OPTIONS FOR REVAMP OF UREA PLANTS

by

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UREA CASALE S.A.

ABSTRACT

UREA CASALE has today Industrially proven technologies available for economical and reliable upgrading of existing urea plants for both reduction of energy consumption and capacity increases.
Conventional total and partial recycle plants as well as stripping plants can be revamped in order to reduce the energy consumption and pollutant emissions, and to improve reliability and product quality in order to bring them to the most updated standards.
Conventional total and partial recycle plants as well as stripping plants can be revamped to increase the capacity by 50 percent, and in certain cases even up to one hundred percent or higher, with investments significantly lower than those required by new plants, achieving at the same time higher reliability and lower energy consumption for the full capacity, comparable to those achieved in today's most advanced modern plants.
Following the concept of always achieving an efficiency upgrade of the plant, CASALE has developed several technologies to obtain the above goals with practically any kind urea plant. CASALE is, in fact, in a position, and has the experience, to revamp any type of urea plant.
The upgrading is generally studied so that it can be made with few tie-ins in the existing plant requiring a minimum downtime, within the limits of a normal turnaround period.
In this paper, an overview of the UREA CASALE new designs for urea plants upgrading is given.
Particular emphasis is given to the operating experience of the new designs used for the revamping of different type of plants.

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1. FOREWORD

A urea plant revamp can touch different areas and is, generally, aimed at improving the performance of an existing plant.
One can identify the following main goals, which can drive a urea plant revamping project:

- increase of plant capacity;
- reduction of energy consumption;
- reduction of NH_3 consumption;
- reduction of emissions to the environment (pollution control);
- increase of product quality;
- increase of corrosion control.

In the next sections, an overview is given of the technologies that have been developed by UREA CASALE for revamping urea plants in the most efficient way in order to reach one or a combination of the above mentioned goals.

Thanks to a team of very skilful people, most of them with a long experience in the urea field, UREA CASALE developed several innovative and very competitive technologies to revamp urea plants to achieve:

- large capacity increases;
- energy saving;
- pollution control;
- improvement in plant reliability.

Among these technologies we have:

- new reactor trays to reduce steam consumption and increase capacity;
- new urea production processes (HEC, VRS) for drastic capacity increase.

In the above activity a wide experience has been acquired by the company in the modernization of urea plants designed according to different technologies, including TEC Total Recycle, Stamicarbon conventional and CO_2 stripping, Snamprogetti NH_3 stripping and other technologies.

The competitiveness and the success of UREA CASALE revamping technologies is proven by the fact that, in the last ten years, more than 50 urea plants, with capacities ranging from 250 to 2400 MTD, have been or are being revamped utilizing these technologies. Of these plants, 70% were originally designed according to stripping technologies.

As an independent company, UREA CASALE S.A. may dispose of its own technology as well as third party technology to combined scheme that best fits with the projects requirement.

In the presentation, the following two main classes of revamping are identify and the possible ways of revamping are discussed:

- Energy saving – Plant improvement - Small to moderate capacity increase;
- Large capacity increase for both stripping and conventional total recycle plants.

One other advantage of UREA CASALE is that, being a member of the CASALE GROUP, it can offer, together with its sister companies, a combination of revamping both Urea and Ammonia plants with a single point of responsibility.

2. CASALE GENERAL APPROACH TO REVAMPING

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.
Every revamping project has to start with the identifications of Client's goals and of the actual plant bottlenecks.

A plant survey is organized 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, UREA CASALE proposes the technical solution that is considered to reach the required goals with the best return. UREA CASALE generally proposes the best combination of its technologies and know-how with third parties technologies available to it.

The following general revamping philosophy is, however, followed for every project:

- always try to upgrade the plant with new technologies;
- maximizes efficiency of synthesis section;
- minimize plant shutdown;
- minimize modification to the existing plant;
- be as simple as possible.

Following this philosophy, UREA CASALE tries to keep the return on the project as high as possible. Generally returns in the order of one to three years are obtained.
The same philosophy has also been the driving force for the development of most of UREA CASALE technologies that are presented in the next sections.
For each class of revamping mentioned in the Foreword, CASALE suggests the use of its own technologies as follows:

- Energy saving – Plant improvement - Small to moderate capacity increase
  - High Efficiency Trays
  - High Efficiency Hydrolyser
- Large capacity increase
  - Vapor Recycle System in combination with:
    - High Efficiency Trays
  - HEC process in combination with:
    - High Efficiency Trays

The application of the above technologies is always tailor-made to the actual plant configuration and to the different client requests, and is always combined with CASALE general know-how on how urea plant can be improved.

All the equipment in the plant is checked in the new conditions and all the necessary modifications are suggested.

If required, third parties technologies for the revamping of the finishing section are used and the best way to revamp the machinery is identified together with the original Manufacturer.

3. ENERGY SAVING, PLANT IMPROVEMENT AND SMALL/MODERATE CAPACITY INCREASE

In this Chapter, we will examine the possible revamping strategies for revamping projects aiming at:

- improving plant performances, by reducing energy consumption and emissions and by improving the product quality;
- moderately increasing the capacity.

Let us first examine both the problems of reducing the energy consumption and of moderately increasing the capacity as they have a common staring point.

The starting point for any CASALE urea plant revamping project aiming at improving the plant efficiency by decreasing the steam consumption, and/or, increasing the plant capacity is the installation of CASALE High Efficiency Trays (HET) in the reactor (see description in the following sections).

In fact, this new type of reactor tray significantly increases the CO_2 conversion (4 to 5 percentage points) reducing the specific amount of steam required to recycle back the unreacted CO_2.

This allows, for the stripping plants, to reduce the specific load of the equipment in the HP loop, and, for the total recycle plants, to reduce the specific load of most of the equipment in the plant.

Let us first consider the case when a reduction of specific steam consumption is required.

The installation of HET in the reactor is, as said above, achieving a substantial decrease in the steam consumption.

In addition, in certain cases, it is possible to further decrease to steam consumption by improving the heat integration in the plant. This is done with no specific technology but just applying the CASALE know-how after a careful evaluation of the existing plant.

As said, the HET are also the starting point for moderate capacity increase. If the required capacity increase is not too high, it is, in fact, enough to install the HET to de-bottleneck the HP section, eliminating the need for additional HP equipment and thus maximizing the capacity increase with minimum investment.

It is, in fact, very important to avoid, for small capacity increase projects, any change in the HP section, which would drastically increase the return time of the investment.
Through a complete check of the downstream section, the few changes /additions necessary to eliminate the bottlenecks that would still be present after HET installation are determined.

With this approach, i.e. installation of HET and few changes/additions in the downstream section, an increase in capacity generally up to 15-20%, and sometimes up to 30÷35%, can be obtained.

Let us now examine the problem of reducing plant emissions.

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 minimize 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 has developed a new hydrolyser of increased efficiency, called High Efficiency Hydrolyser (HEH), which allows to completely eliminate Ur from the process condensate.

In order to obtain also a complete elimination of NH_3, the HEH is used in a high efficiency wastewater treatment section. The process condensate is first send to a desorbtion column where most of the NH_3 and CO_2 is eliminated.
The condensate is then sent to the HEH to completely eliminate the Ur and finally to a stripping column where the NH_3 is eliminated.
The recovered NH_3 and CO_2 are sent back to the synthesis.
Water with about 3 ppm of UR and NH_3 can be obtained and can be used as boiler feed.

In order to reduce the emissions from the vent (or vents), proper scrubbing systems can be studied in order purify the inerts before discharging them to the atmosphere.

In case of capacity increase, the HEH can be very conveniently utilized to debottleneck existing hydrolyzers adding it in series to the existing one.
The existing desorbers can be conveniently revamped by changing the trays with one of improved design.

Finally, let us examine the problem of improving the product quality.
In order to improve the quality of the product, CASALE has access to third parties technologies to improve the quality of the prills (improved bucket by Tuttle) and to cool down efficiently the prills (bulk flow cooler by Bulk flow technology).

CASALE has an exclusive agreement with Bulk flow technology for the commercialization of the Bulk flow cooler. The Bulk flow cooler is a very efficient solid cooler that uses cooling water as cooling medium. In this way it is possible to cool down solid products with a very simple piece of equipment without the need of a fluid bed that consumes much more energy and requires higher capital investments.

The approaches described above can be applied for both CO_2 and NH_3 stripping plants and for conventional total recycle plants.

UREA CASALE High Efficiency Trays

Urea synthesis reactor is a vapor-liquid heterogeneous reaction system. All along the reactor both the vapor phase (containing free CO_2, NH_3, some water and inerts) and the liquid phase (containing NH_3, ammonium carbamate, bicarbonate, urea and water) are present. The reactants are progressively transferred from the vapor to the liquid phase, where CO_2 reacts with NH_3, producing carbamate and then urea and water with a continuous exchange of CO_2 and NH_3 between the two phases.

In such a system, the formation of urea is not only controlled by the chemical kinetics and thermodynamics, but also by factors that affect the physical elementary processes, i.e.:

- mass and heat transfer coefficients;
- fluid-dynamics and flow patterns of the two phases;
- interface areas between vapor and liquid and boundary areas between the emulsion and the clean liquid;
- total recirculated flowrates.

Most of the above factors are influenced by the geometry of reactor vessel and its internals (i.e. trays).

A significant part of the total residence time into the reactor is, therefore, justified by the necessity to reach the maximum amount, compatible with the operating conditions, of vapors transported into the liquid phase. The optimum conversion to urea, in fact, could be obtained only on the basis of that condition.

On the basis of the general concepts exposed above, it can be deduced that a majority of the existing urea reactors cannot reach the complete equilibrium, as there is strong evidence that an excess of vapors containing CO_2 and NH_3 are still present at reactor outlet.

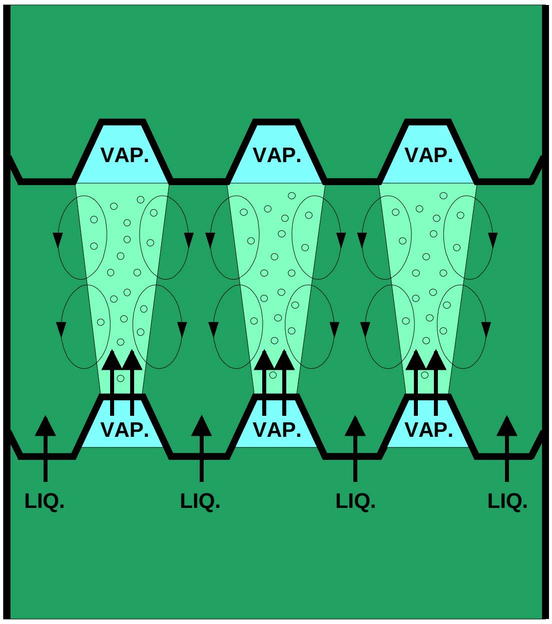
CASALE, together with Prof. Dente, has supposed that in the design of urea reactors, the fluid-dynamics and transport phenomena aspects could have been, in the past, underestimated (or even neglected). The supposition has also a very macroscopic self-commenting proof: the experimental liquid temperature profile in any existing type of reactor is always monotonically increasing from the bottom to the top of the reactor. On the contrary, if the mass and produced heat transfer of the reactants into the liquid phase would be a process extremely faster than the chemical reaction (as was a diffused opinion in the field), then, considering that the carbamate formation is very exothermic, whilst the dehydration of carbamate to urea is endothermic, a maximum of the temperature near the reactor inlet would have to be observed (and then, hypothetically, the temperature should decrease up to reactor top).

After having found that heat and mass transfer phenomena are limiting the efficiency of most of the existing urea reactor as the tray design is not optimal, new reactor tray designs have been developed (and fully patented) in order to improve heat and mass transfer rates.

This new design, in fact, improves the tray geometry realizing much better contact patterns of the phases, reducing the path length of the eddies' streamlines into the emulsion (mixed phase of bubble and liquid) and drastically increasing emulsion to clean liquid boundary surface.

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 larger surface of exchange between emulsion and clean liquid is created;
- The quite shorter path length of recirculation streamlines into the emulsion phase significantly decreases the transport resistances.



Casale-Dente High Efficiency Trays

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.

High Efficiency Hydrolyser

With the help of UREA CASALE's new High Efficiency Hydrolyser (HEH - see description below), 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.

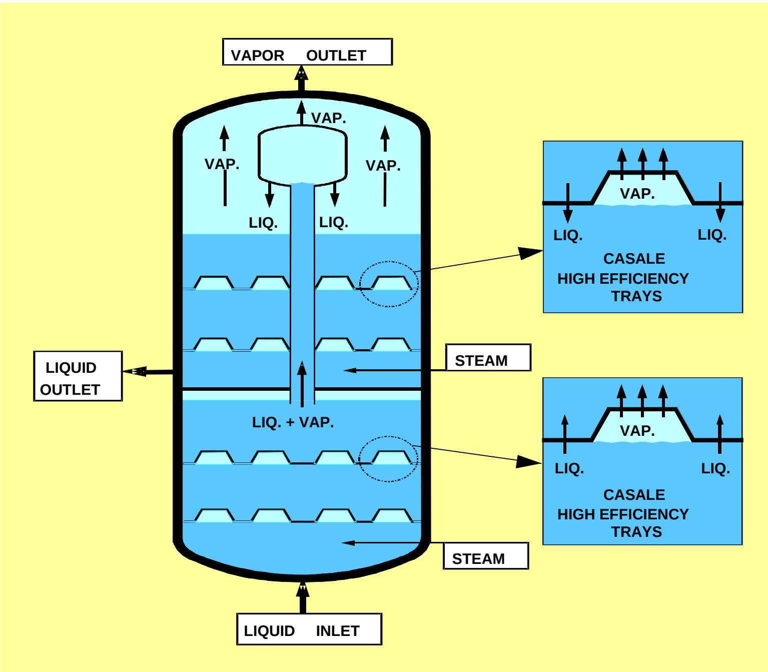
The High Efficiency Casale Hydrolyser makes efficient use of the stripping action of steam to remove the NH_3 and CO_2 from the treated urea plant waste water condensate in order to maximize the hydrolysis of the urea content.
The efficiency is enhanced by the fact that the hydrolyser is divided in two 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 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 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 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.



High Efficiency Hydrolyser

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

Industrial Experience

In the last three years a total of thirty-four (35) projects involving installation of HET have been carried out or are under completion for plants having capacities ranging from 250 to 2100 MTD. Thirty one (31) plants are already successfully operating with CASALE HET obtaining increases in conversion up to 5÷6 percentage points and reductions of specific steam consumption up to 200÷250 kg/MT.

Many of the above projects are in connection with energy reduction and plant improvements and some are even in connection with moderate capacity increases. Two applications in the CSI is outlined below:

A two-case history within the CSI for the application of HET with capacity increase

The Toaz project:

At the beginning of the nineties, Toaz asked Urea Casale to study the revamping of the its 1500 MTD Urea plants to increase the capacity by 15 % decreasing the energy consumption and increasing plant reliability.

Casale concluded that the following modifications were required to reach the new capacity:

- installation of Casale High Efficiency trays (HET) to increase reactor efficiency.
- replacement of CO_2 compressor internals to increase its capacity.
- replacement of the internals of the carbamate pumps.
- replacement of prilling bucket.

In order to reduce the energy consumption and the plant reliability, the following was suggested:

- installation of a heat recovery section to recover the heat from the MP evaporator vapours using it to evaporate the water from the urea solution.
- installation of the URS to reduce the urea carry over from the vacuum evaporator.
- installation of the CCPS to reduce the corrosion of the HP carbamate condenser.

It is to be noted that the installation of the Casale HET and the replacement of the CO_2 compressor internals are also contributing to the reduction of the energy saving.
During 1993 and 1994 the above modification for the capacity increase have been carried out in both plants achieving the 15 % capacity increase.

In addition, the following benefits in terms of energy consumption reduction have been obtained:

- the compressor was able to compress 15% more CO_2 with the same amount of steam, this means that the steam consumption of the turbine has decrease by 15%.
- the steam consumption of the stripper has decreased by ab. 200 kg/MT due to the fact that the CO2 conversion in the reactor has increased by ab. 4-5 percentage points.

For the other modifications Casale has completed the supply but the erection has not completed yet.
From previous experience, the following benefits are expected:

- saving of ab 200 kg/MT of LP steam
- decrease of the urea content in the process condensate down to 500 ppm.
- drastic reduction of the corrosion in the HP carbamate condenser and increase of its exchange coefficient allowing to operate the stripper with a lower pressure (few bar) increasing its efficiency.

During the revamping of the urea plants, Casale has also supplied a replacement stripper (of the same size of the existing) for one line were the existing stripper reached the end of life.

Styrol project

In 1997, Styrol asked Urea Casale to study the revamping of its 1000 MTD Urea plant to increase the capacity by 35 % decreasing the energy consumption and increasing plant reliability.

Casale concluded that the following modifications were required to reach the new capacity :

- installation of Casale High Efficiency trays (HET) to increase reactor efficiency.
- Installation of a new CO_2 compressor to increase CO_2 compression capacity.
- modification of the ammonia and carbamate pumps.
- installation of additional heat exchange surface to the cooling water system of the HP scrubber.
- installation of additional heat exchange surface to the LP decomposer and condenser.
- installation of additional heat exchange surface to the vacuum evaporators and condensers.
- installation of the URS to reduce the urea carry over from the vacuum evaporator.
- replacement of trays in the desorbers of the waste water treatment section.
- replacement of prilling device.

During 1997 the HET have been installed in the reactor achieving the energy saving and creating the potential for the capacity increase.

During 1999 the rest of the modifications for the capacity increase were carried out achieving the 35 % capacity increase, and at the same time, with a significant increase of reactor conversion and consequent decrease of steam consumption.

Other projects in connection with moderate capacity increases are outlined below:

- Yunnan - China: one 1630 MTD production line originally designed according the CO_2 stripping process was revamped increasing the capacity by 15%. The only changes necessary to reach the increase in capacity were the installation of the HET and of the URS and the modification to the CO_2 compression system. The steam consumption has been reduced by 150 MTD.
- Arcadian - Trinidad: two 1700 MTD production lines originally designed according the NH_3 stripping process were revamped increasing the capacity by 9 %. In this case the sole installation of HET was necessary to reach the required capacity. The steam consumption was reduced by 180 kg/MT.

In connection with the above projects, the High Efficiency Hydrolyser has been also successfully installed in four plants.

4. LARGE CAPACITY INCREASE FOR STRIPPING PLANTS AND CONVENTIONAL TOTAL RECYCLE PLANTS

If the required capacity increase were too high, the addition of the HET alone would not be enough to avoid the need for modification in the HP equipment. In fact, due to the overly high decrease in the residence time in the reactor, its efficiency will not increase, if not even decrease, even with the HET.

In this case, UREA CASALE proposes different approaches with an even more drastic upgrade of the synthesis section, which could guarantee to minimize the addition of HP equipment, and by consequence, the investment as well.

For this purpose, new technologies have been developed, namely:

- the Vapor Recycle (VRS) for the revamping of stripping plants;
- the HEC for the revamping of conventional total recycle plants.

The two concepts will be described in the next sections.

VRS TECHNOLOGY

As it is well known, in all "total recycle stripping" urea production plants, the residuals NH_3 and CO_2 at the H.P. loop outlet are recycled to the loop itself, after being separated from urea in the decomposition and finishing sections, in the form of carbamate aqueous solution. Water is, in fact, the essential carrier of such substances (in some cases, part of the NH_3 is also recycled in the form of pure liquid NH_3).

This recycled water is evidenced by the fact that the H_2O/CO_2 molar ratio at reactor inlet is higher than zero (generally in the range of 0.5 to 0.8).

The recycle of the H_2O heavily affects all the process phases, namely, the higher the amount of H_2O:

- the lower the conversion in the reactor is;
- the lower the decomposers (i.e. stripper, M.P. and L.P. decomposer) performance is;
- the higher the quantity of H_2O to be treated is.

Our new 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 is distilled, instead of being sent the H.P. section, 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.

Revamping of Stripping Plants with VRS
The existing plant 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%).

The figures below show respectively the CO_2 and NH_3 stripping plants revamped according to the VRS concept.

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.

Casale, however, studies the behavior of all the existing equipment in the new operating conditions and determines the minor changes necessary. A detailed check of all the instrumentation and piping is also done.

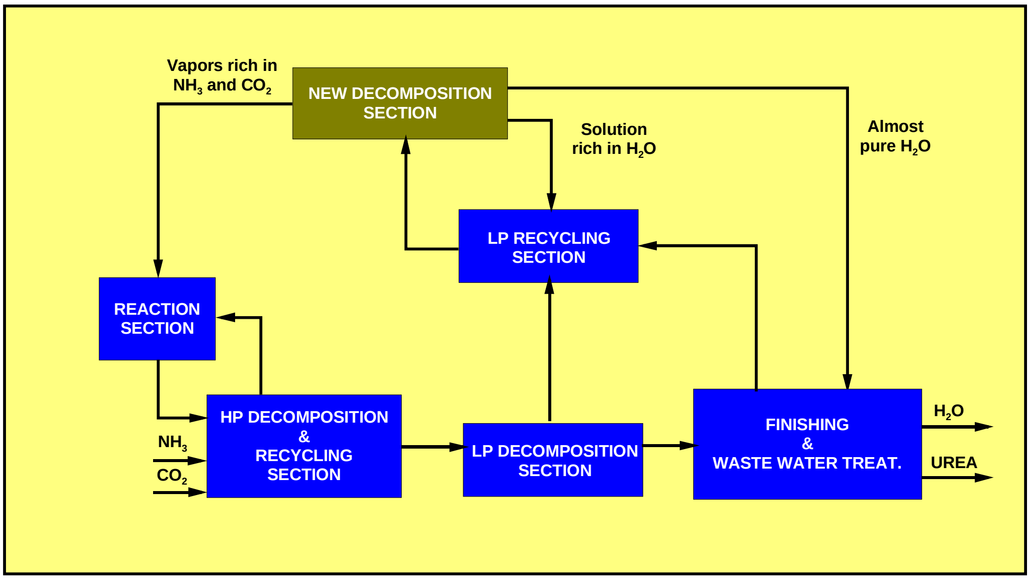
With this approach, an increase in capacity up to 50÷60% can be obtained.

After revamping, the following consumptions can be obtained:

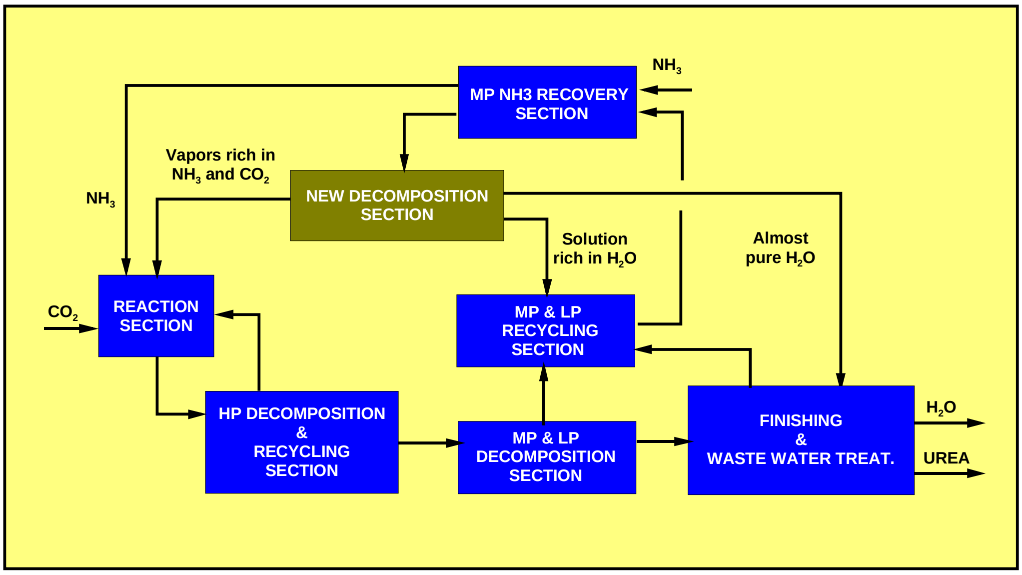
- raw materials almost steichiometric;
- MP steam ab. 800 kg/MT.

(The above values are based on actual experience and studies performed and can vary depending on the capacity increase required).

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 upset or shutdown can be recovered very quickly.
The VRS concept offers also big advantages when the urea plant has to treat the off-gases from a melamine plant. The increase in water caused by the integration between the melamine and urea plant can be eliminated by the VRS without causing decrease of efficiency of the synthesis section.



CO_2 stripping plant revamped according the VRS concept



NH_3 stripping plant revamped according the VRS concept

Industrial application of VRS

The VRS concept is currently operating at the Agrium plant in Canada. A description of this project is given here below.

Agrium's Carseland, Alberta, Canada, Nitrogen Operations were commissioned in 1977. The Operation included a 1043 mt/d Kellogg Ammonia Plant and a 1350 mt/d Stamicarbon Urea Plant plus the design was such that was a zero discharge of effluent water to any water course. All process waters were either irrigated or evaporated on site.

Over the years, the Urea and Ammonia Plants had been expanded to produce 1250 mt/d Ammonia and 1825 mt/d Urea.
In 1995, UREA CASALE "Vapor Recycle System (VRS)" was selected to increase the capacity of the plant up to 2400 MTD.

CASALE proposed its VRS concept in order to fulfill all the requirements in the most economical way. With this concept it was, for instance, possible to avoid any addition of reaction volume and practically no other modifications to the existing plant were needed other than the addition of a couple of vacuum condensers, some surface to the second vacuum evaporator and few trays in the desorber.
The de-bottleneck of the raw material feed equipment and of the finishing section was carried out directly by the owner. Due to maintenance reasons, the HP condenser was changed with a slightly larger one.
The designed capacity of the revamped plant is 2400 MTD.

The project was designed, equipment procured and construction completed in just 14 months from actual approval to proceed.

Much of the construction occurred while the Plant was running in order to facilitate project tie-ins and completion during a three-week turnaround.

The results are that the Plant is presently running up to 2300 mt/d on the Urea side.

The expected performances of the VRS system have been also confirmed by the plant operation. The main features obtained can be summarized as follows:

- low H_2O/CO_2 molar ratio at reactor (about 0.25);
- high CO_2 conversion even at high capacity (64%);
- high stripping efficiency;
- high Ur concentration at stripper and LP decomposer exit.

North American plant revamped according the VRS concept

As expected, the lower H_2O content (due to the low H_2O/CO_2 molar ratio) and the lower CO_2 content (due to the higher CO_2 conversion) allowed not only to reutilize the existing HP decomposition section without changes, but also to achieve a higher efficiency in the decomposition. This de-bottlenecked not only the LP section, but also the first vacuum evaporation stage that is now fed by a more concentrated solution.

The Urea Plant use of the VRS system resulted in several operational surprises other than the tonnage gains. One was the quickness of eliminating water from the high-pressure synthesis loop during start-up or upset conditions.

The second is the stability of the operation at the high rates. These two items alone have the operators putting the unit on line as soon as the start-up is practical.

HEC TECHNOLOGY

UREA CASALE has developed, some years ago, a new urea process named HIGH EFFICIENCY COMBINED Process. This process, based on the combination of a very efficient "once-through" reactor and a conventional total recycle one, presents the unique feature of having a very high average CO_2 conversion and by consequence a low energy consumption.

An interesting characteristic of this new concept is that it can be very conveniently applied to the revamp of existing plants achieving the following:

- capacity increase by 50% or more;
- energy consumption reduction;
- minimum investment;
- minimum modification to the existing plant;
- minimum shut-down time.

The main concept of the HEC process is to obtain most of the urea product in a "once-through" reaction section.

In the absence of recycle water, the conversion of carbamate to urea is favored and a high conversion of CO_2 to urea in single pass (75 to 80%) is obtained.
The small amount of residual carbamate is decomposed, condensed and recycled as aqueous solution to a second reaction section (operating at lower pressure) that converts it to urea at a lower conversion efficiency (typically 55).

Now, by feeding all the fresh reactants to the high-pressure reactor without any aqueous recycle, most of the product (75÷80%) is obtained at high conversion efficiency and only a small amount (20÷25%) at reduced efficiency. The weighted average conversion efficiency results in the 70-76% range, a value much higher than the one obtained even in modern urea plants. Consequently, the amount of steam required by the decomposition section is greatly reduced.

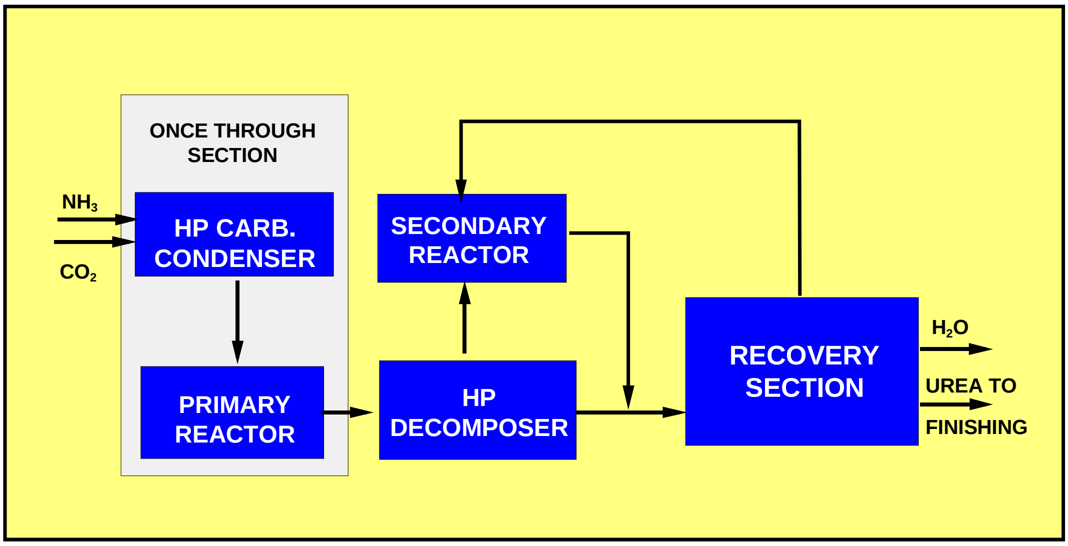
The Figure below shows a schematic representation of the HEC process.

The "once-through" reaction section designed by CASALE for the HEC process consists of the following items in series:

- the carbamate condenser, a U-tube, kettle type heat exchanger where part of the ammonium carbamate is formed and part of reaction heat is taken out, generating steam, in order to control the temperature of the primary reactor;
- the primary reactor, fitted with Casale High Efficiency Trays can operate at a pressure of 200-240 ata.

The second reaction section (secondary reactor) is also fitted with Casale High Efficiency Trays and operates at a Pressure of 155-160 ata.
Between the "once-through" and the second reaction section, there is a first HP recycle of unreacted NH_3 and CO_2 in vapor phase through a high-pressure decomposer, where carbamate is decomposed at the same pressure of the second reactor.

The remaining unreacted NH_3 and CO_2 are recycled to the second reactor through a conventional decomposition and recycle section in form of liquid carbamate.



HEC Process – main concept

Features of HEC Process

Thanks to the utilization of the Casale High Efficiency reactor trays and to the fact that the main reactor is of "once-through" type, the HEC process has the following unique features:

- very high (average) CO_2 conversion, i.e. ab. 72%;
- very low H_2O/CO_2 ratio, i.e. 0.3.

Thanks to these features, the HEC process has the following performances:

- low specific steam consumption, i.e. 900 kg/MT;
- small-size of all the decomposition and recycle equipment (In particular, the size of HP decomposer and condenser is much smaller than in the most advanced processes.

Revamping of Conventional Total Recycle Plants with HEC Process

Thanks to the above features, 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 60%, 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. 6).

The existing synthesis section will, therefore, be transformed in a HEC synthesis section.

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.
CASALE, however, studies the behavior of all the existing equipment in the new operating condition and determines the minor changes necessary. A detailed check of all the instrumentation and piping is also done.

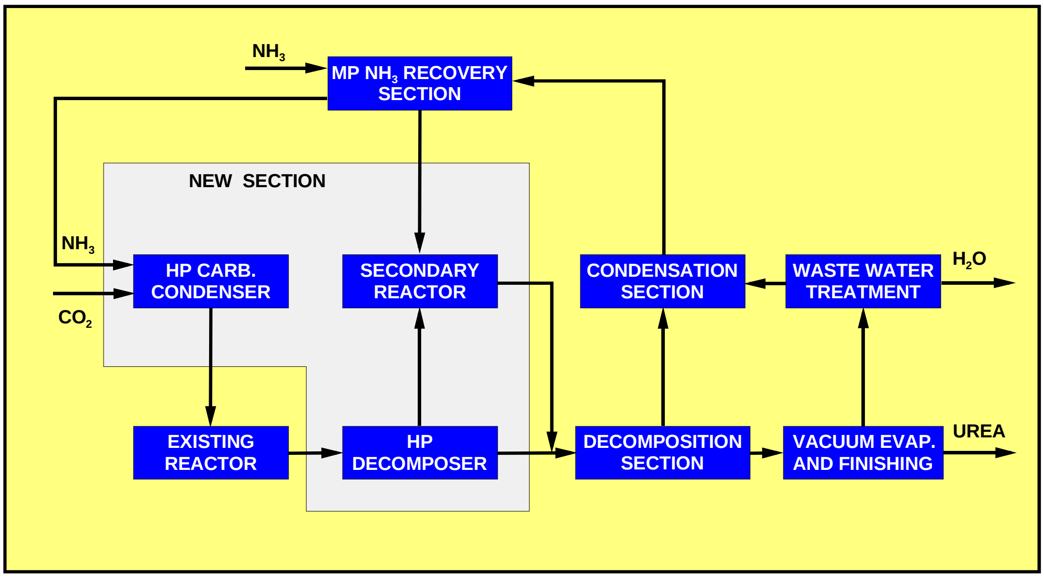
With this approach, the highest possible utilization of the existing equipment is reached, keeping the investment as low as possible.

Increases even higher than 60% can be obtained if, instead of the secondary reactor, the primary reactor is added, together with the HP condenser and decomposer. In this case 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.

(The above values are based on actual experience and studies performed and can vary depending on the capacity increase required).



Conventional Total Recycle Plant revamped with the HEC

The HEC process is very versatile and can be used, in slightly modified form, to revamp all different type of conventional total recycle and partial recycle plants.

Industrial application of HEC

The HEC process has been used in several application to drastically increase the capacity of conventional plants.

The way conventional total recycle plants are revamped using the HEC concept is illustrated using the revamping of a North American plant carried out by Casale as an example.

In 1993, CASALE was asked to study the revamping of a 465 MTD Toyo conventional plant in order to reach a capacity of 750 MTD. The urea was produced in two existing lines having the following capacity:

- No. 1 195 MTD (conventional partial recycle);
- No. 2 270 MTD (conventional total recycle).

CASALE, therefore, suggested to retrofit line No 2 using a new front end, designed by CASALE according to its High Efficiency Combined Process Technology (HEC), sized for 75% of the final capacity and consisting of:

- a new "once-through" reactor, working at 240 bar, 197°C;
- a new HP carbamate condenser generating 6.5 bar steam upstream the "once-through" reactor;
- a new HP decomposer working at 155 bar fed by the once-through reactor outlet stream.

In this way, it was possible to keep the same equipment down stream the existing reactor and to minimize the modifications to it.
Line No. 1 was idled and some equipment used including the NH_3 and carbamate compression. The CO_2 compression as well as the finishing section capacity were also increased.
No other new equipment was needed other than two condensers and an additional vacuum section.

This was also possible, because the stream feeding the decomposition sections then had a CO_2 conversion efficiency of almost 80%.

The revamped plant was started up in December 1995 and operated at 550 MTD until June 1996 due to an unforeseen bottleneck in the existing NH_3 recovery section. In order to overcome this bottleneck, in July 1996 an idled NH_3 absorber from Line No. 1 was used and a NH_3 absorber pre-condenser and a vent scrubber were added.

From July 1996, the plant has been running with a capacity up to 800÷810 MTD.

All guaranteed values have been met and the expected performances of the HEC system have been also confirmed by the plant operation.

Two other Toyo conventional total recycle plants have been revamped in a very similar way as just described, one is successfully in operation since December 1996 in New Zealand after a capacity increase of 50% and a second is under start up in Brazil and will also reach a 90% capacity increase over the design capacity.
Two conventional partial recycle plants have been revamped with HEC, one is in operation since 1998 in Canada after a 50% capacity increase and a second will start up in few months in Iran also reaching 50% more capacity.
CASALE is also completing the start up of conventional total recycle plant originally designed by Tecnimont for NFL in India. The plant is a 1000 MTD single line plant revamped increasing the capacity by 450 MTD.

North American Plant revamped according to HEC Concept

5. CONCLUSION

UREA CASALE has developed, since the start of its activity, several technologies to upgrade urea plants.
Some of these technologies have proven to be real "breakthroughs" in the urea field, such as the HEC and VRS processes.
Nobody in the field would have imagined, just few years ago, that the CO_2 conversion in urea synthesis reaction sections could be drastically increased even if at the same time the capacity is significantly increased, as CASALE proved with the application of its technologies.

Thanks to these technologies and to the know-how in the field, CASALE can bring up to date existing urea plants in order to decrease consumption and emission and to improve reliability.
With its new HEC and VRS processes, CASALE can also offer to the Urea Industry an economical way of significantly incrementing the capacity of urea plants.
This becomes very competitive versus increasing the capacity by adding new plants.
The CASALE concept, in fact, reaches the increment in capacity with an investment, which is a fraction of the cost of a new plant. And, as all the new equipment can be erected with the plant running and the modifications to the existing plant are reduced to a minimum, this is obtained with a required shut down time no longer than a major maintenance shut-down.

These technologies opened new horizons in the field of urea plant modernization, making the revamp of existing plants possible even when large capacity increases are required.

This offers the market very competitive and flexible alternatives to the construction of new plants in today's growing demand for fertilizers, also in view of the fact that CASALE technologies can be applied to almost any kind of urea process.