Latest Casale technologies for grass-root fertilizer and methanol plants

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CasaleGroup

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Abstract

The founding company of the Casale group, Ammonia Casale, has long been active in designing grass root ammonia plants, mainly in the first half of the last century.

Since the end of the 70's, the Casale group has gained a worldwide reputation for the revamping of existing ammonia, urea and methanol plants of any kind gaining a leading position in this kind of activity.

More recently Casale has developed advanced technologies for the design of grass-root ammonia, urea and methanol plants, according to which grass-root plants have been designed.

This paper gives an overview of these technologies highlighting their most significant features and advantages.

The paper presents also the applications of these technologies, showing the role Casale can play being able to supply advanced designs for grass-root plants for all above type of plants as single point of responsibility.

Content

FOREWORD

Ammonia Casale S.A. is one of the oldest companies active in the field of synthetic ammonia production, having been established in Lugano (Switzerland) in 1921 for the industrial development and commercialization of Dr Luigi Casale's inventions for the catalytic synthesis of ammonia.

Since the very beginning, and for many years now, Ammonia Casale has been active in the construction of new plants, with over 200 such plants built worldwide.

More recently the activity of Ammonia Casale has been expanded also in the fields of urea and methanol production, and presently Casale is a group of companies active in various fields with its main focus on the development of technologies for the production of ammonia, urea and methanol.

The main strength of Casale lies in the licensing of its technologies. Most of the technologies are developed in house by a team of very specialized and experienced people.
Thanks to the innovative trend set by founder Dr Luigi Casale, plus the heritage and background of subsequent management teams, Casale invested significantly in technology.

During the last decades this discipline evolved from an empirical art with an intuitive sense for good design into a more rationalized activity.

Process design is now supported by sound insight into the chemistry of the processes, catalyst behaviors, kinetic data, heat and mass transfer phenomena, fluid mechanics, science of construction materials, and cost analysis.

Casale Technical Services avail themselves of specialists in all the above fields, as well as of sophisticated tools for investigating, analyzing and picturing complex phenomena in a way unachievable with ordinary skilled manual calculations. The process design is based on advanced computer-aided techniques with applications ranging from process flow-sheeting to kinetics, to fluid dynamics simulations and mechanical stress analysis.

Casale has been, in the last decades, very active in revamping existing plant and has extensive experience in the design and implementation of complete plant revamping projects, including major modifications to key equipment.

Casale's plant revamp strategy has always been to develop and apply new, advanced technologies to obtain the best possible improvement in plant performance at the minimum cost; with the aim of reducing the energy consumption and/or increasing the capacity.

With the same strategy Casale has also developed, as a natural evolution of its revamping activity; new technologies for grass root ammonia, urea and methanol plants. This paper will present these technologies highlighting their features and some applications.

TECHNOLOGIES FOR GRASS ROOT AMMONIA PLANTS

Through its company Ammonia Casale, the Casale group can offer very efficient designs for the construction of grass root ammonia plants.

For plant capacities up to 2500-3000 MTD, Casale proposes its Standard process, while if a capacity higher than 3000 MTD is required Casale can design the plant according to the MEGAMMONIA® process.

In the next sections, the two above mentioned processes are described.

The Standard Ammonia process

The Casale Standard process for natural gas based ammonia plants is based on the classical steam reforming route.

The main process steps are, as shown in fig.1:

- Desulphurization
- Primary and Secondary Reforming
- HT and LT Shift Conversion
- CO2 removal
- Methanation
- Syngas drying
- Compression
- Ammonia Synthesis
- Hydrogen Recovery

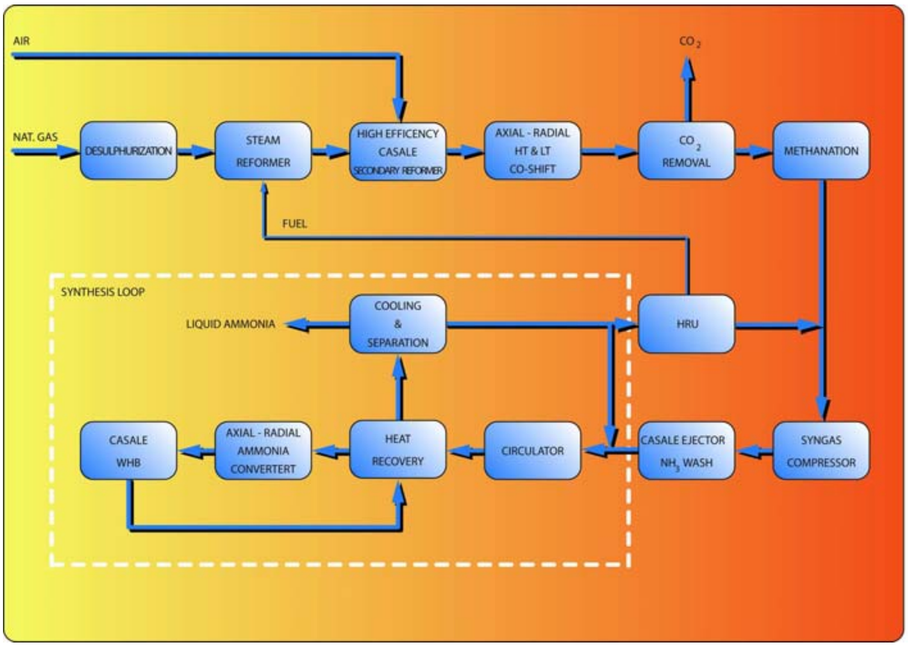

Fig 1 – Casale Standard Ammonia process

Casale Standard Ammonia Process –Characterizing Elements

The main characterizing elements of the Casale process are:

- **Casale High Efficiency design for the secondary reformer.**
- **Casale axial-radial technology for the shift conversion.**
- **CASALE Ejector ammonia wash system.**
- **Casale axial-radial technology for the Ammonia Conventer.**
- **Casale advanced Waste Heat Boiler design in the synthesis loop.**

Casale High Efficiency secondary reformer design is based on the most advanced CASALE secondary reformer burner technology, which has been developed, using Casale deep knowledge of combustion and fluid dynamic phenomena, to achieve very high combustion efficiency with low energy consumption.
The CASALE Advanced Secondary Reformer Burner has the following features:

- superior mixing in the flame;
- low pressure drop in both air and process streams;
- homogeneous gas composition and temperature distribution at catalyst bed entrance;
- reduced flame length, avoiding catalyst impingement even at high operating loads;
- low temperature of the burner surfaces exposed to the flames;
- protection of the refractory lining from the hot core of the.

Thanks to the above features of the burner, the CASALE High Efficiency secondary reformer design minimizes the size of the item guaranteeing also a high reliability with a long duration of the burner itself.

Casale Axial-Radial technology is used for the design of both the shift converters and the ammonia converter.
In an axial-radial catalyst bed (see Fig. 2) most (about 90%) of the gas passes through the catalyst bed in a radial direction, resulting in very low pressure drop. The balance passes down through a top layer of catalyst in an axial direction, thus eliminating the need for a top cover on the catalyst bed.
Mechanically the bed is very simple, being made only of the two vertical perforated walls and of one bottom closure plate. The absence of a top cover greatly simplifies and facilitates the construction of the converter internals.
The essential advantages of the axial-radial catalyst bed concept are the same wherever in the ammonia plant it is applied, namely:

- low pressure drop;
- high efficiency thank to the use of small-size catalyst.

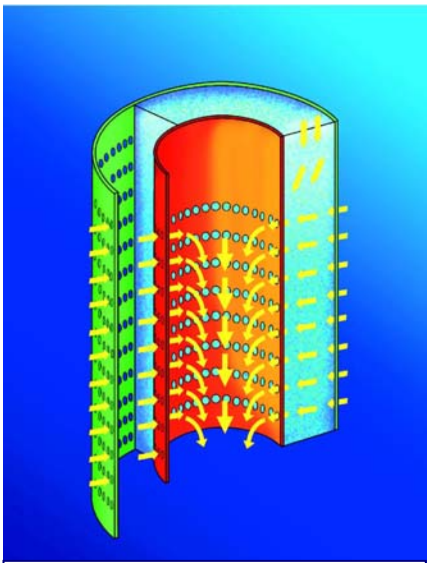

Fig 2 - Axial-Radial bed

High efficiency and low pressure drop are important features to minimize equipment size and energy consumption.

The use of Casale Axial-Radial technology in both **HT and LT shift converters** guarantees, in addition to the above mentioned features, the following advantages:

- low average CO outlet concentration.
- high reliability and longer catalyst life thanks to higher resistance to poison and water carry over.
- longer catalyst life thanks to the fact that the pressure drop across the unit remains stable all along the catalyst life.

Before entering the synthesis loop, the syngas is dried using the **CASALE Ejector ammonia wash system**, which is based on the ammonia wash technology that uses liquid ammonia to dry the syngas.
CASALE Ejector ammonia wash system consists of a specially designed ejector, which guarantees a perfect contact between the liquid ammonia and the syngas, followed by a separator, and is, therefore, very simple and efficient completely removing water and CO_2 from the syngas.
The main advantages of this system are the following:

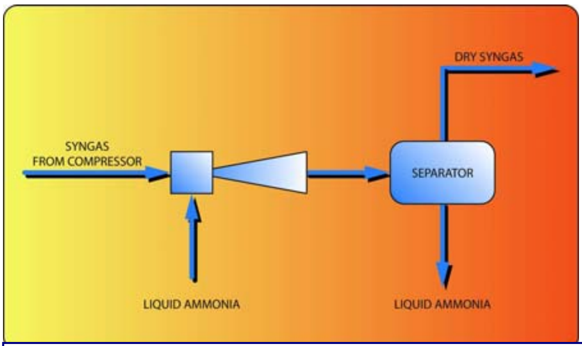

Fig 3 – Ejector ammonia wash system

- minimize the energy consumption of the refrigeration compressor as the syngas can be sent straight to the ammonia converter
- minimize the energy consumption of the circulator as its suction temperature becomes very low
- obtain a pressure recovery on the syngas.

The ammonia synthesis converter is also based on the Casale Axial-Radial technology.
This technology is combined, in the **Casale axial-radial Ammonia Conventer,** with a three beds configuration, with two interchangers, to reach a very high thermodynamic efficiency and catalyst volume utilization.
The conversion per pass is, therefore, maximized, minimizing the energy consumption of the loop and the size of the loop equipment.

An important feature in the design of the ammonia synthesis loop is the Casale advanced design for the **Waste Heat Boiler** that is downstream the converter.
The Casale Waste Heat Boiler is a U tubes exchanger with the boiling water on the tube side and the process gas shell side. The pressure shell is kept cooled by the outlet colder gas flow.
The only ferritic parts in contact with the hot gas are the tubes, which are cooled by the boiling water. With this special design it is possible to avoid any risk of nitrading.

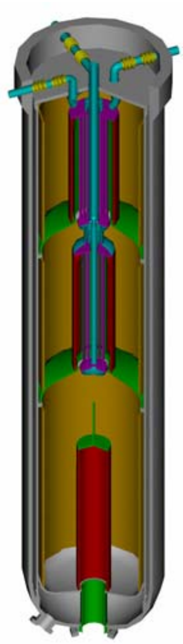

Fig 4 – Axial-Radial Ammonia converter

All the above mentioned characterizing elements used in the Casale Standard Ammonia Process have been used in many applications proving their efficiency, reliability and long operating life.

Casale Standard Ammonia Process – Performances

Thanks to those characterizing elements, whose features have been explained in the previous sections, the Casale Standard Ammonia process has very outstanding performances:

- Steam to carbon ratio (referred to NG stream only): 2.9 to 1
- CO slip from LTS: less than 0.3% vol. (dry base)
- CO2 slip from absorber: less than 300 ppm vol.
- Ammonia loop pressure: 140-160 bar
- Ammonia conversion: ab 20 %

and very low total energy consumptions (evaluated as feeds + fuel + steam import from package boiler and steam export to urea):

- ab. 7.0 Gcal/MT of produced ammonia

The high efficiency of the Casale Standard Ammonia process, which is shown also by the above performances, make it possible to reduce, for a given capacity, the size of the equipment and, therefore, to build a plant with lower investment costs then with other processes.

Casale Standard Ammonia Process – Environmental impact

The CASALE ammonia process has been designed in such a way as to minimize the environmental impact.
In fact, the only liquid wastes are the boiler blow down and the air compressor interstage coolers condensate. The boiler blow down, after flashing and cooling, is used as cooling water make-up for the cooling water loop. The same for the air compressor interstage condensate, which is returned to the cooling water return header.

The only gaseous waste is the flue gas from the primary reformer that contains about 110 mg/Nm3 of NOx. The guaranteed figure of NOx is less than the one required by the European Community for new plants (140 mg/NM3 calculated at 3% oxygen excess).

The MEGAMMONIA® process

The MEGAMMONIA® process has been developed by Casale together with Lurgi for the design of natural gas based single line ammonia plants with very high capacities.

The main concept of the MEGAMMONIA® process is to use an Autothermal Reforming to generate the syngas at a higher pressure than in the Standard process, use a physical process for the CO_2 removal (Rectisol®), which gives, at higher pressure, much higher efficiency than standard chemical processes, and a highly efficient design for the Shift and Ammonia Synthesis converters, which enables, in combination with the use of the Nitrogen wash unit, to keep the size of these converters and of the entire synthesis loop within constructible size even at very high capacity.

As illustrated in fig 5 the MEGAMMONIA® process comprises the following main steps:

- Air Separation (ASU)
- Desulphurization
- Autothermal Reforming (ATR)
- HT Shift Conversion
- CO_2 removal
- Nitrogen wash
- Compression
- Ammonia Synthesis

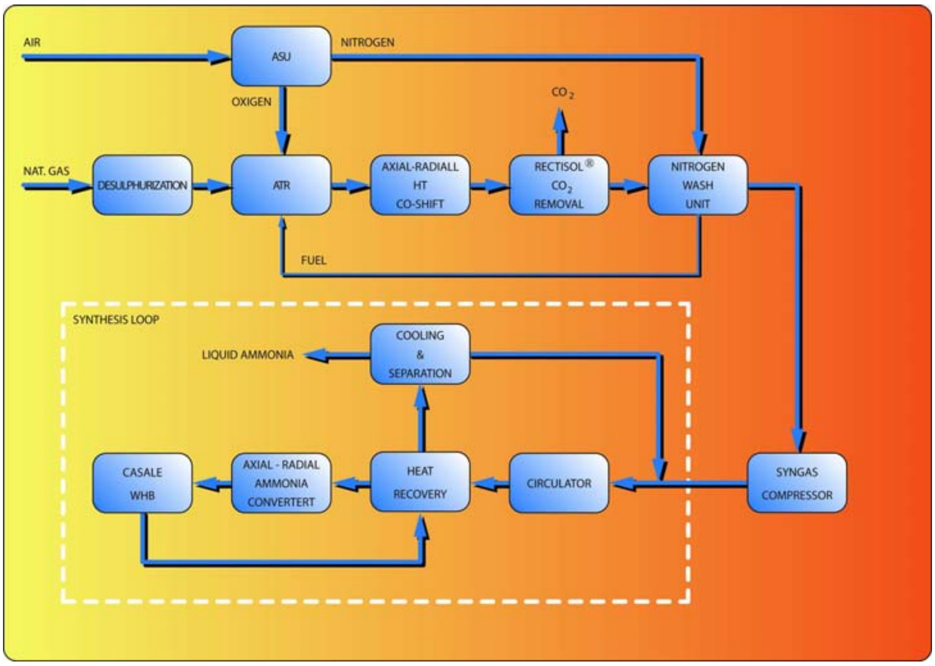

Fig 5 - Block Diagram of the MEGAMMONIA® Process

The ASU, which is a well known and widely used process, is used to produce the gaseous stream of almost pure oxygen required in the Autothermal Reformer, and a stream of pure nitrogen, which is used to dry the syngas and eliminate all the inerts supplying at the same time the required amount of nitrogen to the synthesis section.

The ATR unit, which follows the desulphurization of the natural gas, consists of a pre-reformer, to convert all higher hydrocarbons to hydrogen and methane, followed by a fire heater, to preheat the gas, and the ATR reactor itself.
The use of the ATR allows the generation of large quantities of syngas without the limitations of the primary reformer in terms of size and operating pressure. The ATR is, in fact, avoiding parallel units and maximizing the plant simplicity, with benefit on the investment costs.
The most advanced designs for the burners are used for the ATR reactor, which are based on the deep knowledge of the combustions and fluid dynamic phenomena, which is available to Casale.

The ATR is followed by the CO-Shift Unit, consisting of two Axial-Radial beds of conventional HT catalyst in series.
The Axial-Radial design, which is described in the previous section, is an essential feature to minimize catalyst volume, pressure drop and vessel diameter, which is extremely important to reach high capacities in a feasible way.

Gas Purification is accomplished in two steps, the first removing CO_2 and the second removing the remaining impurities; namely CO, CH_4 and Ar.
CO_2 is removed by absorption in cold methanol, according to the well known Rectisol® process. This process, which is a physical absorption process, is the best suited to minimize the size of the CO_2 removal unit as it features high efficiency if it is operated at relatively high pressure as in the MEGAMMONIA® process. Again, this is very important to reach large capacity in a simple and cost effective way.

CO, CH_4 and Ar are removed by washing the gas with liquid nitrogen, which is produced in the ASU. The recovered impurities, CO, CH_4 and Ar are recycled to the ATR Unit for use as fuel in the fired heater.
The added nitrogen remains in the synthesis gas and is sent, with H_2 and N_2 in the correct stoichiometric proportion, to the Ammonia Synthesis Unit.

The Ammonia Synthesis Unit is based on the Casale Axial-Radial design described in the previous section. The ammonia converter has a three beds configuration, with two interchangers, already described in the previous section.
This most efficient converter design, combined with the absence of inerts, enable to reach very large capacity of the synthesis loop with a still feasible size of its equipment.

The converter is followed by a boiler designed according to Casale most advanced design, as described in the previous section.

Megammonia Process – Performances

Thanks to its innovative and novel design and to its special features, which have been explained in the previous section, the MEGAMMONIA® process has very outstanding performances, such as a very low total energy consumptions (evaluated as feeds + fuel + steam import from package boiler and steam export to urea):

- ab. 6.75-7 Gcal/MT of produced ammonia

These outstanding performances make it feasible to build plants with very large capacity, 4000 MTD and higher, in a real single line.

TECHNOLOGIES FOR GRASS ROOT UREA PLANTS

Urea Casale is the company in the Casale group that is active in the urea field and that has developed a novel process to design grass root urea plant.
This process is called the Casale **Split Flow Loop™** process, and is an improved CO_2 stripping process.

Casale Split Flow Loop™ Process

The main concept of the **Split Flow Loop™** process is to split the total amount of inerts present in the CO_2 feedstock so that only a minority portion is sent to the reactor, which is operating with the lowest possible amount of inerts. In addition, high condensation efficiency is reached in the HP carbamate condensation using a submerged condenser. This is achieved with the following steps:

- The vapours, containing NH_3, CO_2, H_2O and inerts, obtained from the HP stripper are split so that a minority portion is sent directly to the reactor while the majority portion is sent to the HP carbamate condenser.
- The portion of vapour sent to the HP carbamate condenser is totally condensed, in a submerged condenser, obtaining a carbamate stream and an uncondensed stream of inerts.
- The stream of inerts leaving the HP carbamate condenser is sent straight to the HP scrubber, bypassing the reactor.

The main steps of the **Split Flow Loop™** process are the following (see Fig. 6):

- The solution from the reactor is first treated in a stripper, operating at the same pressure of the reactor, where, using steam and CO_2 as stripping agent, most of the unreacted NH_3 and CO_2 are recovered.
- Part of the unreacted NH_3 and CO_2 recovered in the stripper are sent directly to the reactor, while the rest is recycled back to the reactor through a HP condenser.
- From the stripper, the urea solution, still containing unreacted NH_3 and CO_2 in form of carbamate, is sent to a low-pressure single decomposition/condensation stage where practically all the remaining unreacted NH_3 and CO_2 is recovered in form of a carbamate solution.
- The urea-water solution, containing only small quantities of NH_3 and CO_2, is then further treated in a two-stage vacuum evaporation section to obtain a urea melt for the prilling tower or the granulator.
- The process condensate, obtained from the vacuum condensers is purified with two columns and one hydrolyser in order to eliminate all NH_3, CO_2 and Urea.
- The carbamate solution obtained in the LP section is sent to the HP scrubber where the inerts leaving the HP loop are washed.

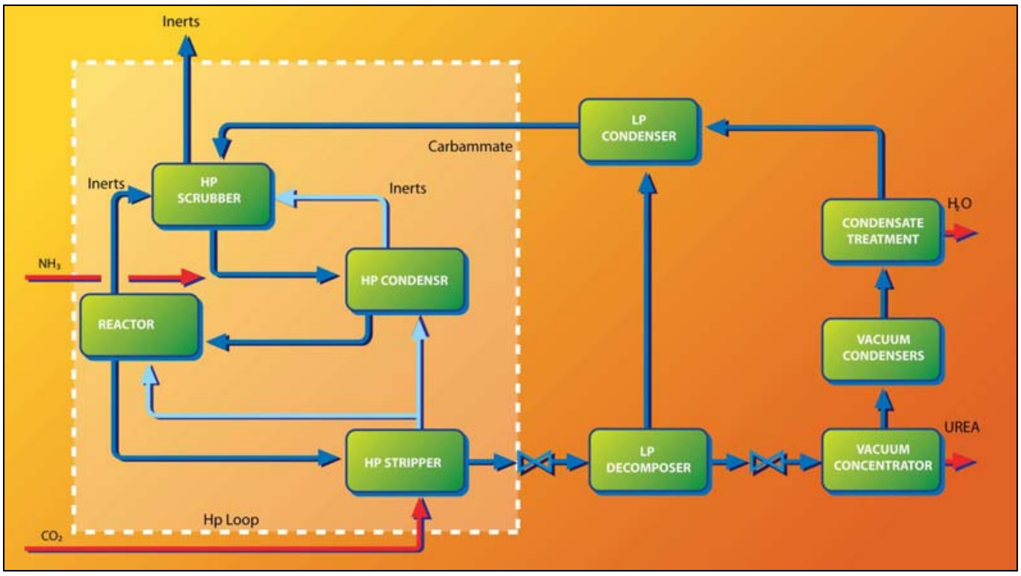

Fig. 6 - Split Flow Loop™ Process

The solution leaving the reactor is treated in the HP stripper where the carbamate present in the solution, containing unreacted NH_3 and CO_2, is decomposed using CO_2 feed as stripping agent.
The vapour stream (NH_3, CO_2 and H_2O) generated in the stripper, containing also all inerts, is split after leaving the HP stripper.
One portion of that vapour stream will go to the HP carbamate condenser (HPCC), while the rest of the vapours bypasses the condenser and goes directly to the reactor.
The HPCC is practically a total condenser of the submerged type and the carbamate flow obtained in this equipment is sent to the reactor.
Total condensation in the condenser is not possible because of the presence of inerts, a small amount of not condensed vapours leaves, therefore, from the top of the condenser and is sent directly to a HP scrubber together with the inerts.
In this way, about 2/3 of the total amount of the inerts present in the CO_2 are not sent to the reactor, and consequently the urea conversion is maximized.
The HP scrubber recovers NH_3 and CO_2 from the inerts streams leaving the HPCC and the reactor using the carbamate flow coming form the LP recovery section. The carbamate flow coming from the HP scrubber is sent to the HPCC, to enhance the condensation, using an ejector driven by the ammonia feed, which is also sent to the HPCC.
In order to keep the correct ratio in the HPCC, part of the CO2 feed is bypassing the HPCC and is sent to the reactor through a new ejector that enhances the driving force for the circulation sucking the carbamate leaving the HPCC.

In the **Split Flow Loop™** process, the synthesis section operates with very low inerts content with the following advantages:

- high CO_2 conversion in the reactor (up to 63-64%)
- high stripping efficiency
- high condensation efficiency.

For this reason, the Casale **Split Flow Loop™** process is a process with high efficiency requiring, for a given capacity, equipment of smaller size with low investment costs.

For what the operating costs are concerned, the **Split Flow Loop™** process has values as low as the most advanced processes.

The Casale **Split Flow Loop™** process is, therefore, suited for plants of large capacity. The most critical equipment are, in fact, smaller, for a given capacity, than in conventional processes.

Casale Split Flow Loop™ process –Characterizing Elements

The main elements characterizing the HP loop of the **Split Flow Loop™** process are:

- the **Casale Full Condenser™**
- the **Casale-Dente high efficiency trays**
- the **Casale High Efficiency Hydrolyser** used in the process condensate treatment unit

The **Casale Full Condenser™** is a submerged condenser with a natural circulation.

A mixed two-phases flow flows up in most of the tubes with a very small amount of tubes, which are left without vapour phase, where liquid flows downward, thanks to the density gradient with the other tubes. This produces an internal natural circulation.
Consequently, the new internal flow regime is a bubble flow inside a continuous liquid. In this way, the interfacial area between two phases (liquid and gas) is significantly increased, so that the transfer performance of the exchanger is highly improved.
Moreover, the HPCC will be even better protected from corrosion in the new configuration, as all tubes surfaces will be better wetted.

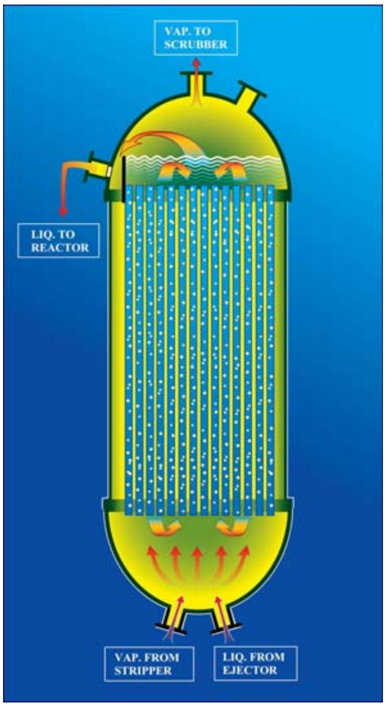

Fig. 7 - Full Condenser™

The new flow patter of the HPCC is shown in the sketch of Fig.7, and can be summarized as follow:

- Vapours coming from HP stripper are fed through one of the bottom nozzle and distributed inside the continuous liquid phase by a distributor on the bottom of the HPCC.
- The two-phase flow, thanks to its lower density, flows upward and along the tubes the vapours condense.
- The two-phase flow exits the tubes from the top tube sheet and the inerts separates from the condensed liquid and exit the condenser from the top nozzle.
- Fresh liquid (ammonia and carbamate mixture) enters the exchanger through the second nozzle in the bottom and is distributed in the tubes.
- A top weir defines the liquid level in the top part of the condenser, the overflowing liquid exits the exchanger through the second top nozzle.

The optimal circulation ratio is determined by Casale in order to achieve optimal condition for the heat transfer in the two-phase upward tubes.

The **Full Condenser™** is a very efficient condenser with 50% higher heat transfer efficiency than a standard falling film condenser.
In addition being a submerged condenser a significant amount of urea is formed in the condenser itself reducing the load of the reactor.

All the above features are obtained with a very simple, proven and reliable mechanical design used in many applications for the falling film configuration. With a very simple improvement in the internal part, the same design can work in a much more efficient configuration.

The **Casale-dente high efficiency trays** are the most efficient trays available in the market and are also an essential element to make **Split Flow Loop™** as efficient as possible.

The Casale-Dente design, in fact, improves the tray geometry realising a very efficient transfer of NH_3 and CO_2 from the vapours into the liquid phase where urea is formed.

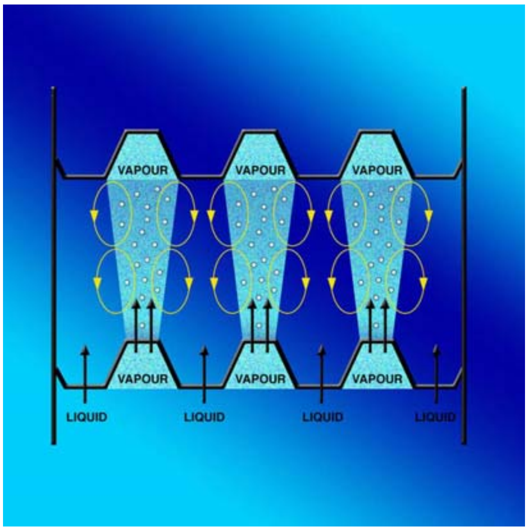

Fig. 8 - Casale-Dente High Efficiency Trays

The new trays (see Fig. 8) 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 vapour and liquid is obtained. Consequently a very high mass and heat transport within the liquid phase is realised.
- With an appropriate design, the diameter of the generated vapour 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.

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 vapours and liquid.

The last important element of the **Split Flow Loop™** process is the **High Efficiency Hydrolyser** that allows treating very efficiently the process condensate, eliminating all NH_3 and Ur, so that it can be discharged without any environmental effects or it can be used as boiler feed water.

With the help of Urea Casale's High Efficiency Hydrolyser (HEH - see Fig 9), 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.

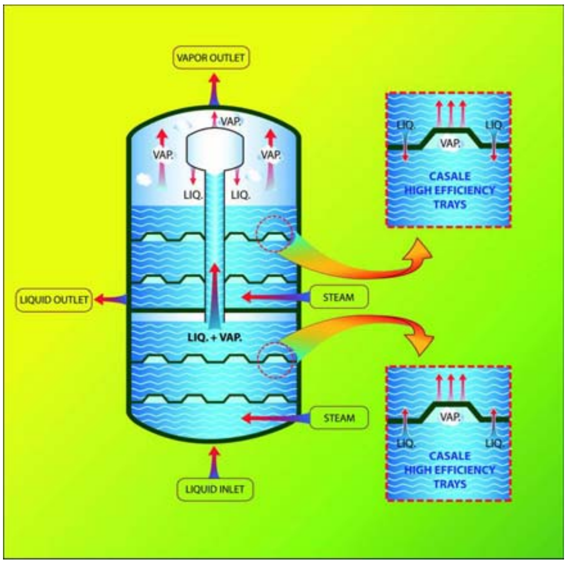

Fig. 9 - Casale High Efficiency Hydrolyser

The High Efficiency Casale Hydrolyser (see Fig. 9) 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 maximise 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 vapours (containing NH_3 and CO_2), creating a multiplicity of streams of vapours, which are injected again into the liquid in form of column of small bubbles maximising the mass and heat transfer.

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

Casale Split Flow Loop™ Process – Performances

Thanks to those elements, whose features have been explained in the previous sections, the **Split Flow Loop™** process has very outstanding performances:

• CO_2 conversion in the reactor	63.5 %
• stripping efficiency	82 %
• pressure of produced LP steam	up to 5 bara
• specific carbamate recycle rate	450 kg/MT

and very low consumptions:

• MP steam consumption (22bar, superheated)	750 kg/MT
• Raw material consumption	almost stechiometric

The high efficiency of the Casale **Split Flow Loop™** process, which is shown also by the above performances, make it possible to reduce, for a given capacity, the size of the equipment and, therefore, to build a plant with lower investment costs then with other processes.

TECHNOLOGIES FOR GRASS METHANOL PLANTS

The Casale group can also offer very efficient designs for the construction of grass root methanol plants through its company Methanol Casale.

For plant capacities up to 3000, Casale proposes its Standard process, while for capacities higher than 3000 MTD and up to 7000-10000 Casale designs the plant according to its Advanced Methanol process.

In the next sections, the two above mentioned processes are described.

The Standard Methanol process

The Casale Standard process for natural gas based methanol plants is based on the classical steam reforming route.

The main process steps are, as shown in fig.10:

- Steam Reforming
- Heat recovery and cooling
- Compression
- Ammonia Synthesis
- Distillation

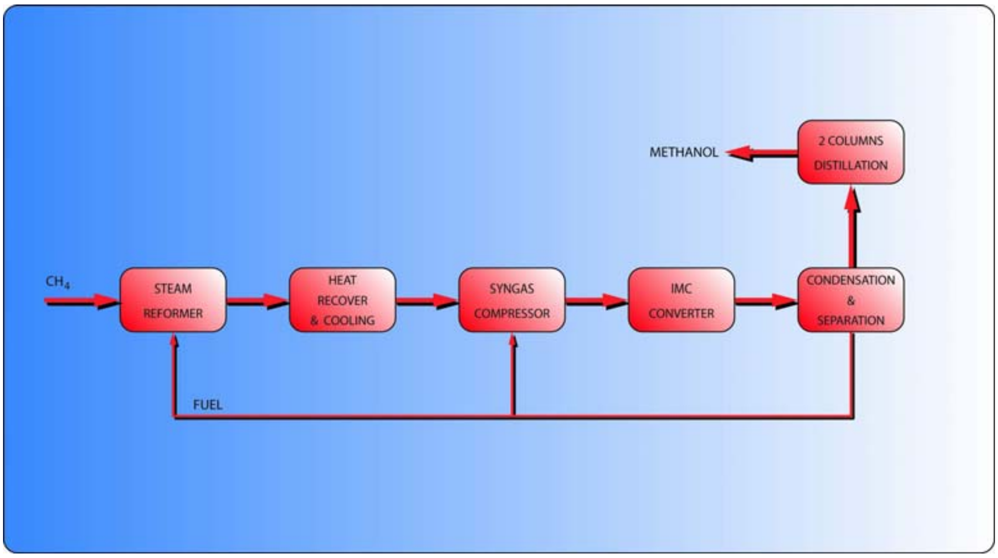

Fig. 10 - Casale Standard Methanol process

Casale Standard Methanol Process –Characterizing Elements

The main characterizing element of the Casale process is the synthesis converter. The synthesis converter plays, in fact, a very important role in a methanol process as the synthesis loop represent a significant part of the entire plant and the efficiency of the converter has a big influence on the size of the loop.

The synthesis converter in the Casale process is designed according to its most advanced methanol converter design which is the IMC, see fig 11.

The IMC is a pseudo isothermal converter in which the heat transfer surfaces are plates instead of tubes, and the catalyst is outside the cooling plates.
This new design has the following main characteristics:

- The heat removal from different parts of the catalytic bed can be controlled independently enabling a perfect control the temperature profile in the catalyst mass so that it becomes possible to operate the catalyst according to the highest reaction rate temperature profile
- Heat can be removed directly from the catalytic bed without the need of tube sheets
- The converter can be designed with Casale axial-radial flow configuration

Thanks to the above features, it is possible to reach the maximum efficiency for given operating conditions and reaction volume and to minimize the size and number of the loop equipment and pipes and the energy consumption and to maximize the carbon efficiency.

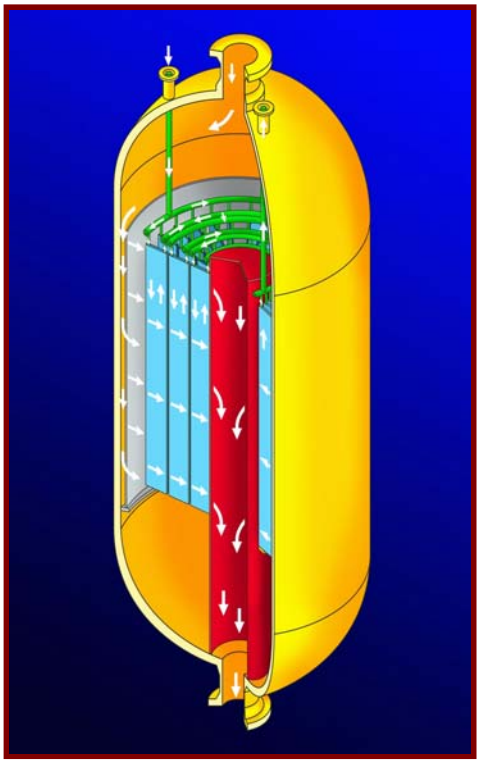

Fig. 11 - IMC converter

The cooling fluid flowing inside the plates can be the fresh converter feed gas, water or other heat transfer fluid. A combination of different fluid is also possible.

Another advantage of the above features is that with the IMC design it is possible to build converters which have a very high capacity in a single vessel.

Casale Standard Methanol Process – Performances

Thanks to those characterizing elements, whose features have been explained in the previous sections, the Casale Standard Methanol process has very outstanding performances, which makes it possible to reduce, for a given capacity, the size of the equipment and, therefore, to build a plant with lower investment costs then with other processes :

- Steam to carbon ratio (referred to NG stream only): 2.5 to 3.0
- Methanol loop pressure: 80 bar
- Methanol conversion: ab 7 %
- Energy consumptions: ab. 7 Gcal/MT of produced methanol

The Advanced Methanol process for large capacity

The Casale Advanced Methanol process has been developed by Casale for the design of natural gas based single line methanol plants with very high capacities, up to 7000 MTD and more.

The main concept of the Casale Advanced Methanol process is to use Combined Reforming scheme (or Banquy scheme) to generate the syngas in large quantity, and to use the Casale IMC converter able to produce very high capacity with a single vessel design.

As illustrated in fig 12 the Casale Advanced Methanol process comprises the following main steps:

- Air Separation (ASU)
- Steam Reforming
- Autothermal Reforming (ATR)
- Heat recovery and cooling
- Compression
- Methanol Synthesis
- Distillation

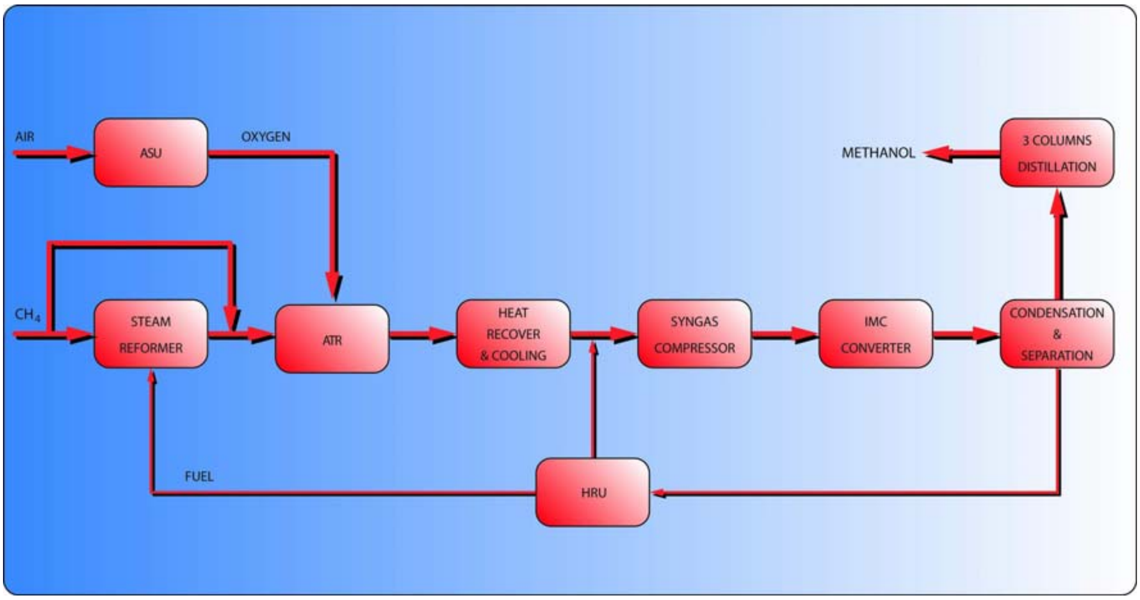

Fig. 12 - Casale Advanced Methanol process

The proposed plant scheme is based on the production of synthesis gas from natural gas with the well known combined reforming scheme, also known as the Banquy scheme, which is the combination of a steam reforming with an auto thermal reforming (ATR) with oxygen.
According to this scheme, the natural gas feed is divided into two fractions, a first fraction is sent to the steam reforming while the second by-passes the steam reforming and is sent straight to the ATR converter, together with the effluent from the steam reforming, where it reacts with Oxygen,

produced by an Air Separation Unit, to generate the syngas with a composition suitable for the methanol production.

Fig. 13 – ATR burner

The ATR is characterized by a special Casale design to achieve a perfect mixing between oxygen and gas obtaining a very good combustion.
This design, which is in service in few methanol and ammonia plants, has the following features:

- High reliability and long durability, with several years of operation without any sign of deterioration.
- High efficiency of conversion of methane to syngas;
- Total absence of soot formation, as evidenced by the analysis and inspections on ATR catalyst and downstream equipment;
- Wide flexibility, it has been successfully operated at temperature conditions, composition and flow rates far from the design ones.

The syngas produced from the combined reforming section is sent, after heat recovery, cooling and compression, to the synthesis section.

The Methanol Synthesis section is based on the IMC design described in the previous section. The methanol converter has a two beds configuration; with one bed using fresh converter feed gas as cooling media, and the other using boiling water.
The very efficient IMC design, combined with the special converter configuration, enables to reach very large capacity of the synthesis loop with a still feasible size of its equipment.

The produced methanol is purified in a fairly standard three-column distillation system.

Advanced Methanol Process – Performances

Thanks to its innovative and novel design and to its special features, which have been explained in the previous section, the Advanced Methanol process has very outstanding performances, such as a very low total energy consumptions: ab. 6.8 Gcal/MT of produced methanol.

These outstanding performances make it feasible to build plants with very large capacity, 7000 MTD and higher, in a real single line.

IMPLEMENTATION OF PROJECTS FOR GRASS ROOT PLANTS

Casale has completed and is also currently working on several projects that are involving the implementation of the technologies described in the previous sections.

The Casale Standard ammonia process is currently operating in a 2050 MTD plant in Iran operated by Razi Petrochemical Company. The new plant that has been designed by Casale, and built by the Iranian contractor Pidec, is in operation since the beginning of 2008.

A second 2050 MTD ammonia plant is under advanced implementation in Iran to be built for Shiraz Petrochemical Company.

Recently, Casale has been awarded with three more contracts for the design of three new 2050 MTD ammonia plants in various location in Iran.



Fig. 14 - Casale Standard Ammonia process in operation in Iran

The **Split Flow Loop™** urea process is operating in Ukraine in a plant that was originally designed according to the CO_2 stripping technology and that was revamped by Casale modifying it according to the **Split Flow Loop™** process.

The plant is also incorporating the Casale High Efficiency Trays design for the reactor and the **Full Condenser™** design for the HPCC, and this makes it a full reference for the Casale **Split Flow Loop™** process as described in this document.

The plant is operating since 2003 according to **Split Flow Loop™** process and is producing 1500 MTD of urea.

The plant was originally designed according to the CO_2 stripping technology with a design capacity of 1000 MTD of Urea.

In conclusion, we can say that the **Split Flow Loop™** process is proven and, as it has demonstrated to be very suited to increase the capacity of existing plants keeping the same equipment, can be conveniently used to design new plants with minimum investment.

Casale has also recently designed, according to the **Split Flow Loop™** process, a grass-root urea plant to be built in France.

Fig. 15 - Split Flow Loop™ Process in Operation in Ukraine

The Casale Standard methanol process is currently operating in two plants in Russia designed for a capacity of 1350 MTD and 1650 MTD respectively.

The plants that have been designed by Casale, who supplied also all engineering and most of the material on EP basis, are in operation since 2000 and 2006 respectively.

A 7000 MTD plant designed according to the Casale Advanced methanol process is under implementation in Iran.

Key components of Casale methanol processes, such as the IMC converter, are in operation at capacities up to 3200 MTD.

Fig. 16
Casale Standard methanol plant in Operation in Russia

CONCLUSIONS

Through the continuous development of its technologies, Casale has been able to develop innovative processes for ammonia, urea and methanol grass root plants.

With these new processes Casale can design world scale fertilizer and methanol plants and is ready to respond to the future market demand in terms of plant capacity with its advanced processes specially conceived to design plants of very large capacity.

Casale is now in the unique position to own proprietary technologies for the design of grass root plants for all three products, ammonia, urea and methanol.