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# REDUCING AND CONTROLLING THE HYDROCARBON EMISSIONS FROM RICH AMINE REGENERATOR UNITS IN THE NATURAL GAS SWEETENING PROCESS: A CASE STUDY AND SIMULATION

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**ABSTRACT**: *Natural gas has been the most popular fossil fuel in recent years, and the demand for it has been dramatic. In fact, natural gas possesses several useful features: it has a high heating value, it can be utilised as a raw material in several petrochemical industries and it is a cheap fuel source. However, raw natural gas usually contains a variety of non-hydrocarbon components, e.g., acid gases, helium, nitrogen and mercury. Raw natural gas sources with large amounts of acid gases are known as sour gas. Sour gases should be treated and sweetened to meet natural gas pipeline specifications and sale contracts. The amine gas sweetening process is widely utilised in the gas industry, either to reduce or to remove acid gases from sour natural gas streams. Indeed, amine gas sweetening has several advantages over other sweetening processes; it is more economical than other processes, and it operates continuously. Indeed, the global hydrocarbon emissions from the oil and gas industries have been dramatic. Moreover, methane, ethane and propane may be the most obvious gases that are emitted by the natural gas industry. In many cases, these emissions occur from gas processing units, e.g., gas sweetening and gas dehydration processes. In fact, these hydrocarbon gas emissions contribute to global warming and environmental pollution. Moreover, hydrocarbon emissions lead to huge losses of precious hydrocarbons every hour. Therefore, this study aims to study the effects of the solvent circulation rate on the hydrocarbon carryover from the amine gas sweetening using Aspen HYSYS software. The study also used a Murban gas stream in the simulation process because it is loaded with a high concentration of acid gases. The study determined that the amine circulation rate may have significant effects on the hydrocarbon losses during the sweetening process. Moreover, the study also recommended several methods to reduce this effect and the emission, e.g., balancing the amine circulation rate with both the sweetening efficiency and the hydrocarbon emissions.*

**KEYWORDS**: Natural gas sweetening, Murban field, Amine solution, Process simulation, Aspen HYSYS, Process optimisation, Global warming, Hydrocarbon emission, Amine circulation

## NOMENCLATURE

| | | | |
|---|---|---|---|
| RMM | Relative Molecular Weight | $H_2S$ | Hydrogen sulphide |
| $CO_2$ | Carbon dioxide | DEA | Dimethylamine |
| BTEX | Benzene, toluene, ethylbenzene, and xylenes | | |


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## INTRODUCTION

In recent years the demand for and consumption of natural gas have been notable. Indeed, natural gas possesses several advantages, e.g., a high heating value, environmental friendliness and low cost. However, raw natural gas may contain several impurities, e.g., water vapour and acid gases [1]. Therefore, it should be processed in a natural gas processing plant to either remove or reduce these impurities (i.e., natural gas sweetening and dehydration). Indeed, during the operation of these processes large quantities of hydrocarbons (for example, methane and ethane) may be emitted into the environment, and these hydrocarbons could be contributing to the global warming phenomena. In fact, global methane emissions from the natural gas industry have been inadequately recognised and quantified in many countries [2]. As a result, in many cases, the emissions are not well known even at the country level [3]. Indeed, in many cases, the emissions from the wellhead and gas processing sector are included but emissions from the equipment associated with the fractionation of propane, butane, and natural gas liquids were excluded [1]. Due to growing environmental concerns, limiting the hydrocarbons emissions (e.g., BTEX and methane) from gas processing plants is of primary importance. Indeed, glycol units have been under scrutiny for some time [2]. However, the amine process has recently been targeted as well. Indeed, switching from coal and oil to natural gas fuels could serve as an interim measure to reduce the effects of global climate change caused by greenhouse gas emissions. Methane is the main greenhouse gases and its content in the atmosphere has increased dramatically over the past 300 years [3]. Amine solutions can absorb a considerable amount of light hydrocarbons, e.g., methane, ethane, propane and BTEX. Furthermore, these dissolved hydrocarbons in rich amine solution are obtained via contact with feed gas during the sweetening process. The rich amine solution with dissolved hydrocarbons is processed in the amine regenerator unit to recover the lean amine and reuse it in the sweetening process [3]. In fact, the dissolved hydrocarbons in the rich amine solution are released in the regenerator's overhead. This overhead either vents to the atmosphere or feeds a sulphur recovery unit. The HC content discharged from the regenerator vent to the atmosphere must comply with the recently established stringent regulations. For acid gas feeds to a Claus unit, a high HC content may result in catalyst fouling, a low quality sulphur product, or the need for a more sophisticated burner design. However, many oil and gas companies may release these hydrocarbons into the environment. Amine gas treatment is considered one of the most common processes in petrochemical plants, onshore refineries and offshore natural gas processing plants, as well as other industries [2].

### Basic Amine Process Descriptions

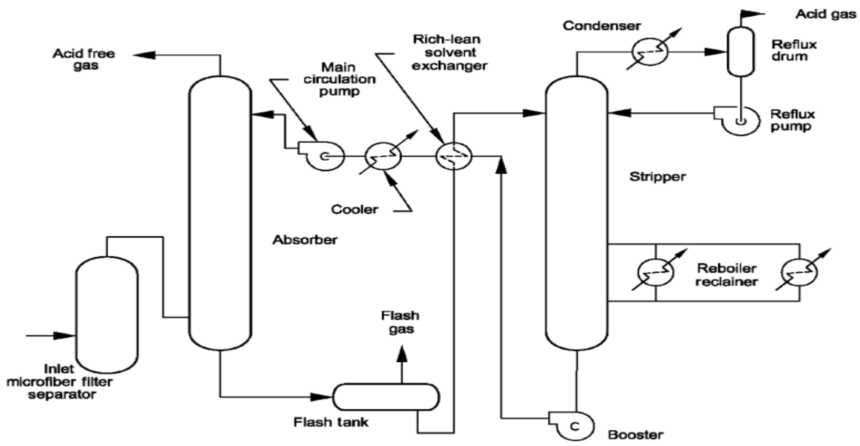
The amine process could be considered the most economical and common process in the gas industry sector. This process is uses an alkanamine solution as a chemical solvent to remove acid gases from natural gas streams [7]. Alkanamines possess high affinity toward acid gases, and there are several types of amines that are used in the amine process, e.g., monoethanolamine (MEA) and dimethylamine (DEA). The amine process consists of several operation units: the contactor tower, regenerator tower and heat exchanger [6]. Figure (1) shows a typical amine process.

The chemical reaction of amines with $H_2S$ and $CO_2$ are given below:

$2RNH_2 + H_2S = (RNH_3)_2S$

$2RNH_2 + CO_2 = RNHCOONH_3R$ *R= mono, di, tri-ethanol.

**Figure 1: General flow diagram for an amine plant [6].**




## Murban Gas Composition and Water Content Calculations

The Murban gas stream composition and operating conditions are show in table (1). Based on the gas composition, it appears that these values were determined on a dry basis. Thus, estimating the water content before the process design or simulation is recommended.

**Table 1: Murban associated natural gas [4].**

| **Murban Field data** | | **Component** | **Mole %** |
|---|---|---|---|
| | | Methane | 76.4 |
| | | Ethane | 8.1 |
| **Location** | United Arab Emirates | Propane | 4.7 |
| **Gas density** | 0.65 Kg/m$^3$ | Butane | 2.6 |
| **Gas S.G (Air=1)** | 0.67 | pentane | 1.9 |
| **Pressure** | 7000 K.pa | Carbon dioxide | 4.5 |
| **Temperature** | 38 °C | Nitrogen | 0.1 |
| **Flow rate (Assumed)** | 120,000 stdm$^3$/hr | Hydrogen sulphide | 1.7 |

The natural gas water content can be estimated using the McKetta-Wehe Chart [6]. Therefore, the raw natural gas water content is approximately 1000 kg/MMstd.m$^3$= 128.265 kg/hr. The new natural gas composition could be calculated and summarised as shown in table (2).


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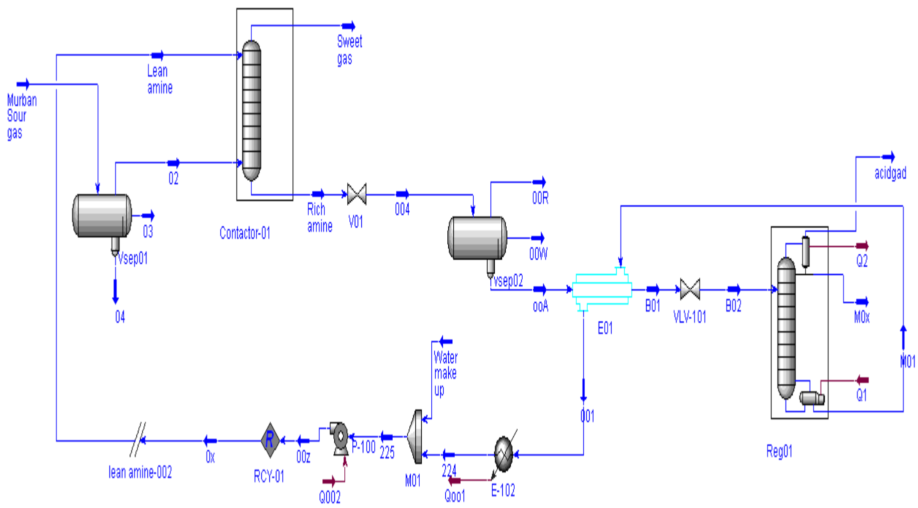
**Table 2: Murban natural gas compositions and quantities (wet basis).**

| Component | Mol% | Mwt | Kmol / hr | kg/hr | Mol% |
|---|---|---|---|---|---|
| $H_2S$ | 1.7 | 34.076 | 91.0145 | 3101.41 | 1.69774 |
| $CO_2$ | 4.5 | 44.01 | 240.921 | 10602.9 | 4.49402 |
| $N_2$ | 0.1 | 28.02 | 5.3538 | 150.013 | 0.09987 |
| $CH_4$ | 76.4 | 16.02 | 4090.3 | 65526.6 | 76.2984 |
| $C_2H_6$ | 8.1 | 30.07 | 433.658 | 13040.1 | 8.08923 |
| $C_3H_8$ | 4.7 | 44.09 | 251.628 | 11094.3 | 4.69375 |
| $C_4H_{10}$ | 2.6 | 58.123 | 139.199 | 8090.65 | 2.59654 |
| $C_5H_{12}$ | 1.9 | 72.15 | 101.722 | 7339.25 | 1.89747 |
| $H_2O$ | | 18 | 7.12585 | 128.265 | 0.13292 |
| TOTAL | 100 | | 5360.92 | 119074 | 100 |

## Murban Sour Gas Sweetening Simulation

The amine gas sweetening plant for Murban sour gas is simulated using Aspen HYSY. DEA is utilised as an aqueous absorbent to absorb acid gases from the sour gas stream. An amine fluid was adopted for the simulation work, and figure (2) shows the Murban sour gas sweetening process. It is important to use an inlet gas separator to remove any undesirable impurities, e.g., solid particulates and liquids. The amine contactor is also an important part of the sweetening plant, and it has certain requirements, for example, stream temperature and pressure. Moreover, the rich amine needs to be regenerate, which could be achieved by installing the amine regenerator after the amine heat exchanger. The installation of a flash tank for the rich amine solution is important to avoid any technical problems that might be caused by rich amine impurities. The water content of the stream should also be considered in the process to maintain the amine concentration during the process. See appendix (A) for more details of the HYSYS work.

**Figure 2: Process flow diagram of the Murban gas sweetening plant.**





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## RESULTS AND DISCUSSION

First, the study used a 35 % (w/w) DEA amine solution to perform the sweetening process, which achieved an acceptable sweetening result. Figure (3) shows the relationship between the amine circulation rate and the hydrogen sulphide mole percent in the sweet gas stream. Furthermore, figure (4) shows the relationship between the amine circulation rate and carbon dioxide mole percent in the sweet gas stream.

**Figure 3: Effects of the 35 % DEA circulation rate on the hydrogen sulphide mole fraction in the sweet gas stream.**

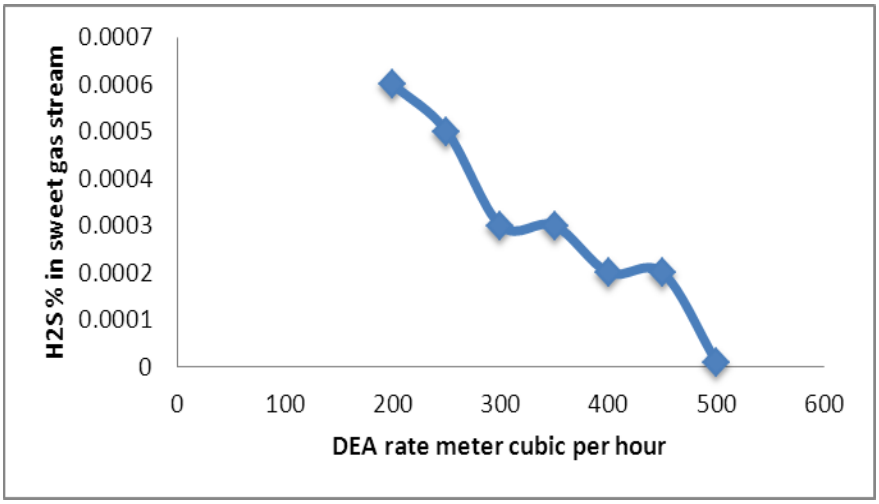
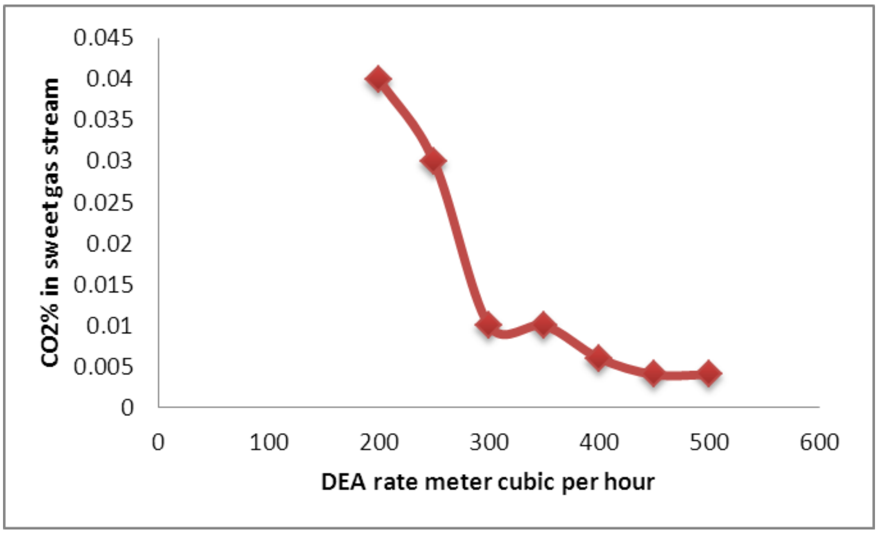



**Figure 4: Effects of the 35 % DEA circulation rate on the carbon dioxide mole fraction in the sweet gas stream.**




Based on figure 3 and 4, increasing the 35 % DEA circulation rate will lead to an increase the acid gas removal. Moreover, at an amine rate of 400 $m^3$/hr the amount of $H_2S$ in the sweet gas was approximately 5 ppm. However, the optimum amine rate is about 300 $m^3$/hr, which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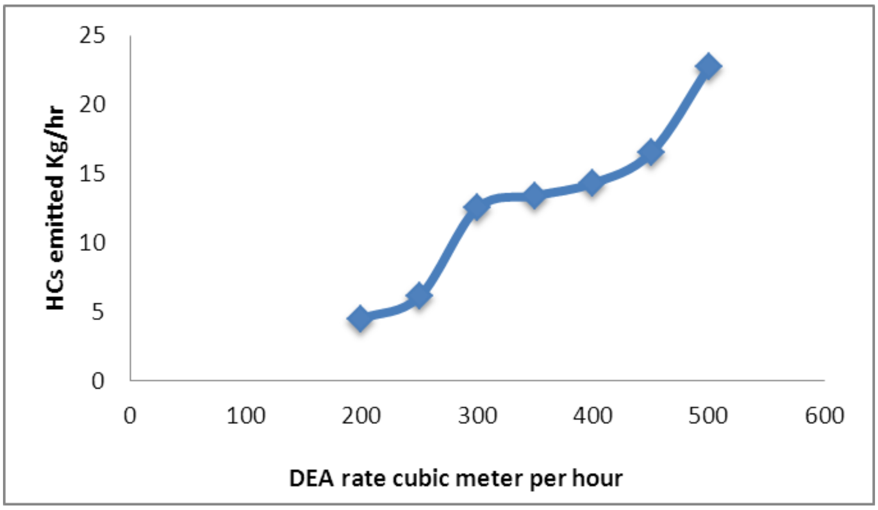
results in 4 ppm $H_2S$ in the sweet gas stream, resulting in the optimum liquid residence time on the tray. However, the cost of the amine process should be considered because any increase in the amine rate leads to an increase in the operation cost.

Figure (5) shows the relationship between the amine circulation rate in cubic meters per hour and the hydrocarbons emission from the amine regenerator unit.

**Figure 5: The relationship between the 35 % DEA rate and the HCs emitted from the amine regenerator unit in kg/hr.**




Based on figure (5), increasing the DEA circulation rate will lead to an increase in the amount of hydrocarbons emitted from the rich amine regenerator unit. The total hydrocarbon emission at an amine circulation rate of approximately 530 $m^3$/hr is quite high, approximately 25 kg/hr. The emissions at 200 $m^3$/hr are lower, approximately 5 kg/hr. Thus, a 300-$m^3$/hr amine circulation rate is recommended because it achieves an acceptable sweetening result and produces a moderate hydrocarbon emission of approximately 14 kg/hr.

## CONCLUSIONS

This study successfully simulated a Murban gas sweetening process using Aspen HYSYS. Moreover, it attempted to investigate and describe the effects of the lean amine circulation rate on the hydrocarbon emissions or losses from the sweetening process. The Murban gas contained a high concentration of acid gases. Moreover, the simulation work showed high removal of the acids, which met the gas pipeline specifications. A 35 % DEA solution with a 300 $m^3$/hr circulation rate achieved optimum gas removal, and the outlet natural gas stream met the gas pipeline specifications. Furthermore, using 35 % DEA is recommended for the process. The amine circulation rate has a significant effect on the hydrocarbon losses from the amine regenerator tower. In other words, increasing the amine circulation rate will increase the hydrocarbon emissions into the environment. Therefore, maintaining a moderate amine circulation rate in the amine gas sweetening process is recommended. Minimising the lean amine circulation rate could reduce the hydrocarbons emissions from amine regenerator unite.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## Appendix (A)

**Figure: Shows the simulation basis manger.**

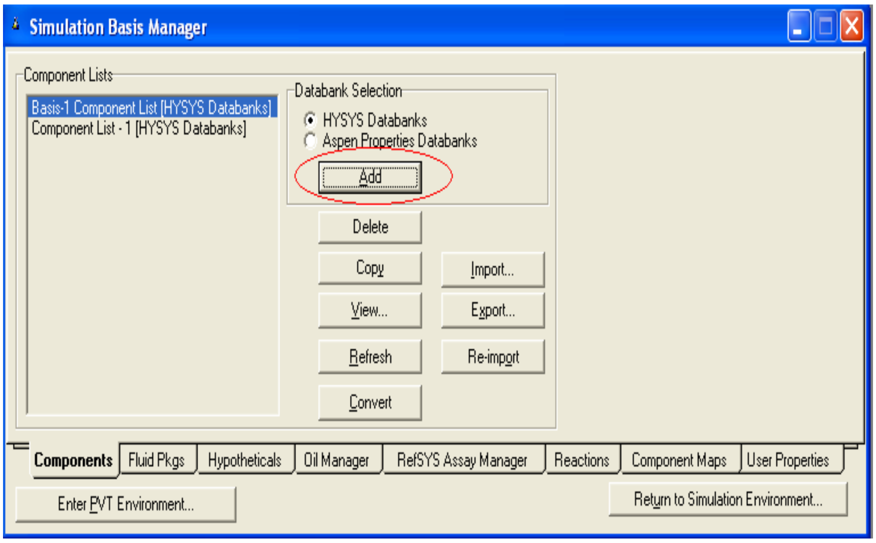


**Figure: Shows the simulation fluid package manger.**

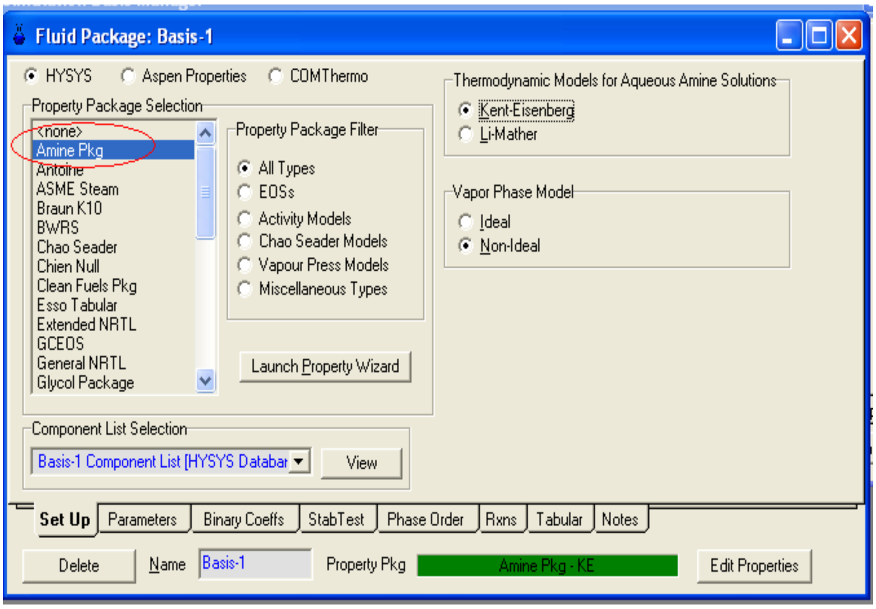



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**Figure: Shows the simulation component manger.**

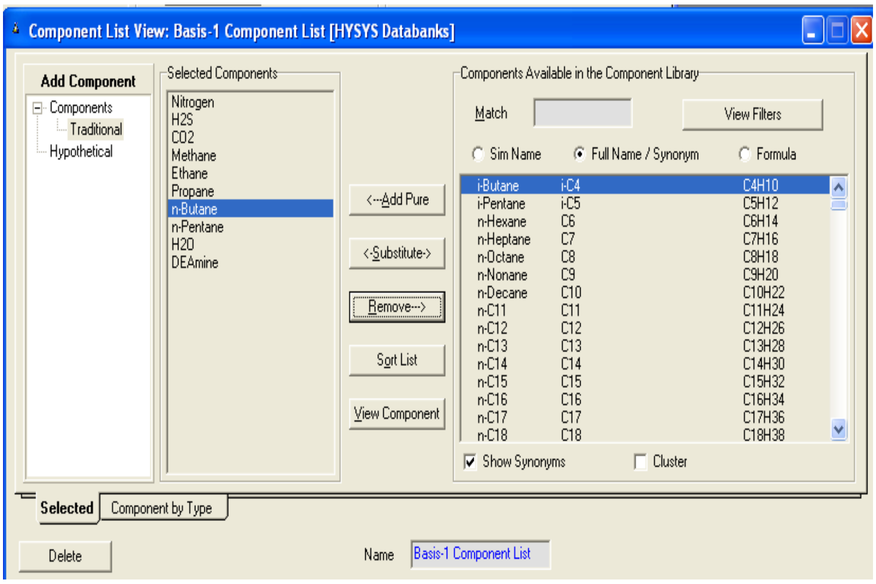


**Figure: Shows the simulation contactor tower manger.**

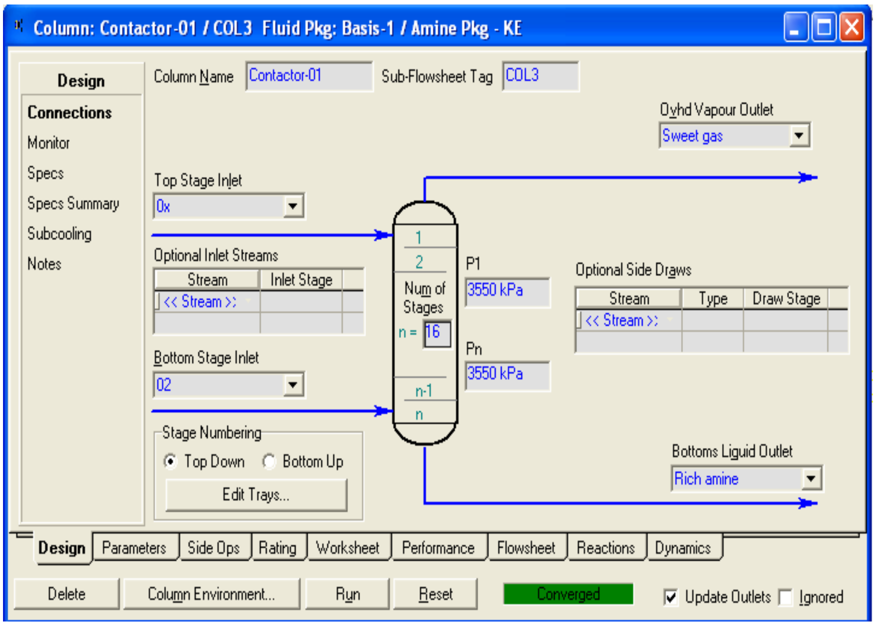

**Figure: Shows the simulation regenerator tower manger.**

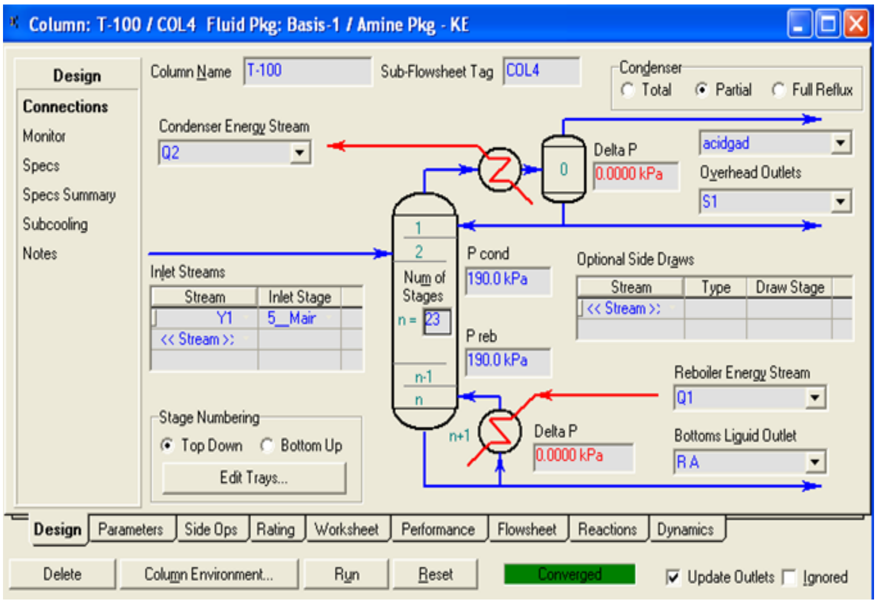


**Figure: Shows the material stream for acid gases that were emitted from amine regenerator unit.**