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Integration of Urea and Melamine Plants Casale Experience

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This paper presents various methods for integrating urea plants with melamine plants which have been proposed by Casale to suit different types of urea plant and client requirements.

The integration procedure normally also entails increasing the capacity of the urea plant.

The inevitable need to utilize the melamine plant off-gas as raw material in the urea plant imposes a heavy penalty on the efficiency of the urea plant on account of the water vapour content of the off-gas. That profound affects the way the urea plant is revamped.

Other important aspects to be considered are the process type of the urea plant being modified (total recycle or stripping process) and whether the technology used in the melamine plant produces a low- or high-pressure off-gas stream.

Some significant examples of integration between the two plants are also described in the paper.

Irrespective of its design, a melamine plant uses urea as its raw material and, along with the melamine, also produces a by-product stream of ammonia and carbon dioxide (off-gas), which in some cases contains water.

The ammonia and carbon dioxide in the off-gas are generated in the dissociation of a large part of the urea feed, which takes place in the melamine formation process. For that reason, a melamine plant always requires a neighbouring urea plant to reprocess the ammonia and carbon dioxide back into urea.

Generally, therefore, melamine plants are erected next to urea plants so as to benefit from both an easy supply of raw material and the capability to reprocess the off-gas back into urea.

Figure 1 is a very generic representation of a urea plant, showing a synthesis section (where urea is formed) followed by a decomposition section working at lower pressure (where un-reacted

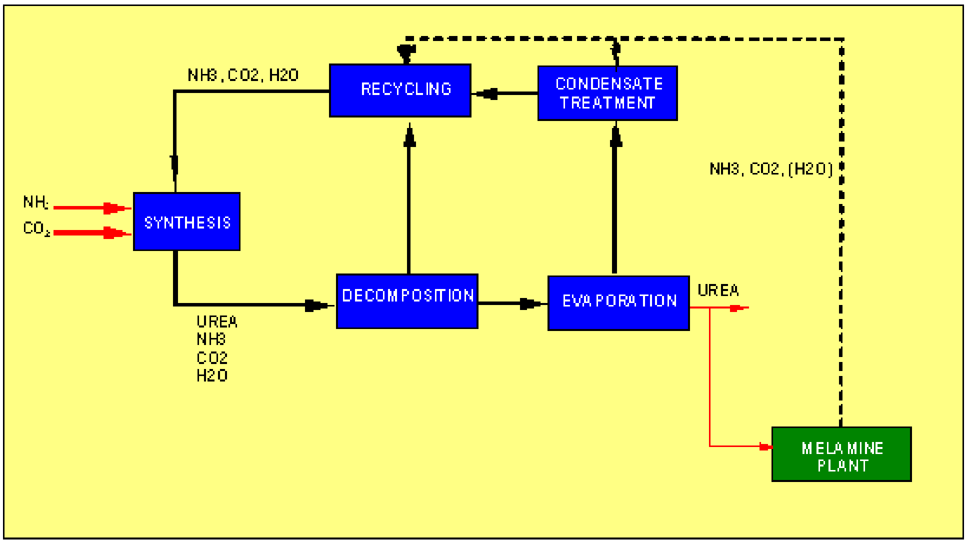

FIG. 1: MELAMINE PLANT INTEGRATED WITH UREA PLANT

ammonia and carbon dioxide from the mixture exiting the reactor are separated) and an evaporation section, in which water is separated from the urea solution.

Free ammonia and carbon dioxide coming from the decomposition section are processed in the recycling section and sent back to the synthesis section in the form of an aqueous solution (carbamate); while the process condensate coming from the evaporation section is treated in a process condensate treatment unit to form clean condensate to be exported and a lean water solution of ammonia and carbon dioxide, which is recycled to the recycling section.

As mentioned above, a melamine plant similarly generates a stream of ammonia and carbon dioxide, and unless this stream is released at a pressure comparable to that of the urea plant synthesis section, it has to be reprocessed in the recycling section of the urea plant. In addition, the melamine plant may also generate process condensate which also needs treatment.

How best to integrate a melamine plant with a urea plant depends on a variety of factors, including the particular combination of melamine and urea plant technology and the ratio of the melamine plant capacity to the urea plant capacity.

The integration of a melamine plant with a urea plant generally causes a drop in the efficiency of the urea plant. It can be a simple task if the melamine plant capacity is low in comparison with the urea plant capacity and no capacity increase is required in the urea plant. But it can pose technical challenges if it significantly reduces the efficiencyof the urea plant.

This paper has the object of providing an overview of the possible scenarios for the integration of a melamine plant with a urea plant; it also describes how Casale technologies can fit the various specific cases. Some case histories are described to provide practical examples of typical configurations.

TECHNICAL PROBLEM

The main technical problems in integrating a melamine plant with an existing urea plant arise from the fact that almost half of the urea fed to the melamine plant is dissociated into ammonia and carbon dioxide, which must be transformed back into urea.

As the urea plant owner generally wants to maximize urea capacity for a given amount of feedstock, after integration with a melamine plant, the urea plant (in particular the synthesis, decomposition and recycling sections) will have to run at a higher capacity to accommodate the additional ammonia and carbon dioxide from the melamine plant off-gas, which are additional feeds. Moreover, the off-gases are generally produced at a lower pressure than the urea synthesis loop pressure, so they have to be condensed to carbamate solution and then be pumped back to the synthesis loop pressure. That overloads the recycling section of the existing urea plant.

Off-gas condensation requires a certain amount of water, which is needed to keep the ammonia and carbon dioxide in solution. That has two negative effects on the plant efficiency.

- The additional water necessary for the off-gas condensation will then be recycled into the synthesis loop, where it has a deleterious effect on the conversion efficiency in the synthesis reaction.
- Per tonne of produced urea, less fresh feed ammonia and carbon dioxide are sent directly to the synthesis section. It is the reaction between the fresh feeds to form ammonium carbamates in the synthesis section which provides the heat needed for the onward conversion of the carbamate into urea and, eventually, for steam production. Thus any decrease in the specific amount of fresh feeds sent directly into the synthesis section impairs both the efficiency of the synthesis section and the heat balance of the plant.

The amount of water depends on the type of melamine technology and on the conditions of the relevant off-gas.

The greater the capacity of the melamine plant in relation to that of the urea plant, the more severe the negative effect of integration on the efficiency of the urea plant will be. And the more the efficiency of the synthesis section is reduced, the greater will be the amount of unreacted ammonia and carbon dioxide that will has to be handled by the remaining sections of the urea plant (decomposition, recycling and condensate treatment), in addition to the extra load imposed by the melamine off-gas.

To summarize, the impact of the integration of a melamine plant with an existing urea plant is the following:

- Increased plant capacity is required to transform the ammonia and carbon dioxide coming from the melamine plant back into urea.
- Conversion efficiency in the synthesis loop is reduced because of the increase in the amount of water in this section resulting from the additional carbamate formed with the ammonia and carbon dioxide recycle from the melamine plant, and the load on the other main sections of the plant is consequently increased.
- The load on the recycling section of the plant is increased by the need to condense the ammonia and carbon dioxide recycle from the melamine plant.

Though the magnitude of the impact on the urea plant varies according to the type of melamine production technology used, every integration project has the same effects to a greater or lesser extent. In other words, the amount of additional water reaching the synthesis section may be different, but it will always have a negative effect.

Very recently, new melamine technologies have been patented that can produce the off-gas at the urea synthesis section pressure. That type of technology would not have such a high impact on the urea plant.

Casale approach to solving the problem

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

- Find a way to minimize the amount of additional water needed to generate the additional carbamate solution from the melamine off-gas.

- Find the best way of revamping the existing urea plant to efficiently increase its capacity and to compensate the negative effect of the melamine plant integration on the plant efficiency.

As a result of various studies that it has done on the integration of melamine plants with urea plants, Casale has developed different designs for the unit that interconnects the melamine plant to the urea plant.

These designs address the first of the above points, providing an efficient way to condense 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 condense and recycle the off-gas.

The design of the off-gas condensation unit is tailor-made to the combination of the type of melamine plant and of urea plant.

Typically, if the off-gas is at low pressure, a multi-step condensation design is used, which allows partial re-evaporation to reduce the amount of water that is otherwise needed to condense the NH_3- and CO_2-rich off-gas stream at low pressure.

If the off-gas is at medium or high pressure, though still lower than the synthesis pressure, the condensation is arranged to make the most efficient possible use of water that is already present in the urea process. A detailed study is performed to identify the most appropriate source of water within the existing urea plant.

For the second part of the problem, Casale is able to draw on its own technologies for revamping any kind of urea plant to improve the the efficiency of the synthesis loop to the greatest possible extent. These technologies have proved in several applications to be able to drastically increase the efficiency of existing urea plants.

CASALE ADVANCED TECHNOLOGIES TO INCREASE UREA PLANTS EFFICIENCY AND CAPACITY

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

For every project involving integration of a melamine plant with a urea plant, Urea Casale proposes one or more of these technologies in order to obtain this integration in the most efficient way.

In this chapter most of the technologies developed by Urea Casale are briefly described.

Casale-Dente High Efficiency Trays

In collaboration with Professor Dente, Urea Casale has been able, by accurate modelling, to identify all the parameters that influence 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.

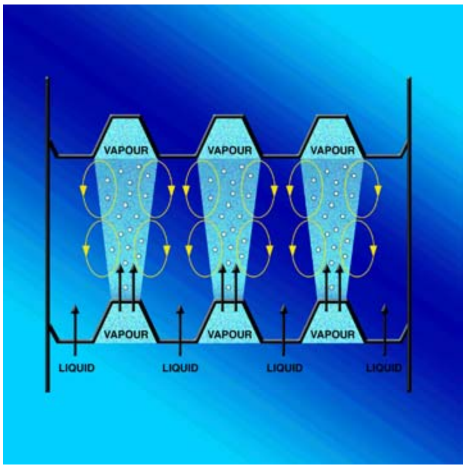

FIG. 2: CASALE-DENTE HIGH - EFFICIENCY TRAYS

The improved geometry of the Casale-Dente High-Efficiency Tray design promotes much more thorough mixing between the liquid and vapour phases.

The advantageous features of the new trays are:

- Vapour and liquid follow separate paths through the tray, as shown in Fig. 2. These are distributed across essentially the whole area of the tray, thus guaranteeing stable and uniform flow of the two phases throughout the whole reactor.
- The separate paths through the tray have been designed so as to result in very high mixing efficiency between vapour and liquid. Consequently mass and heat transfer within the liquid phase is very efficient.
- The vapour ports are designed to give far smaller bubbles of vapour than in any previous design. In consequence, the interfacial surface for mass and heat transfer is increased.
- Mixing within the liquid phase is also much more thorough.

The trays are made up of 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 vapours and liquid.

Casale-Dente High Efficiency Trays are used for any project aiming at reducing steam consumption or increasing the plant capacity or both. They can also conveniently be used to increase the efficiency of the synthesis section of any kind of urea plant that needs to be integrated with a melamine plant. So far Casale-Dente High Efficiency Trays are operating in more than 50 urea plants.

HEC (High Efficiency Combined) process

The development of this process opened the way to very large increases – 50% or more – in the capacity of conventional total recycle plants.

This process (Fig. 3), based on the combination of a very efficient "once-through" primary reactor and a conventional total recycle secondary reactor, boasts the unique feature of having a very high average CO_2 conversion (70-75%) and, in consequence, low energy consumption.

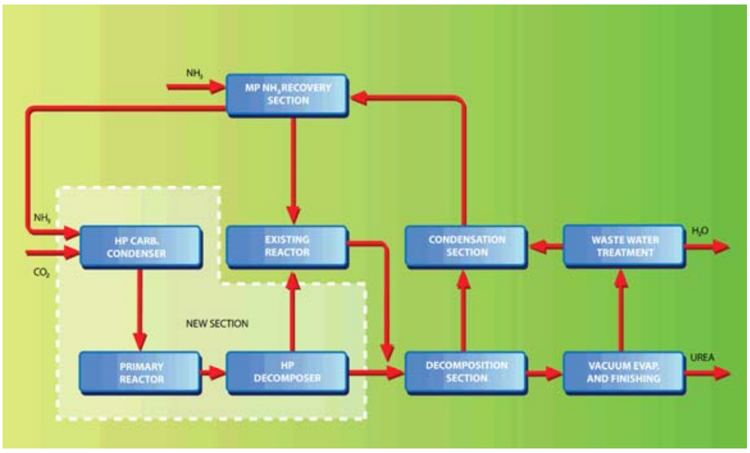

FIG. 3: CONVENTIONAL TOTAL RECYCLE PLANT REVAMPED WITH THE HEC CONCEPT

Most of the urea is produced, in the absence of any water, in the primary reactor at a high yield, generally 75%. This reactor has a carbamate condenser upstream, for controlling the heat balance, and a high-pressure decomposer downstream to recycle most of the unreacted ammonia and carbon dioxide directly into the secondary reactor, which operates at lower pressure.

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

The capacity of conventional total recycle plants can be drastically increased by application of the HEC concept, which entails additing only a 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 HETs) is used as primary reactor;

- a section consisting of the secondary reactor, an HP carbamate condenser and an HP decomposer is added (see Fig. 3).

The existing synthesis section will, therefore, be transformed into an HEC synthesis section and, on account of the much higher conversion obtained in the HEC synthesis section, the existing back-end of the plant can be re-utilized at higher capacity with only minor modifications.

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 new primary reactor is added while the existing reactor is used as secondary reactor.

After revamping, the following consumptions can be obtained:

- raw materials almost stoichiometric
- MP steam at about. 900 kg/tonne

This technology whose features have just been described is well suited for revamping a conventional total recycle plant that is being integrated with a melamine plant, providing the requisite boost in capacity and compensating for the loss of efficiency coming from the integration.

Split-Flow Loop™ and Full Condenser™ concepts

These technologies are a powerful tool to increase the capacity of CO_2 stripping plants in a very efficient and, therefore, economical way.

According to the **Full Condenser™** concept (Fig. 4), an existing HPCC is modified so that:

- Vapours and inerts coming from the HP stripper are fed through one of the bottom nozzles and dispersed into the continuous liquid phase in the bottom header space by a distributor in such a way that they flow upwards through the majority of the tubes.
- Under the levitational influence of the dispersed vapours, a mixture of liquid and vapour bubbles rises through the tubes, in the course of which the condensable vapours are absorbed into the liquid phase.
- In the minority of tubes which the vapours do not enter, the denser liquid phase descends, producing an internal natural circulation.
- The small remaining gaseous content of the two-phase flow exiting the tubes into the top header space comprises essentially non-condensable inerts, which separate from the condensed liquid and exit the condenser from the top nozzle. Liquid leaving the top header space returns to the urea reactor.
- Fresh liquid (NH_3 + carbamate) enters the exchanger through the second bottom nozzle and is distributed in all tubes.

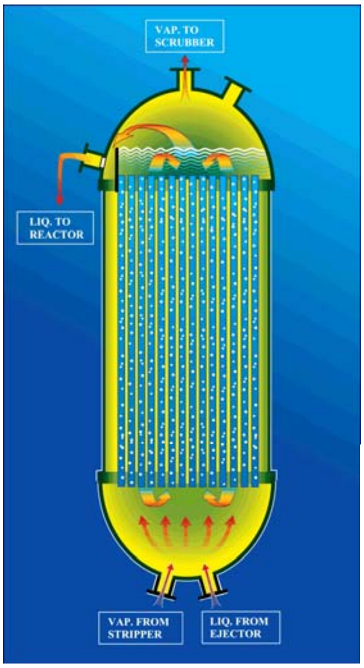

FIG. 4: FULL CONDENSER™ CONFIGURATION

Because the new internal flow regime is a bubble flow inside a continuous liquid, the interfacial area between two phases (liquid and gas) is significantly increased, so the transfer performance of the exchanger is highly improved.

With the **Split Flow Loop™** concept (Fig. 5), the HP loop is modified so that:

- The HPCC is practically a total condenser and is fed with only the amount of vapours that actually has to be condensed (i.e. about 2/3 of the total vapour coming from the stripper).
- The rest of the vapours, which in the standard configuration would leave the HPCC un-condensed, by-pass the condenser and go directly to the reactor.

- Total non-condensable inerts leave from the top of the condenser and are sent directly to the scrubber together with the some uncondensed ammonia and carbon dioxide.
- The liquid from the total condenser is sent to the reactor through a new ejector, which enhances the driving force for the circulation. The new ejector is driven by part of the ammonia feed that by-passing the condenser.

In this way, about two thirds of the total amount of the inerts present in the CO_2 are not sent to the reactor; consequently the urea conversion increases.

Transforming the loop of a CO_2 stripping urea plant into the **Split Flow Loop™/Full Condenser™** configuration makes it more efficient, allowing its capacity to be increased by up to 50% and reducing energy consumption.

The **Split Flow Loop™/Full Condenser™** configuration is a also very powerful tool for debottlenecking CO_2 stripping plants which are being integrated with a melamine plant.

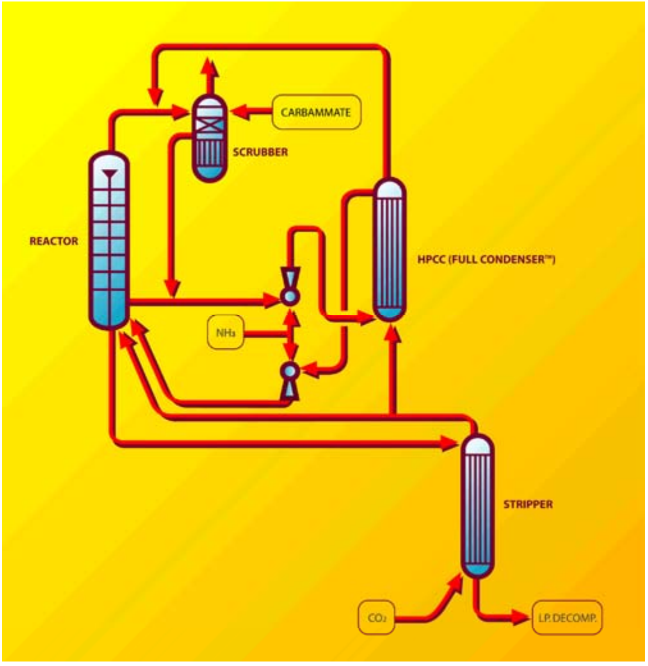

FIG. 5: SPLIT FLOW LOOP™ CONFIGURATION

VRS (Vapour Recycle System) process

This technology has been developed for revamping stripping plants and is used in certain cases where a drastic capacity increase is required.

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

- Instead of being sent to the HP section, the carbamate solution obtained in the downstream process sections is distilled in an HP decomposer working in parallel to the existing stripper.
- The vapours thus obtained (containing NH_3, CO_2, and a little water) are sent to the HP section (HP 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 ammonia and the carbon dioxide 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 HP 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 is modified according to the VRS concept by adding a new decomposition section in parallel to the existing plant (Fig. 6). The HP carbamate is sent to the new section, where it is decomposed. The released vapours, rich in ammonia and carbon dioxide, 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 0.2-0.25), a high CO_2 conversion is obtained (66-70%).

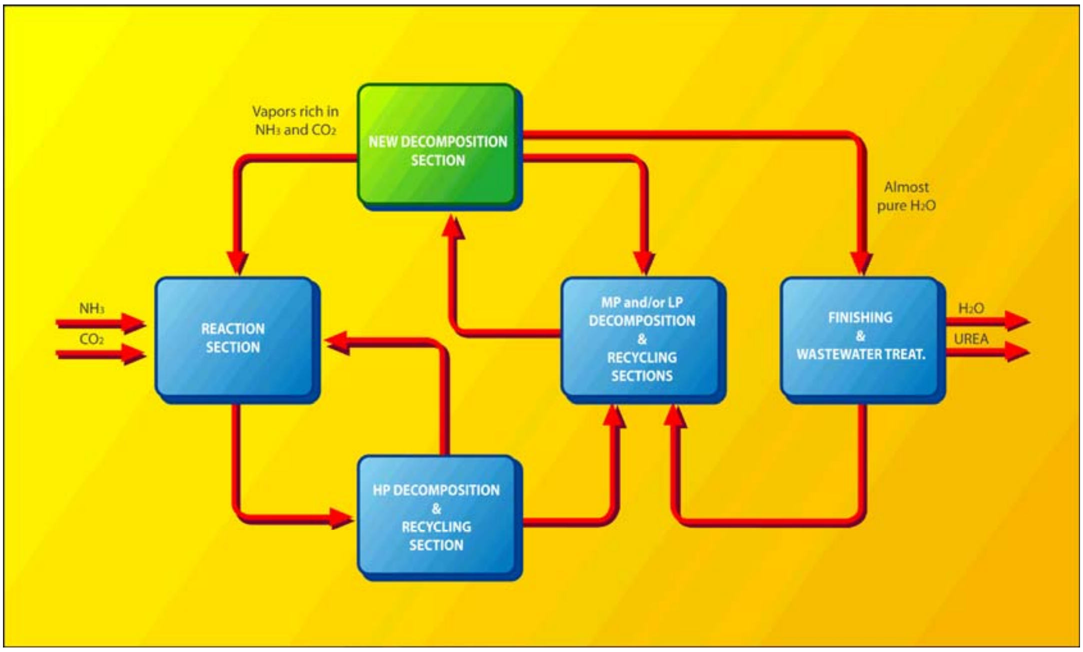

FIG. 6 - STRIPPING PLANT REVAMPED ACCORDING THE VRS CONCEPT

Because, in the modified plant, the new conversion is much higher and the water content much lower than before the modification, an 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.

Using the VRS process, it is possible to reduce the effect of the additional water introduced with the integration with the melamine plant by cutting it off from the carbamate stream. Stripping plants that need to be integrated with melamine plants can be conveniently revamped with the VRS process.

CASALE EXPERIENCE IN MELAMINE/UREA PLANT INTEGRATION

Casale has performed a number of studies on the integration of melamine plants with existing urea plants, some of which have resulted in projects that either have been or are in the process of being implemented. With the benefit of its detailed investigations on different design options for the melamine / urea plant interconnection, Casale has the best experience to study the same for various types of melamine processes. In addition, Casale also has probably the most extensive and wide-ranging experience in revamping existing urea plants.

Table I lists the most significant projects and studies that Casale has carried out or is carrying out in the field of melamine integration to urea plants.

The melamine plants considered in the various listed projects were of different types, such as low-pressure catalytic or higher-pressure non-catalytic, including also the new high-pressure process.

It is significant to mention that Casale has also studied the possibility of designing a urea plant dedicated entirely to the production of urea for the melamine unit, recovering the off-gas from the melamine itself.

Case histories

This paragraph provides details of some practical and representative cases of melamine integration with urea plants that have been studied and/or implemented by Casale. They have been selected to provide a benchmark of the wide range of possibilities that can be faced. In particular, three scenarios are considered:

Table I
Casale Experience for Integration of Melamine Plants with Urea Plants

	Name of plant	Location	Original design technology for Urea Melamine	Capacity, t/d Original New	Status	
1	Khorasan	Iran	- CO_2 stripping - Eurotecnica	1500 1700	In operation	Licence, basic eng. package, detailed eng. & material supply
2	BASF	Germany	- Total recycle (Toyo) - BASF	800 1800	Cancelled after basic design	Licence, basic eng. package & material supply
3	Confidential	Confid.	- Total recycle (Toyo) - Eurotecnica	1000 1610	Under design	Licence, basic eng. package & material supply
4	Triad	USA	- CO_2 stripping - Melamine, Inc.	1200	Completed	Paid study
5	Melamine, Inc.	USA	- New plant - Melamine, Inc.	(1)	Completed	Paid study
6	Fertil	Abu Dhabi (UAE)	- CO_2 stripping - Agrolinz	1500 2700	Under execution	Licence, basic eng. package & material supply
7	Liahoe	China (PR)	- CO_2 stripping - Eurotecnica	1620 1970	Completed (on hold)	Study
8	Hejiang	China (PR)	- NH_3 stripping - Eurotecnica	1760 2255	Completed	Study
9	Microchemie	Holland	- Total recycle (Toyo) - Low pressure	515 567	Completed	Study
10	PT Sri Melamine	Indonesia	- New plant - Eurotecnica	(1)	Under design	Study

(1) Urea plant designed only for the necessity of melamine unit

i. Integration of a CO_2 stripping process urea plant with a Eurotecnica melamine plant without additional increase of final urea production.

ii. Integration of a CO_2 stripping process urea plant with a Agrolinz melamine plant with an additional increase of urea production.

iii. Integration of a total recycle process urea plant with a Eurotecnica melamine plant without additional increase of urea production.

i. Integration of a CO_2 stripping process urea plant with a Eurotecnica melamine plant without additional increase of urea production

The original urea plant was of 1,500 t/d capacity, utilizing CO_2 stripping technology, and it was integrated with a 20,000-t/a melamine plant based on Eurotecnica technology. Integration with this type of melamine unit would lead to an increase of urea synthesis capacity of about 13% and of water recycled to the loop of about 15% in comparison with the figures for a stand-alone plant. A block diagram of the project is shown in Fig. 7.

Table II
Characteristics of Eurotecnica Melamine Off-Gas

Parameter	Unit	Value
Temperature	°C	160
Pressure	bar	20
Flow	kg/h	~ 9,000
Ammonia	% wt.	44%
Carbon dioxide	% wt.	36%
Water	% wt.	20%

In fact the off-gases from this kind of melamine unit have the characteristics in Table II. It is, therefore, fundamentally important to prevent or minimize any further introduction of water in the system in order to avoid detrimental condition of the urea reactor in the urea synthesis loop and to improve to the maximum possible extent, with the minimum investment, the performance of the urea reactor.

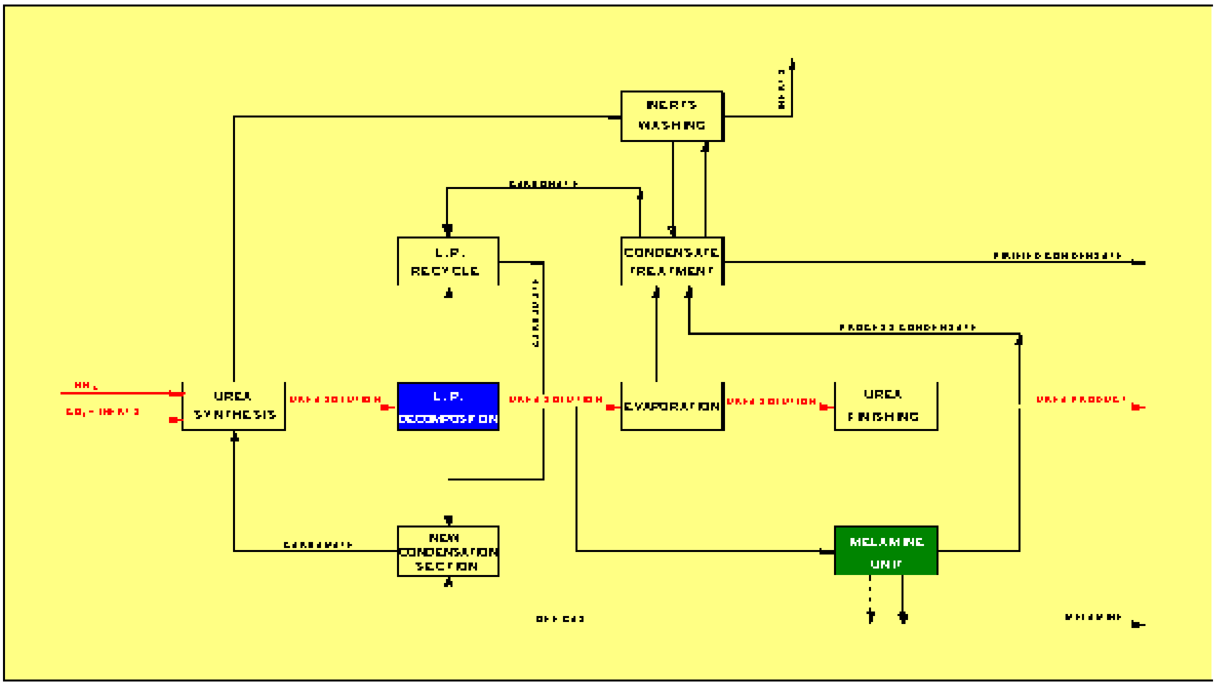

FIG. 7: CO_2 STRIPPING UREA PROCESS INTEGRATED WITH EUROTECNICA MELAMINE PROCESS

Casale's approach to the first problem is to maximize the utilization of the water already present in the process in order to ensure the proper condensation of the melamine off-gases. A new condensation section working at a pressure of about 18 bar was installed (Fig. 8).

The new section is provided with a condenser and a closed-circuit cooling system to remove the heat of condensation of the melamine off-gases. The required amount of condensing water is provided by the carbamate solution leaving the existing LP recycle section of the urea plant. The resulting solution is then fed through the existing HP recycle carbamate pumps into the HP loop.

The melamine off-gas condenser operates at medium pressure (MP), higher than in the LP section of the urea plant, so the solution produced can be more concentrated than the LP carbamate. Therefore, the water present in the LP carbamate can absorb,at MP, more ammonia and CO_2. Using the LP carbamates it is possible tocondense the off-gases at MP with the minimum of additional water.

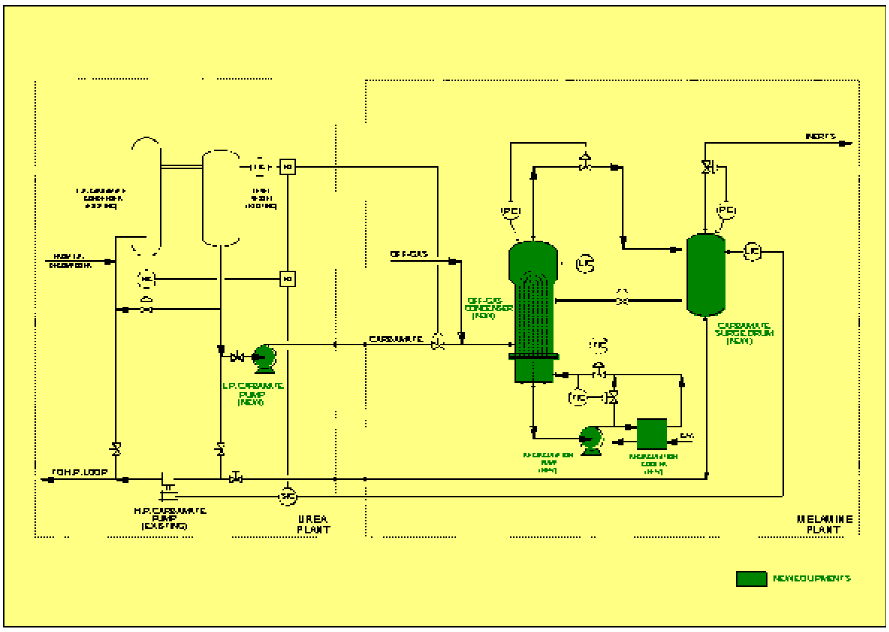

FIG. 8: NEW OFF-GAS CONDENSATION SECTION

The water content of the LP carbamate recycle of a stand-alone plant is typically 33% wt, but integration of the melamine plant reduces it to 30% wt.

Table III compares carbamate parameters before and after integration. Though the specific carbamate recycle flow is 19% higher after integration, the specific water recycle flow is only 7.7% higher.

Table III
Carbamate Parameters Before and After Integration

Parameters	Unit	Before	After	Incr.
Synthesis capacity	t/d	1,500	1,700	13%
Carbamate recycle	kg/h	37,500	50,000	34%
Specific carbamate recycle	kg/t	595.4	705.7	19%
Water flow recycle	kg/h	12,300	15,000	22%
Specific water flow recycle	kg/t	196.5	211.7	7.7%

The second problem – improving the performance of the reactor – has been addressed by adopting Casale's proprietary High-Efficiency Tray technology, which, in spite of the increased H_2O/CO_2 ratio in the reactor, has raised its efficiency by more than 1.5%.

Table IV
Performance Before and After Integration

Parameters	Unit	Before	After
Total urea production	t/d	1,500	1,700
Prilled urea production	t/d	1,500	1,500
Urea solution production	t/d	-	200
N/C ratio	-	3.1	3.2
H/C ratio	-	0.5	0.56
Reactor conversion	% wt	58.7	60.4
Steam consumption	kg/t	840	830

Table IV provides a comparison of the performance figures before and after melamine integration. It is clear that such a scheme can be used only if the ratio between the urea plant capacity and the melamine plant capacity is sufficiently high to prevent an extremely high H_2O/CO_2 ratio in the reactor, which would drastically depress the urea reaction and, therefore, the synthesis efficiency. Otherwise a more significant modification of the HP loop would be necessary so as to compensate for the reduction in the efficiency of the reactor.

New installation/modification

As already anticipated, the main goal of the project was to maintain the total urea prill production, integrate the melamine with the urea plant and limit the investment of the project.

The objective was completely achieved either from plant performances point of view, as describe above, or from the commercial one. In fact, the adopted modifications were the following:

- New High-Efficiency Trays in the urea reactor
- New circulation water cooler for the HP scrubber
- Additional surfaces on recirculation heater and L.P. carbamate condenser
- Additional atmospheric evaporator and condenser
- Melamine feed pumps.

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

ii. Integration of a CO_2 stripping process urea plant with an Agrolinz melamine plant with an additional increase of urea production

The original urea plant capacity was of 1,500 t/d utilizing CO_2 stripping technology. The plant is now running at an overall capacity of 1,800 t/d. The client asked Casale to increase the urea capacity to 1,900 t/d and to integrate it with an 80,000-t/a melamine plant based on Agrolinz technology. That would lead to an increase in urea synthesis capacity of about 50% and raise the water recycled to the loop by about 25% in comparison with the figures for a stand-alone plant.

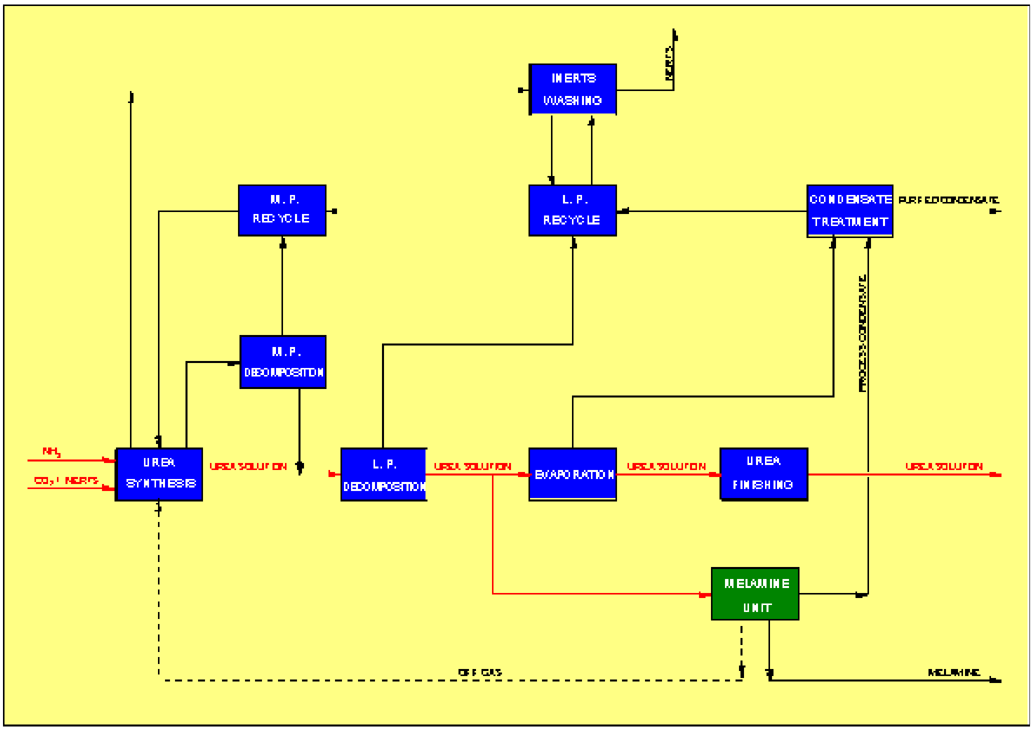

FIG. 9: UREA CO_2 STRIPPING PROCESS INTEGRATED WITH AGROLINZ MELAMINE PROCESS

For this particular case the off-gases from the melamine unit are recycled in liquid form since the condensation is performed within melamine battery limits.

Figure 9 is a block diagram of the project. The off-gases from this kind of melamine unit have the composition shown in Table V.

This case has, of course, a lower impact in terms of recycled water in comparison with the previous one because the off-gases from the melamine unit are produced at high pressure and, therefore, require less water for condensation. On the other hand, in view of the very high capacity of the melamine unit and the capacity increase required in the urea plant as a consequence, the existing equipment of the HP loop would not have be in a position to handle the high output (2,700 t/d) with the existing scheme.

Table V
Agrolinz Melamine Off-Gas

Parameter	Unit	Value
Temperature	°C	150
Pressure	bar	147
Flow	kg/h	~ 32,500
Ammonia	% wt	42%
Carbon dioxide	% wt	47%
Water	% wt	11%

By application of its own its own technologies, however, Casale was able to adopt an approach that would save all the equipment of the HP loop except for the HP carbamate condenser, which needed replacing in any case, since it was close to the end of its life. The urea reactor has been modified by installing the Casale High-Efficiency Trays, which again increase conversion by about 1.5% even when the reactor is running at a higher H_2O/CO_2 ratio (0.52) than originally (0.43).

In addition, Casale has applieded its innovative Split Flow™ and Full Condenser™ technologies, which allow a much smaller HP carbamate condenser to be used than is needed in a traditional CO_2 stripping plant. For a loop capacity increase of 50%, the surface area of the new condenser surface is only 10% larger than that of the the existing one.

Moreover, thanks to the Split Flow™ technology, only one third of the inerts volume fed to the plant is introduced into the urea reactor, which improves the reactor performance.

The only remaining factor in the HP loop limiting the synthesis capacity was the stripper. Casale has provided a new section working at about 20 bar in parallel to the existing stripper, as shown in Fig. 10. About 25% of the liquid leaving the reactor is diverted through the new section, which is

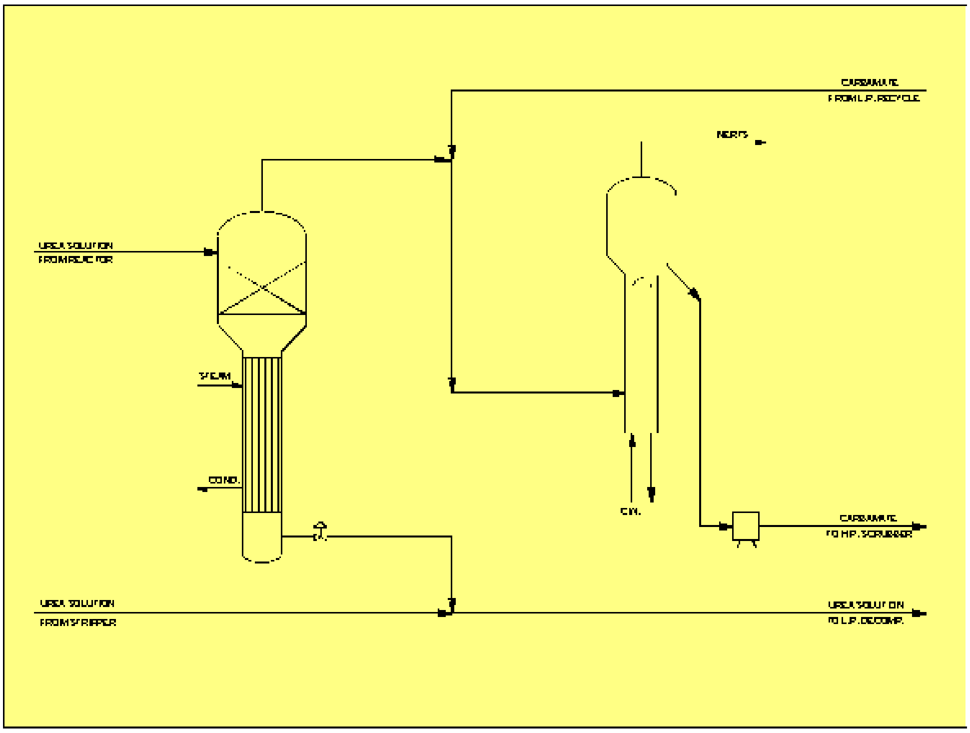

FIG. 10: NEW 20-BAR PARALLEL SECTION

equipped with a decomposer and a condenser. The bottom of the decomposer is joined to the bottom of the stripper and feeds the LP recirculation following the original routing. This modification entails a moderate increase in carbamate recycle but obviates the need to replace the stripper, which is the most costly piece of equipment of the urea plant.

Table VI shows some basic figures for the plants before and after melamine integration and capacity increase, from which it is clear that the specific recycle flow of carbamate has significantly increased (by more than 50%) because of the high melamine plant capacity and the introduction of the parallel unit. On the other hand, it has to be underlined that, in spite of the huge increase in carbamate recycle, the increase in the specific water recycle has been limited to only 9%.

Table VI
Characteristics of CO_2 Stripping Urea Plant Before and After Integration with Agrolinz Melamine Unit

Parameters	Unit	Before	After	Incr.
Synthesis capacity	t/d	1,800	2,700	50%
Carbamate recycle	kg/h	41,300	95,400	130%
Specific carbamate recycle	kg/t	551	848	54%
Water flow recycle	kg/h	12,900	21,100	63%
Specific water flow recycle	kg/t	172	188	9.3%

New installation/modification

In view of the high capacity of the melamine unit (80,000 t/a) and the requirement for an increase in the final output of urea product, the project is clearly of a much bigger magnitude in comparison with the first one presented. Therefore, the modifications and additions are much more extensive. Yet it has been accomplished while still achieving the fundamental target of avoiding new HP equipment, apart from the worn-out HP condenser. This has been made possible through the provision of the additional parallel section running at about 20 bar. And even the replacement HP condenser is considerably smaller than it would have been in a traditional plant of the new capacity.

Some more details of the modifications are listed below.

- High-Efficiency Trays in the reactor
- New HP carbamate condenser (Full Condenser)

- Parallel section decomposer and condenser with relevant tempered water system
- Additional HP ammonia and carbamate pumps
- Additional CO_2 compressor
- New recirculation heater and additional LP condenser
- Melamine feed pumps
- New distillation column
- High-Efficiency Trays for urea hydrolyser
- Additional pumping capacity of wastewater treatment unit.

As mentioned above, the off-gas condensation section is outside the Casale design and the off-gases are available under liquid form.

iii. Integration of a total recycle process urea plant with a Eurotecnica melamine plant without additional increase of urea production

The original urea plant had a capacity of 1,000 t/d and utilized total recycle technology. The plant is now running at an overall capacity of about 1,300 t/d.

The client asked Casale to integrate the existing urea plant with a 60,000-t/a melamine plant designed according to Eurotecnica technology. The integration with this type of melamine unit would entail an increase of urea synthesis capacity of about 25% and raise the water recycle rate to the loop by about 62%.

In the case of a total recycle plant, the increased water recycle has a direct impact on the conditions in the reactor because the carbamate recycle is fed directly into the reactor, affecting the H_2O/CO_2 ratio in the reactor.

Some characteristics of the off-gases from this kind of melamine unit are given in Table VII.

A block flow diagram of the project is shown in Fig. 11.

Table VII
Off-Gas Characteristics from Eurotecnica Melamine Plant

Parameter	Unit	Value
Temperature	°C	160
Pressure	bar	20
Flow	kg/h	~ 27,000
Ammonia	% wt	44%
Carbon dioxide	% wt	36%
Water	% wt	20%

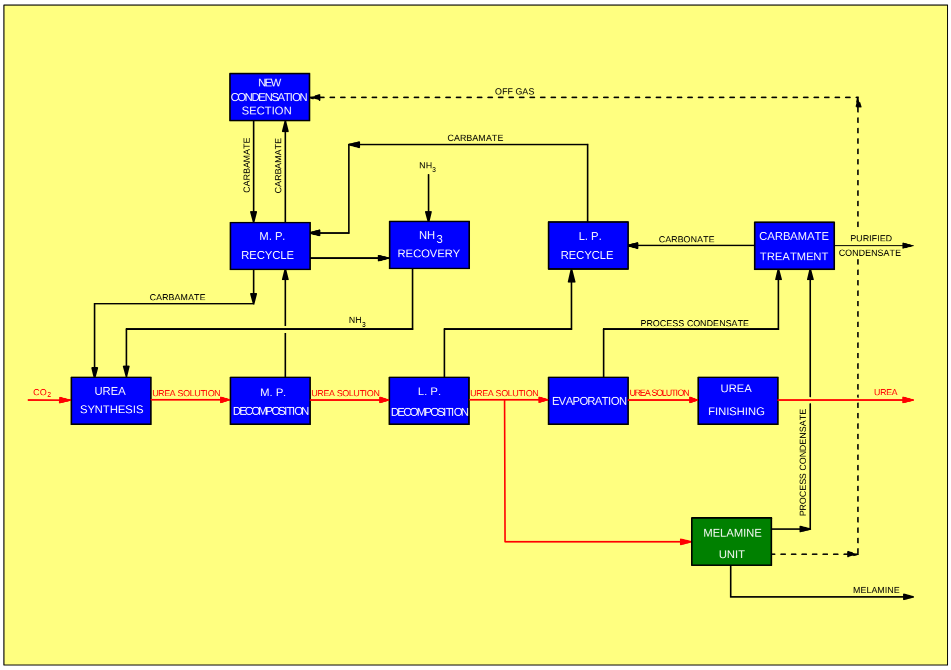

FIG. 11: UREA TOTAL RECYCLE PLANT INTEGRATED WITH EUROTECNICA MELAMINE PROCESS

Analysing the parameters of the project, it should be pointed out that the existing synthesis loop of the urea unit has only the reactor as a main equipment item. As mentioned above, it was designed for a stand-alone plant of 1,000 t/d. After integration of the melamine plant, it would need to run at 1,610 t/d with increased carbamate recycle flow. So it is clear that the reactor efficiency would be significantly impaired owing to the reduced residence time and the increased water content, and that would direct on the downstream medium and low-pressure recycling sections that are heavily overloaded.

Apart from the pure process aspect of providing additional surfaces as well as pumping capacities, the main constraints on the project are restricted site space and the lack of shut-down time available for installation of the new equipment.

Casale chose to adopt a different approach aimed at improving the synthesis efficiency to a level where the downstream sections would not be significantly affected by integration with the melamine plant. Moreover, the new melamine off-gas condensation unit is added with the objective of maximizing the utilization of the water already present in the process.

The modification of the synthesis loop is shown in Fig. 12, while off-gas condensation system is illustrated in Fig. 13.

In order to improve the synthesis loop efficiency Casale adopted its High-Efficiency Combined (HEC) technology, introducing a secondary reactor, with the relevant stripper used as reboiler and working the existing primary reactor with once-through configuration together with the new carbamate condenser. This modification actually raises the conversion efficiency of the loop even though it is running at a drastically worse H_2O/CO_2 ratio: before modification, the loop was running at an H_2O/CO_2 ratio of 0.57 and a conversion efficiency of 64%, and after integration of the melamine plant, even though the H_2O/CO_2 ratio has gone up to 0.93, the conversion efficiency of the loop has increased to 70%, thanks to installation of HEC.

The result of this modification is that the medium- and low-pressure sections have not needed any significant modifications and the new added HP section can be easily and quickly tied in, thus limiting the shut-down period to the minimum.

Table VIII contains basic figures for the plants before and after melamine integration. They show that the introduction of the Casale HEC technology enables the HP loop capacity to be increased thanks to the improvement of the synthesis efficiency. The specific carbamate recycle flow has

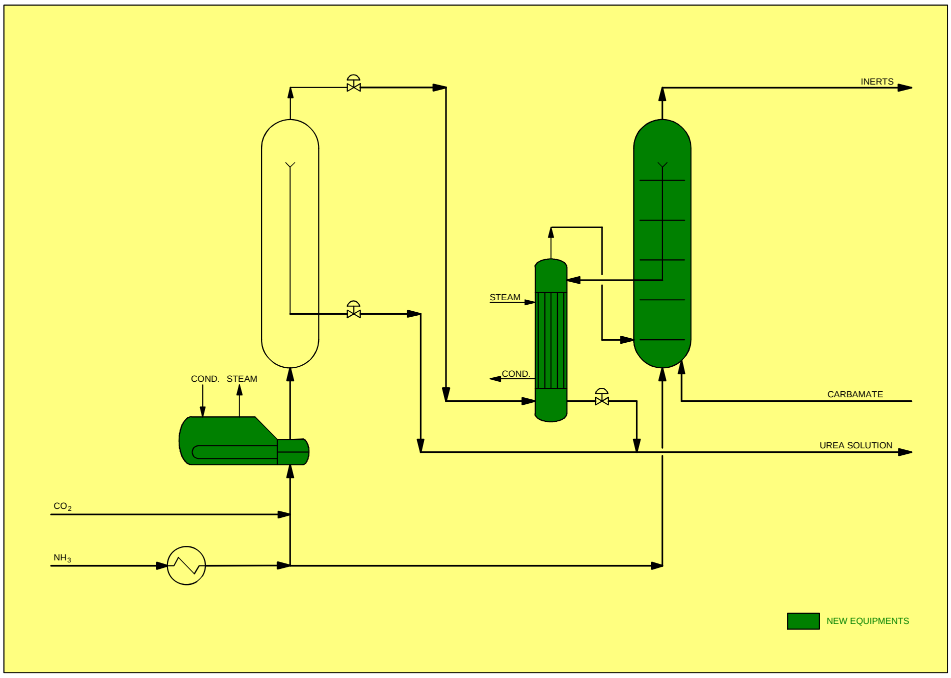

FIG. 12: NEW HEC LOOP OF TOTAL RECYCLE UREA PLANT

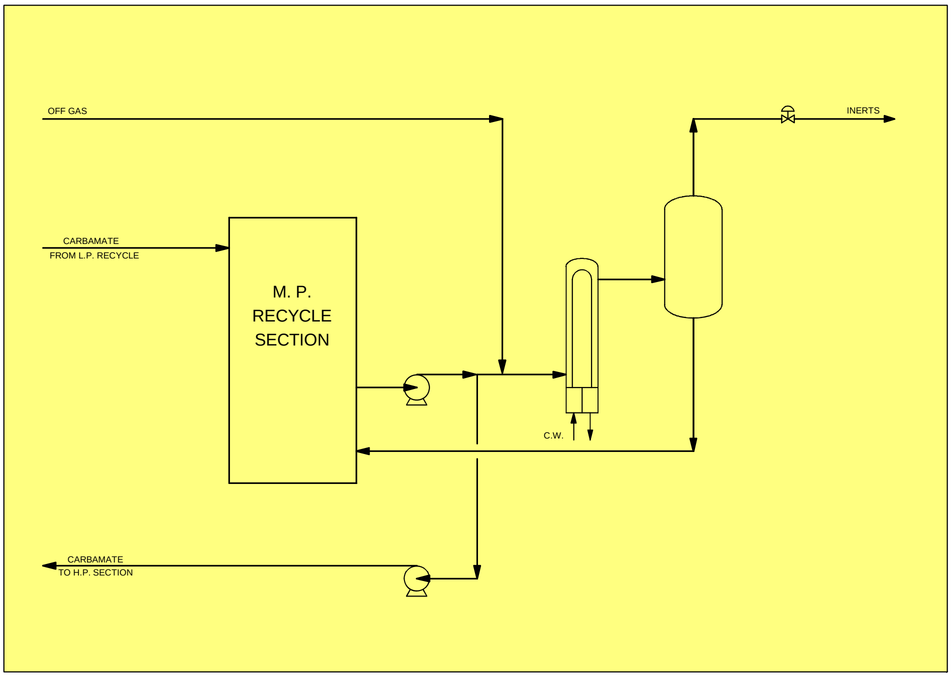

FIG. 13: NEW OFF-GAS CONDENSATION SECTION

increased by only 20% in spite of a carbamate flow increase of about 50%, which is a further confirmation of the improved efficiency of the system.

New installation/modification

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

- New secondary reactor equipped with High-Efficiency Trays
- New stripper
- New carbamate condenser
- New carbamate pumps (replacement of existing)

Table VIII
Results of Integration of Total Recycle Urea Plant

Parameters	Unit	Before	After	Incr.
Synthesis capacity	t/d	1,300	1,610	25%
Carbamate recycle	kg/h	67,000	100,000	50%
Specific carbamate recycle	kg/t	1,237	1,490	20%
NH_3/CO_2 loop ratio	-	3.48	3.58	-
H_2O/CO_2 loop ratio	-	0.57	0.93	-
Synthesis loop conversion	%	64	70	6%

In addition to these, a new off-gas condensation section was added consisting of LP carbamate pumps and an off-gas condenser with relevant tempered cooling water system.

Besides the melamine integration, the project comprehended the replacement of crystallization facilities with an evaporation section and the provision of a brand new waste-water section.

CONCLUSIONS

This paper provides some significant examples of the application of Casale technologies the in integration between urea and melamine units. Thanks to the flexibility and expertise of Casale specialists, who deal on a daily basis with different plants of various technologies, and the wide range of technologies developed and available to Casale, clients may have confidence that the required target will be achieved with the maximum energy-efficiency and limited investment.