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APPLICATION OF THE HEC UREA PROCESS TO PARTIAL RECYCLE PLANTS

by
R. Allaby, SIMPLOT CANADA LTD.
and
F. Zardi, UREA CASALE S.A., Switzerland

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1. ABSTRACT

Industrially proven technologies are available today for economical and reliable upgrading of existing urea plants for large capacity increases.

Conventional total and partial recycle plants capacity can be increased 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.

Several partial recycle plants have been built in the past years based on “once through” technologies. Contrarily to the most modern technologies which foresees a full recycle of both NH_3 and CO_2 using water as a carrier i.e. in form of carbamate, those technologies are foreseeing to recycle to the reactor NH_3 and CO_2 separately as pure components, and in most of the cases, in practice only NH_3 is recycled to the reactor. Such “once through” plants combine a very efficient synthesis section with a less efficient recycle section as the separate recycle of NH_3 and CO_2 as pure components requires a lot of energy.

By adding a new synthesis section according the **HIGH EFFICIENCY COMBINED Urea Process** (HEC) concept, these types of plants can be conveniently transformed into total recycle plants achieving also a capacity increase and a decrease of energy consumption.

The upgrading can be made with few tie-ins in the existing plant with minimum downtime, within the limits of a normal turnaround period.

In this paper, an overview of the Urea Casale new designs for conventional total and partial recycle urea plants upgrading is given.

Particular emphasis is given to the operating experience of the new designs used for the revamping of one North American partial recycle plant that was recently started up after being transformed to a total recycle plant with drastic capacity increase.

R. Allaby,
SIMPLOT CANADA LTD., Canada

F. Zardi,
UREA CASALE S.A., Switzerland

2. INTRODUCTION

Urea Casale has been active in the urea field since 1985, first as Ammonia Casale and from 1991 as an independent company.

From the very beginning, the activity of the company has been concentrated on revamping existing urea plants.

In the current situation, with a constantly increasing urea demand and economical uncertainty, there is, in fact, a high demand for plant upgrading which can give additional capacity at a cost lower than through new plants construction.

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, **VAPOUR RECOVERY SYSTEM (VRS)** for drastic capacity increase

The general approach of Urea Casale to urea plant revamping is to upgrade the reaction section in order to increase its efficiency, rather than just adding additional equipment, and most of the technologies have been developed to accomplish this goal.

Urea Casale revamping technologies can be applied to plants originally designed according to any kind of urea process.

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

3. INDUSTRIALLY PROVEN TECHNOLOGIES AVAILABLE FOR LARGE CAPACITY INCREASE IN UREA PLANTS

Casale General Approach to Revamping

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

After this first phase, Urea Casale proposes the technical solution, which it considers will reach the required goals with the best return. Urea Casale generally proposes the best combination of its technologies and of third parties technologies available to it.

The general revamping philosophy as listed here below, however, is followed for every project:

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

The implementation of small and cheap changes, like the introduction of High Efficiency Trays in the reactor, would, however, not be sufficient to obtain large capacity as the upgrade of the synthesis is only moderate.

Following the aforementioned guidelines when aiming at large capacity increases, therefore, requires the development of new revamping 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, the following two new technologies have been developed:

- the Vapor Recycle System (VRS) for the stripping plants revamping
- the High Efficiency Combined (HEC) for the conventional total and partial recycle plants revamping

The high efficiency combined (HEC) technology will be described in the next sections.

4. LARGE CAPACITY INCREASE FOR CONVENTIONAL TOTAL AND PARTIAL RECYCLE PLANTS: CASALE HEC PROCESS

Urea Casale has recently developed a new urea technology named **HIGH EFFICIENCY COMBINED Urea Process** (HEC). 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 lower energy consumption than any conventional total recycle plant.

Thanks to the above features, this new concept can be very conveniently applied to the revamp of existing conventional total recycle plants for large capacity increases, 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), which 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 70-75% 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 comparable to the one of most modern plants.

Fig. 1 shows a schematic representation of the HEC process.

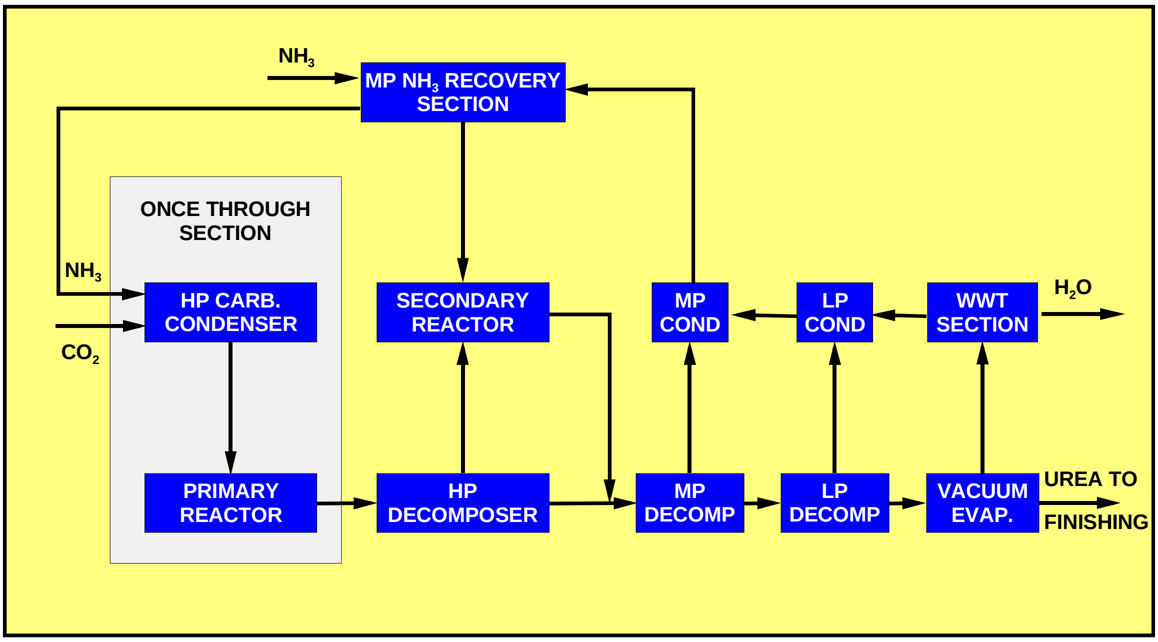

FIG. 1 – HEC Process

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 (with a pressure as high as 9 ata), in order to control the temperature of the primary reactor.
- The primary reactor, fitted with Casale High Efficiency Trays operating in the following conditions:

NH_3/CO_2	=	3.6
H_2O/CO_2	=	0
Outlet temperature	=	195 °C
Pressure	=	240 ata
CO_2 conversion	=	77 %

The second reaction section (secondary reactor) is also fitted with Casale High Efficiency Trays and operates in the following conditions:

NH_3/CO_2	=	4.5

H_2O/CO_2	=	1.3
Outlet temperature	=	190 °C
Pressure	=	155 ata
CO_2 conversion	=	55 %

All the CO_2 feed enters the "once-through" reaction section it reacts with NH_3, which is sent in the quantity necessary to keep the desired ratio.

About 77 % of the total production is obtained in this section where steam is also generated (up to 9 ata).

The solution from the top of the primary reactor is flashed down to a pressure of 157 ata and enters the high pressure decomposer where carbamate is decomposed by means of MP saturated steam (20 to 25 ata), increasing the temperature of the solution up to 205°C.

The high-pressure decomposer top vapor enters the secondary reactor to supply part of the heat necessary to control the outlet temperature.

The solution discharged from the secondary reactor together with the solution leaving the high-pressure decomposer are feed the MP decomposer first, and then to the LP decomposer and to a two-stage (operating at 0.3 and 0.03 bar) vacuum concentration section to obtain the urea melt which feeds the finishing section.

The MP and LP decomposer overhead vapors are condensed respectively into the MP and LP condensers.

The two-phase mixture, from the MP condenser enters the NH_3 recovery section where the total amount of CO_2 is condensed and the resulting carbamate solution is recycled to the secondary reactor.

The pure ammonia recuperated in the recovery section is recycled to the primary reactor.

The urea melt obtained from the vacuum concentration section can be sent to any conventional finishing section.

The process condensate obtained from the vacuum concentration section is treated in a process condensate treatment section where NH_3 and CO_2 are recovered.

5. FEATURES OF THE 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 (average) H_2O/CO_2 ratio, i.e. 0.3

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

- low specific process 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).

6. 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 by 60 %, Casale proposes to install its HET (High Efficiency Reactor Trays) 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. 2).

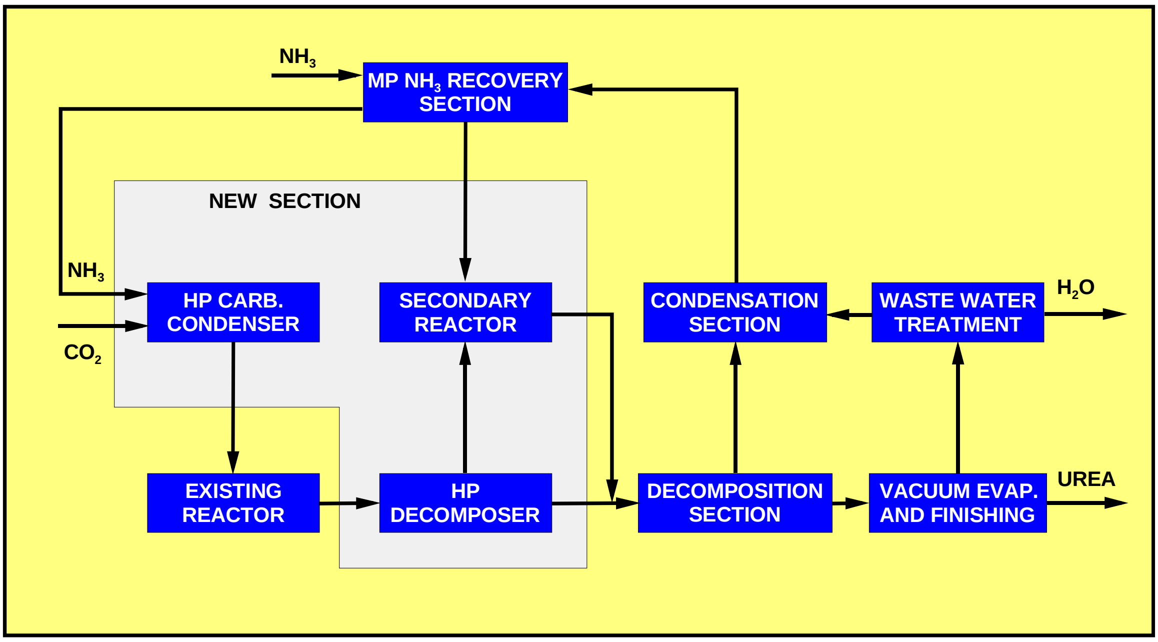

Fig. 2 - <u>Conventional Total Recycle plant revamped with the HEC concept</u>

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

Due to the much higher conversion obtained with the HEC synthesis section, the amount of NH_3 and CO_2 feeding the existing sections downstream the new reaction section is, for a capacity increase up to 60 %, still lower than before the revamping.

The existing back-end of the plant can take a higher production (60 % or more) without being overloaded and can, therefore, be re-utilized at higher capacity with only minor modification (especially in the vacuum evaporation and finishing sections).

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.

7. REVAMPING OF PARTIAL RECYCLE PLANTS WITH HEC PROCESS

The HEC Process can be applied successfully also to the partial recycle plants in order to reach large capacity increase and energy consumption reduction.

The partial recycle plants are based on "once-through" technologies with no recycle of NH_3 and CO_2 in form of carbamate solution to the reactor.

Such plants combine a very efficient synthesis section with less efficient recycle section where, in most of the case, only NH_3 is recycled to the reactor. The NH_3 is often recuperated with MEA processes using a lot of energy.

The main partial recycle technologies are Weatherly and Vulcan.

In order to increase the capacity of partial recycle plants, Casale proposed to install its HET in the existing "once-through" reactor (if possible) and to apply its HEC concept as follows (see Fig. 3 ad Fig. 4):

- a section consisting of the secondary reactor and of a HP decomposer is added (The HP decomposer is added downstream the existing reactor as shown in Fig. 3 or, if it is not possible, downstream the new secondary reactor as shown in Fig. 4).
- MP and LP condenser, and a NH_3 recovery column are also added in order to recover unreacted NH_3 and CO_2 in the form of carbamate solution to be recycled to the new secondary reactor.

In this way, the above types of plants can be conveniently transformed into total recycle plants achieving also a capacity increase and a decrease of energy consumption. The capacity increase results from reacting, in the additional reactor, the unreacted CO_2 coming from the existing reactor, which normally is lost in partial recycle plants. As the CO_2 conversion is typically 70% to 80% for such type of plant and, therefore, the unreacted CO_2 is 20% to 30%, the capacity increase can be at least 25% to 45%. Higher increases can, however, also be obtained.

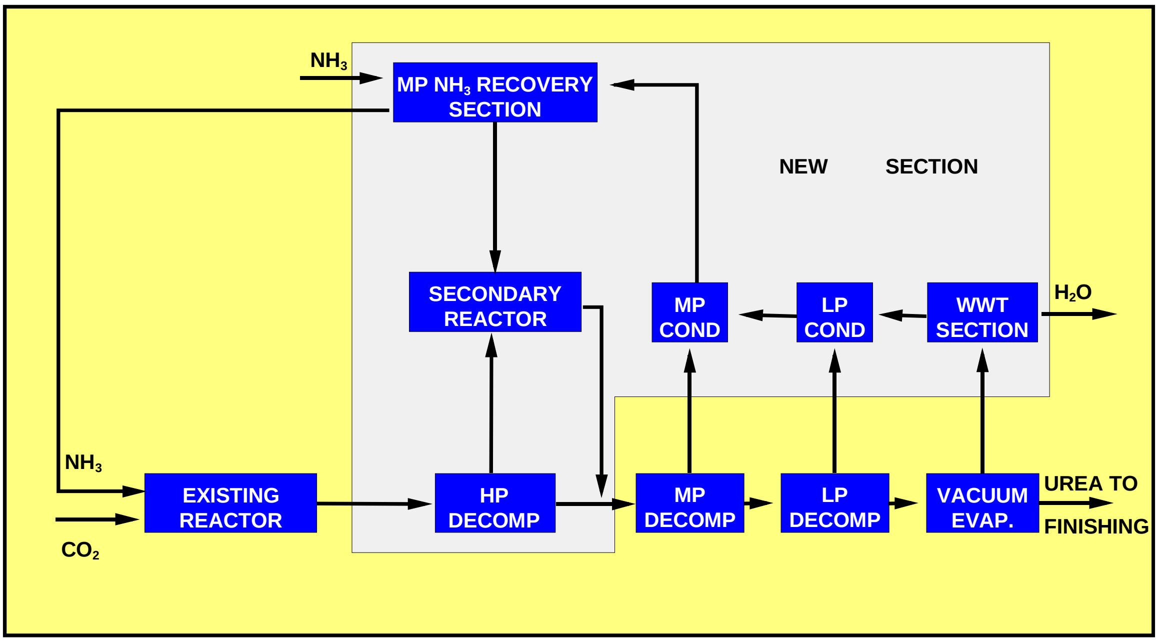

Fig. 3 – Partial Recycle Plant revamped with HEC concept

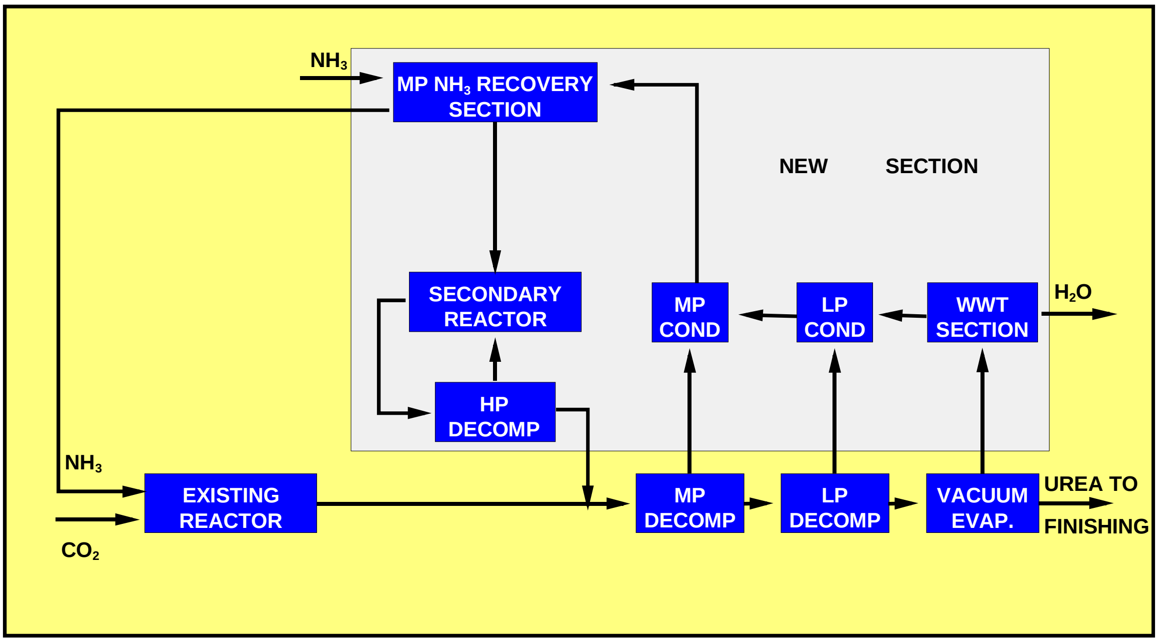

Fig. 4 – Partial Recycle Plant revamped with HEC Concept

The existing MEA ammonia recovery systems are eliminated.

In any case, the upgrading can be made with few tie-ins in the existing plant with minimum downtime, within the limits of a normal turnaround period.

8. APPLICATION OF THE HEC UREA PROCESS TO PARTIAL RECYCLE PLANTS.

The revamping of Simplot Canada Ltd. urea plant located in Brandon, based on the Weatherly technology, represents an application of the HEC casale process to partial recycle plants.

The process used in Brandon is based on the "once through" technology. The reactor is operated with pure NH_3 and CO_2. No water containing streams are recycled to the reactor, permitting high CO_2 conversion rates.

In order to recycle both ammonia and carbon dioxide as pure gases the MEA system is used with a high energetic cost for the separation.

As CO_2 is also recycled to the reactor, this plant cannot be considered a real partial recycle plant but it has the typical configuration of the partial recycle plants with the MEA system to recover NH_3.

The plant was originally designed to produce 315 MTD and was producing 410 MTD. The client wishes to reach a capacity of 625 MTD.

To accomplish the required capacity increase, Casale applied its HEC process by installing the new synthesis section where all the unreacted NH_3 and CO_2 is recycled to and converted into urea allowing the elimination of the MEA system. (see Fig. 5)

As the required capacity increase was app. 50%, it was necessary to add a new decomposition line, in parallel to the existing one, downstream the new reactor.

Finally, with a common condensation and NH3 recovery section, all the vapor streams coming from new and existing sections, are recovered and recycled back to the new synthesis loop in the form of carbamate solution.

A new treatment section was also foreseen to clean the process condensate.

The revamped capacity of 625 MTD was reached producing 456 MTD (73%) in the "once-through" train (existing primary and secondary reactors) and 169 MTD (27 %) in the new auxiliary reactor.

The urea production was maximized in the existing "once-through" reactors in order to reduce the steam consumption to a maximum extent.

All the CO_2 feed and the main part of the liquid ammonia (feed and recycle) are fed to the "once- through" reactors while all carbamate recycle solution is sent to the new auxiliary reactor together with the ammonia needed to match the material balance and the overhead vapors from the new carbamate stripper operating at the same pressure of the auxiliary reactor.

The operating conditions in the primary and secondary reactors have been slightly changed. A set of eight Casale High Efficiency Trays and a vapor sparger have been installed in the secondary reactor to replace the existing baffles.

Ammonia and carbon dioxide are mixed immediately upstream the existing primary reactor (a horizontal U- tube heat exchanger) where they react quickly in the tubes, releasing heat, which is in part recovered at 6.2 bar steam. The hot carbamate stream from the primary reactor flows to the secondary reactor operating at the following conditions:

- NH_3/CO_2 mol ratio 3.3
- H_2O/CO_2 mol ratio 0
- CO_2 conversion 73 %
- Pressure 228 bar
- Temperature 195 °C

The new auxiliary reactor operates in the following conditions:

- NH_3 / CO_2 mol ratio 4.5
- H_2O /CO_2 mol ratio 1.5
- CO_2 conversion 55 %
- Pressure 148 bar

- Temperature 190 °C

The weighted average conversion of the revamped plant thus results as approximately 68%.

The effluent from the new auxiliary reactor is fed to the new carbamate stripper, which is a falling film type heat exchanger heated by 24.5 bar steam.

The purpose of this equipment is:

- to remove most of the free ammonia and some carbamate from the urea solution
- to supply heat to the auxiliary reactor.

The liquid effluent from the carbamate stripper, containing about 30 % urea is further purified in the new three decomposers operating at decreasing pressure (18 – 3.5 –1.2 bar abs.).

A new condensation section recovers all the ammonia, carbon dioxide and water vapors generated in the three new decomposition stages and in the existing ones.

The whole MEA section is idled after revamp except for some equipment used for the new wastewaters treatment section.

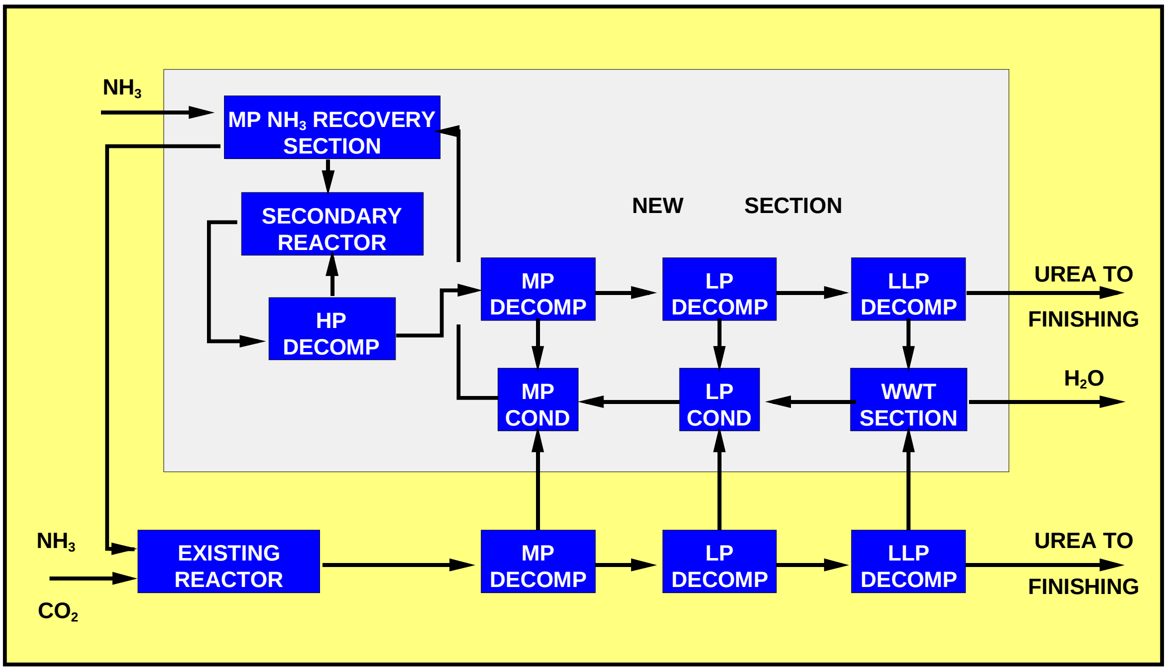

Fig. 5 – <u>Simplot Canada Ltd. Plant revamped according to HEC concept – Block Diagram</u>

The revamped plant was started up in fall 1998 and from then the plant has been running with all process parameters under control; the plant's performance is above 100 % capacity and the all consumption figures are lower than those guaranteed (see Fig. 6).

In fact the following production and consumption data have been obtained:

Urea production	655 te/day	(625 te/day guarantee)
Ammonia	614 kg/te	(624 te/te guarantee)
Carbon dioxide	735 kg/te	(925 kg/te guarantee)
Steam	863 kg/te	(880 kg/te guarantee)

9. OTHER APPLICATIONS OF THE HEC PROCESS

Other plants revamped with the HEC technology are the following:

- Terra (Canada) plant
  470 MTD in two lines Toyo plant revamped to 850 MTD using only one 270 MTD line and idling the second one – started up in December 1995

- Petrochem (New Zealand) plant
  480 MTD single line Toyo plant revamped to 750 MTD – started up in December 1996

- Razi (Iran) plant
  500 MTD single line Vulcan plant revamped to 875 MTD – start up by 2000

- Petrobas (Brazil) plant
  800 MTD single line Toyo plant revamped to 1500 MTD – start up by 2000

- Nangal (India) plant
  1000 MTD single line Tecnimont plant revamped to 1650 MTD – start up by 2001

Fig. 6 – Simplot Canada Ltd. Plant revamped according to HEC concept

10. CONCLUSIONS

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 its new HEC and VRS processes, Casale can 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, therefore, opened new horizons in the field of urea plant modernization, making the revamp of existing stripping 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.