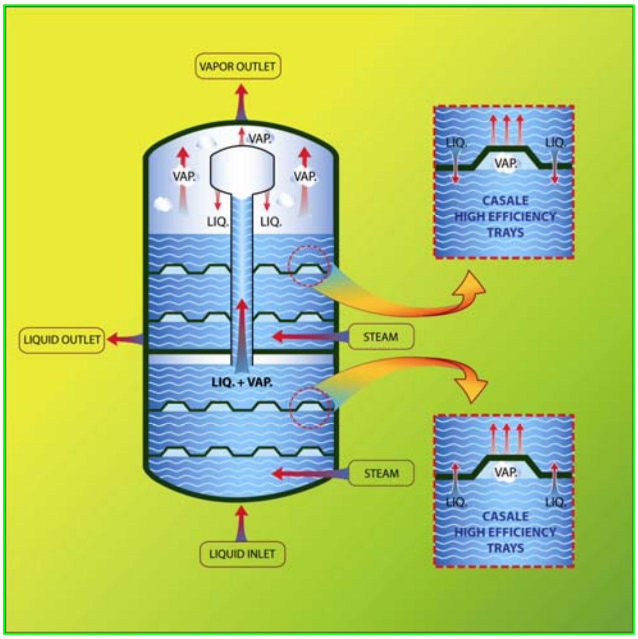

Fig. 3 - High Efficiency Hydrolyser

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 vapors (containing NH_3 and CO_2), creating a multiplicity of streams of vapors, 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:

First Zone

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 vapors 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 vapor going upward. Fresh 22-24 bar steam is injected again in the bottom of this second zone. The driving force for the extraction of NH_3
and CO_2 is, in this way, increased, allowing to reduce urea content to less than 3 ppm.

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

With the help of Casale High Efficiency Hydrolyser, 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.

2.4 Product Quality Enhancement

Casale is collaborating with the major designers of technology for the finishing section in order to guarantee the best solution for improving the quality of the product.

In addition Casale has also ongoing developing programs for new technologies aimed at further improving the product quality.

2.5 Capacity Increase

The way a capacity increase project is approached depends, of course, from the required increase. In general, in order to maximize the return of such kind of projects, it is essential to be able to increase the efficiency of the existing plant by upgrading the most important items or the entire process itself.

In case of a small to moderate capacity increase the investment should be kept as low as possible to guarantee a reasonable return, and the High Efficiency Trays is most appropriate technology to increase the efficiency of the plant with minimum investment. The installation of these trays is, in fact, minimizing the modifications required to the rest of the plant.

In case of a large, or very large, capacity increase, a more substantial increase in the plant efficiency is required. In this case Casale has developed various technologies, which are the HEC, the VRS and the Split Flow Loop™ / Full Condenser™, in order to approach the revamping for large capacity increase of the different type of urea plants. These technologies are described here below.

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.

In combination with other Casale technologies such as the High Efficiency Trays, these technologies are conveniently applied, by transforming the existing plants to the new configurations, to increase the capacity of existing plants.

Particularly simple is the transformation of existing CO_2 stripping plants into the **Split Flow Loop™ / Full Condenser™** configuration, which is obtained 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

HEC (High Efficiency Combined) Process

The development of this process opened the way to very large capacity increases, 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 out flowing the secondary reactor and together they feed a two stages recycling section with NH_3 recovery column.

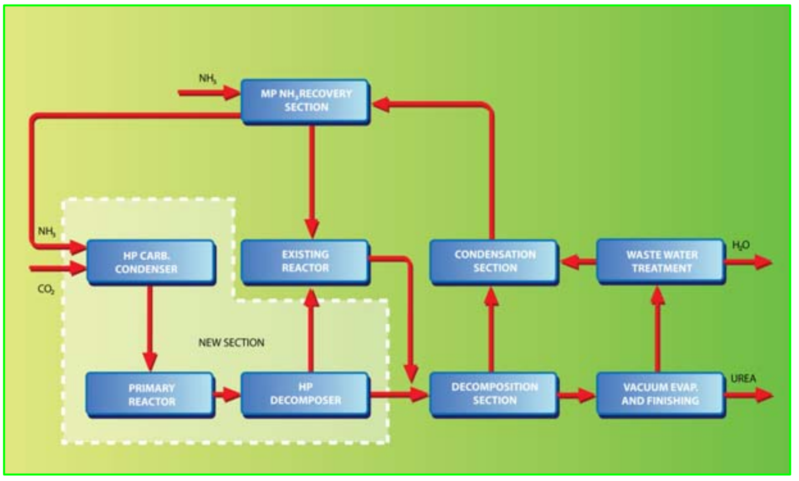

Fig. 4 - Conventional Total Recycle Plant revamped with the HEC Concept

The capacity of conventional total recycle plants can be drastically increased 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 primary reactor;
- a section consisting of the secondary reactor, an HP carbamate condenser and an HP decomposer is added (see Fig. 4).

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 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. 5) 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.

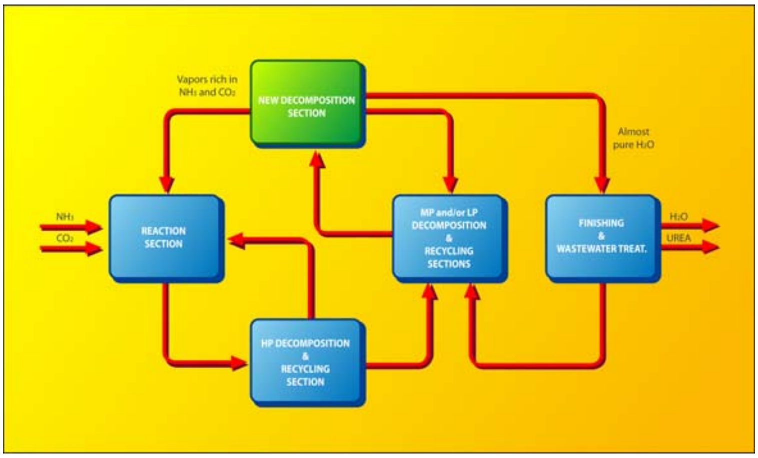

Fig. 5 - Stripping Plant Revamped according the VRS Concept

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 modification.

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

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.

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

Split Flow Loop™ and Full Condenser™ Concepts for CO_2 Stripping Plant Revamping, the Latest Development of Casale Technologies

The development of these two technologies is the result of Casale constant research of improvements in urea plants and the latest example of how, also in urea field, the modeling 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

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. 6), 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 straight back to the reactor a good quantity of unreacted NH_3 and CO_2.
All the vapors 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 vapors from the HP stripper are sent to HP Carbamate Condenser (HPCC), which is a co-current falling film condenser with the vapors entering from the top and condensing forming a film on internal surface of the tubes.

In the above described configuration, all those inerts introduced into the HP loop, through the CO_2 fed to the HP stripper, are reaching the reactor, through the HP stripper and the HPCC.

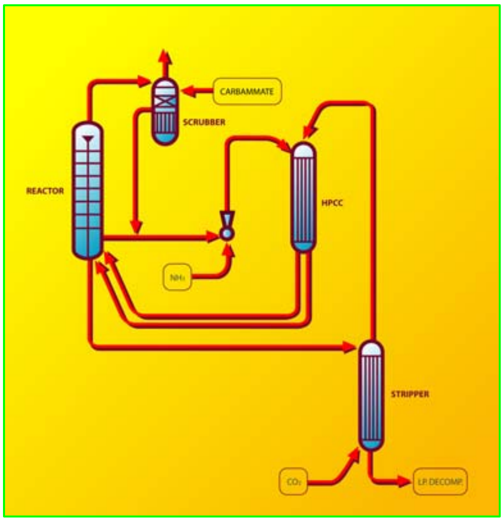

Fig. 6 - HP Loop of CO_2 Stripping Plants

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 does not give the best condensation efficiency, and that the condensation efficiency could be improved if a bubble flow configuration (see Fig.7) is adopted, and this thanks to the fact that the bubbles give a much higher surface at disposal for the mass (and heat) transfer.

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

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

Using a commercial package for the simulation of heat exchanger combined with its physical-chemical equilibrium models for urea,

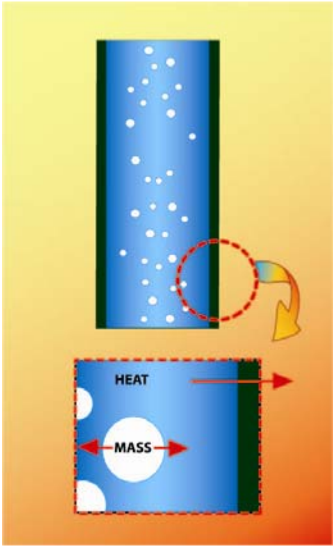

Fig. 7 - Bubble Flow Configuration

Casale made rigorous simulations of the two configurations mentioned above proving what said above, and also that an improvement of the tube side coefficient, by changing the flow regime inside the tubes to the bubble flow regime, would lead to an improvement in the overall coefficient.

Full Condenser™ Concept

In order to improve 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.

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 tubes are left without vapor 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.

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

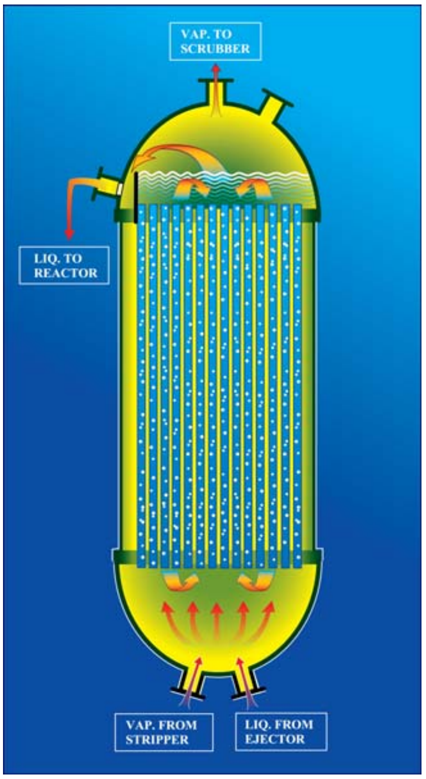

Fig. 8 - Full Condenser™ Configuration

The new flow patter of the HPCC is shown in the sketch of Fig. 8, and can be summarized as follows:

- Vapors 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 vapors condense.
- A 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 all 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 optimal condition for the heat transfer in the two-phase upward tubes.

Split Flow Loop™ Concept

Once transformed to the Full Condenser™ configuration, the HPCC can easily operate as a total condenser with only inerts and a small amount of vapors leaving the condenser uncondensed. This opens the way to a further improvement in the HP loop.

In order and to take most advantage from the Full Condenser™ configuration, and obtain also an increase in the efficiency of the loop, and in particular of the reactor, Casale has, therefore, studied a new configuration of the HP loop, called the Split Flow Loop™.
In this new configuration, the HPCC is operating as a total condenser and only the amount of vapors that actually has to be condensed in this equipment will go to the condenser. This is about 2/3 of the total vapor coming from the stripper.
The rest of the vapors, 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 not condensed vapors leaves from the top of the condenser and is sent directly to the scrubber together with the inerts.

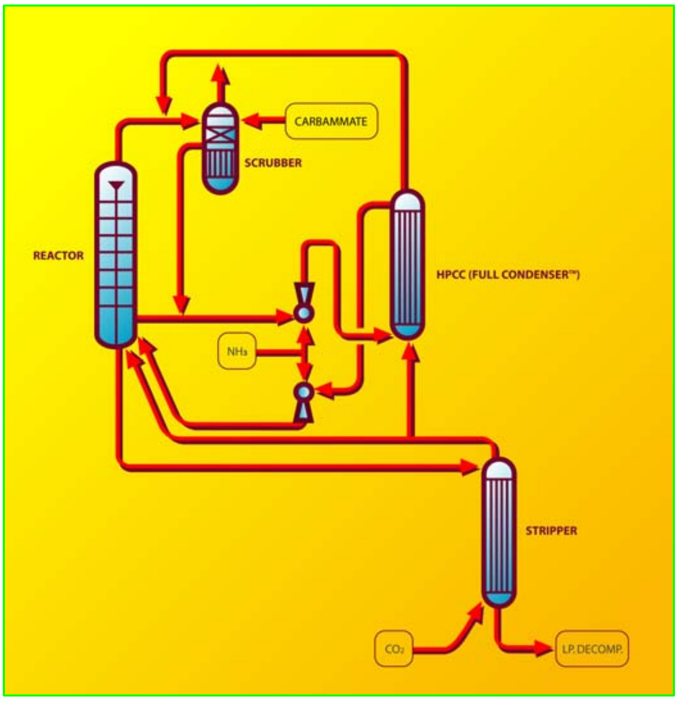

Fig. 9 - Split Flow Loop™ Configuration

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.9.
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 equipment in terms of corrosion, and this amount is much more than the amount required for the passivation of the reactor.

With the Full Condenser™ concept, the overall Heat Transfer coefficient (OHTC) of vertical HPCC can be increased by at least 50%, and with the Split Flow Loop™ concept it is possible to improve the efficiency of the HP loop increasing the CO_2 conversion in the reactor by 2.5÷3 percentage points and increasing also the stripper efficiency. The Full Condenser™ concept also boosts the capacity of the existing reactor as urea is formed in the condenser.
Thanks to the obtainable increase of the HP loop efficiency, with the Full Condenser™ and Split Flow Loop™ concepts it is possible to increase the capacity of existing plants up to 50%.

2.6 Integration with Melamine Plant

A melamine plant, regardless of its design, is utilizing urea as raw material and, together with melamine, is producing also a by-product stream of NH_3 and CO_2 (off-gas), containing in some cases water.
Generally, a melamine plant is, therefore, erected next to an existing urea plant in order to have an easy supply of the raw material and to have the possibility to reprocess the off-gas back into urea (see Fig. 10), and generally the existing urea plant needs to be revamped in order to be integrated with the melamine plant in the most efficient way.

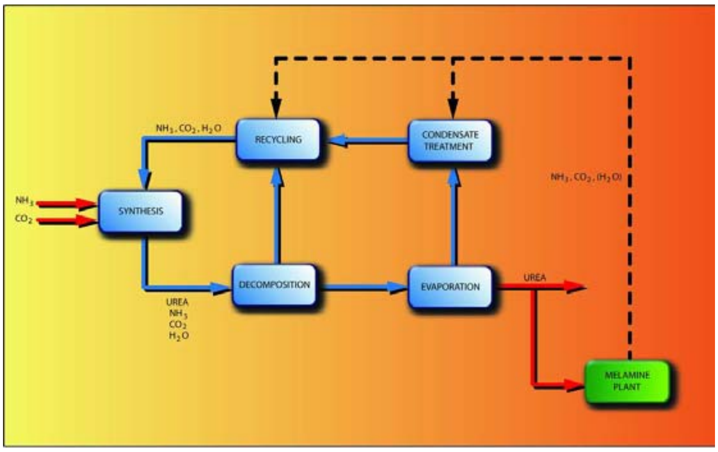

Fig. 10 - Melamine Plant Integrated with Urea Plant

The main technical problems relevant to the integration of the melamine plant with an existing urea plant is connected with the fact that almost half of the urea fed to the melamine plant is dissociated into NH_3 and CO_2 that need to be transformed back to urea.

The impact of the integration of a melamine plant with an existing urea plant can be summarized as follows:

- Higher plant capacity is required to transform the NH_3 and CO_2 coming from the melamine plant back into urea, as the urea plant owner generally wants to maximize urea capacity for a given amount of feed stocks.
- Lower efficiency is reached in the synthesis loop due to the higher amount of water in this section coming from the additional carbamate formed with the NH_3 and CO_2 recycle from the melamine plant, with the consequent higher load to the main section of the plant.
- Higher load required to the recycling section of the plant for the condensation of the NH_3 and CO_2 recycle from the melamine plant.

Depending of the type of technology used for the melamine production, the magnitude of the impact to the urea plant can be different, but will always have the above type of drawback.

The solution of the technical problems of integrating a melamine plant with a urea plant in the most efficient way can be reduced at the end to find the best solution to the following two points:

- Find the way of minimizing the amount of additional water needed to generate the additional carbamate solution from the melamine off-gas.
- Find the best way to revamp the existing urea plant in order to efficiently increase its capacity and in order to compensate the negative effect of the integration on the plant efficiency.

To find the best solution to the second part of the problem, CASALE makes use of its own technologies to revamp any kind of urea plants improving to the maximum extent their efficiency, as described in the previous sections.

In additions, Casale has developed different proprietary designs for the unit that is interconnecting the melamine plant to the urea plant, which address the first of the above points providing an efficient way to condensate the off-gas from the melamine without overloading the existing condensation section, and, at the same time, reaching the goal of keeping to the minimum the amount of additional water needed to condensate and recycle the off-gas.

3. Latest Evolution of Casale Technologies: from Revamping to New Plant Design

Since the first application of its Split Flow Loop™ and Full Condenser™ concepts, Casale realized that these technologies could be used to design very efficient grass root urea plants.

Casale has, therefore, developed the Split Flow Loop™ process, deriving directly from the above mentioned concepts, which is licensed for the construction of new urea plants.

The Split Flow Loop™ is an improved CO_2 stripping process based on the Split Flow Loop™ concept explained in the previous sections. It also features Casale most advanced designs for key equipment such as the reactor, based on the HET technology, the HP condenser, based on the Full Condenser™ technology and the hydrolyser, based on the HEH technology. Fig. 11 is showing a simplified block diagram of the Casale Split Flow Loop™ process.

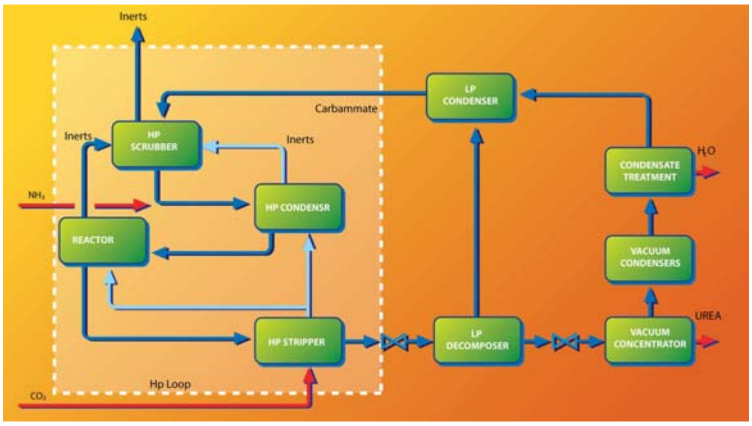

Fig. 11 - Split Flow Loop™ Urea Process

Thanks to its high efficiency, this process has quite low energy consumption and can reduce investment costs.

One plant designed according to the Split Flow Loop™ process is currently under construction in Europe.

4. Recent Revamping Projects involving Casale Technologies

In this section, we describe recent projects that have been carried out or under implementation by Casale and show how the technologies described in the previous section are applied to the revamping of different type of plants.
In particular, we will describe the following cases:

- Revamping of CO_2 Stripping Plant for energy saving and capacity increase
- Revamping of Ammonia Stripping Plant for energy saving and capacity increase
- Revamping of conventional Total Recycle Plant for melamine integration and capacity increase
- Revamping of CO_2 Stripping Plant for melamine integration and capacity increase
- Revamping of IDR Stripping Plant for melamine integration

Revamping of CO_2 Stripping Plant for Energy Saving and Capacity Increase

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 using the following Casale technology:

- Casale-Dente High Efficiency Trays

Any further modifications to the existing equipment in the HP loop were avoided, and all modifications were limited to:

- HP pumps and CO_2 compressor
- additional heat exchange surfaces for the LP decomposer and condenser and for the vacuum evaporators and condensers
- some modifications in the desorbers, in the WWT section and in the prilling system.

Casale supplied the following scope:

- License, Basic & Detailed Engineering
- All equipment and materials

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 to further increase the capacity to 1500 MTD (50% of the original design capacity).

Thanks to the spare capacity in the reactor resulting from the 1999 HET retrofit, and of a slightly larger stripper, installed in the meantime to substitute the existing one for maintenance reason, Casale could achieve the required goal with a very low investment using the following technology:

- Split Flow Loop™ / Full Condenser™ concepts.

Casale supplied the following scope:

- License, Basic & Detailed Engineering
- All materials

Thanks to a CO_2 conversion in the reactor of 3 %age points higher than the value previously obtained with the High Efficiency Trays at 1,350 MTD, to the consequent increase in the stripper efficiency and to the higher pressure of the LP steam produced in the HPCC, the downstream sections of the plant could be debottlenecked without any modifications.

The revamped plant is in operation since 2003 and the new capacity of 1500 MTD has been reached even though, at the time of the modification, more than 10 % of the tubes in the HPCC, which was still the original size, had been plugged.

Revamping of NH_3 Stripping Plant for Energy Saving and Capacity Increase

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.

The desired goal could be achieved with the lowest investment using the following Casale technology:

- Casale-Dente High Efficiency trays in the reactor
- improved heat integration scheme.

The High Efficiency trays, which are increasing the reactor conversion, are reducing 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 is the goal of the client.

In addition to the High Efficiency trays has, therefore, also improved the heat integration scheme recovering heat from the MP vapors as described in the previous sections.

Casale supplied the following scope:

- License, Basic & Detailed Engineering
- All equipment

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

Table1: Plant Performances Data before and after Revamping

		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

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

Thanks to the increase in efficiency of the HP loop resulting from the first revamping, a potential spare capacity has been created so that the new capacity can be reached with the following Casale technology:

- Casale High Efficiency hydrolyser
- Improved scrubbing system (modifications to the existing inerts washing unit and new scrubber collecting all plant vent streams)

Any further modifications to the existing equipment in the HP loop were avoided, and all modifications were limited to:

- limited modifications to the MP and LP decomposition sections.
- new stripping column in the WWT section

Casale supplied the following scope:

- License, Basic Engineering
- All major equipment

The new revamping step will be completed in 2008.

Revamping of Conventional Total Recycle Plant for Melamine Integration and Capacity Increase

Casale has been asked to revamp 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). Moreover, the client also whished to eliminate the existing crystallization unit.

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.

Casale has analyzed all the parameters, especially the significant reactor efficiency decrease, of the project and concluded that the required goals could be reached in the best way using the following technologies:

- Casale-Dente High Efficiency trays in the reactor
- High Efficiency Combined (HEC) technology
- Casale High Efficiency hydrolyser
- Casale melamine off-gas condensation unit

The approach selected by CASALE aimed at improving the synthesis section efficiency up to a level where the downstream section would not be significantly affected by the integration with the melamine plant. A conventional approach of providing additional surfaces as well as pumping capacities, would, in fact, not only become uneconomical but also hit the main constrains of the project, which are the limited space and the reduced shut down time available to implement the new installations.

The main modifications introduced, mainly by the adoption of the HEC technology, 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)

The new off-gas condensation section that was added was consisting of L.P. carbamate pumps, off-gas condenser with relevant tempered cooling water system.

A brand new waste-water section was designed by Casale including its High Efficiency Hydrolyser technology.

Casale supplied the following scope:

- License, Basic & Detailed Engineering
- All equipment and material

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

Revamping of CO_2 Stripping Plant for melamine Integration and Capacity Increase

Casale has been asked to revamp a 1'500 MTD plant originally designed according to the CO_2 stripping technology and 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 and therefore Casale suggested the following technologies to reach the requested goal:

- Casale-Dente High Efficiency trays in the reactor
- The Split Flow™ / Full Condenser™ technology
- Casale High Efficiency Hydrolyser (transforming the existing hydrolyser)
- Casale melamine off-gas condensation unit

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.

The application of the above technologies limited the required additional modifications to the following:

- 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).

Casale supplied the following scope:

- License, Basic & Detailed Engineering
- All major equipment

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

Revamping of IDR Stripping Plant for Melamine Integration

Casale has been asked to revamp a 2’000 MTD plant originally designed according to the IDR stripping technology.

The client asked CASALE to integrate it with an 30.000 T/y melamine plant designed with Eurotecnica technology, keeping the present capacity of 2000 MTD with an increased reliability.

Considering that the integration with the melamine unit leads to an increase of water recycled to the reactor, that the plant needs a higher reliability and that two strippers are already present in the original design, Casale suggested the following technologies to reach the requested goal:

- Casale-Dente High Efficiency trays in the reactor
- The VRS technology

The application of the above technologies is practically avoiding the need for any additional modifications

Casale supplied the following scope:

- License, Basic Engineering
- All equipment

The revamped plant is expected to be in operation in 2009.

5. CONCLUSIONS

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 modeling capabilities could 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 come to the successful development of the Split Flow Loop™ / Full Condenser™ concepts.

This new concepts has 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 most advanced technologies for equipment design (High Efficiency Trays, Full Condenser™, High Efficiency Hydrolyser) offers to the industry a very efficient process for the construction of new plants.
A new urea plant designed according to the Casale **Split Flow Loop™** process is under construction in Europe.

Those last developments are the last 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 to the world the most advanced state-of-the-art technology and expertise.

Lugano, March 2008
Paper/conferences/Ur/meetings/NITROGEN08/Nitrogen08 urea paper