MODERNIZE AN INTEGRATED UREA COMPLEX THROUGH INTRODUCTION OF CASALE'S ADVANCED TECHNOLOGIES

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In September 2007 UREA CASALE signed a Contract with a Polish leading producer of chemicals and fertilisers aimed at supplying the technology for the major revamping project of the Urea Production Unit. The project is described under the name of MODERNIZATION of INTEGRATED UREA COMPLEX.

The project of revamping consists of wide interventions and application of proprietary technologies focused at achieving specific targets as summarized in the following:

1. *Revamping and linkage with Melamine Plants of "Isobaric Double Recycle" Urea Plant (IDR) originally designed according to the Tecnimont – Montedison technology*

2. *Debottlenecking of Toyo Urea Plants including Urea Concentration Section.*

3. *Design of a new Waste Water Treatment plant.*

DESCRIPTION OF THE INTEGRATED UREA COMPLEX

The Integrated Urea Production unit consists of Urea Plants system connected with external process units.

The system is designed to supply urea solution to Melamine Plants external to the battery limits.

The urea solution is concentrated in the evaporation section of each Melamine Plant. The process condensate obtained is partly sent back to the integrated system.

The Melamine Plants are generating condensed aqueous rich off gas containing unconverted ammonia and carbon dioxide to be recovered in the urea plants.

The not negligible amount of process solution to be injected in the Urea Plants system represents a problem for the operation of the plants, worsening the stability of the run, increasing the ammonia and utilities consumption and reducing the urea production capacity.

The total urea capacity of the plants (as per design) is 3'200 MTD. In this configuration all the plants are running without recovering any solution from the Melamine Plants.

When the Melamine units are running then the aqueous rich process solutions have to be recovered having serious impact on the performance.

In the existing plant configuration the off gas from melamine are mainly fed to the TOYO lines while the IDR Plant is kept running stand alone.

The main consequences of recovering process solution in the urea plants is the reduction of the total production from 3'200 MTD (design) to 3'000 MTD having furthermore operation stability problems and important increase of steam and ammonia consumptions.

The IDR Plant is preferable running stand alone but it remains very delicate and problematic in the operation.

The High Pressure Double Stripping system performance is very sensitive to the reactor conditions (N/C, H/C, pressure, conversion etc.). Especially if the water content in the carbamate is increasing then the ammonia recovery efficiency in the HP loop in dropping. Very limited amount of carbamate from melamine could be recovered without impact on the process performance and stability.

The reactor is working at about 18 MPa and 192°C with molar ratios N/C 4.0 and H/C 1.0 having a conversion about 68%.

Due to high N/C and H/C ratios in the reactor then it is difficult to ensure good composition at the outlet of the carbon dioxide stripper.

The solution from the carbon dioxide stripper contains about 15% of ammonia, 15% of carbon dioxide and about 40% urea.
Due to the bad composition of the solution at the outlet of the carbon dioxide stripper then the performance of the downstream sections is greatly affected.

The existing Medium Pressure Section receiving the solution from the HP loop is very sensitive to the variations on the stripper outlet composition having impact on the pressure stability and ammonia venting problems.

All the ammonia is fed from the battery limits directly to the HP loop and there is no ammonia recovery and recycle system in the MP section forcing to operate the plant in a narrow range of conditions.

The high amount of water injected along with the condensates from Melamine generates additional waste condensates to be treated.

The existing treatment unit installed in the IDR plant battery limits is suffering for the load increase and the performance is coming down.

A part of the process condensate from the Melamine Plants is sent to treatments units outside the battery limits to allow the operation of the existing treatment facility.

PROJECT OBJECTIVES

Starting from the operative problems of the plants in the existing configuration then the following revamping targets are defined:

- to find out the most efficient configuration to fulfil the integration among the Melamine Plants and the Urea Plants.
- to maximize the urea output of the Integrated Urea Complex.
- to guarantee the highest operation flexibility of IDR and TOYO plants from 60% up to 100%.
- to minimize the utilities consumption.
- to ensure reliable and stable operation with special reference to the IDR Urea Plant.
- to minimize the number of equipment to be modified and to be added.
- to add a new process condensate treatment unit recovering inside the Integrated Urea Complex all the condensates from Melamine Plants.

MODERNIZATION OF IDR UREA PLANT

To fulfil the revamping objectives the IDR Plant is modernized to run fully linked with Melamine Plants

In particular, the injection of process streams from Melamine Plants permits a capacity increase of about 20% recovering directly in the plant condensed off gas containing about 28 %wt of water.

DEBOTTLENECKING OF TOYO UREA PLANTS INCLUDING UREA CONCENTRATION SECTION

The TOYO Urea lines are revamped to maximize the urea production running stand alone when the off gas from Melamine Plants are injected back to the IDR Urea Plant.

In the existing configuration the TOYO Plants are running linked with the Melamine at reduced capacity.

Modernizing the IDR Plant to treat all the condensed off gas from Melamine Plants is possible to run all the TOYO lines at maximum capacity. All the plants are revamped to maximize the production when running in stand alone configuration.

The total production of the TOYO Plants is so increased by about 30%.

WASTE WATER TREATMENT PLANTS

The system consists of an existing waste water treatment plant designed to treat the condensate from IDR and a new unit specifically designed to process the exceeding waste condensate from the system.

The new treatment unit is specifically designed to treat inside the battery limits of the Integrated Urea Complex all the condensates from Melamine Plants and additional sources.

The process condensate sources are here below summarized:

- IDR Urea Plant operating at full load integrated with Melamine Plants
- TOYO Plants and urea concentration unit running at full load stand alone
- Melamine Plants running at full capacity
- Additional external water sources (washing systems)

The New Waste Water Treatment plant generates clean water with an expected urea and ammonia residual content of 3 ppm wt and a concentrated carbonate solution (abt 50 %wt water) to be recycled back to the urea plants system.

The unit is fully integrated in the plant compound permitting high flexibility in the load and composition changes of the waste water.
The distilled carbonate solution from the new treatment plant could be sent back to the IDR Plant or to the TOYO lines.

SPECIFIC CASALE TECHNOLOGIES FOR THE REVAMPING PROJECT

To fulfil the revamping targets of each plant section UREA CASALE developed dedicated technologies as per the summary in the following.

Modernization of IDR Urea Plant

The revamping of the IDR Plant was mainly aimed at capacity increase recovering fully the condensed off gas from Melamine Plants. Another important target is to improve the operation stability.

The Melamine Plants are equipped with dedicated off gas condensation units outside the battery limit of the project generating aqueous rich carbamate solution.

In the same way the evaporations section of the Melamine Plants is sending back process condensate to the urea plant.

As a matter of facts the main problem of the melamine integration with urea plants is the carbamate overloading which is responsible for a big impact on the synthesis performance and all the decomposition train.

A very efficient technology for the revamping of urea plants based on the Stripping technology is the CASALE VRS concept (Vapours Recycle System).

The VRS concept is essentially shown in the block diagram in the figure 1.

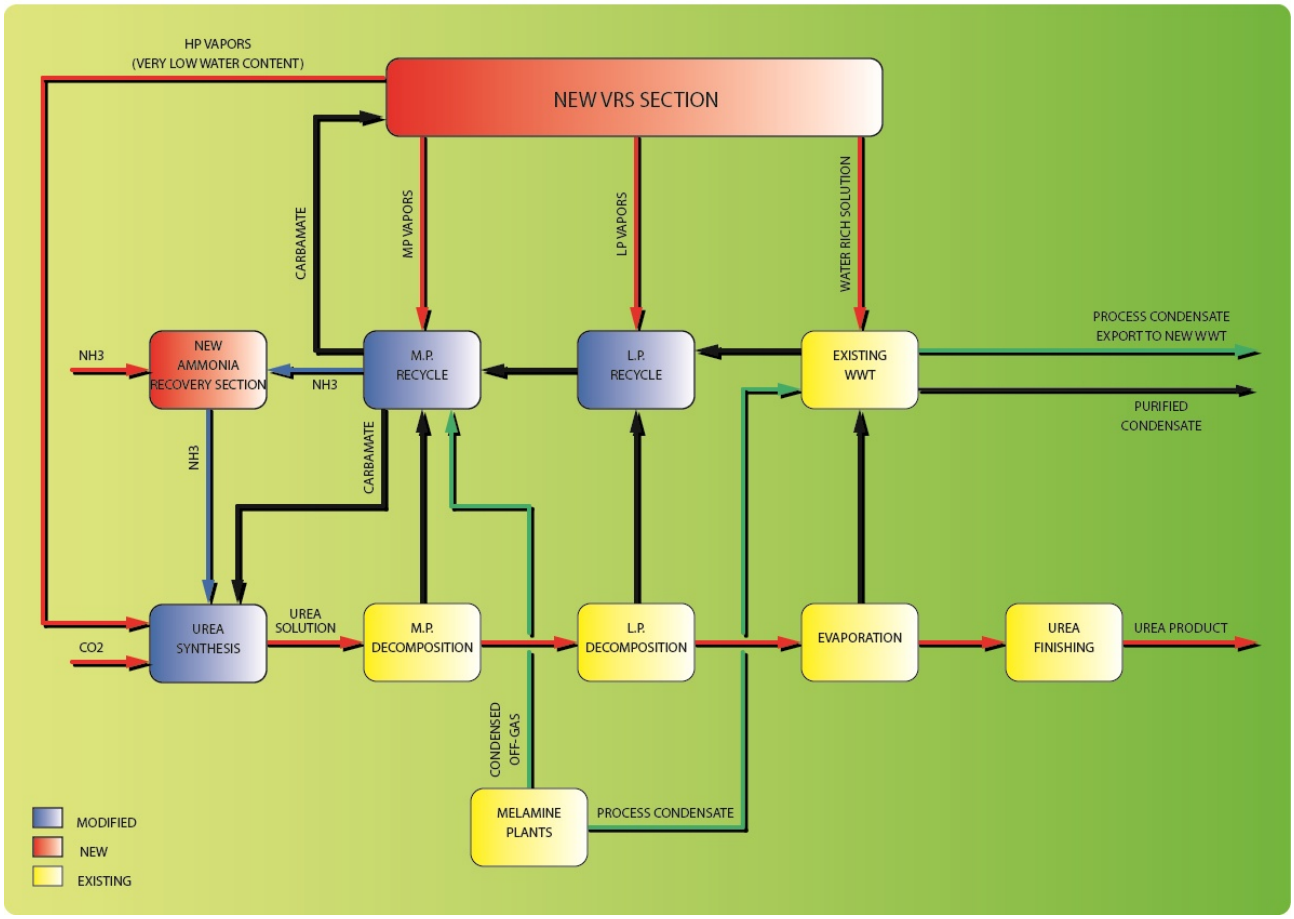

Fig. 1 - IDR Plant Revamping scheme

A new section named "Vapours Recycle System" is installed in parallel to the condensation and recycle stages of the plant.

The VRS section is fed with the majority of the carbamate solution from the MP recycle unit. A minor carbamate flow is injected into the synthesis loop to guarantee the high pressure vapours condensation and keep proper condition in the reactor.

The VRS is in the general concept a carbamate distillation unit with the aim to create a barrier to the water contained into the carbamate to avoid the HP loop overloading

The carbamate solution is distilled in a multi-stage decomposition train.

The high pressure distillation is isobaric with the synthesis loop generating NH_3-CO_2 rich vapours recovered back directly in the HP section.

The solution is then going through further MP and LP decomposition steps. The vapours from each stage are recovered in the relevant recycle unit of the urea plant.

The solution (abt 95% water) from the bottom of the LP decomposition stage is sent to the plant downstream section and then to the waste water treatment unit.

Thanks to the VRS concept the HP synthesis loop of the urea plant is improved having the following advantages:

- high CO_2 conversion in the reactor due to lower H/C molar ratio
- high stripping efficiency
- higher urea concentration in the solution to the downstream hence lower amount of water to be treated in the existing decomposers, evaporators and waste water treatment units.

A big advantage is due to the fact that the VRS is essentially a section parallel to the plant. This solution permits to be installed while the plant is running and, since few tie-ins are needed, the shut-down period for the modification is minimized.

As per the description above, the VRS concept is a technology that could fit the need of Plant capacity increase and/or melamine integration in case of Urea Plant based on stripping technology.

Depending on the starting technology of the Urea plant, the VRS concept is then developed with the aim of finding out the most suitable configuration in order:

- to minimize the utilities consumption
- to ensure operation flexibility and stability
- to minimize the number of modifications to existing equipment and new equipment to be added
- to minimize the shut-down period needed for the modifications

On the basis of the above considerations the specific case of the IDR plant revamping has been developed.

The process scheme is modified as per following

HP Section

The HP synthesis loop has been simplified to be easier in the start-up / shut down, smooth and flexible in the operation.

These objectives have been reached through the following modifications. No additional new HP equipment have been added or substituted.

- Starting from a double HP stripping scheme, only one stripper (existing carbon dioxide stripper) has been used to treat the solution from the reactor. Modifications to the internal parts ensured better stripping efficiency improving the liquid distributor/ferrule system at the top.

- Installation of a new HP ejector to allow easy circulation of the carbamate in the loop

- Installation of CASALE-Dente High Efficiency Trays (HET) in the synthesis reactor to maximize the efficiency

- Installation of CASALE improved loop for Stripper passivation purpose

- Minor modifications to the internals of the HP vent condenser and the HP carbamate separator permitted to improve the process stability and reliability.

On this basis the original Isobaric Double Recycle scheme has been modified to a CASALE Improved Design Single Stage Ammonia Stripping scheme.

The HP vapours from the VRS unit are directly recovered in the loop.

After revamping the HP loop appears like the sketch in the figure 2.

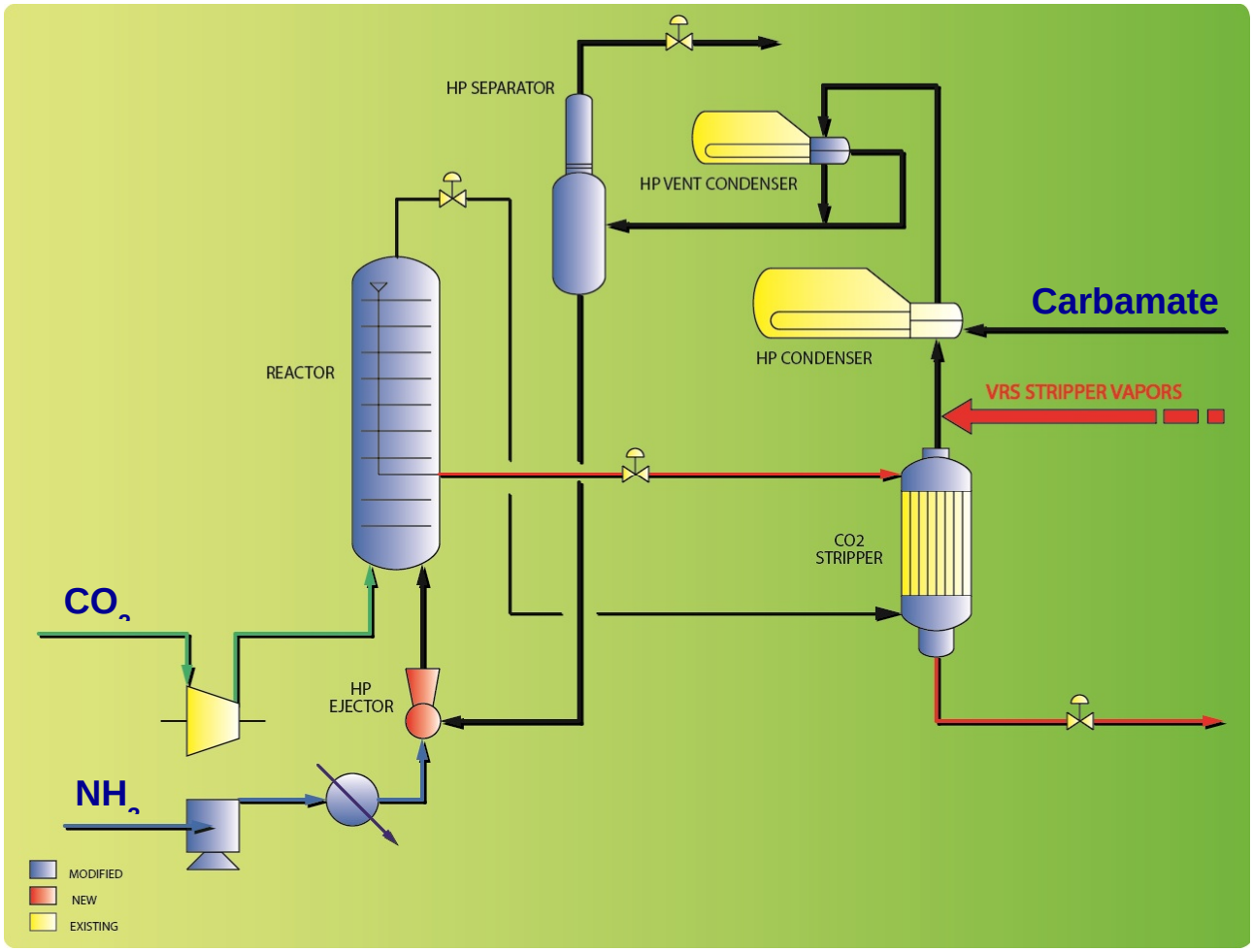

Fig. 2 – CASALE Improved HP loop

VRS Section

A new VRS section has been added for the carbamate distillation. The unit has been specifically designed for the case and consists of a three stages carbamate distillation system integrated with the urea plant in the gas phase side.

In particular the VRS consists of:

- Existing ammonia stripper working as HP carbamate decomposer directly linked to the HP vapours circuit from the main stripper. Modifications to internal parts ensured better stripping efficiency improving the liquid distributor/ferrule system at the top.

- New HP Carbamate preheater installed to recover the heat from the steam condensate for heating up the carbamate to the VRS thus reducing the HP steam consumption.

- New MP decomposer (falling film type) acting as Medium Pressure carbamate distillation stage, recovering the vapours directly to the MP condensation system.

- The decomposer consists of a double exchanger to provide a part of the heat from the steam condensate thus reducing the steam consumption

- New LP stripping column. Integrated in the LP condensation unit of the plant, the aim of the stripping column is to recover in the Low Pressure Stage the remaining ammonia e carbon dioxide sending to the waste water treatment unit a water rich solution (about 95% water).

- The water rich solution form the column could be sent directly to the existing WWT or in case to the transfer network to be treated in the new WWT unit.

The VRS section appears like the sketch in the figure 3.

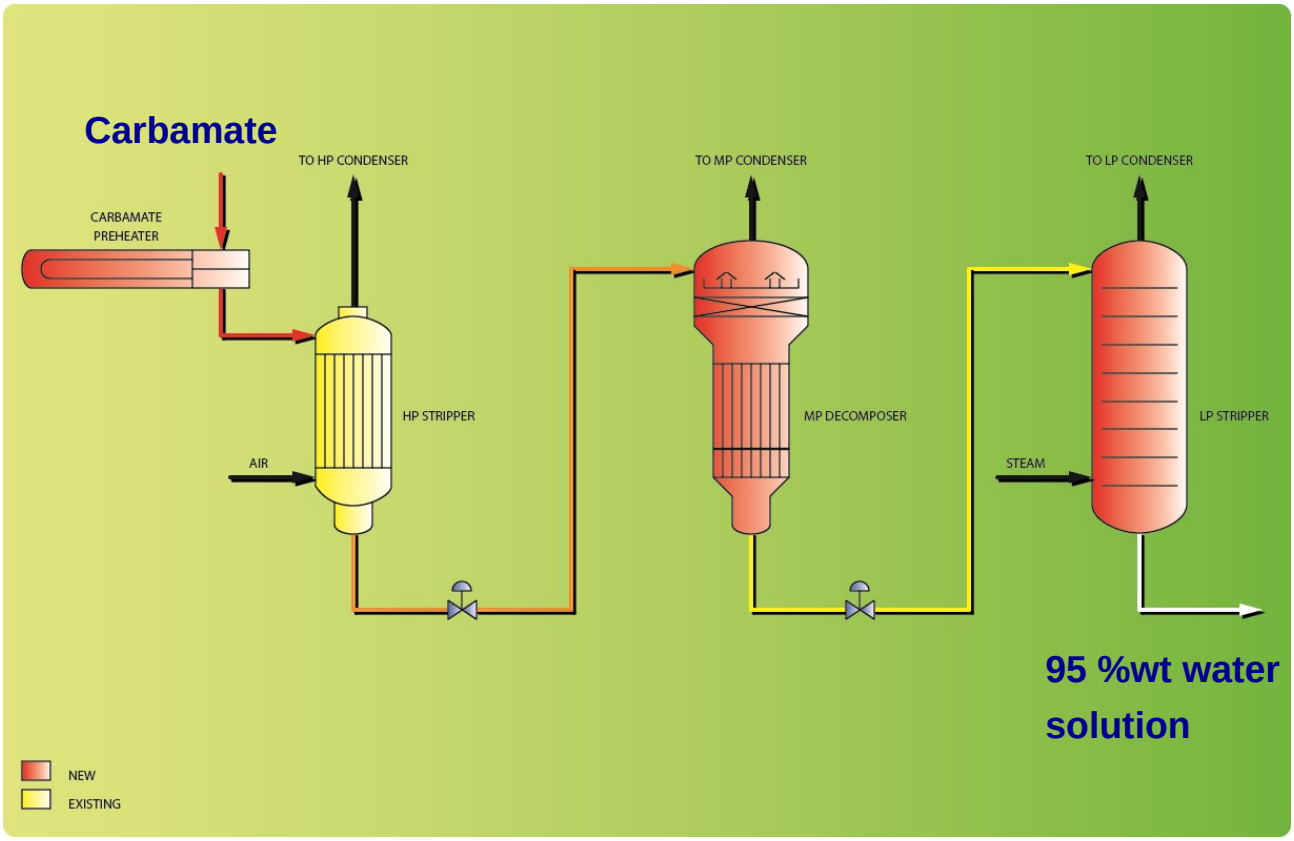

Fig. 3 – VRS section

MEDIUM PRESSURE Section

Thanks to the VRS section the load of the MP decomposer is lightened and no modifications are needed.

The vapours from the MP decomposer both from VRS section and urea train side are jointly sent to the condensation unit.

To improve the system flexibility and minimize the ammonia specific consumption new MP ammonia recovery section has been added.

This section is responsible for the recovery of the ammonia excess at the outlet of the existing stripper minimizing the emission to the atmosphere. High operative flexibility is guaranteed permitting to regulate the ammonia recycle and operate the reactor in a wide range of N/C ratio.

The intervention on the existing MP section consists of:

- Installation of a new Improved Medium Pressure Absorber (CASALE patented system)

- Installation of a new ammonia condenser

- Installation of a new ammonia receiver with integrated inert scrubbing system.

The Improved and patented Medium Pressure Absorber is designed to ensure high reliability and high tolerability of the process disturbances increasing the stability of all the process.

The Medium Pressure Absorber is normally a weak point in the urea plants and is not rare the possibility to entrain carbon dioxide from the column top to the ammonia condensation/recovery circuit leading to the plant shut down.

The innovative design of the column and the proper selection of the internals is able to guarantee a very efficient barrier against the carbon dioxide entrainments.

This is possible through the implementation of the following concepts:

- high gas/liquid disengagement efficiency of the two phase stream from the condenser. No mist or carbamate droplets are entrained to the top part of the column

- injection of carbonate solution from LP stage directly in the column acting as a first barrier against the carbon dioxide vapours. A packing is installed inside to provide adequate surface for the mass/heat transfer.

- Installation of a chimney tray to collected the carbonate solution and pumping it to the MP carbamate condenser maintaining the optimum condensation performances.

- Installation of high ammonia residence time bubble cup trays in the column top acting as a second multi-stage barrier against the carbon dioxide vapours coming uncondensed from the packing.

- high efficiency liquid distribution system installed in the between of the top trays and the packing permitting high mixing efficiency of the ammonia from the trays and the carbonate and high spreading capacity of the solution to the packing.

After revamping the MP section appears like the sketch in the figure 4.

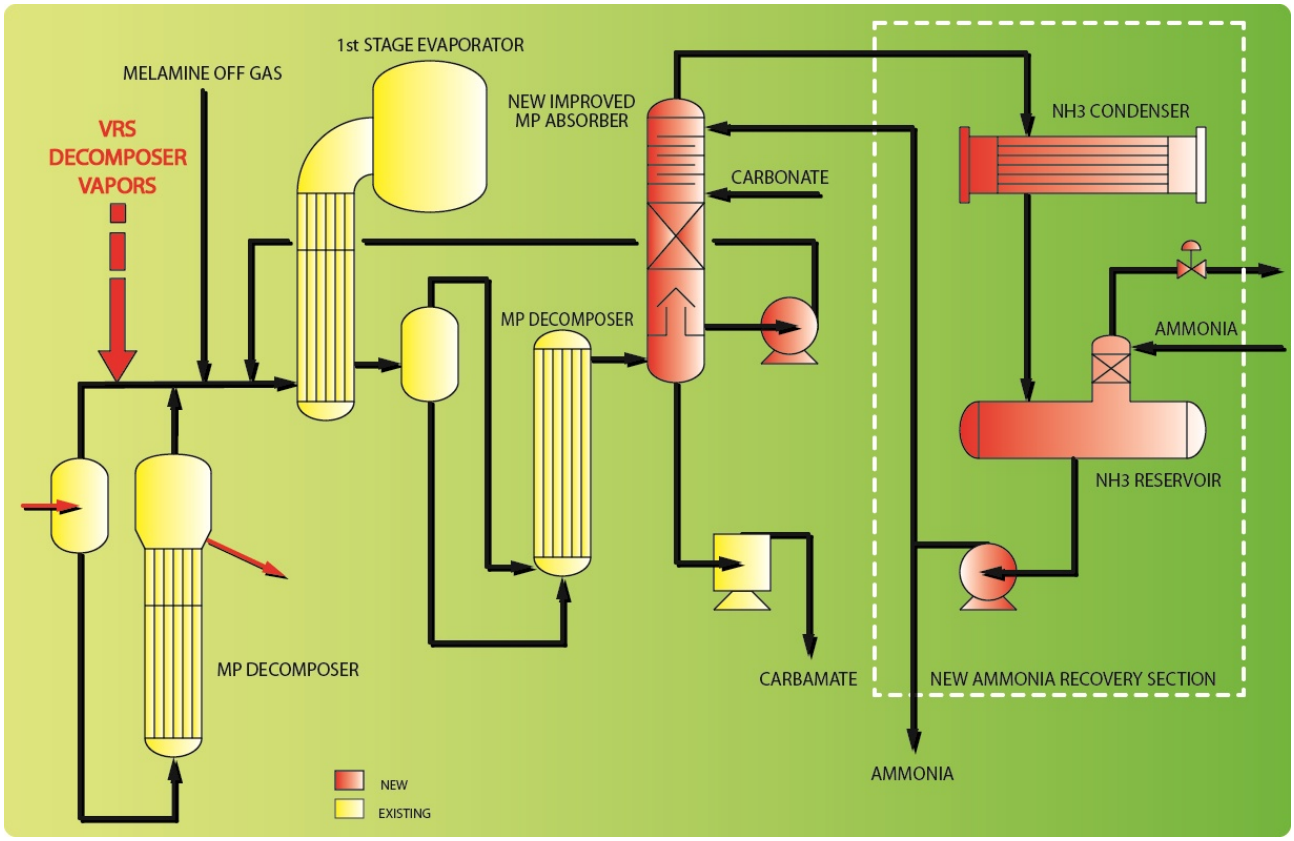

Fig. 4 – MP section

LOW PRESSURE and FINISHING Sections

To improve the condensation capacity of the existing LP condenser in view of the introduction of the new LP stripping column in the VRS stage only the LP condenser has been modified adding new surface in series.

After revamping the LP section appears like the sketch in the figure 5.

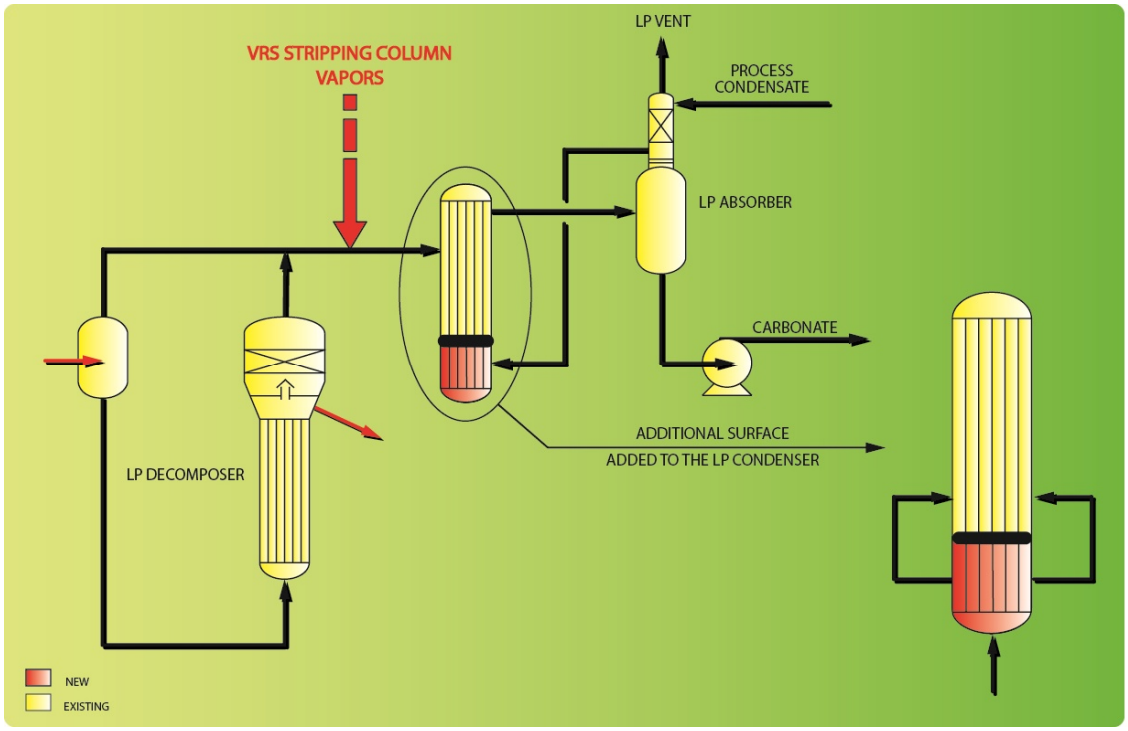

Fig. 5 – LP section

Revamping of Toyo Plants including Urea Concentration Section

The revamping of the TOYO Plants was mainly aimed at the capacity increase in stand alone configuration.

In this case the capacity increase (10% in respect to design, 30% in respect to the run integrated with melamine) has been achieved through the installation of High Efficiency Trays (HET) in the reactors of all the lines. A new additional atmospheric condenser has been added in all the lines to increase the condensation capacity.

Thanks to the modifications the plants are now running at higher capacity improving the ammonia efficiency of the whole system.

Waste Water Treatment Plants

The Urea Plants Integrated system is generating an increased amount of process condensate to be treated.

A new waste water treatment unit has been added in the integrated system. A process condensate transfer network is allowing high flexibility in the operation permitting the waste condensate to be shifted among the treatment units through a transfer tanks integrated circuit.

The new waste water treatment plant has been designed to ensure high flexibility of the operation in respect of the load changes maintaining very good performances in a wide range of load and composition of the feed.

The section is equipped with a deep hydrolysis system designed according to the CASALE High Efficiency Hydrolyser (HEH) concept.

The high efficiency of the treatment unit permits to minimize the specific ammonia consumption of the urea plants discharging clean condensate (expected 3 ppm urea and ammonia).

PROJECT EXECUTION AND MAIN MILESTONES

The Contract has covered the provision of the following services:

- License of technologies
- Basic Engineering
- Assistance and check of the Detail Engineering
- Supply of all itemized equipment
- Site Assistance during construction
- Site Supervision during commissioning, start-up and test-run

During the Basic Engineering phase a HAZOP analysis of the revamped plant was performed.

Detail Engineering and Construction have been done by local companies under assistance and supervision of UREA CASALE.

Project Main Milestones

- Effective Date of Contract: September 2007
- IDR Plant shut-down in June 2010
- IDR Plant successfully restarted at the end of October 2010
- Condensed off gas from Melamine Plants available in December 2010. First VRS Section start-up: December 2010
- Full load of IDR Plant (more than 2'000 MTD) achieved in January 2011
- Performance Test Procedure prepared, discussed and agreed during February 2011
- Successful Test run done at the beginning of April 2011

CONCLUSIONS

Through the application of the VRS concept and the optimization of the process schemes the revamping objectives have been perfectly satisfied.

In particular:

Urea Production, Ammonia and Steam Consumption

The total urea Production of the Integrated Urea Complex has been increased by more than 20% recovering fully the aqueous rich condensates from Melamine Plants.

The global specific ammonia consumption has been reduced by 17 Kg/MTurea while the specific steam consumption has been reduced by about 180 Kg/MTurea.

Plant Operability

IDR PLANT

- High stability of the HP synthesis loop modified from a double stripper to a single stripper system.
- High stability of the HP loop on a wide range of operative conditions. Possibility to operate the reactor with wide range of N/C molar ratio thanks to the new ammonia recovery system
- High stability of the MP condensation system thanks to the new Medium Pressure Absorber. Extremely high plant reliability and low shut down risk due to carbon dioxide carry over to the ammonia condensation system.

Minimization of the investment costs

IDR PLANT

- No additional HP equipment has been added in the synthesis loop. Only a new HP ejector has been installed to allow the carbamate circulation at high pressure.
- Installation of a new VRS section. A three stage VRS concept has been developed for the case. The existing ammonia stripper has been reused. A new carbamate preheater has been installed for energy saving purposes.
- No modifications to the carbamate decomposers and vacuum system on the urea train
- Minor modifications to the vapours condensation systems. Additional surface added to the LP condenser.
- Installation of a new MP ammonia recovery section.

TOYO PLANTS

- Guaranteed capacity increase of 10% through the installation of CASALE HET trays in all the reactors and installing an additional atmospheric condenser.