Revamping of the PCS Nitrogen 03 Plant in Trinidad

Elizabeth West-Toolsee
PCS Nitrogen Trinidad Ltd, Trinidad, West Indies.

Ermanno Filippi
Ammonia Casale S.A., Switzerland.

Prepared for Presentation at

The 50th Annual Safety in Ammonia Plants and Related Facilities Symposium
Toronto, Canada - September 25-29, 2005
Paper No. 2c

Revamping of the PCS Nitrogen 03 Plant in Trinidad

The 03 ammonia plant at PCS Nitrogen in Trinidad is an original Braun 1965 design plant. A recent revamp of this plant has increased its capacity from 830 STPD to 1,050 STPD and has converted the plant from a Braun 50 % excess air operation to a conventional ammonia plant design. This revamp involved the installation of the first Ammonia Casale Isothermal Converters in ammonia service.

Elizabeth West-Toolsee
PCS Nitrogen Trinidad Ltd, Trinidad, West Indies.

Ermanno Filippi
Ammonia Casale S.A., Switzerland.

Introduction

The 03 ammonia plant is an original C.F. Braun design that was constructed in 1965 in Brea California. The plant was relocated to Trinidad in 1994. The design capacity at that time was 750 STPD. Some minor modifications increased the plant's production rate to 830 STPD.

Following a recent plant revamp engineered by Ammonia Casale, the plant production is now 1,050 STPD while the energy consumption is now 34.85 mmBTU/ST. The revamp involved converting the plant from the original Braun purifier design operating with 50% excess air in the front end, to a conventional ammonia plant operation. The purifier was idled and a hydrogen recovery unit was installed to treat the purge gas from the synthesis loop.

The two existing converters were retrofitted with Casale isothermal design converter baskets. These are the first of their kind to be installed in ammonia service. They provided reduced pressure drop and improved conversion.

Selection of Revamp Scheme

Prior to embarking on this particular revamp scheme, several other options had been considered all of which incorporated the purifier in the redesign. Certain basic criteria were applied in all instances.
These included:

- Sound engineering
- Limited capital cost
- Schedule
- Minimum downtime for implementation
- Improved reliability
- Maximum energy savings
- Minimum rotating equipment changes
- Minimum additional heat to the CW system

A total of three (3) revamp options were considered and the Ammonia Casale one was selected.
The major influencing factors were:

1. Desired production increase with greatest energy savings.
   The Casale revamp targets were 1,050 STPD with a guaranteed energy saving of 3.1 mmBTU/ST (LHV).
2. Removal of the air limitation problem on the plant.
   The existing air compressor train was limiting at the old rates because of the 50 % excess air requirements at the secondary reformer. With the removal of the purifier and hence the change in operating philosophy, marginally less air is required for the revamp scheme than

before. This negates the need for air compressor modifications. It also results in the front-end equipment/piping, between the secondary reformer and the CO_2 removal section, being adequate for the revamp conditions.

3. The capital cost and the execution time were both in keeping with the set targets.
4. There is an option for even further revamp to 1,200 STPD with a proposed Phase II.

This plant revamp was conducted at a very rapid pace. The major milestones were as follows:

- April 2004, Ammonia Casale was selected to perform the engineering phase of the revamp along with the supply of the isothermal converter baskets.
- July 2004, the basic engineering was completed.
- August 2004, ABS Consulting conducted a HAZOP for the revamp
- December 2004, the detailed engineering phase was completed.
- January 2005, the Casale converter baskets were on site.
- March 5^{th} 2005, the plant was shutdown for execution of the revamp.
- April 9^{th} 2005, ammonia product to storage.

The selected mechanical contractor for the job was Cust-O-Fab.

Revamp Scheme

As previously mentioned, the main revamp concept was the transformation of the plant from a Braun excess air design to a conventional design ammonia plant.

The Braun process is characterized by the introduction of excess air in the secondary reformer. This reduces the load of the primary reformer and requires a cryogenic purifier, downstream of the methanator, to remove the excess nitrogen. This purifier removes almost all of the inerts contained in the gas. There is however, an expander located immediately upstream of the purifier and this creates a large pressure drop.

The transformation of the Braun design to a conventional design, without excess air and without the expander, improves the conditions in most of the plant.

- It makes the excess capacity of the air compressor available.
- Reduces the hydraulic load on all equipment downstream of the secondary reformer.
- Increases the suction pressure of the synthesis gas compressor.

On the contrary it increases both:

- The duty of the primary reformer
- The concentration of the inerts in the make-up gas to the synthesis loop.

Therefore, the two main areas that needed to be improved were the reforming section and the synthesis loop.

The Casale engineering study identified the following major changes required for the revamp:

1. Installation of a Pre-reformer.

This comprised of:

   a. A Pre-Reformer with Casale designed axial-radial internals.
   b. A new fired heater to recover the resulting temperature drop, in the mixed feed gas to the primary reformer, from the endothermic pre-reforming reaction.

2. Revamp of the Primary Reformer.

This was handled separately by Onquest Engineering Inc. and involved:

   a. Replacement of the catalyst tubes.
   b. Extension of the radiant section.
   c. Replacement of the mixed feed coil.
   d. Installation of a combustion air blower to supplement the Gas Turbine Exhaust (GTE).

3. Installation of a quench nozzle on the HTS quench.
4. Upgrade of the CO_2 removal system.
   This comprised:
   a. Replacement of the trays in the MDEA Regenerator.
   b. Installation of an additional steam reboiler.
   c. Installation of two additional Regenerator Overhead Condensers.
   d. Installation of an additional Regenerator Overhead Separator.

5. Idling of the Purifier section.
6. Replacement of the synthesis gas compressor HP rotor.
7. Replacement of the existing two converter internals with the Casale isothermal basket design. This consists of an arrangement of exchanger plates in the axial-radial catalytic beds.
8. Installation of a BFW heater.

9. Installation of a Hydrogen Recovery Unit. This is a used unit that was refurbished and was handled as a joint effort between Air Products and PCS Trinidad.
10. Changes in the ammonia recovery section.
    a. Replacement of the MP ammonia absorber with a high pressure absorber.
    b. Installation of a new HP Absorber feed pump.
11. Replacement of the ammonia product pumps. This was handled as an internal project at PCS.
12. Replacement/Addition of control valves and PSVs.

Process Details

Reforming

The reforming stage consists of three main sections;
1. Pre-Reforming
2. Primary Reforming
3. Secondary Reforming

Pre-Reforming

The pre-reformer section was installed to increase the total reforming capacity of the plant. This became necessary for two reasons:
1. To compensate for the elimination of the excess air at the secondary reformer.
2. To increase overall plant capacity.

Mixed feed, desulphurized feed gas and process steam, with a steam/carbon ratio of 3.2, flows through the mixed feed coil in the primary reformer convection section, is heated to 1,000 ^{o}F and flows to the pre-reformer.

The pre-reformer is an Ammonia Casale designed axial-radial adiabatic reactor loaded with a nickel based steam reforming catalyst. Its low pressure drop, of approximately 3 psig, is characteristic of the axial-radial design.

The gas leaving the pre-reformer is partially reformed and has a methane slip of 67 %. Due to the endothermic nature of the reaction, the gas leaves at 820 ^{o}F. It then flows to the fired heater, which supplies the heat necessary to increase the temperature to the reformer tube inlet temperature, 1,150 ^{o}F.

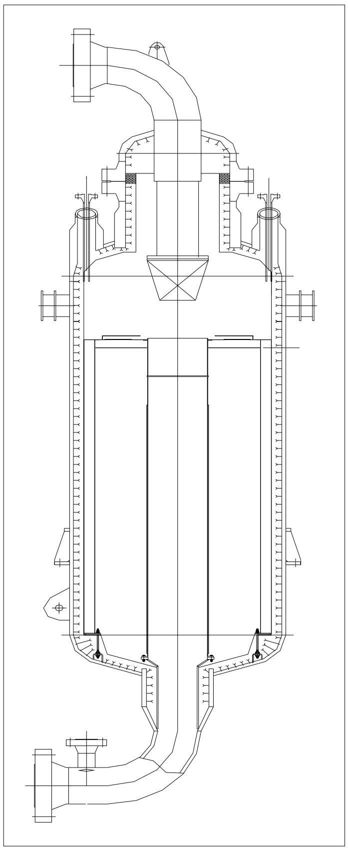

Fig. 1 - PCS Axial Radial Pre-Reformer

Primary Reformer

The primary reformer was an original Foster Wheeler design side-fired reformer. The tubes were at their end-of-life and the frequent failures were causing severe plant reliability issues. The upgrade of the primary reformer was performed by Onquest Engineering and was done in tandem with the revamp requirements. The major changes were:

- Tube arrangement changed from staggered to inline.
- Number of tubes increased from 136 to 152.
- Extension of the radiant box, 20'.
- Installation of 40 additional burners.
- Replacement of the old burner tips.
- Replacement of the mixed feed coil.
- Replacement of the inlet header and pigtails.
- Replacement of the outlet header and pigtails.
- Change from counter weights to spring support system.

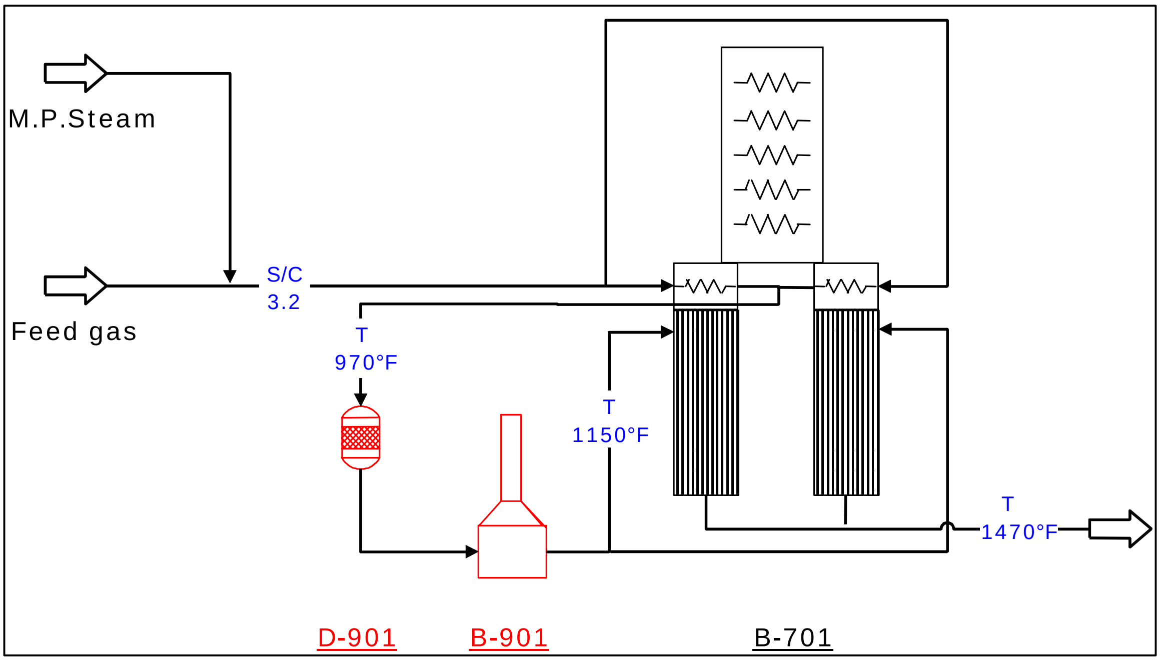

Fig. 2 - Pre-Reformer Arrangement (new items in red ink)

The radiant box extension was shipped in sections with insulation pre-installed, ready for assembly. The insulation however was damaged in shipping and was replaced on site.

The new primary reformer design inlet temperature is 1,150 °F while the outlet temperature is 1,470 °F. This corresponds to a radiant duty of 159 mmBTU/hr and a
convection duty of 182 mmBTU/hr. The gas ex the reformer has a methane slip of 11.7 %.

The composition of the fuel gas to the burners was changed with the elimination of the waste gas from the purifier section. The burner tips were replaced due to the much lower flow from the Hydrogen Recovery Unit (HRU).
The Gas Turbine Exhaust (GTE), which supplies oxygen to the burners, was deemed to be insufficient and an auxiliary air blower was installed to supplement the oxygen supply. The exhaust of this blower was tied into the GTE ducting.

Fig. 3 - Photo of the Primary Reformer and Fired Heater

Shift Conversion

The shift converters, both HTS and LTS, were found to be adequate for the revamp and the only change made in this section was the installation of a BFW quench system to control the HTS inlet temperature. This was necessary because of the limitation of the secondary reformer waste heat boiler.

CO_2 Removal

In reviewing the CO_2 removal system the key parameter used for design was the specific energy consumption. At the old rates this value was 54,700 BTU/lbmolCO_2, and the revamp sought to maintain this. To do so, an additional demand of 23 mmBTU/hr was required. This was supplied by installing an additional steam reboiler. In keeping with the increase in reboiler duty, the capacity of the Methyl Diethyl Ammine (MDEA) Regenerator Overhead Condensers had to be increased. This was achieved by installing two additional exchangers.

To maintain stripping efficiency, the MDEA strength was increased from 40 % to 45 %, and the circulation rate was increased to 2,100 gpm. The system hydraulics were reviewed and it was necessary to replace the MDEA Regenerator trays with new high efficiency design trays.

Synthesis Gas Compressor

The LP stage of the compressor was found to be suitable for the capacity increase. This was primarily due to the significant increase in suction pressure, 380 psig up from 315 psig, caused by the decommissioning of the purifier section.

The HP stage was limiting with the increased volumetric flow and had to be retrofitted. A new rotor was installed.

Synthesis

The plant is fitted with two ammonia converters operating in parallel. The revamp of the synthesis section demanded a very significant efficiency improvement because of:

1. The large capacity increases and
2. The higher concentration of inerts in the circulating gas due to the front-end transformation.

This entailed the retrofit of the converter internals with Ammonia Casale isothermal design. This new design allowed a significant reduction in the circulation flow and consequently a considerable decrease in the specific duties of the exchangers. The lower recycle flow resulted in a smaller heat recovery in the synthesis waste heat boiler. To overcome this, a BFW pre-heater was installed and recovers 50 mmBTU/hr. Additionally the increased ammonia conversion to 17 % in the synthesis loop translated into no additional load on the refrigeration system, which in turn meant no modification to the refrigeration compressor.

The Isothermal Ammonia Converter (IAC) design abandons the use of multiple adiabatic catalyst beds, commonly used in the ammonia industry for the pseudo isothermal design, and offers a higher conversion per pass. The new design is based on the use of plates immersed in the axial-radial catalyst bed to remove the reaction heat while it is formed.

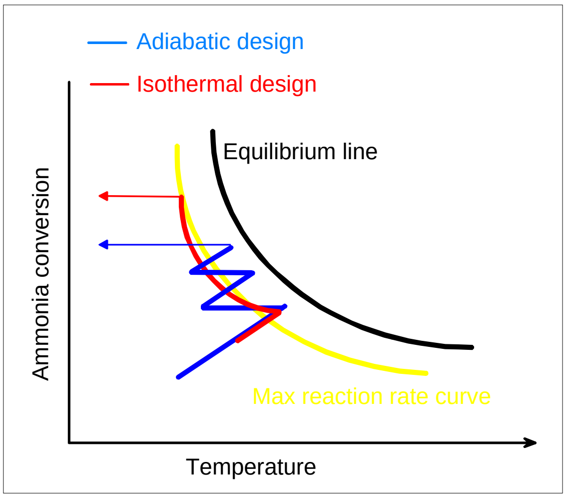

Fig. 4 - <u>Temperature Profile of the IAC</u>

As indicated in the Fig. 4 above, the temperature profile achieved in the catalyst bed follows the line of maximum reaction rate, so obtaining the highest possible conversion per pass from a given catalyst volume.

The use of plates for cooling, allows the design of a pseudo isothermal converter without tubesheets, eliminating the size restriction and simplifying the construction of the internals and the operation of catalyst loading and unloading. In addition, the non-adiabatic beds are axial-radial, featuring a low pressure drop and allowing the use of small size, high activity catalyst.

The new IAC is a very efficient design and is also suited for the very high capacity mega-ammonia plants that are becoming popular on the market, with production rates greater than 4,500 STPD.

Fig. 5 - Photo of Converter Basket being lifted into place

Purge Gas Treatment

With the change in front end operating philosophy, the concentration of inerts in the loop has significantly increased, resulting in a much higher purge gas flow from the loop. The purge gas flow rate has increased to 15,000 lbs/hr up from 7,000 lbs/hr.

To recover the hydrogen in the purge, a Hydrogen Recovery Unit, HRU, has been installed. This is an old unit that was purchased and a joint effort between PCS and Air Products resulted in the successful refurbishing of the system.

The hydrogen product is recycled back to the synthesis gas compressor and the reject or waste gas is used for dryer regeneration and sent to the primary reformer burners as fuel.

Fig. 6 - Photo of the refurbished HRU

Steam System

HP steam generation has increased from 316,000 lbs/hr to 385,000 lbs/hr, but no equipment modifications were necessary.

Execution

The procurement of all materials was performed by PCS, with the exception of the pre-reformer and converter internals, which was done by Ammonia Casale. In several instances available used equipment was procured and adapted accordingly. This proved to be advantageous both for equipment delivery time and cost.

In an attempt to minimize plant downtime (the duration of the outage was 34 days total downtime, from production to production), a large amount of work was done before the actual shutdown. Some of the major pre-shutdown work included:

- Assembly and loading of the converter catalyst baskets.
- Piling for the radiant box extension, pre-reformer vessel, fired heater, BFW exchanger.
- Installation of these vessels as well as the HRU, air blower, MDEA reboiler and Regenerator overhead condensers.
- Pre-fabrication of piping.

Plant Performance

	Pre-Revamp	Post Revamp	
		Guarantee	Actual
Production, stpd	830	1,050	1,055
Energy Saving, mmBTU/ST		3.4	4.2
Sp. Energy, mmbtu/ST	39.1	35.7	34.9

Table 1

Following the revamp, both the daily production and the specific energy consumption, were superior to the guaranteed figures. Typical figures are illustrated in the table 1 above.

We have not yet conducted the performance test at the new increased rates, but the normal operating data indicates that the plant has successfully achieved its performance targets.

Potential for Further Capacity Increase

There is potential for further plant capacity increase to a daily rate of 1,150-1,200 STPD. The major bottlenecks identified in moving to that stage are mainly rotating equipment.

They can be summarized as follows:

1. LP stage of the synthesis gas compressor.
2. Refrigeration compressor.
3. Combustion air blower.
4. Convection section coils.
5. Hydraulics of the CO_2 system.
6. Synthesis gas dryers.

The 1,050 STPD revamp was engineered with this potential Phase II in mind. Most of the additional or replaced equipment was sized for this increased plant rate.

This includes:

1. The pre-reformer and fired heater.
2. The primary reformer was designed with the potential for eight (8) additional tubes (redundant)
3. The new high efficiency MDEA regenerator trays.
4. The Regenerator overhead condensers.
5. Synthesis gas compressor HP rotor.
6. Casale Isothermal Converter baskets.
7. BFW pre-heater in the synthesis loop.

Conclusion

The revamp constraints, particularly the tight schedule, presented many challenges to both PCS and Ammonia Casale and indeed to all the other parties involved in the project.

Several things made this project unique including:

- The very tight schedule, 12 months from start of engineering to implementation.
- The first transition of a Braun design plant to a conventional ammonia design.
- The first installation of the Ammonia Casale Isothermal converters in ammonia service.

From the results obtained since startup on April 9th 2005, it is evident that the plant revamp was indeed a success. The plant, besides having increased its rated capacity, is now much more efficient.