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# Process design for the treatment of the Irving Oil refinery flue gas: heat recovery, energy analysis and $CO_2$ capture

Matteo Gilardi[a,*], Stefania Moioli[a], Davide Bonalumi[b]

*[a] Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta", Politecnico di Milano, Italy.*
*[b] Dipartimento di Energia, Politecnico di Milano, Italy.*

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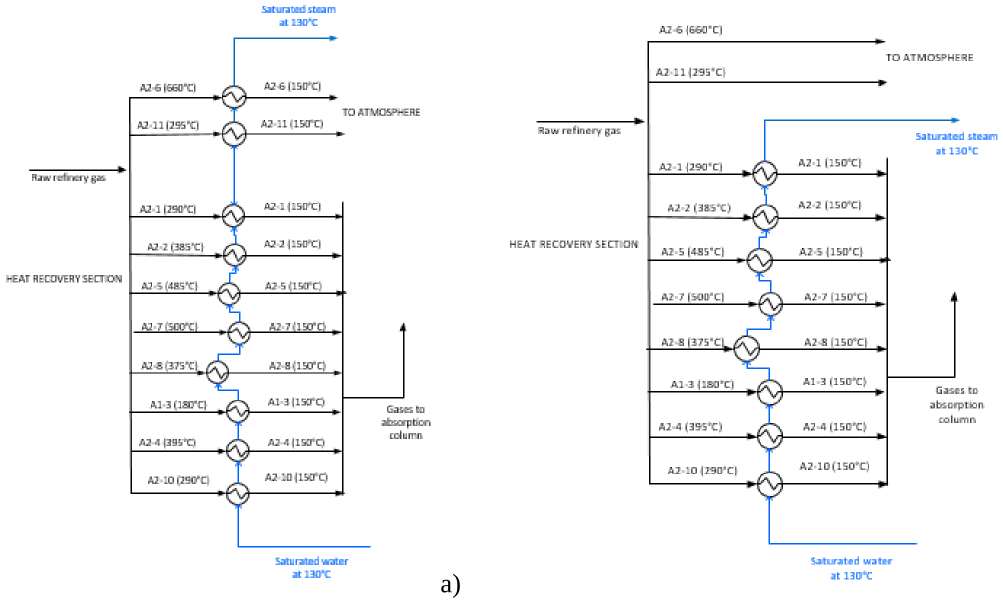
**Abstract**

The application of $CO_2$ capture for the treatment of several kinds of gaseous streams is seen as a very promising route towards the decarbonization of the power and industry sectors, which are responsible for over half of the worldwide $CO_2$ emissions (epa.gov). In this scenario, the international REALISE project, funded by the European Community, aims to integrate a $CO_2$ capture facility to treat the flue gas by the Irving Oil refinery located in Cork, Ireland.
The most widely exploited technology to remove $CO_2$ from gaseous streams is chemical absorption. This technology is characterized by high efficiency, but, at the same time, it requires high thermal powers in order to regenerate the solvent. As a consequence, the development of an optimally designed network of heat exchangers for process heat recovery is essential to guarantee the economic feasibility of such a project.
In this article, a simplified process flowsheet for capturing 90% of the $CO_2$ present in the refinery flue gas is designed in Aspen Plus®, considering a MEA 30 wt% solution as solvent for chemical absorption. The simulations have been carried out using the ENRTL model with the default interaction parameters proposed by AspenTech®. The rate-based model has been selected to run both the absorber and the regeneration column, which are packed with Mellapak 250X (Sulzer). Data related to each stream composition, flowrate and temperature provided by the Irving Oil Refinery and published as proprietary material within the REALISE project have been exploited.
A preliminary detailed energy analysis has been carried out in order to quantify how much heat can be recovered from the refinery flue gases. In fact, the residual heat present in the flue gas streams, which are available at temperatures in a range between 180 and 660°C, can be exploited in order to reduce the amount of heat to be provided by an external heat source to regenerate the solvent. In this way, flue gas cooling is thermally coupled with the reboiler of the regeneration column. The flue gas outlet temperature is set to 150°C in order to keep a 20°C approach temperature between the flue gas and the steam side. Two of the ten streams having a negligible $CO_2$ content are supposed to be directly discharged to the atmosphere. For what concerns heat recovery, two scenarios are considered. In the first case-study, all the flue gas streams are conveyed to heat recovery (see Figure 1a). In the second case-study, instead, only the eight flows to be treated in the carbon capture facility and allowing a more efficient heat recovery are considered (see Figure 1b), in order to find a trade-off between the OPEX reduction and the corresponding increase in CAPEX associated to the need for the additional heat recoveries. Since on the utility-side the temperature remains constant, the specific configuration selected for heat exchange (i.e. exchangers in series or in parallel) does not have any impact on the energy requirements.




a) b)

Figure 1. Heat recovery schemes for the first (a) and the second (b) scenario.

The heat recovery exchangers network has been simulated in Aspen Plus® using the IDEAL model. For the sake of knowledge, the same calculations have also been repeated using more accurate models such as the PR EoS and the ENRTL (for the sake of homogeneity with the simulation of the $CO_2$ capture plant). As expected, no relevant variations in the observed results were noticed.

The heat exchangers have been optimally designed with Aspen EDR (Exchanger Design and Rating), selecting plate-type heat exchangers. The optimally designed exchangers are characterized in terms of geometry (number of channels, total exchange area), steam-side outlet vapour fraction, cold-side and hot-side pressure drops and a preliminary costs estimation is presented. The results point out that the total expected capital cost is in the order of 1 Million Euros, the flue gas-side pressure drop is about 0.1 bar, while the utility-side estimated pressure drop is 0.157 bar, which turns out in an outlet temperature for saturated steam equal to 128°C, which is still acceptable to guarantee that the requirement of a minimum approach temperature equal to 8°C is fulfilled.

The amount of heat recovered in the heat recovery section is compared with the total heat duty required in order to regenerate the solvent. The residual heat necessary to meet the overall energy requirements is supposed to be provided by a natural gas-fed steam boiler. As a consequence, also the flue gas stream originated by the steam boiler is supposed to be treated in the $CO_2$ capture plant, in order to get a 90% $CO_2$ abatement of the overall plant emissions. It is pointed out that about 16.64 MW, which is over 47% of the overall required heat duty (36.37 MW), can be saved by exploiting the heat recovery exchangers configuration in which all the flue gas streams are accounted for. In order to meet the total energy consumption, 8.74 kg/s of steam have to be generated in the steam boiler. According to the second investigated scenario, the recovered heat duty reduces down to 14.1 MW.

Finally, the total operating and capital costs associated with all the main unit operations involved in this study are estimated, for both the discussed case studies for heat recovery.

*Keywords:* $CO_2$ Capture; Energy Analysis; Refineries; Heat Recovery Systems.

References

1. Epa.gov. https://www.epa.gov/ghgemissions/overview-greenhouse-gases (accessed October 2021).