Applied Engineering Solutions to Solve Production Problems in Carbon Monoxide Unit of Fanavaran Petrochemical Complex

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***Abstract*—** In this paper we present and explain innovative methods to solve problems cause of plugging a Brazed aluminium plate-fin heat exchanger as a part of the carbon monoxide processing cold box and focused to share the engineering techniques that were applied to figure out the problems and found solutions. Although the deplugging of the Brazed Aluminum Plate Heat Exchanger was not completely done, but with other solutions such as new methods of cleaning, designing and installation a new heat exchanger for pre-cooling Co-Recycle gas and try to modify some process Equipment, we succeeded to solve the problems and furthermore achieve to higher efficiency in Carbon Monoxide production. Conclusions of this paper contain experiences those are useful for Cryogenic industries with cold box problems.

Keywords—Cold box, Brazed Aluminum Plate-fin Heat Exchanger, Gas Dryer, Molecular Sieve, Plugging, Cartridge Filter

I. INTRODUCTION

A. *Cryogenic Process Overview*

The Cryogenic unit consist of three main Process Areas consist of Feed gas pretreatment, Cryogenic Separation and Co product compression Fig1.

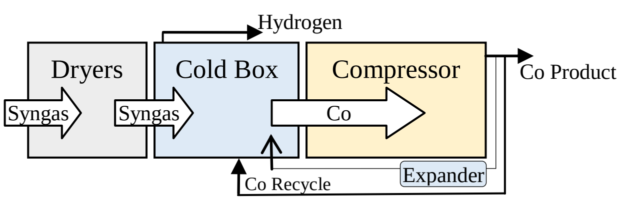

Fig.1 Simplified block diagram of Cryogenic Process

The feed gas pre-treatment section removes water and carbon dioxide from the feed gas down to a level that will prevent freezing in the cold box. Tow thermally regenerated adsorber vessels containing molecular sieve and silica gel adsorbents are used to remove the water and carbon dioxide. Regeneration is achieved using low pressure offgas from the cold box, which is heated against steam in the generation gas heater to provide the energy required from desorption.

The cold box unit uses a methane wash process in which cooled synthesis gas is scrubbed by cold methane derived from, the distillation of carbon monoxide and methane at the cold end of the process. The hydrogen leaving the top of the wash column is scrubbed of carbon monoxide, minimizing losses into the hydrogen product. The methane wash is carried out at the essentially feed gas pressure, which avoids the need of any hydrogen product compression or any feed gas compression. The hydrogen deficient stream leaving the base of the methane wash column is stripped of remaining hydrogen in a small stripping column. This is necessary, because any hydrogen that enters the final carbon monoxide/methane distillation would contaminate the product carbon monoxide and reduce its purity to below the required product specification.

The carbon monoxide/methane stream leaving the base of hydrogen stripper is fractionated to give a high purity gaseous carbon monoxide product and high purity liquid methane stream. The methane stream is used for scrubbing hydrogen. Carbon monoxide in the methane not only reduces overall carbon monoxide recovery, but also contaminates the hydrogen product. The methane stream therefore contains minimal carbon monoxide. This liquid methane stream is pumped to adequate pressure to provide methane wash to the wash column. The balance of the methane is evaporated and exported at low pressure.

Because of the feed gas nitrogen level is low; the nitrogen is allowed to leave with the carbon monoxide product without the need for final nitrogen/carbon monoxide fractionation.

The process requires external refrigeration, both to given an overall energy balance and to ensure that refrigeration is available at appropriate temperatures in the process. An open loop carbon monoxide refrigeration cycle provides both Co product compression of the recycled refrigerant stream. The supply of refrigeration in the process is optimized, by evaporation carbon monoxide at intermediate Co Cycle compressor pressure. Finally due to the high product recovery and purity specification, additional external refrigeration is needed to meet the overall cold box energy balance, which is provide by carbon monoxide expander.[1]

B. *Cold Box*

Packaged units also known as cold boxes are utilised in a wide range of applications for the treatment of cryogenic fluids and gases. The cold box contains the cryogenic heat exchangers, distillation columns and associated valves and piping. Because parts of this system are very cold, all components are mounted inside the cold box and then encased in perlite insulation. [2]

C. *Cold box heat exchangers*

Brazed aluminium plate-fin heat exchangers (PFHE) are the most compact and energy efficient heat exchangers for handling a wide range of services. Their ability to carry multiple streams, occasionally up to 12 or more, allows process integration in certain industrial processes, establishing them firmly in air separation processes and other cryogenic systems. The very large surface area per unit volume is

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particularly advantageous when low temperature differences apply. Fig 2

Fig.2 Illustration of a Typical Multi-Stream Brazed Aluminium Plate-Fin Heat Exchanger. [1]

A Brazed Aluminium Plate-Fin Heat Exchanger consists of a block (core) of alternating layers (passages) of corrugated fins. The layers are separated from each other by parting sheets and sealed along the edges by means of side bars, and are provided with inlet and outlet ports for the streams. The block is bounded by cap sheets at the top and bottom. [1]

II. MAJOR OVERHAUL

Major overhaul of carbon monoxide unit in November 2017 were done with the aim of increasing capacity. The most important actions were the following:

1- Replacing Reformer catalyst tubes with new tubes
2- Replacing Filter Pad, Molecular Sieve and Silica Gel of R-3001 A / B Reactors (Dryers).

After Start-up, the Cold Box internal exchangers and equipment faced with a sudden increasing in temperature, which resulted in the inability to increase the capacity (preventing the injection of more gas into the cold box) and consequently a severe drop in carbon monoxide production.
With the aim of compensating production drop, the volume of gas entering the Cold Box increased, but due to the lack of increase in production capacity, the assumption was that the solid particles were transferred from dryers into the Cold Box. A summary of the cryogenic unit can be found in Fig. 3.

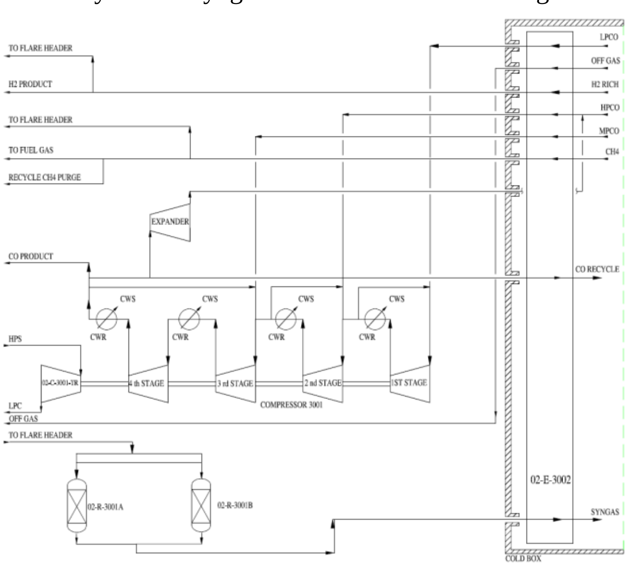


Fig3. A summary of the Carbon monoxide unit

After the shutting down the carbon monoxide unit to find out the causes of production problems, the strainer at entrance of the E-3002 was inspected and discovers the molecular sieve particles in the strainer. Fig.4

Fig. 4 molecular sieve particles in the strainer.

Passing the molecular sieves from the Dryer(R-3001) and blocking the passages could be the main reason of preventing entering gas to the Cold Box and cause of production problems. Due to the passing of a significant amount of Molecular Sieve from the filter pad and the reduction of the catalyst level(catalyst bedding), filter pad was changed, repair and sealing the side wall of the reactor by Rope was done, and the molecular sieve an silica gel was charged again. Fig 5

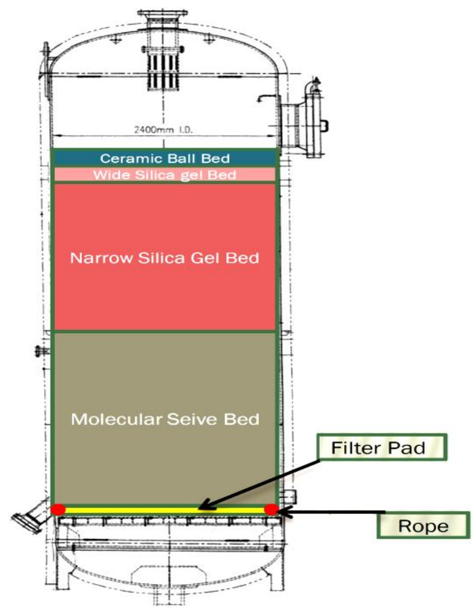


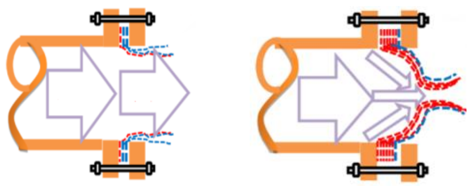
Fig5. Absorber vessel R-3001

Considering the entry of particles into the E-3002, the cleaning operation based on the manufacturer's instructions was done. [3]
Co-Recycle Passages have been Reverse Blow(Flushing) repeatedly Up to 7Barg; Then the unit was start, but after start-up, the unit was not on normal production and we had to forced shut down and it was decided to repeat the cleaning procedure again.
Although the Flushing operation was repeated many times, but the desired result was not achieved, then a Quick Opening

Valve was used, which also led to Dust evacuation, but after commissioning, the previous problems still remained.

Through field studies and studying articles on similar solutions, we found the PTT Gas Separation Plant in Thailand which faced with similar problems, and negotiated with Technical inspectors from the Technical Services department of them and then they shared with us their experiences about flushing methods with more efficiency.

According to the proposed method of PTT, instead of using of plastic sheets for bursting disc, it was proposed to use a BLUE SHEET gasket, which, due to its lack of availability, sheet gasket was used. The use of this method has this advantage that sudden burst of the gasket led to a sudden evacuation more volume of gas and a stronger shock than plastic layers. Fig6. [4]



a. Blue sheet (Gasket) b. Plastic layers

Fig6. Comparison flushing methods

With the explanations given in the last paragraph, with using the new Flushing method and after the commissioning, it was possible to achieve continuous production with low capacity.

Due to the fact that the passing of molecular sieve and dusts from the dryers filter was the main cause of blocking E-3002, and in order to prevent repeating this problem, by Organizing teams of engineering and process experts and consulting with the manufacturer companies the filters has been design for filtration of particles larger than one micron. Fig 7

Fig7. Cartridges

After design and manufacturing filters (F-3001), they are mounted on the dryer outputs (R-3001).Fig 8

Fig8. Filters after installation

In order to investigate the function of the filters, after about one month of commissioning, one of the filters was opened and it was observed that the implemented design for the filtering had a good result. Fig 9

Fig9. Result of Filtration

According to the conducted studies and correspondence with the manufacturing companies (Nordon and Costain), the possibility of blocking of the E-3002 by particles passing through the dryers and thus reducing the efficiency of the Exchanger E-3002 seemed probable, Thus, the Cold Box energy loss rate was calculated by process experts, and according to reports, the total cooling capacity of the Cold Box has dropped from 324 kW to 255.6 kW and thus a large part of this loss due to blocking of heat exchanger E -3002.

The result of the studies of the engineering teams in order to compensate of the wasted energy and the reduction of the efficiency of the E-3002, was suggested that the fourth stage exchanger of the compressor (C-3001-E2D) and the Final Gas Cooler (E-2005) that cooled by cooling water They were cooled by chilled water, and because of the chiller unit was not enough Capacity for this purpose, only C-3001-E2D was cooled down by the chilled water. Fig 10

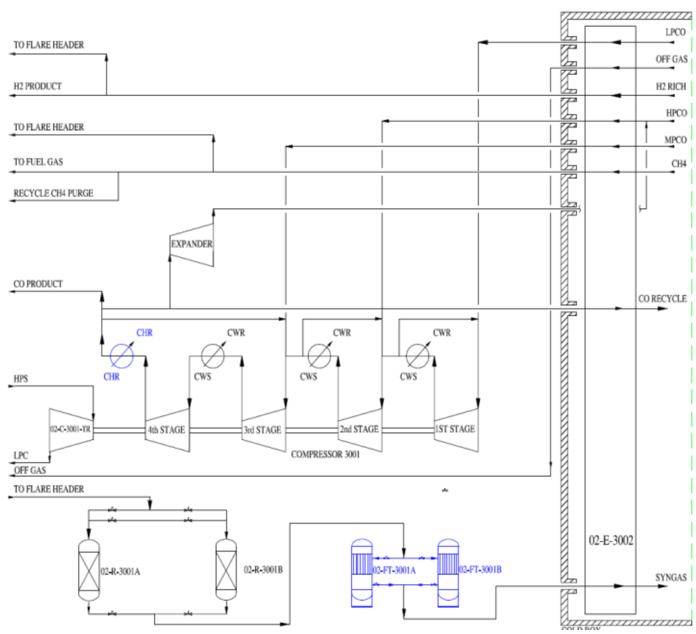


Fig10. After modification

CONCLUSION

The substitution of chilled water instead of cooling water was resulted in better process conditions. Table 1

TABLE 1
CASE1. BEFORE MODIFICATIONS, CASE2.AFTER MODIFICATIONS

item	Descrition	Case1	Case2
1	Production(Kg/hr)	8500	12200
2	Temp. E-3002 in (°C)	23-30	15-23
2	Feed Gas(Nm3/hr)	33000	45000

Regarding the optimization and modifications, the production of carbon monoxide unit remained stable and Due to the very positive effect of pre-cooling the co-recycle before entering the Cold box, in order to cool down and reduce the consumption of chilled water and reach a more favorable temperature, install a new shell and tube exchanger (E-3010) after the C-3001-E2D and before entering the Cold box. The expected actions to be implemented in the future are:

-Replacement of E-3002

-Install the Coke filter on the Co Recycle path

-Provide Molecular Sieve and Silica Gel from Licensor-approved manufacturers

-Grid Support Design and Molecular Sieve Fixing

-JT Valve Performance Modification

-Correction of communication lines insulation

-Perlite modification and examination of the use of paint coatings with insulating properties.

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