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CASALE GROUP EXPERIENCE IN REVAMPING AMMONIA AND UREA PLANTS

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ABSTRACT

This paper presents the approach taken by CASALE Companies (AMMONIA, UREA,) to revamp ammonia and urea in order to reduce the energy consumption and/or increase their production capacity with a minimum investment cost and the highest benefits.

This approach is based on a number of new technologies developed on purpose by The CASALE companies, that are here illustrated.

1. INTRODUCTION

AMMONIA CASALE S.A. of Switzerland is an independent engineering company that has been operating world-wide for more than 77 years in the field of ammonia and methanol plants. More recently the range of products has been widened entering also in the field of urea and formaldehyde plants.

For that purpose the company has been split in four, AMMONIA CASALE S.A., UREA CASALE S.A., METHANOL CASALE S.A. and CASALE CHEMICALS S.A., each one taking care of the relevant processes.
All four companies are fully owned by CASALE Holding S.A.

The common targets of CASALE Companies gain substance from the sale of:

* licenses for the exploitation of technologies;
* engineering services;
* equipment and materials;
* complete plant units;
* technical assistance services.

The most outstanding characteristic of all the CASALE Companies is their philosophy of developing new technologies in their field of operation and to market these new technologies.

That is quite different from most engineering contractors that normally obtain licenses from the technology owner. Therefore, the main goal of most contractors is to sell man-hours and materials, from which they obtain their profit.

This leads to the fact that when they tackle a revamping job, the result is a very large project, involving the replacement of many items and a lot of engineering man-hours, rendering it an expensive approach.

On the contrary the CASALE philosophy is to find a way to overcome the existing plant constraints with the smallest effort by applying new ideas and technology, thus reducing amount of items to be replaced to a minimum and the man-hours as well.

The general approach of CASALE to plants revamping is to upgrade the efficiency of the plant's key equipment with innovative technology rather than just increasing the size and/or adding additional equipment.
Most of the technologies have been developed by CASALE to accomplish these goals.

Another unique characteristic of CASALE is that disposing of both ammonia and urea technologies, it is the only company world-wide that can offer integrated packages for revamping both plants, without the difficulties due to the presence of two different engineering companies working in the same plants.

Based on these ideas, CASALE has developed a number of solutions that are here illustrated to revamp ammonia and urea plants for capacity increase and energy efficiency improvements.

2. AMMONIA CASALE S.A.

In the early thirties the Casale share of total world ammonia production (1 million t/y at that time) was about 60 %; in the early eighties it was only 8 % of the total 95 million t/y world production and today is one third of 130 million t/y world production.

The above is thanks mostly to the revamping of synthesis units. The development effort of Ammonia Casale is quantified in Table 1.

As shown in the table, although the total capacity of new plants by Ammonia Casale continued to increase with time, the new entries reduced progressively the Casale share of the total market, until the new deal of plant modernization activity started during early eighties, regaining for Ammonia Casale an evenly increasing share.

The Company is at the present time a leading licensor of the ammonia synthesis technology. The following international companies are Ammonia Casale S.A.'s licensees:

- Chiyoda Corporation Japan
- ICI Katalco U.K.
- Linde AG Germany
- Technip France
- Ube Industries Ltd. Japan

Table 1: AMMONIA PRODUCING PLANTS CONSTRUCTED OR RETROFITTED BY AMMONIA CASALE S.A. IN COMPARISON TO THE TOTAL WORLD PRODUCTION OF AMMONIA

Year	Number of units con-structed or retro-fitted	Total capacity (t/d)	Average capacity (t/d per unit)	Total Cumulative capacity (t/d)	Total Cumulative capacity (10^3 t/y)	World production (10^3 t/y)	World capacity (10^3 t/y)	% of the total world capacity
1922-1930	120	4'180	34	4'180	1'400	1'150	2'400	58
1931-1940	9	320	35	4'500	1'500	3'300	5'000	30
1941-1950	12	740	62	5'240	1'700	6'000	6'500	26
1951-1960	38	4'190	110	9'430	3'100	14'700	17'000	18
1961-1970	35	11'270	320	20'700	6'800	49'200	62'000	11
1971-1980	5	1'890	380	22'590	7'500	94'200	95'000	8
1981-1990	50	50'410	1'000	73'000	24'000	117'000	123'000	20
1991-1997	58	62'930	1'070	134'930	44'500	125'000	130'000	34

3. REVAMPING OF AMMONIA PLANTS

3.1 Primary Reformer modification, Case history

In ’94, due to the rise of methanol prices and to the low price of ammonia, a large ammonia producer in Russia, namely TOAZ, asked Methanol Casale to study the possibility to transform one of the 3 GIAP AM 76 ammonia plants in one methanol plant keeping the same production capacity.
At the end of ’95 TOAZ decided not to transform one of the existing ammonia plants, but to build a new methanol plant, using as many as existing pieces of equipment possible in its warehouse, originally designed for the eighth ammonia plant.
A new methanol plant with a capacity of 1350 MTPD (1477 STPD) was designed by Methanol Casale S.A. taking into account TOAZ's requirements not only to maximise the use of the equipment present at site, but also to maximise the manufacturing of the new equipment inside the C.I.S. countries that was done under Casale supervision and responsibility.

There are two main features of the new methanol plant:

1. the redesign of the existing ammonia reformer in order to meet the requirement of a new methanol reformer;

2. the new horizontal methanol converter.

In this paper the transformation of the primary reformer is presented.

3.2. Steam Reforming Revamping

The process scheme of the GIAP ammonia reformer, which is very similar to a Kellogg, is detailed in fig. 1 together with the convection section.

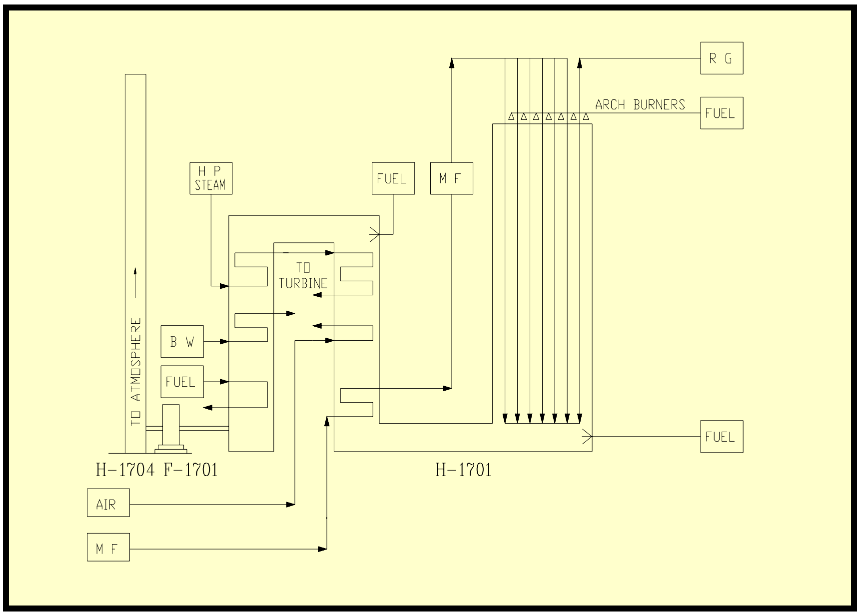

Fig. 1: Existing Reformer Process Scheme

In order to reach the guaranteed 1360 MTD methanol, the new reformer configuration required the process design modifications as per fig. 2.

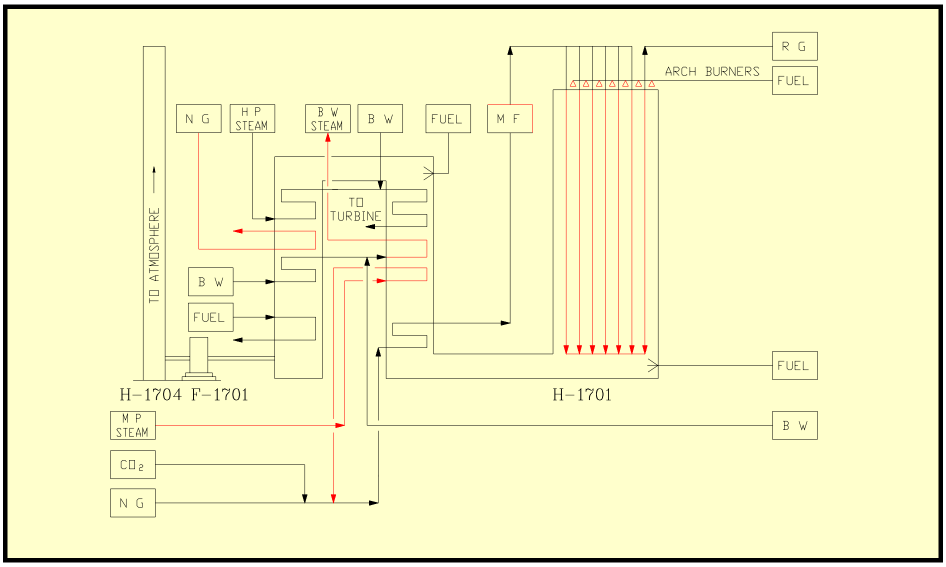

Fig. 2: Retrofitted Reformer Process Scheme

The main revamping features were the following:

- Increase of reforming catalyst quantity from 20,8 m3 to 37,6 m3 by changing catalyst tubes;
- Increase of radiant heat liberation from 170'000'000 kcal/h to 227'000'000 kcal/h by modification of roof burners;
- Addition of one BFW heater/boiler convection coil;
- Addition of one natural gas preheater convection coil;
- Utilization of existing air preheater convection coil to heat MP process steam;
- Addition of inline de-superheater between 1st and 2nd stage H.P. steam superheaters to control the temperature at H.P. turbine inlet.

3.3 New Catalytic Tubes

In order to increase the volume of catalyst new catalytic tubes were designed.
The new tubes were increased in diameter from 114 mm to 121 mm and decreased in thickness from 21 mm to 12 mm.
The decrease of thickness was possible thanks to the use of new material 25Cr 35NiNb microalloy, which has proven its reliability in industrial application in the last ten years.
In this material the Niobium and other elements are added in calculated quantities to improve creep strength, ductility at high temperatures and strain relaxation.
Thanks to the reduced thickness the thermal stress in the tube wall during start-up and shut-down is decreased with consequent expected longer tube life.
The tubes were shipped in preassembled harps in order to minimise the number of welds at site.

3.4 Increase of Burners Heat Liberation

The existing burners were designed for a total heat liberation of 188'000'000 kcal/h, while the new required heat liberation is 227'000'000 kcal/h.
Therefore, the existing burners were simulated in the new conditions to check if they were suitable for the new capacity and if the new flame did not impinge on the catalytic tubes.
The check revealed that only the burner nozzle had to be resized and replaced for the new conditions.

3.5 Modification of Convection Section

The new process design of the methanol plant has required the following retrofitting of the reformer convection section.

Process steam heater

The existing air preheater has been utilised to heat process steam before mixing with natural gas.
No modifications were required in this coil.

BFW heater/boiler

Between the process steam heater and the 2nd stage steam superheater a new BFW heater has been inserted.
In this coil the BFW is heated up to boiling point and a part of it is evaporated.
The new coil is made of 40 tubes in 2¹/₄ Cr 1Mo material derived in two rows (see Fig. 3).

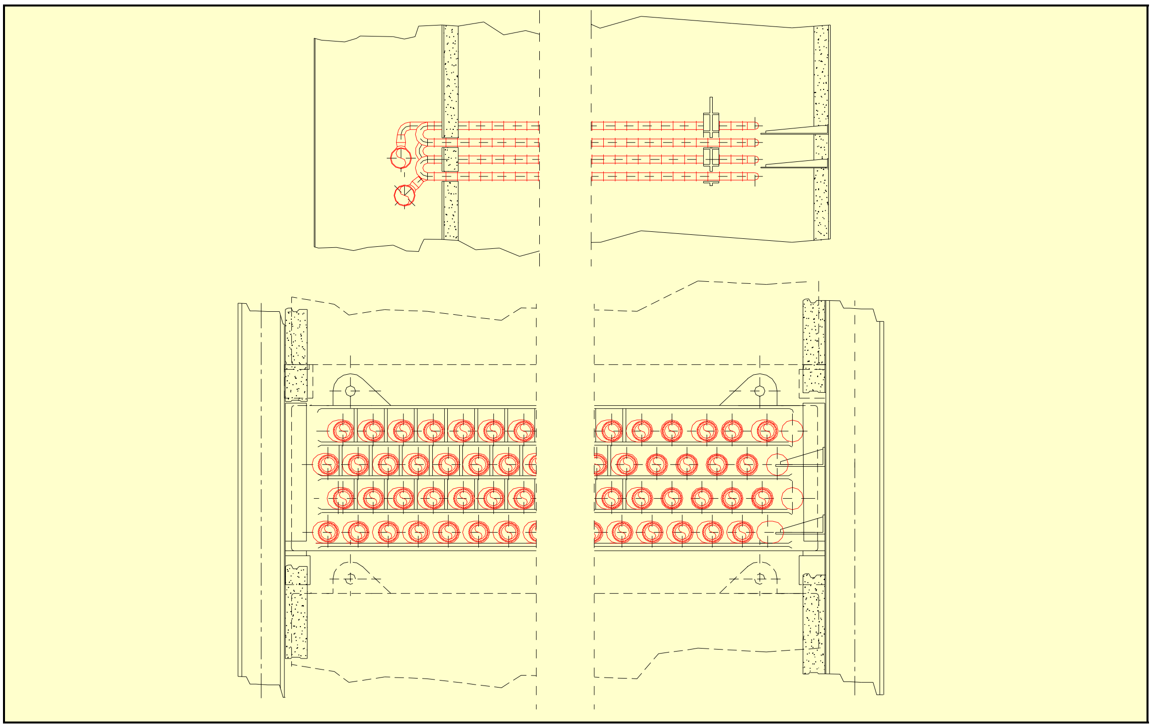

Fig. 3: New BFW Heater/Boiler

H.P. steam desuperheater

A new H.P. steam desuperheater was inserted between 1st and 2nd stage steam superheaters to control the steam temperature at inlet of H.P. steam turbine.
The desuperheater is characterised (see Fig 4) by a steam stud with atomiser which produces fine water drops.

Downstream the superheater the steam flows in 18 m long pipe to evaporate the water drops completely before entering the next stage of coil steam superheater.

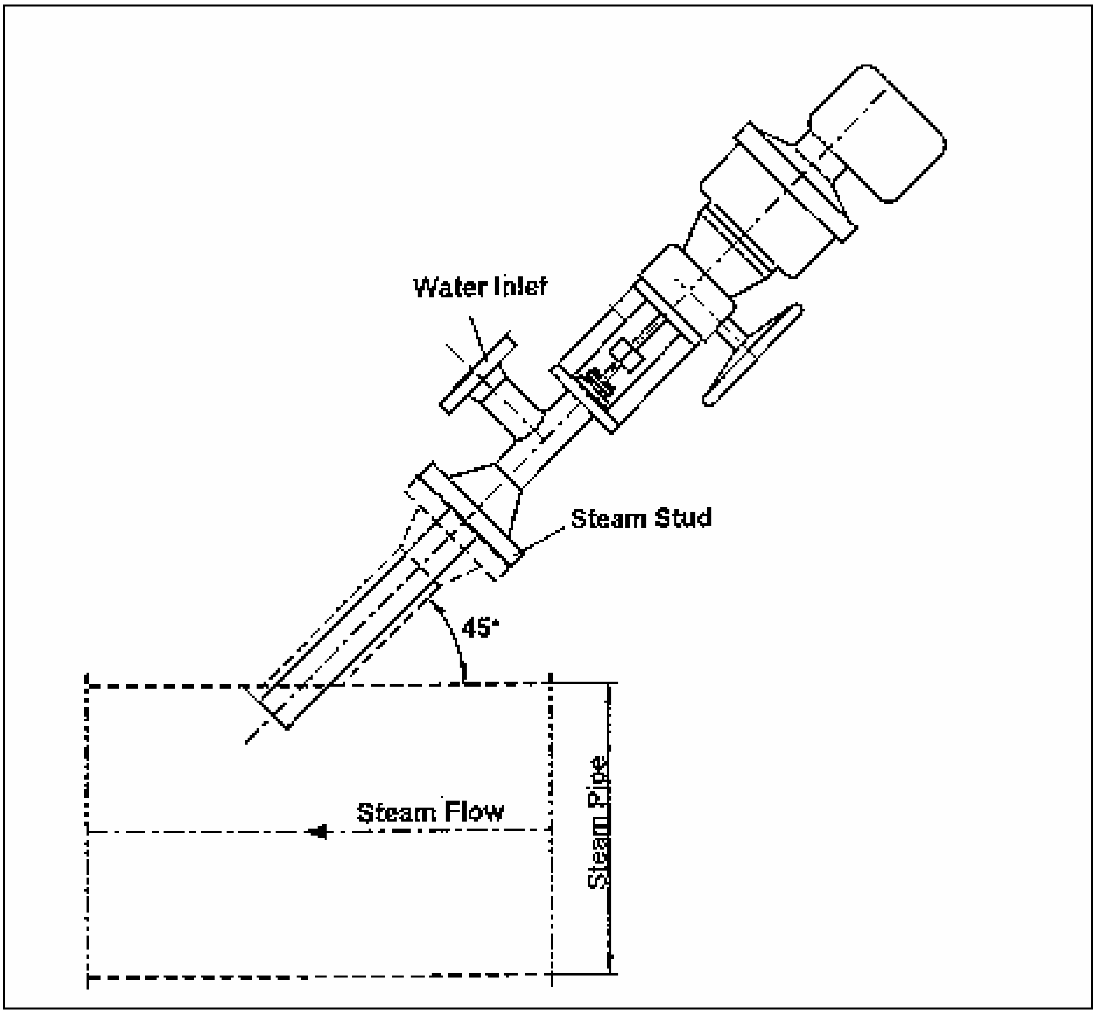

Fig. 4: H.P. Steam Desuperheater

Natural gas preheater

The new natural gas preheater is installed between the 1st stage steam superheater and the BFW preheater.
The new coil is made of 88 tubes in 2$^{1}/_{4}$ Cr 1Mo material devided in 4 rows (see Fig. 5).

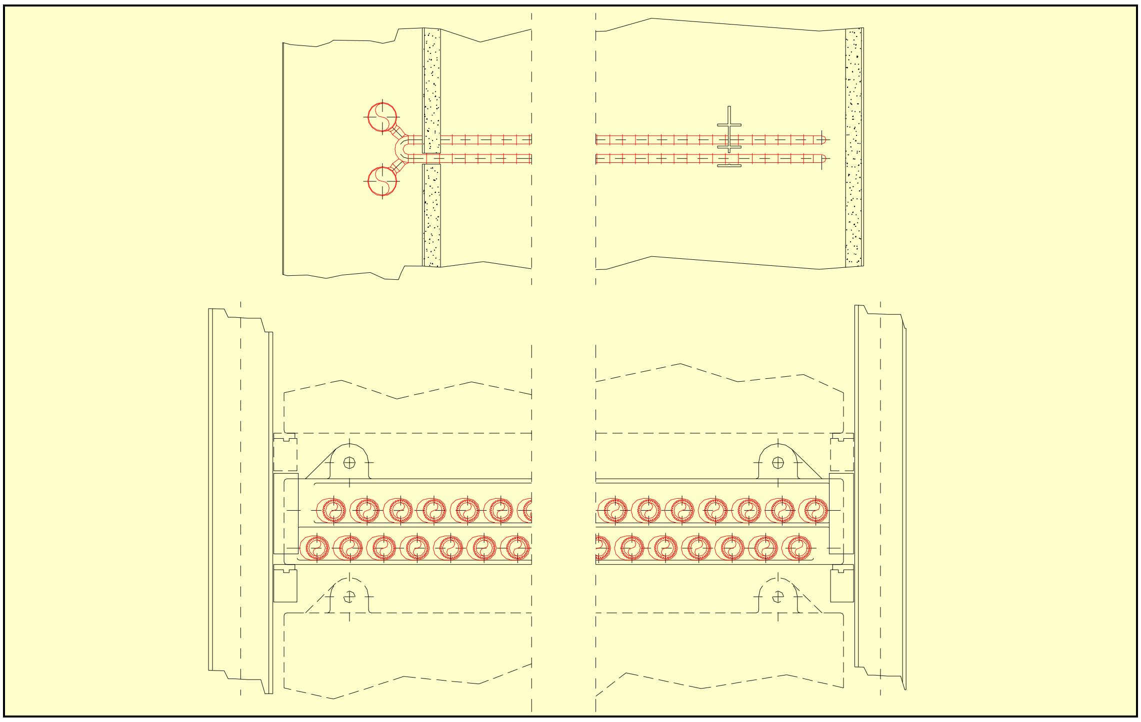

Fig. 5: New Natural Gas Preheater

3.6 SECONDARY REFORMER BURNER

Historically, ammonia plant Secondary Reformers conventional design was based on a multiple nozzle burner for injecting pre-heated air into the primary reformer effluent gas. In the common design, the burner is placed at the end of the air feed pipe at the top of a conical combustion chamber. The primary reformer gas flows trough an annular tube concentric to the air tube. Mixing and combustion take place into the cone and the combustion product flows down into the catalyst bed (Fig 6).

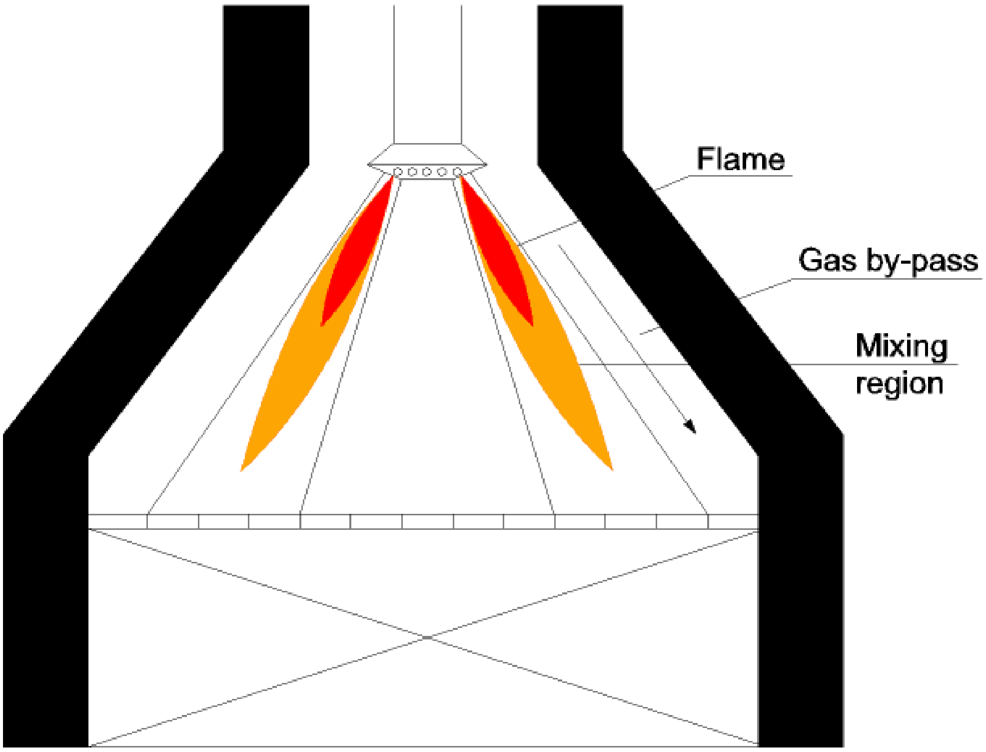

FIG. 6

The high temperature on the surfaces exposed to the flames for convection and radiation has always caused problems to the burner.
With the introduction of the air preheat (600°C), in order to reduce ammonia plant energy consumption, the burner surface cooling has become one of the major issues in the secondary reformer design.

In the last 25 years of conventional design to maintain the burner temperatures within reasonable values, the air was forced to flow in complex paths inside the burner head with high pressure losses. Non-even temperature and composition distribution of the gas also characterized some old burner design with temperature hot spots on the catalyst surface and uneven catalyst gas load.

In the early '70s the flow field and the gas mixing inside the conical chamber were not well understood and the computational fluid dynamics technique, used today for the combustion simulation, were at an early stage of development and not applicable for industrial design.

Nowadays advanced fluid dynamic simulation techniques are more easily available, and with their utilization Casale has develop an innovative design for Secondary Reformer Burners.

The burner is a key element in the secondary reformer design, because it mixes the air and primary reformer effluent gases in a diffusion flame. The flame core temperature is very high, often above 2000°C; consequently heat transfer to the burner from the flame, and the other hot surfaces as well, by radiation and by convection from the recirculating gases must be minimized.
Hence, burner design must combine fluid dynamic principle of mixing and combustion processes to maintain a safe operation and a long equipment lifetime.

The goal was to develop a simple design capable of withstanding the severe operating condition in a safe, reliable and cost effective manner.

The Computational Fluid Dynamic (CFD) simulations of the velocity, temperature and composition fields inside and outside the burner and in the combustion chamber were performed interfacing a commercial CFD software with 'in house' developed combustion subroutines.

During the design of the Casale Advanced Secondary Reformer Burner these engineering aspects were of major importance:

- Low pressure losses of both air and primary reformer stream (much lower then the existing design).
- Low temperature of the burner surfaces exposed to the flames.
- An almost perfect mixing in the diffusion flame.
- Reduced flame length in order to increase the catalyst volume for high load operations.
- Soot free combustion.
- Homogeneous gas composition and temperature distribution at catalyst bed entrance.
- Protections of the refractory lining from the flame hot core.

The recirculation of the reacted gases protects the refractory and the burner from the hot core and also ensures a homogeneous gas and temperature distribution at the catalyst bed entrance (Fig 7).

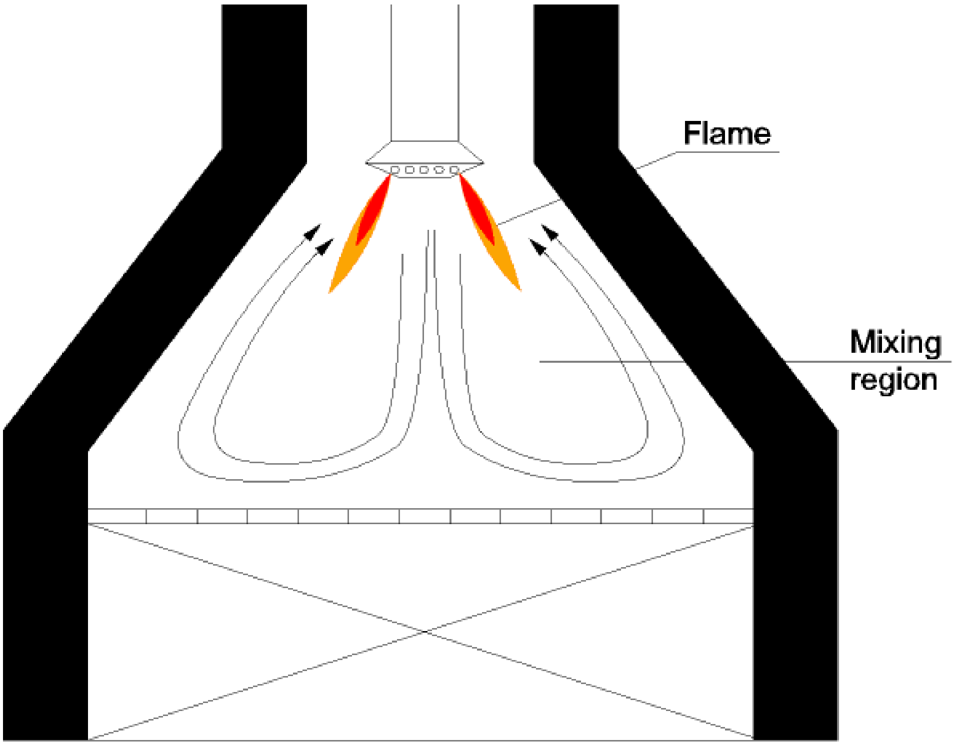

FIG. 7

The air flow inside the burner was simplified and optimized redesigning the internal shape of the burner to improve the heat transfer in order to have the necessary level of cooling of the burner surfaces exposed to the flame and at the same time, to reduce the pressure losses.

The expected performances of the Casale Advanced Secondary Reformer are:

• Maximum pressure loss for the air stream:	0.35 bar
• Burner wall temperatures:	700-800 °C.
• Temperature spread on the catalyst surface:	Uniform within a few Celsius degree range
• Composition spread on the catalyst surface:	Almost Homogeneous

At present one burner is already in service since December 1998 and in more severe conditions than those of an ammonia plant secondary reformer, i.e. in the production of synthesis gas through partial combustion of hydrocarbon and heavy residuals with pure oxygen.

The burner operates with an average temperature of the main recirculating gases of about 1300°C, that is 300 to 400°C over the mean temperature of the secondary reformer recirculation, and after being inspected showed no signs of deterioration whatsoever.

The design process parameters have been met in terms of pressure drop and uniformity of temperature and composition in and after the flame as it is testified by the analysis of the exit gas.

3.7 SHIFT CONVERTERS REVAMPING

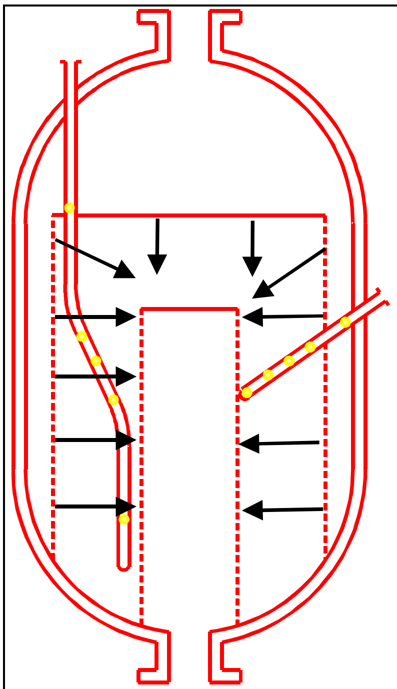

Fig. 8 - Revamped Shift Converter

This new configuration has an inherently low pressure drop of the catalyst bed, and in addition, makes it possible to use small-size, more active catalyst.

The low pressure drop helps eliminate the hydraulic constraints in having more flow through the front end, while the small-size, more active catalyst eliminates the possible constraints due to a fixed catalyst volume that may be insufficient for the new operating conditions of high flow and low steam/carbon ratio.

In an axial-radial catalyst bed the gas distribution is such that most (about 90 %) of the gas passes through the catalyst bed in a radial direction, resulting in a much lower pressure drop when compared with the axial flow.
The balance passes down through a top layer of catalyst in an axial direction, thus eliminating the need for a top cover of the catalyst beds, *(see figure 8).*
This feature is an essential factor for an easy and simple construction of any type of converter internal and for an effective elimination of the catalyst caking problem.

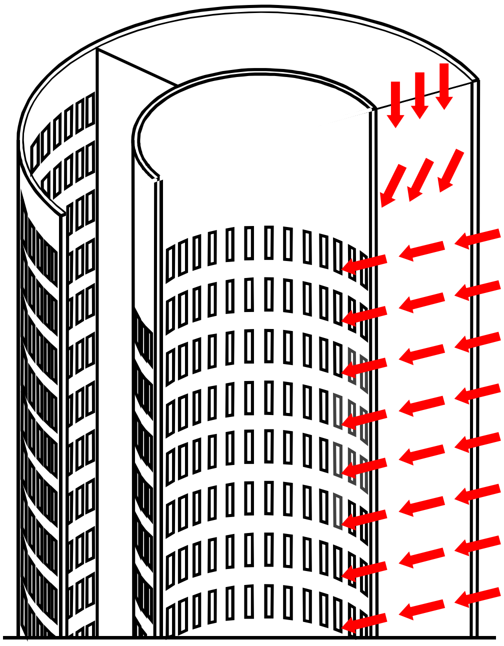

Fig. 9 - Axial-radial Bed, Gas Distribution

The main features of CASALE patented design for both H.T.S. and L.T.S. converters which lead to the following advantages, are:

* an axial-radial flow path of the gas crossing the catalyst resulting in a low pressure drop;
* use of small-size, more active and more resistant to poisons catalyst;
* protection of catalyst from water droplets carried over from secondary reformer heat recovery train or others;
* possibility to load different volumes of catalyst easy operation.

<u>Advantages of the Axial-Radial Shift Converters</u>

There are many advantages of the axial-radial technology over the axial one, both when revamping plants for capacity increase and for energy savings, as well as for new converters, and they can be summarised as follows:

<u>*Revamping for capacity increase*</u>

* no pressure drop limitation due to lower differential pressure within the axial-radial technology;
* no bigger catalyst volume required because of the use of smaller catalyst size with higher activity;
* longer operation at equilibrium with higher product purity (H_2 plants) or higher production rates (NH_3 plants);
* longer operation at equilibrium with the consequence of higher plant capacity;
* longer catalyst life due to higher catalyst activity and poison resistance;
* protection of catalyst from water droplets with the consequence of an extended catalyst lifetime.

<u>*Revamping, same capacity*</u>

* energy saving, thanks to the lower pressure drop;
* reduced catalyst volume (30 - 50 %) for the same catalyst life;
* same catalyst volume for longer life.

3.7.1 Shift converter industrial experience

AMMONIA CASALE has revamped three shift converter trains, the first two in 1995 and 1996, each made by one HTS and one LTS, in two Kellogg ammonia plants in the P.R. of China.
The last revamped HTS was started up in October 1998 in the USA, at the AGRIUM plant in Borger, Texas and runs according to the following parameters:

			Prior to Revamp	**Axial-Radial Revamp**
	Plant Capacity	[stpd]	1450	1600
	Catalyst Volume	[m³]	38	42
	Catalyst Size	[mm]	9 × 6	6 × 3
SOR	Inlet Temperature	[°C]	360	343 (1)
	Pressure Drop	[bar]	0.8	0.45 (1)
	CO Leakage, dry	[vol%]	2.45	2.20 (1)
EOR	Inlet Temperature	[°C]	372	370
	Pressure Drop	[bar]	1	0.45
	CO Leakage, dry	[vol%]	3.0	2.95
	Catalyst Lifetime	[years]	6	6 - 7

(1) Test-run value.

3.8 AMMONIA SYNTHESIS CONVERTER

The ammonia converter is, of course, one of the most important items when planning a revamp for energy saving or capacity increase, and in fact it is, in most cases, the first item to be revamped thanks to the relatively low cost and very high return.
AMMONIA CASALE is very active in this field and has introduced fundamental innovations in the converter design and revamping, such as the "in situ" modification of bottle-shaped converters as the Kellogg ones, and the three-bed intercooled configuration that is being used by CASALE for over ten years now.
This activity has been very rewarding and now AMMONIA CASALE has more then 100 converters on stream, out of which about 50 are "in situ" modifications, and the majority of the others are revamps of full-bore opening converters.
The most important ingredients for this success are the axial radial beds, described above *(see figure 9)*, and the three-bed configuration adopted both for revamping of any kind of converters and for new converters as well *(see figure 10)*.

These two elements give the highest utilization of the catalyst volume available, thanks to the axial-radial configuration, and the most thermodynamically efficient cartridge configuration, the three-bed interchanger one, with cooling achieved by means of heat exchanger both between 1st and 2nd bed and between 2nd and 3rd bed.

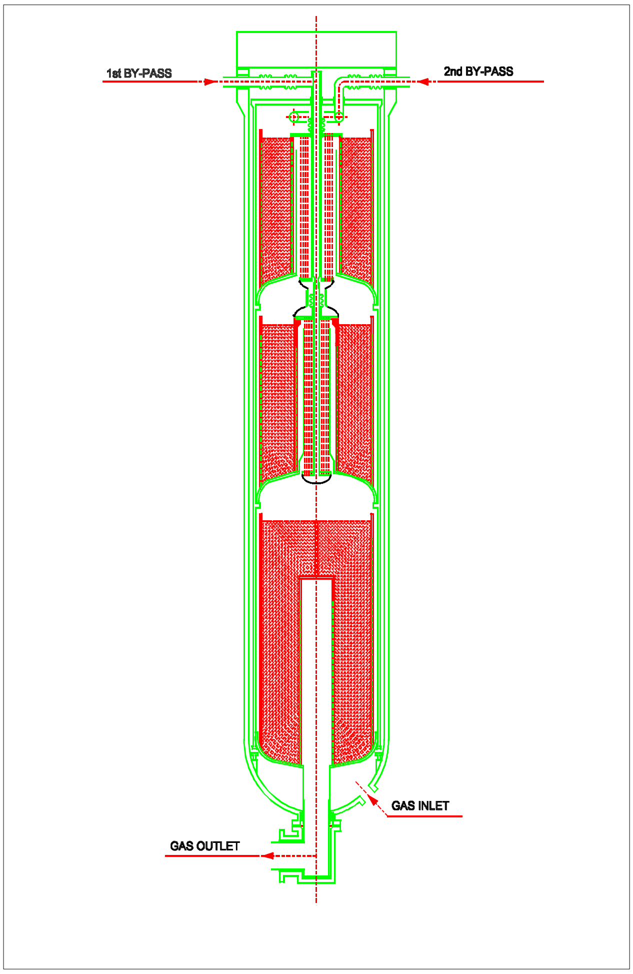

Fig. 10 - CASALE 3-BEDS 2-INTERCHANGERS CONVERTER

It is possible to use small-size, more active catalyst with the axial-radial configuration, and it is well known that small-size catalyst is more efficient than the large-size one.

Therefore, the design of the cartridge lay-out with three adiabatic beds and two interchangers, and the use of 1.5 ÷ 3 mm size catalyst, makes it possible to obtain a high ammonia conversion and a low pressure drop.

A particular feature of the design is its simplicity: the catalyst-containing baskets are easy to be handled and have a low cost. Moreover, the use of a reverse bottom increases the catalyst filling efficiency *(see figure 10)*.

3.8.1 Ammonia converter industrial experience

ACSA has revamped and started up three out of four 1000 STP MW Kellogg ammonia converters at CFI Industries, Louisiana, USA and the last one is due on stream next spring.

These converters were already revamped in '86 adopting the 1st generation of internals (4 beds, 3 quenches) and now at the end of the catalyst life have been revamped again adopting new and more efficient internals: 3 beds, quench and interchanger.

In the following Table 2 the achieved performances of these converters has been indicated.

Table 2: Operating data ACSA revamping for Kellogg ammonia converter
1st generation: 4 beds, 3 quenches; 2nd gen.: 3beds, quench interchanger.

CASE		ACSA-MWK 4 beds	3 beds retrofit
Ammonia production	[MTD]	1287	1475
Catalyst age	[years]	10	10
Inerts concentration at 105-D inlet	[mol%]	9.8	7.7
NH_3 concentration at 105-D inlet	[mol%]	2.6	1.4
Temperature at 105-D inlet	[°C]	139	148
NH_3 concentration at 105-D outlet	[mol%]	14.4	16.9
Pressure at 105-D outlet	[bar a]	137	138
Temperature at 105-D outlet	[°C]	299	371

4. UREA CASALE S.A.

UREA CASALE has been active in the urea field since 1985, first as AMMONIA CASALE and from 1991 as an independent company.

From the very beginning, the activity of the company has been concentrated on revamping existing urea plants.
In the current situation, with a constantly increasing urea demand and economical uncertainty, there is, in fact, a high demand for plant upgrading which can give additional capacity at a cost lower than through new plants construction.

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

The general approach of UREA CASALE to urea plant revamping is to upgrade the reaction section in order to increase its efficiency, rather than just adding additional equipment, and most of the technologies have been developed to accomplish this goal.
UREA CASALE revamping technologies can be applied to plants originally designed according to any kind of urea process.

Thanks to the revamping activity with the use of innovative technologies, 24% of today's 96 million tons world production of urea represents the Casale share of retrofitted capacity, mostly based on the upgrading of synthesis units. The evolution of Urea Casale presence in this field is shown in Table 3.

Primary international companies are licensees of the Urea Casale S.A., namely:

- Fluor Daniel — Canada
- Ube Industries Ltd. — Japan

Table 3: UREA PRODUCING PLANTS MODERNIZED OR UNDER MODERNIZATION BY UREA CASALE IN COMPARISON TO THE TOTAL WORLD PRODUCTION OF UREA

Year	Number of units constructed or retrofitted	Total capacity (t/d)	Average capacity (t/d per unit)	Total cumulative capacity (t/d)(10^3 t/y)	World production (10^3 t/y)	% of the total world production
1985-1990	5	6'700	1'340	6'700 2'200	70'460	3
1991-1992	11	12'100	1'100	18'800 6'200	73'260	8.5
1993-1994	9	13'580	1'510	32'380 10'700	84'160	13
1995-1996	17	27'800	1'640	60'200 19'900	95'000	21
1997-1998	8	10'100	1'264	70'300 23'200	96'000	24

A quick overview of the most advanced CASALE technologies is given considering the main classes of possible revamping:

* **SMALL TO MODERATE CAPACITY INCREASES (UP TO 30 - 35 %)**

CASALE High Efficiency trays *(See figure 11)* drastically increase the efficiency of the urea reactor (up to 4-5 percentage points) debottlenecking the HP synthesis section allowing to achieve capacity increases up to 30 - 35 % with only minor (and limited to the synthesis section downstream equipment) additional modifications to the plant.

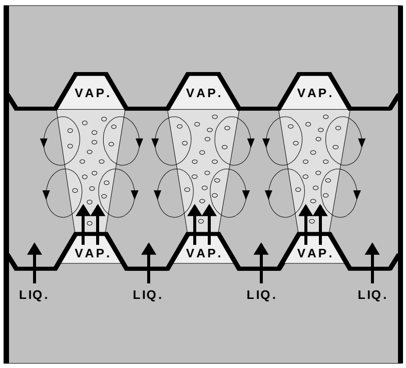

Fig. 11 - High Efficiency Reactor Trays

* **LARGE CAPACITY INCREASES (60 % OR MORE)**

CASALE **HEC Process** and **Vapor Recycle System (VRS)** obtain an even higher increase in the urea reactor efficiency.

The HEC process, used for the revamping of conventional total recycle plants *(see figure 12)*, combines a very efficient "once through" synthesis section with the conventional reactor obtaining an average conversion of 72 % (at increased capacity).

The VRS, used for the revamping of stripping plants *(see figure 13)*, eliminates the water from the recycle carbamate before sending it to the synthesis section obtaining conversions up to 67 - 68 % (at increased capacity).

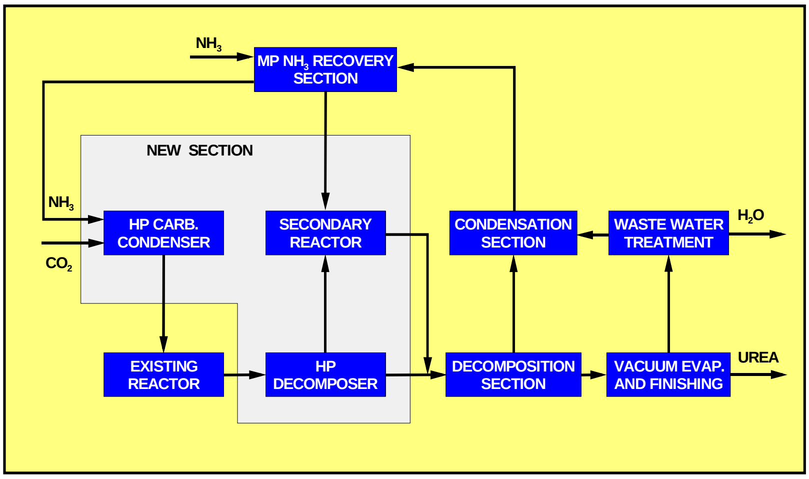

Fig. 12 - Conventional Total Recycle plant revamped with the HEC concept

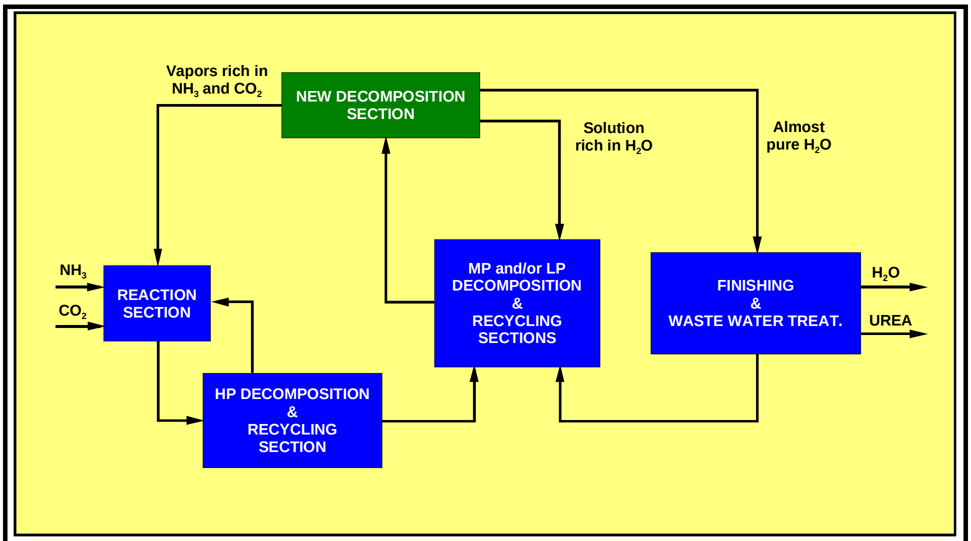

Fig. 13 - Stripping plant revamped with the VRS concept

For both approaches, thanks to the improvement of the conversion rate, a large capacity increase can be obtained with minimum amount of additional equipment and minimum shut down time.

* **ENERGY SAVING**

  With the use of the above mentioned **CASALE High Efficiency trays** the specific steam consumption can be reduced. Reductions up to 200 kg/MT have been obtained.

* **POLLUTION CONTROL**
  With the use of **CASALE High Efficiency Hydrolyser**, it is possible to eliminate completely NH_3 and urea from the process condensate before discharging it.
  If a complete reduction of urea is not required, very low urea contents can still be obtained using the **UREA Recovery System**.

* **IMPROVEMENT IN PLANT RELIABILITY**
  With the **Carbamate Condenser Passivation System** it is possible to increase the corrosion resistance of horizontal HP condensers.

4.1 Urea industrial experience

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

Casale Revamping Experience Using HET Technology

A total of thirty-eight (38) projects involving installation of HET have been carried out or are under completion for plants having capacities ranging from 250 to 2100 MTD.

We give you here below some details of main projects for which CASALE's HET Technology has been applied in connection with capacity increase.

Togliatti (Russia) plant
Two 1'500 MTD production lines originally designed according the NH_3 stripping process have been revamped increasing the capacity by 17%.
The installation of High Efficiency Trays together with the modification of the CO_2 compressor (new internals) were the modification carried out to reach the new capacity.
The revamped plant is in operation since '93. A significant reduction of the steam consumption was also obtained.

Yunnan (China) plant
One 1'630 MTD production line originally designed according the CO_2 stripping process was revamped increasing the capacity by 15%.
The changes necessary to reach the increase in capacity were the installation of the High Efficiency Trays and of the Urea Recovery System and the modification to the CO_2 compression system.
The revamped plant is in operation since '94. The steam consumption has been also reduced by 150 MT/D.

Arcadian (Trinidad) plant

1'700 MTD production lines originally designed according the NH_3 stripping process was revamped increasing the capacity by 9%.
In this case the sole installation of High Efficiency Trays was necessary to reach the required capacity.
The revamped plant is in operation since '94. The steam consumption was also reduced by 180 kg/MT.

Gorlovka (Ukraine) plant

One 1'000 MTD production line originally designed according to the CO_2 stripping process is under revamping increasing the capacity by 35%.
The installation of HET together with the installation of a few pieces of LP equipment, modification to the existing HP pumps (some new internals) and a refurbished CO_2 compressor (compressor supplied by CASALE after refurbishing) were the only modifications carried out to reach the new capacity. The revamped line has just been started up.

Neyveli (India) plant

Four 116 MTD production lines originally designed according to the conventional total recycle technology is under revamping to increase the capacity each line to 150 MTD. The installation of HET together with the installation of a few pieces of LP equipment and some modifications to the wwt section were the only modifications carried out to reach the new capacity.

Casale's Revamping Experience Using VRS Technology

One large stripping plant has been revamped by Casale achieving large capacity increase. Some details about this project are given below :

Agrium's Carseland, Alberta, Canada, Nitrogen Operations were commissioned in 1977. The Operation included a 1,043 MT/d Kellogg Ammonia Plant and a 1,350 MT/d Urea Plant based on CO_2 Stripping Process, plus the design was such that there was a zero discharge of effluent water to any water course. All process waters were either irrigated or evaporated on site.

Over the years, the Urea and Ammonia Plants had been expanded to produce 1,250 MT/d Ammonia and 1,825 MT/d Urea. It was decided to look at what the maximum that the Ammonia Plant could be deployed to and match that to an increase in the Urea capacity. Indications were that we could take the Ammonia plant to 1,600 MT/d and the Urea to 2,350 MT/d.
Several methods of expansion were evaluated and in the Urea Plant, Agrium chose to use a novel approach referred to by Urea Casale as the "Vapour Recycle System (VRS)".

Casale proposed its VRS concept in order to fulfil all the requirements in the most economical way. With this concept it was, for instance, possible to avoid any addition of reaction volume and practically no other modifications to the existing plant were needed other than the addition of a couple of vacuum condensers, some surface to the second vacuum evaporator and few trays in the desorber.

The VRS concept was applied adding a kit to the existing plant consisting of:

- a new HP decomposer
- a new LP decomposer
- a new MP separator and condenser

The de-bottleneck of the raw material feed equipment and of the finishing section was carried out directly by the owner. Due to maintenance reasons, the HP condenser was changed with a slightly larger one.
The designed capacity of the revamped plant is 2400 MTD.

The project was first proposed in March of 1995, with a target start-up date of June, 1996. Due to equipment delays the start-up took place in October, 1996. Because of project fast tracking requirements a team of Agrium personnel, along with the engineering companies Fluor Daniel and Urea Casale was put together. The project was designed, equipment procured and construction completed in just 14 months from actual approval to proceed.

Much of the construction occurred while the Plant was running in order to facilitate project tie-ins and completion during a three week turnaround.
This was for the most part, accomplished and with the knowledge gained by this team improvements could be made in this area.

The results are that the Plant is presently running at 1,485 MT/d on the Ammonia side and 2,300 MT/d on the Urea side due to lack of CO_2 .

The expected performances of the VRS system have been also confirmed by the plant operation. The main features obtained can be summarised as follows :
- low H_2O/CO_2 molar ratio at reactor (about 0.25)
- high CO_2 conversion even at high capacity (64 %)
- high stripping efficiency
- high Urea concentration at stripper and LP decomposer exit

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

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

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

Casale Revamping Experience Using HEC Technology

Four projects involving high capacity increase of conventional total recycle plants have been carried out, some details of which are given here below.

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

- No 1, 195 MTD
- No 2, 270 MTD

Line No. 1 was a partial recycle line with a one-stage decomposition/recycling section and the NH_3 recovery section.

Line No. 2 was a total recycle line with a three-stage decomposition/recycling section and the NH_3 recovery section. A one-stage vacuum evaporation section was producing the urea solution of the desired concentration.

It was desirable to shut down line No. 1 and to have only one line for the new capacity. Due to the extremely high capacity increase required from line No. 2 (almost three times higher), a drastic increase in the efficiency of the synthesis section was necessary in order to avoid a very complicated approach with a lot of parallel equipment.

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

- a new “once-through” reactor, working at 240 bar, 197°C
- a new HP carbamate condenser generating 6.5 bar steam upstream the “once-through” reactor.
- a new HP decomposer working at 157 bar fed by the once-through reactor outlet stream.

In this way, it was possible to keep the same equipment down stream the existing reactor and to minimise the modifications to it.

Line No. 1 was idled and some equipment used, namely the NH_3 condensation section and the machinery for NH_3 and carbamate compression. The CO_2 compression as well as the finishing section capacity were also increased.
No other new equipment was needed other than two condensers and an additional vacuum section.

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

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

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

All guaranteed values have been met.

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

- high (average) CO_2 conversion : 70 %
- low (average) H_2O/CO_2 molar ratio : 0.3.

A second plant revamped by Casale using the HEC technology is in operation since December 1996 in New Zealand.
This plant was originally designed to produce 480 MTD in a single line according to the Toyo conventional total recycle technology.
The revamped plant is designed to produce 750 MTD.
All guaranteed values have been met.

A third plant revamped by Casale using the HEC technology is in operation in Canada since November 1998.
This plant was originally designed to produce 316 MTD in a single line according to the Weatherly conventional partial recycle technology.
The revamped plant is designed to produce 625 MTD.

In addition to the just described projects, it is worth mentioning the following projects which are under implementation by Casale using the HEC for large capacity increase of conventional total recycle plants:

- one 500 MTD single line Vulcan plant in Iran is being revamped to 875 MTD; start-up by 2000.
- one 800 MTD single line Toyo plant in Brazil is being revamped to 1500 MTD; start-up within first half of 2000.
- one 1000 MTD single line Tecnimont plant in India is being revamped to 1500 MTD - start-up by 2001.

5. CONCLUSION

Proven technologies are available within the Casale companies for the revamping of a whole Ammonia/ Urea production complex.

Such revamping can be done with a single point of responsibility with several advantages for the clients.

Thanks the wide range of the technologies available within the Casale companies combined with their wide experience, Casale can handle not only capacity increase projects (up to very large increase) but also just energy reduction projects or project dealing with increasing of plant reliability or with plant optimisation.