MEMBRANE CONDENSER: DIRECT AND INDIRECT SUPPORT TO CO_2 CAPTURE AND STORAGE

Enrico Drioli[1,2,3,4], Francesca Macedonio[1]
[1] Institute on Membrane Technology (ITM-CNR), National Research Council, c/o The University of Calabria, Cubo 17C, Via Pietro Bucci, 87036 Rende CS, Italy
[2] University of Calabria - Department of Environmental and Chemical Engineering, Rende, Italy
[3] Hanyang University, WCU Energy Engineering Department, Seoul 133-791 S. Korea
[4] Center of Excellence in Desalination Technology, King Abdulaziz University, Jeddah Saudi Arabia

Today membrane technology for gas separation (GS) is a well-consolidated technique, in various cases competing with traditional operations. The separation of air components, H_2 from refinery industrial gases, natural gas dehumidification, separation and recovery of CO_2 from biogas and natural gas are some examples in which membrane technology is successfully used in industry. Recent constraints and regulations on CO_2 emissions from power plants have forced researchers to focus on the separation of CO_2 from flue gas streams and to develop specific CO_2 capture technologies that can be retrofitted to existing power plants as well designed into new plants with the goal to achieve 90% of CO2 capture limiting the increase in cost of electricity to no more than 35%.

Currently, the main strategies for the carbon dioxide capture in a fossil fuel combustion process are: Oxy-fuel combustion, pre-combustion capture and post-combustion capture.

The main technical problems are related to the fact that polymeric membranes cannot withstand, however, high temperatures and/or chemically harsh conditions. Refinery gas streams contain impurities such as water vapor, acid gases, olefins, aromatics and other organics. Heavy hydrocarbons can be present in the feed also in petrochemical plants and natural gas treatment, representing a problem, mainly in hollow fiber modules. At relatively low concentrations, these impurities cause membrane plasticization and loss of selectivity, while at higher concentrations they can condense on the membrane surface which could be damaged. Many polymers are swollen or plasticized in presence of hydrocarbons or CO2 at high partial pressure: the result is a significant reduction in their separation performance, or, their damage. Another issue is physical aging which negatively affect the properties of interesting polymers (PTMSP, PIMs, etc.) and limit their applicability. The solution for a successful operation of polymeric modules is a careful selection of feed pre-treatment. In this field, membrane condensers can be considered as a proper solution for pre-treating the flue gas streams that have to be fed to another membrane unit for CO_2 separation and whose performances are strongly affected by the presence of such contaminants as SO_x, NH_3, etc.

In a membrane condenser, the waste gaseous stream (e.g. flue gas) from an industrial plant at a certain temperature and, in most cases, water saturated, is fed to the membrane condenser kept at a lower temperature for cooling the gas up to a super-saturation state. The water condenses onto the membrane surface and the hydrophobic nature of the latter prevents the penetration of the liquid into the pores, letting the dehydrated gases pass through the membrane and retaining the liquid water at the retentate side. In comparison with other technologies, the membrane condensers offer higher water recovery and are not affected by desiccant losses, corrosion phenomena typical of traditional condensers or desiccant units. Compared with the dense membrane technology, the latter requires a high pressure difference between the two membrane sides to promote the permeation of water vapor but allows the recovery of a very pure stream. On the contrary, the purity of the water recovered in membrane condensers can be affected by the possible condensation of contaminants – if present in the gaseous stream – but it is sufficient for cooling tower or boiler make up. However, further purifications would be needed to make it drinkable. Moreover, the possibility of controlling, by opportunely tuning the operating conditions, the condensation of contaminants in the liquid water recovered in the retentate side of the membrane condenser could lead to two different options for its use: as a unit for water recovery, minimizing the contaminants content, or, as the pre-treatment stage in post-combustion capture, forcing most of the contaminants to be retained.

References

Macedonio F., Brunetti A., Barbieri G., Drioli E. Membrane Condenser as a new technology for water recovery from humidified “waste” gaseous streams. *Industrial & Engineering Chemistry Research*, 2012; *52*(3): 1160-1167.

Macedonio F., Cersosimo M., Brunetti A., Barbieri G., Drioli E. Water recovery from humidified waste gas streams: Quality control using membrane condenser technology. *Chemical Engineering and Processing: Process Intensification*, 2014; *86*: 196-203.