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ENERGY REDUCTION IN UREA AND AMMONIA PRODUCTION AT THE AGRIMONT FERRARA PLANT

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INTRODUCTION

Agrimont's ammonia and urea plants at the Ferrara factory, with capacities of 1500 and 1700 MTPD respectively, have been in operation since the end of the seventies.

The ammonia plant is based on H.TOPSOE technology and the urea plant is based on Montedison technology.

The original project of the urea plant employed the conventional process of separating the produced urea from unreacted carbamate leaving the reactor.

According to conventional urea processes, the ammonium carbamate was decomposed into the raw materials by reducing the pressure of the solution removed from the reactor, thus allowing part of the unreacted ammonia and carbon dioxide to flash off; this operation was normally performed in a series of vessels at different pressures.

In 1987, Agrimont decided to modify the existing reaction section by adopting the IDR process.
The purpose of this modification was to cut energy consumption and, at the same time, realize a full-scale demonstration plant.

Another aim was to avoid the risks connected with the scaling-up of the technology already tested on a semi-industrial scale at the 300 MTPD urea plant located at San Giuseppe di Cairo (Savona).

The new section at Ferrara was started up in 1988.

The results regarding energy cost reduction and the operating and maintenance problems found during the first adjustment period and the main differences between the 300 MTPD reference plant at S.Giuseppe and the 1700 MTPD at Ferrara are shown later on.

The replacement of the catalyst charge of the converter in the ammonia plant was planned for 1990, after having been in operation for twelve years.

Agrimont decided to take this opportunity to improve the energy efficiency of the whole plant by substituting the internal apparatus, the cartridge, of the ammonia converter.

This new installation will be introduced in the converter in June 1990.

This modification and the substitution of the catalyst charge will reduce the energy consumption by 260 Kcal/Kg produced ammonia (expected value).

DESCRIPTION

1) UREA PLANT MODIFICATION

The modification consisted in installing a new synthesis section based on the IDR tecnology at the Ferrara urea plant.

The IDR(Isobaric Double Recycle) technology features high conversion of reagents into urea and consequently low energy consumption and easy recycling of the unreacted materials to the reactor.

Figure 1 shows the typical flowsheet of this process.

The high conversion of ammonium carbamate into urea is obtained by operating at high NH_3/CO_2 molar ratios, whereas the recycle of the unreacted carbamate and the free NH_3 in excess is carried out in the two decomposers operating in series at the same pressure as the synthesis reactor, the first one operating with NH_3 excess and the second one operating with CO_2 excess.

This technology was developed by Montedison and tested at the San Giuseppe di Cairo urea plant with a capacity of 300 MTPD, which is not considered representative of the more recent urea plant having a capacity of 1500-2000 MTPD.

The adoption of the new technology for an existing production line based on the previous total recycle MONTEDISON Know-how with heat recovery was obtained by replacing the existing reactor with new equipment operating at the same pressure as the reactor and which constitutes the IDR loop.

However, the installation of the IDR section was not only limited to a simple scaling-up of the equipment of the IDR loop.

Infact, the Ferrara plant has characteristics that differ from those of S.Giuseppe di Cairo, particularly as regards to the distillation stages downstream of the reaction section.

Figure 2 shows the flowsheet of the Ferrara urea plant before modification.

Figure 3 shows the flowsheet of the S.Giuseppe urea plant.

At the S.Giuseppe plant the urea solution leaving the IDR loop is flashed to 25 bar and fed to an existing distiller heated by recovered steam.

The condensation heat of the resulting vapors is used to distillate the urea solution in the second distillation stage, which operates at about 5 bar and in the first stage of the urea vacuum concentration, thus achieving significant heat recovery.

At the Ferrara plant, the urea solution leaving the IDR loop is flashed to 70 bar and fed to an existing distiller heated by medium pressure steam.

The condensation heat of the resulting vapors is used to produce low pressure steam (about 3 bar) to be recovered within the plant's limits. Figure 4 shows the flowsheet of the Ferrara plant after modification.

Another feature differentiating the Ferrara urea plant from the S.Giuseppe plant is the driving system of the CO_2 compressor.

The first is driven by vapor turbine and the second by electric motor.

The limitation imposed by the existing driving system so as not to increase the investment costs was another limit.

This required a different subdivision of the thermic loads in order to reduce the medium pressure steam consumption and utilize low pressure steam produced compatibly with the characteristics of the equipment existing downstream of the IDR section.

2) AMMONIA PLANT MODIFICATION

The original apparatus was a Topsoe S100 cartridge, consisting of two adiabatic catalyst beds (size 1.5 - 3 mm) with intermediate direct cooling achieved by means of quenching (a portion of cold unreacted synthesis gas was injected to the reacted gas leaving the first catalyst bed).

The flow arrangement in both of the catalyst beds was radial.

Among other options for the new installation, Agrimont chose a cartridge especially designed by Ammonia Casale for the following reasons:

1) Ammonia Casale submitted a very large reference list, included many ammonia converters (supplied or modified) operating all over the world.

   In particular, Ammonia Casale had already modified another ammonia converter of ours at Priolo (Sicily) two years ago.

   This was a Kellogg four-bed converter with a nominal capacity of 1000 MTPD.

The Casale modification maintained the existing quench converter's arrangment of four beds with quenches for interbed temperature control.

The modification mainly concerned the latter two beds, that were transformed from axial to axial-radial flow.

This allowed the use of a smaller size catalyst (1,5-3 mm instead of 6-10 mm), which is more active, and reduces the overall pressure drop of the converter.

The converter was started up successfully in 1988 and, together with another improvement in the refrigeration section of the synthesis loop, gave an energy saving of 350 Kcalories per metric ton of product ammonia, which has not altered over the past two years.

The lump sum, turnkey contract including all the subcontractors was carried out under the supervision and responsibility of Ammonia Casale, who did an excellent job.

2) The Casale option had a rate of return slightly higher than those of other competitors.

The new Casale installation for the Ferrara converter consists of three catalyst beds arranged in axial-radial flow.

The first interbed cooling is achieved by means of direct quenching whereas the second by indirect cooling through a heat-exchange surface (an interbed exchanger between the second and the third catalyst bed completes the pre-heating of the cold inlet gas to the first bed temperature).

An important design feature is that no modification of the existing pressure shell was required.

The new catalyst charge (all pre-reduced, size 1,5-3 mm) was supplied by H.Topsoe.

The new cartridge is planned to be installed in the converter by the end of June and the plant to be restarted in July, so that precise operating data are not available as yet.

To give an idea of the expected energy saving generated by this modification we have made a comparative calculation utilizing our kinetic simulation program, based on the well-known Temkin-Pyzev equation.

In both cases the inlet gas composition (inerts=12%v., H_2/N_2=3) and the total catalyst volume (approx.46 m3) are the same.

The result of the calculation is that the new cartridge gives the same performance (the same conversion per pass with the same circulation rate of 714.000 Nm3/h) at a loop pressure of 204 bar abs., instead of 232 bar abs. required by the former cartridge.

The catalyst has been considered at its end of run activity level (aged) in both cases.

The plant operators can then take advantage of this situation in several ways, such as

a) by allowing the loop pressure to decrease, thus saving energy in the make-up gas compressor,

b) by increasing the load of the plant, provided the corresponding additional make-up gas is available,

c) increasing the level of inert gas in the loop by reducing the purge rate, thus increasing the overall conversion yield,

d) increasing the conversion per pass by reducing the circulation rate, provided the design temperature at the converter outlet is not exceeded, results in an increase in the recovery of the reaction heat and in energy saving in the circulation and refrigeration compressors.

Whichever option is chosen, the expected overall energy saving will be in the order of 260 Kcal/MT of ammonia.

EXPERIMENTATION RESULTS

The experimentation following the installation of the IDR section in the existing Ferrara urea plant was heavily conditioned by the peculiarity of the factory.

Infact, the urea plant is a single train having a high capacity of 1700 MTPD, which represents about 60% of Agrimont's total production in the nitrogen fertilizers field.

Moreover, the urea plant is strictly connected to the ammonia plant which has a capacity of 1500 MTPD.

An ammonia limited storage capacity of 10000 MT and operating limits in the ammonia shipment have greatly reduced the operating time required by the adjustment of the new section.

The interconnections between the two synthesis sections, old and new, don't exist as the passage from a run type (with IDR) to the other one (without IDR) is not direct.

The valves on the in and out streams for the two synthesis sections are the same.

Therefore, before converting the plant from one run type to the other, it is necessary to restore the correct connections and to install the appropriate blind flanges in the foreseen points.
This choice, which has been justified by technical considerations (in order to avoid dead zones, sources of

corrosion) involves quite a long time to pass from one run type to the other, time that is not often compatible with the production requirements.

Because of all these reasons, it took quite sometime to solve the mechanical problems that were met during the experimentation.
However, from a technological point of view the adjustment of the new section took only a short time.

Infact after two weeks from the start-up of the IDR loop (June '88) the urea plant was running regularly at nominal load.

After a few months of regular running, some operating difficulties emerged due to leakage from the flange couplings in the high pressure piping consequently causing the restart-up of the old section.

A careful examination of all the couplings showed insufficient thickness of the installed gaskets which were substituted with other thicker ones.
The project had foreseen the use of new materials for higher corrosion resistant piping and with improved mechanical characteristics in respect to the previous experiences.

This brought about a reduction of the piping thickness, which together with the considerable increase of the diameters of the Ferrara plant (DN 250 against DN120) made the experience acquired previously insufficient for the specific mechanical problem.

After having rectified this problem, the IDR section was installed and started up in the second half of 1989.

The plant ran regularly with good performances until January 90 when the ammonia plant was shut down and consequently the urea plant too, and Agrimont then decided to carry out an internal inspection of the IDR equipment to check the internal status after the first run period.

An accurate inspection showed there was no corrosion, thanks to selecting the right construction materials and using an original passivation tecnique on the vessel surfaces.

Only the welding on the seal partition plate which divides the reactor into two parts was found to be defective.

The IDR section will be reinserted in July '90 after the shut-down for maintenance work of the whole factory has been carried out.

Now, we'll go on to show the performance of the urea plant after the IDR section installation.

It is important to specify that when we speak about the plant performances, we mean the energy consumptions because the plant capacity, the product quality and the external conditions (effluents discharges) have not altered with the existing situation.

We report here below the various steam users.
For every steam users, we indicate the plant section, the type of steam used and instrument items for the flowrate recording.

In order to simplify thus:
VM : the 22 bar steam
VB : the 7 bar steam
VR : the 3 bar steam

UREA PLANT STEAM USERS

PLANT SECTION	USER	STEAM USED	INSTRUMENT ITEM
Loop IDR	E-1001	VM	FR-2/905
	E-1002	VM	FR-2/906
	D-1010	VM	(1)
Purification	E-901	VM	FR-2/912
	E-903	VB	FR-2/913
	E-905 bis	VB	FR-1014
Vacuum concentration	E-907	VR	FR-935
	E-907 bis	VB	FR-936
	E-909	VB	FR-938
	EJECTORS	VR	(1)
NH3 preheating	E-910 bis	VB	FR-914
Water distillation	E-912	VB	FR-975
Ureic sol. concentration	E-917	VR	FR-971
L.P. Tracing	D-1012	VB	(1)

(1) Not measured

The urea plant involves two different steam pressure level productions at 7 and 3 bar respectively.

This steam is used in the urea plant and the recovery steam excess is exported and used in the Ferrara factory.

For all steam productions the plant section, the steam type and the instrument item for the flowrate recording are reported.

UREA PLANT STEAM PRODUCTIONS

PLANT SECTION	RECOVERER	STEAM TYPE	INSTRUMENT ITEM
Loop IDR	E-1003	VB	FR-2/908
Purification	D-907	VR	FR-920

For the steam consumptions assessment only the process consumption has been taken into consideration.

The driving steam of the CO2 compressor has not been considered because it is strictly connected to the features and limitations of the existing driving system (condensation turbine and a limited condensable quantity extraction).

Because of these limitations and in order to reduce the adjustment works on the existing plant as much as possible we consider the total steam consumption of the urea plant as the difference between the total steam consumption and the total steam production both referring to 660 Kcal/Kg.

In the following table we have indicated the S.Giuseppe di Cairo extrapolated data in the first column, the traditional plant (before modification) data in the second column and the IDR plant data in the third column.

TABLE 1: FERRARA UREA PLANT STEAM EXPRESSED IN KG/T UREA PRODUCED(Referred at 660 Kcal/Kg).

	S.Giuseppe extrapolated	Traditional plant	IDR plant
<u>Total input</u>			
MP steam	586	1.173	741
<u>Total output</u>			
Steam export	0	113	164
<u>Plant consumption</u>			
total steam consumption	1.564	1.844	1.723
<u>Production</u>			
Recovery steam prod.	978	784	1.146
<u>Difference</u>	586	1.060	577

The energy saving obtained on the basis of a year's production of 560000 MT of urea is:

$$(1060 - 577) \times 560000 \times 660 = 1{,}785 \times 10^{11} \quad \text{Kcal/y} = 17.850 \quad \text{TEP/Y}$$

CONCLUSION

We may conclude from the previous table, the medium pressure steam consumption of the Ferrara IDR plant is greater than that of the S.Giuseppe, whereas the net difference between the total consumption and the production is better.

This, besides improving the return on investment, has allowed some limitations that were imposed by the existing plant to be overcome and, at the same time, to reduce the modification costs to a minimum.

This has been possible thanks to a particular situation existing in the Ferrara factory which allows the recovery of the low pressure steam excess produced by the urea plant in the same factory.
It must be underlined that the performances relevant to the IDR section have confirmed the experimental results obtained at the S.Giuseppe di Cairo plant.
Therefore, the process can be licensed for any capacity with different reference plants.

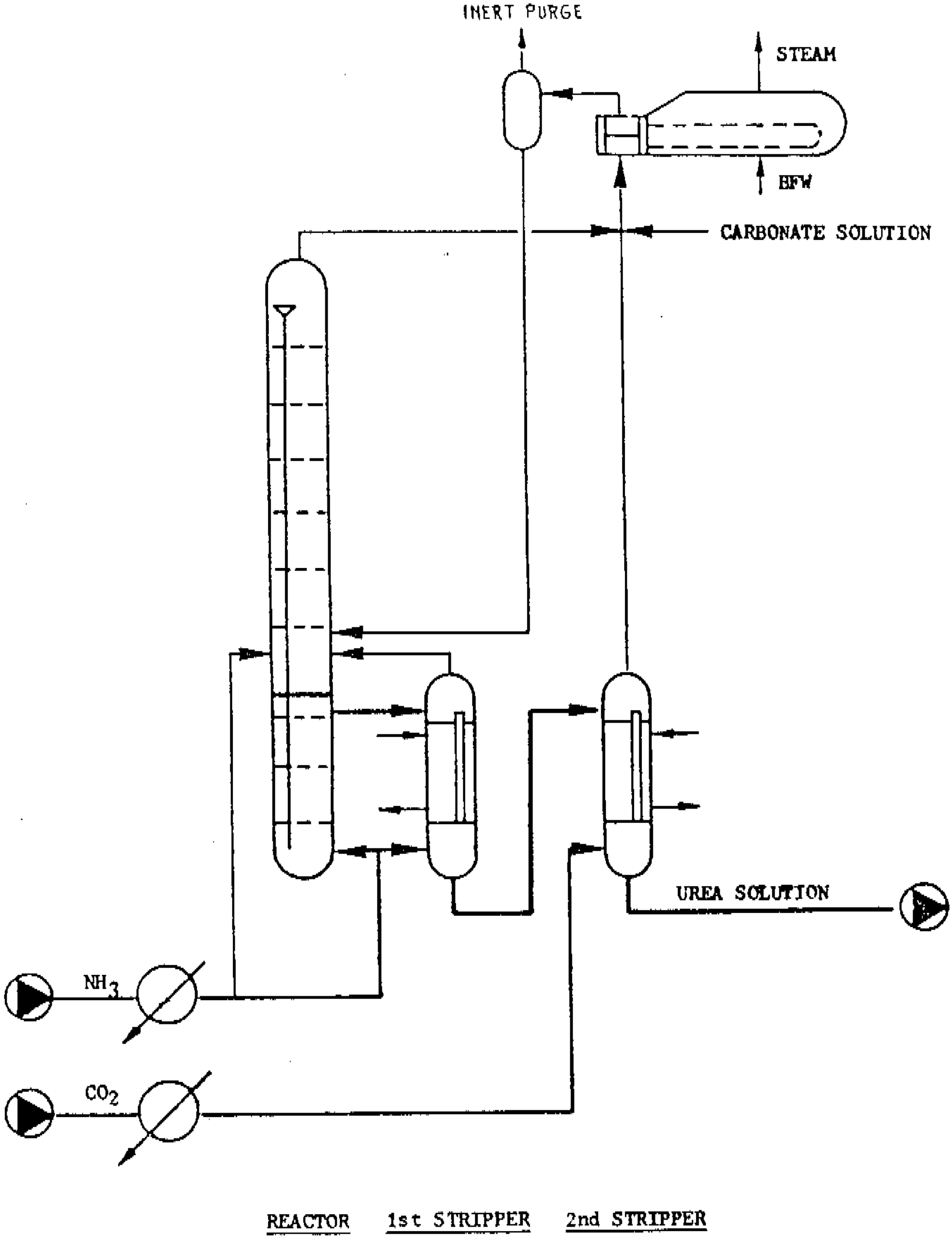

Fig. 1 The Isobaric Double Recycle (IDR) process.

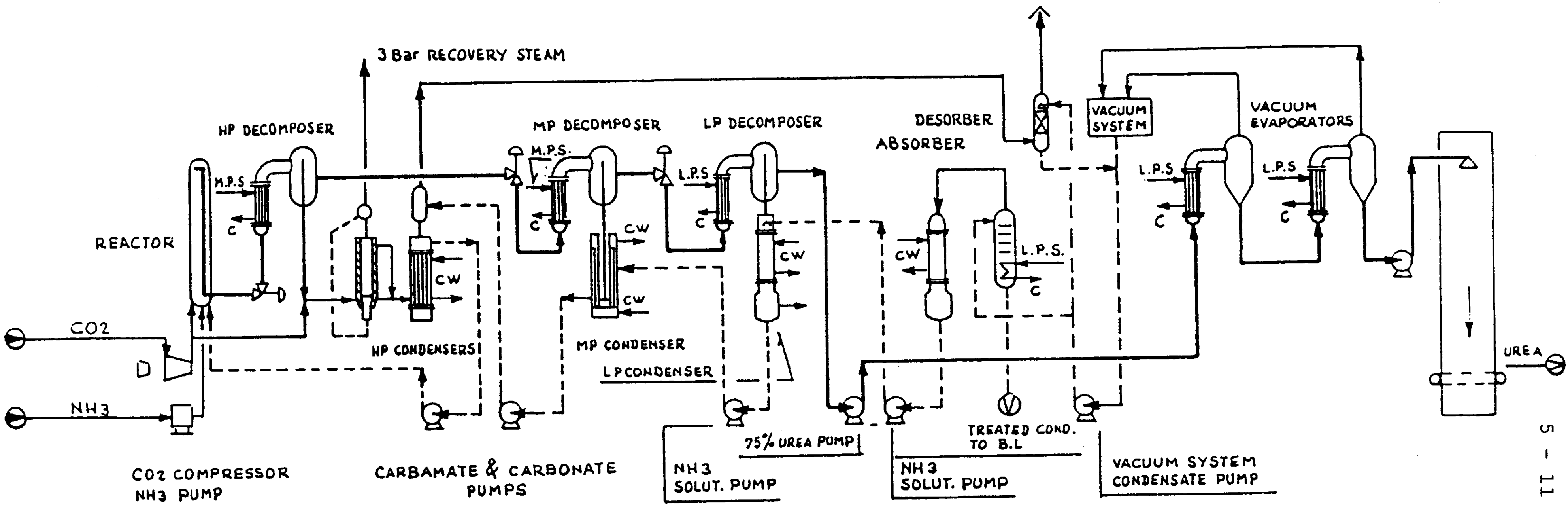

Fig.2 Original flow-sheet of the Ferrara urea plant.

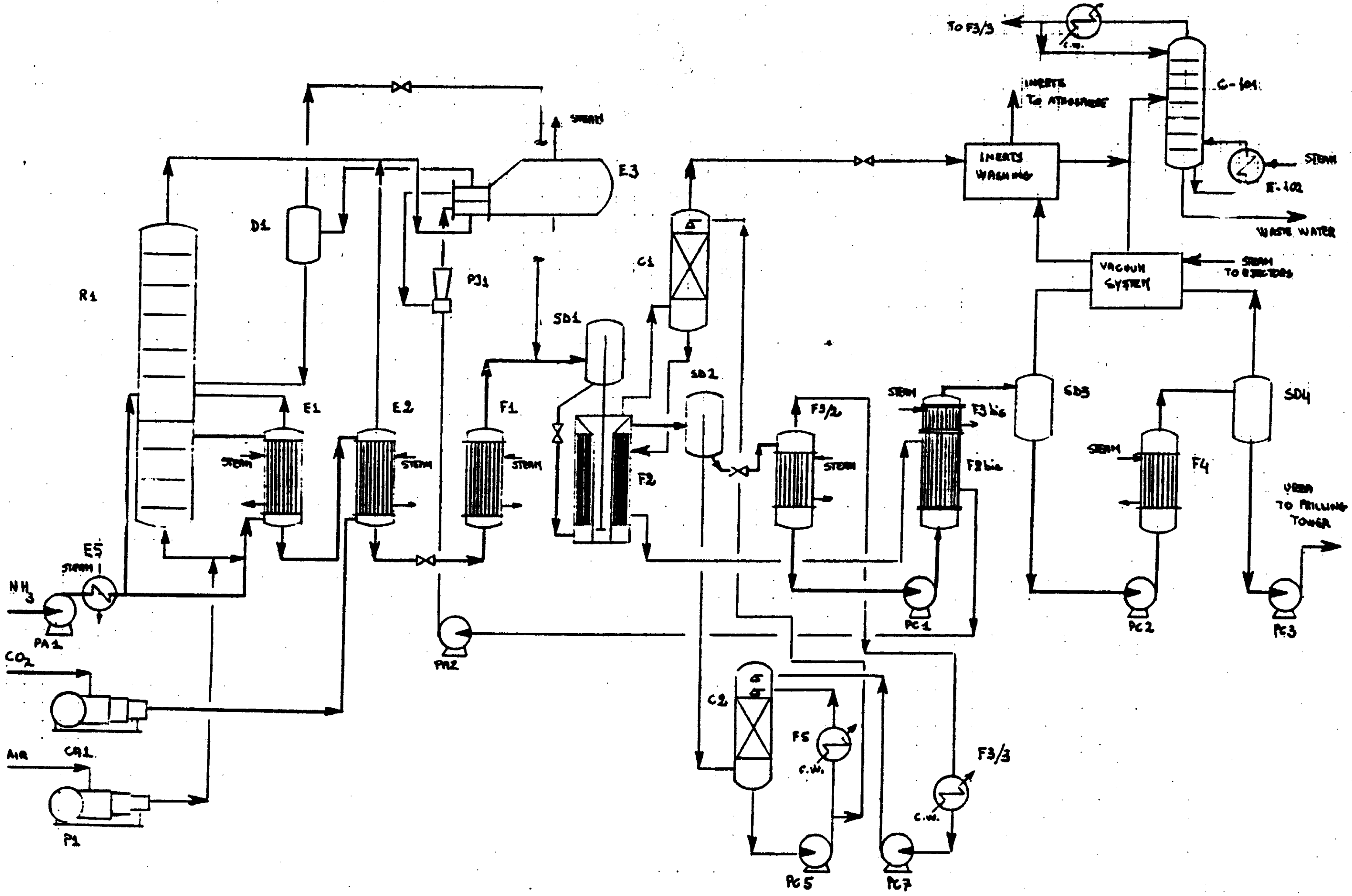

Fig.3 Flow-sheet of the S.Giuseppe urea plant.

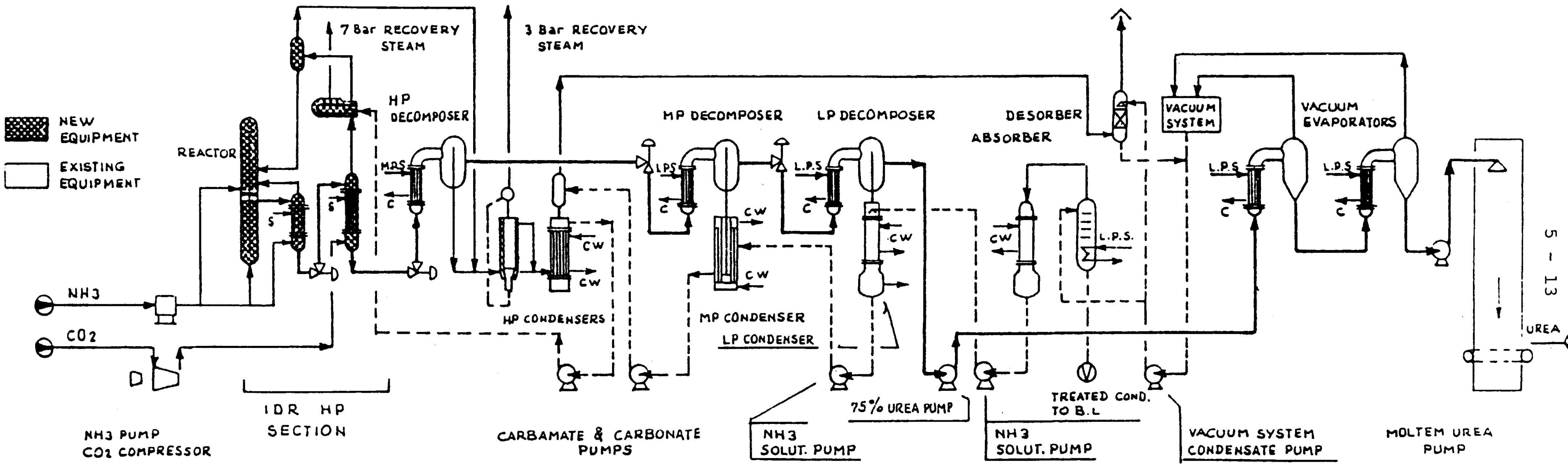

Fig.4 Flow-sheet of the Ferrara urea plant retrofitted according to IDR technology.