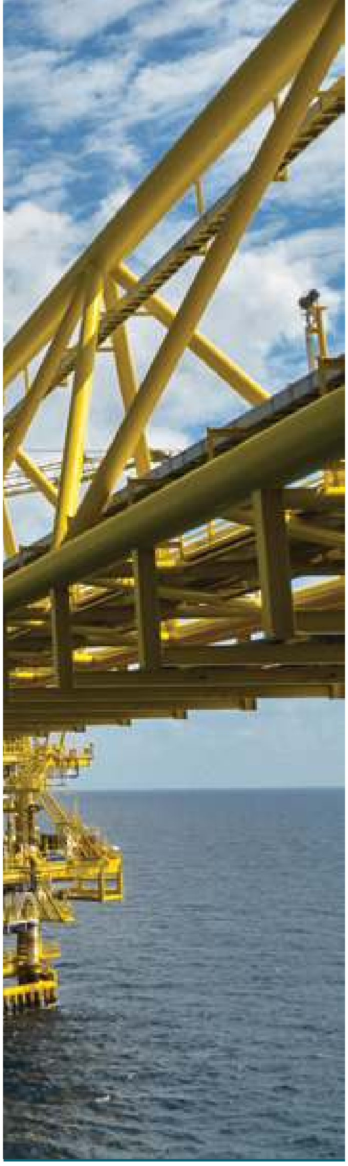
Oxygen removal from injection seawater in offshore platforms: vacuum tower versus membrane deaeration technology

The study realized by Artes Ingegneria has the aim to compare two technologies for offshore injection water oxygen removal: Membrane Deaeration (MDA) and Vacuum Towers (VT).
Performance, technical and economic aspects were investigated, the results demonstrate that MDA is the best choice when it comes to reaching a very low oxygen concentration.

Study presented by ARTES Ingegneria at Membrane Technology for Climate Change Workshop in Korea, June 21st-24th 2017



This paper aims at making an overall comparison between two technologies for oxygen removal from injection seawater in offshore platforms: vacuum towers and membrane deaeration. The comparison was made between an executed vacuum towers based project (treating an overall inlet water flow rate of 92.5 m^3/h coming from pretreated seawater) and the equivalent membrane deaeration (MDA) project configuration obtained by the replacement of the towers and its ancillaries with the membrane deaeration. The two deaeration modules systems were compared in terms of the following characteristics:

- Performance of deaeration treatments: measured in terms of oxygen concentration in the outlet treated water stream;
- Equipment configuration: the configuration of both systems including all the valves/instruments and the service equipment were analyzed;
- Costs evaluation: Both Capital costs (CAPEX) and Operative costs (OPEX) associated with the two systems were evaluated;
- General characteristics: Footprint and weights, Chemicals consumption, systems' operability and transportation.

The results showed that for the specific case taken into consideration, higher performances can be reached by membrane deaeration system: in fact an outlet oxygen concentration lower than 10 ppb was reached by membrane deaeration while higher oxygen concentration (about 50 ppb) was reached by vacuum towers. In terms of costs, capex saving resulted by using membrane deaeration instead of vacuum towers while higher opex are associated with MDA. Finally, weights and volumes were lower in case of degassing by MDA than by VTs.

1. Introduction

In many Oil & Gas offshore operations, the amount of recovered oil from the reservoirs is increased by means of several engineered techniques: among these, the injection of seawater into the wells plays a very important role.

Before being injected into the oil reservoirs, preliminary seawater treatments must be performed such as the reduction of suspended/dissolved solids, dispersed oil and dissolved gases. Oxygen, carbon dioxide and hydrogen sulfide are the dissolved gases frequently found in injection water. In particular, the content of oxygen must be reduced in order to avoid such problems of corrosion and biogrowth which may affect the integrity of the reservoir.

A conventional approach for oxygen removal from injection water is the utilization of vacuum tower removing other than oxygen, carbon dioxide and all the other dissolved gases.

In a vacuum tower the reduction of gases is carried out by reducing system pressure and consequently gases solubility in agreement with the Henry Law; the gases which are separated from the water are vented from the deaerator.

This approach presents many limits one of them is the low performance in the oxygen reduction: in many cases an outlet oxygen concentration lower than 50 ppb cannot be reached with the exclusive use of this treatment, so it is necessary the additional supply of an oxygen scavenger.

Italian deletegates attending the 10th "Membrane Technology for Climate Change" workshop, in Daejeon, Korea, June 21st -24th 2017.
The event was organized by Korea Research Institute of Chemical Technology (KRICT) with the collaboration of the Italian Institute on Membrane Technology (ITM-CNR)

Moreover, high system footprint/volume and weight may limit its utilization in an offshore application where compactness and lightness are required from the plant.
On the other side, in the last years membrane deaeration is gaining relevance as an attractive alternative to the vacuum tower for degassing of injection seawater. This technology has been already tested in the field of seawater injection: different pilot scale plants have been built in order to evaluate the performances in oxygen removal and to optimize the most suitable seawater pretreatments upstream of membrane deaeration.
Currently membrane deaeration is already successfully used in many applications such as electronics, boiler feed water and food industries.
The aim of the present work is to make a comparison between vacuum towers and membrane deaeration in seawater offshore applications. In details, the comparison was made between an executed offshore project, where the seawater deaeration was operated by a two stages vacuum tower and the simulated equivalent project obtained at the same operating conditions and performances, by replacing the existing vacuum tower with membrane deaeration modules.
The comparative analysis was carried out in terms of process performances, economical aspects (CAPEX and OPEX) and general characteristics of the two degassing systems such as the equipment weight, the footprint/volume and the amount of consumables and/or chemicals consumed during operation.

2. Vacuum towers based project

The reference executed project was an offshore seawater injection treatment plant operating in the Baltic Sea with an overall design flow rate of 92.5 m^3/h coming from pretreatment system.
The package included seawater treatments for the removal of both solid particles (required outlet solid particles concentration: 0.1 ppm) and dissolved oxygen (request outlet concentration: < 20 ppb) from seawater in order to avoid environmental alteration of the wells during injection.
Feed water characteristics and treated water requirements can be found in **Table 1**.
A first seawater treatment was carried out by means of two fine filters, where solid particles with a diameter 2 μm and larger were removed with an efficiency of 98%.
Each filter was composed by two different granular media layers: the anthracite as the upper one and garnet as lower layer. Polyelectrolyte and coagulant were dosed in the seawater (downstream the injection feeding pumps) in order to facilitate the precipitation of carry over particles.
During normal operation both filters were in operation while in case of high pressure across the filters, the backwashing/regeneration phase was required. Each filter was design to treat the 100% of the inlet flow rate so that backwashing/regeneration sequence was performed on both the filters sequentially.
After being filtrated, the seawater was fed

	Feed Water (IN)	Outlet Water (OUT)	Unit
Design Flow Rate (min/max)	14.5/92.5	14.5/92.5	m^3/h
Operative Temperature (min/max)	+4/+32	+4/+32	°C
Operative Pressure (min/normal/max)	2/3/4	5	barg
Total Suspeded Solids	4.5 (max size 25 μm)	0.1 (max size 2 μm) efficiency 98%	mg/l
Oxygen Concentration	13.88 mg/l	≤ 20 ppb	-
pH	7.83	7 – 8	-

Table 1. Feed water characteristics and product requirements

to the vacuum deaerator column in order to reduce oxygen concentration thus avoiding corrosion problems and bacterial proliferation. Upstream the vacuum tower, different chemical products such as antifoaming and two different types of biocides were introduced for a further inactivation of sulphate reducing bacteria (SRB).

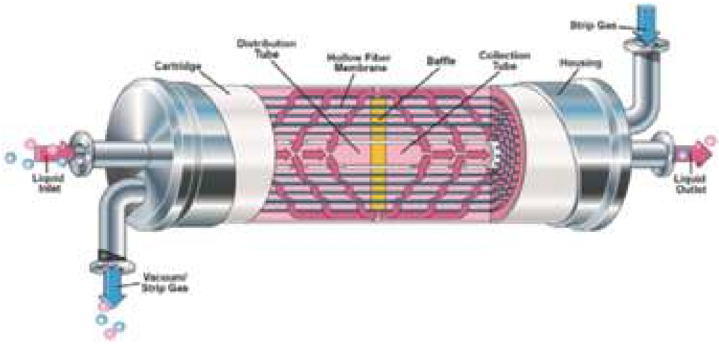


Figure 2. Scheme of membrane deaeration operation mode

The vacuum tower was a two stages columns composed by two packed beds separated by an hydraulic interstage seal; each packed bed was filled by random nominal 2” polypropylene mass transfer packing type elements. Vapor extraction from the two packed sections was made by the vacuum system which was composed by 2 x 100 % liquid ring vacuum pumps and one air ejector. Residual oxygen content in outlet water from the deaerator was 50 ppb after packed sections. Because of the limited performance in oxygen removal of the vacuum tower, the residual oxygen reduction to the request value (lower than 20 ppb) was obtained only through oxygen scavenger dosing.

Artes Ingegneria is qualified by 3M as a system integrator for injection water degassing

3.Membrane deaeration based project

Membrane deaeration represents a promising alternative to the vacuum towers in the removal of dissolved oxygen from injection water, by providing high efficiency mass transfer between gas and liquid. **Figure 1**. They are based on the utilization of hydrophobic microporous hollow fiber membranes made of polypropylene which contain large surface area.
In a typical design, the water flows in one of the two membrane sides (shell side) while gas flows in the opposite lumenside: since the membrane is hydrophobic and contains very small pores, it does not allow the passage of the water acting as a stable barrier between gas and liquid.

Figure 1. Membrane Deaeration skid

As shown in **Figure 2**, water is fed in the MDA through a central distribution tube and is forced to follow a tortuous path until reaching an anular space between the fiber cartridge and the housing wall.
As explained, the separation principle by membrane deaeration differs from other membrane separations such as filtration and gas separation. In fact in LiquiCel membrane deaeration selected for this study, there is no convective flow through the pores since the membranes act as an inert support that brings the liquid and gas phases into direct contact without any dispersion.

3.1Membrane deaeration sizing

In order to carry out a comparison between membrane deaeration (MDA) and vacuum towers (VT) based deaeration system, an executed VT based project was analyzed. This project was compared with the equivalent process obtained by replacement of vacuum towers with membrane deaeration modules.
The sizing of the membrane deaeration system and all the ancillaries, was made at the same inlet water characteristics (flowrate, temperature and inlet oxygen concentration) and output process specifications of the vacuum towers based project.
In particular, membrane deaeration system sizing was made by means of simulation Tool jointly with LiquidCell, by 3M, worldwide leader in membrane deaeration production. Once selected the number of modules, the vacuum level and the purity of the Nitrogen used as stripping gas, a prediction of performance based on the regression of experimental data was provided by the tools.
As pretreatment for seawater upstream to the membrane deaeration, a combination of Dual media filters (> 98 % @ 2 μm) was selected. In fact, a minimum filtration pretreatment was recommended by LiquiCel in order to prevent potential membrane fouling and blockage: solid particles could create a high pressure drop across the contactors and reduce the flow through the contactors system.

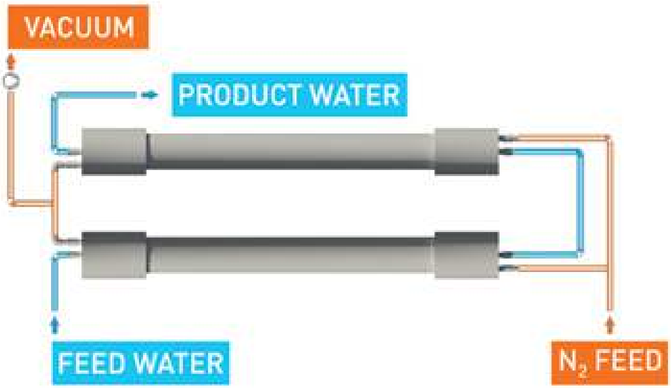


Figure 3. Membrane deaeration system in "Combo" mode

	Value	Unit of Measure
Design Flow rate	92.5	m³/h
Nitrogen Purity	99.99	**%**
Quantity of contactors in parallel	10	**-**
Operative min temperature, T	4	°C
Vacuum level	67	mbar
Gas (Nitrogen) sweep rate per contactor	1.6	Nm^3/h
Inlet dissolved Oxygen (Saturation @ T)	13.8	ppm
Flow rate per contactor	9.2	m^3/h
Sizing factor (Filtration > 98% @ 2µm)	2.5	-
Average expected DO	2.7	ppb
Maximum Dissolved Oxygen (DO)	6.9	ppb
Total sweep gas (Nitrogen)	16.1	Nm^3/h
Vacuum Load	321.8	m^3/h
Max Pressure drop across membranes	0.8	bar

Table 2. Membrane deaeration package sizing

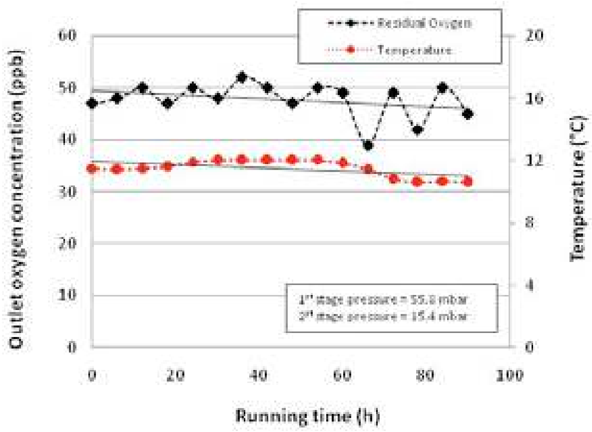


Figure 4. Residual oxygen concentration in VT vs running time

Since very low oxygen levels were required in the project, the most efficient configuration was selected: the Combo Mode (**Figure 3**).
This configuration implies both the application of the vacuum and the supply of Nitrogen as inert gas for the deaeration.
A vacuum level of 67 mbar and a gas sweep rate for each contactor of 1.6 Nm³/h were selected as operative conditions from lumen side. Sizing showed that a number of 10 LiquiCel contactors 8x80 (8 inches of diameter and 80 inches of MDA length), was necessary for the selected separation. **Table 2** summarizes the results of MDA system sizing deriving from Liquicel calculation tool.

4.Vacuum Tower vs Membrane Deaeration

4.1 Performance analysis

The comparison between MDA and VT was made considering the same inlet water characteristics and treated water requirements. In fact, in both cases, an inlet water flow rate of 92.5 m³/h was considered and an inlet oxygen concentration of 13.88 mg/L. As inlet oxygen concentration, was considered that at saturation conditions at minimum operative temperature (4°C), thus considering the worst conditions for the sizing.
As for process specification, the outlet oxygen concentration in the treated water was required to be lower than 20 ppb. Oxygen removal by vacuum towers based system allowed an outlet oxygen concentration of 50 ppb after the two packed stages (Figure 4). Moreover, the addition of an oxygen scavenger to the outlet water from VT was required in order to satisfy the outlet specifications.

The membranes are the valid alternative to the vacuum towers in the case that very low oxygen concentrations are required and/or when the adoption of chemicals such as oxygen scavenger is not possible or not available

On the other side, if injection seawater was deaerated by membrane contactors with Combo Mode (configuration consisting in the use of vacuum plus Nitrogen stream), an average outlet oxygen concentration of 2.7 ppb was guaranteed corresponding to a maximum oxygen concentration of 6.9 ppb (by considering that a 2µm filtration pretreatment is applied before MDA).
The vacuum level that should be applied in order to reach the desired outlet oxygen concentration by

ITEM	QUANTITY
Cartridge Filters	2x100%
Membrane Contactors Skid	2x100% (10 contactors operating in parallel)
Liquid Ring Vacuum Pump	2x100%
Preassure Swing Adsorption Nitrogen Generation Skid	2x100% adsorbent vessels; 1x100% receiver vessel
CIP Skid	1x100% pump; 1x100% tank; 1x100% Cartridge filter
Instrumentation and Local Control Panel	Included
Piping, Valves and Wiring	Included

Table 3. MDA Module Scope of supply

ITEM	QUANTITY
Vacuum Deaeration Tower	1x100%
Vacuum Generating System	1x100% pump, 1x100% ejector
Injection Booster Pump	1x100% booster pump
Biocide I Chemical Dosing Skid	1x100% pump, 1x100% tank
Biocide II Chemical Dosing Skid	1x100% pump, 1x100% tank
Antifoaming Chemical Dosing Skid	1x100% pump, 1x100% tank
Oxygen Scavanger Chemical Dosing Skid	1x100% pump, 1x100% tank
Instrumentation and Local Control Panel	Included
Piping, valves and Wiring	Included

Table 4.Vacuum Tower Scope of supply

TREATMENT	MDA	VT	
Parameter			**Unit of Measure**
Design Flow rate	92.5	92.5	m^3/h
Nitrogen Purity	99.99	NA	%
Quantity of contactors in parallel	10	NA	-
Operative Temperature	4	4	°C
Vacuum level	67	42.9/9.7	mbar
Gas (Nitrogen) sweep rate per contactor	1.6	NA	Nm^3/h
Vacuum Load	321.8	319.0	m^3/h
Inlet dissolved Oxygen (Saturation @ T)	13.8	13.8	ppm
Flow rate per contactor	9.2	NA	m^3/h
Pretreatment	Filtration> 98% @ 2 µm	Filtration> 98% @ 2 µm	
Maximum Dissolved Oxygen (DO)	6.9	50	ppb
Total sweep gas (Nitrogen)	16.1	NA	Nm^3/h

Table 5. Performances comparison between MDA and VT

membrane contactors is lower (67 mbar) if compared with both the pressure levels that should be guaranteed in the first (42.9 mbar) and the second (9.7 mbar) vacuum towers stages to gain the same performance. In fact, the lower applied vacuum is compensated by the use of Nitrogen stream in the removal of oxygen from water. Plants components of both vacuum towers and membrane deaeration project are summarized in **Table 3** and **Table 4**.
Results show that membrane deaeration allows, at the same operative conditions, better performances than the vacuum towers (**Table 5**). Moreover, the membranes are the valid alternative to the vacuum towers in the case that very low oxygen concentrations are required and/or when the adoption of chemicals such as oxygen scavenger is not possible or not available.

4.2 Footprint, volumes, weights and other aspects of comparison

In addition to the previous analysis in terms of performance, the two treatments were also compared in terms of overall size (footprint and volume) and weight (**Table 6**). This information is very important in order to evaluate any equipment limitations during in site installation. In such cases, where there is limited space for installation, it could be very important to have compact and/or low height equipment. In other cases, a limitation on equipment weights can be applied as in the case of oil & gas offshore sites.
The calculation of volume, footprint and weights in vacuum towers project included the following equipment: vacuum tower itself, vacuum generation system, Chemical skids and Booster pump skid. In the case of Membrane deaeration systems, the calculation included the following equipment: Membrane deaeration, vacuum generation system, Cleaning in place skid (CIP) and Nitrogen Generation system. As for the costs comparison, the equipment and/or the instruments which were common to the VT and MDA systems were not included in the comparison such as the Dual media Filters and the feeding pump. The evaluation were made by the help of the 3D models of the two systems, MDA (**Figure 5**) and VT (**Figure 6**).
Results show that the deaeration plant based on the utilization of VT has size comparable with that of the equivalent project using MDA (both footprints are about 33 m^2) while volume of VT project is slightly higher (90 m^3) than that in case of MDA (71 m^3).
Also the weight of the vacuum tower system is higher (28 Ton) than that of membrane contactors'project (10.2 Ton). Moreover, the innovative deaeration system based on the membrane contactors implies lower volume as well as lower weights.
In order to close the comparison between the

Parameter	MDA	VT	Unit of Measure
Total Dry Weight	28	11	Ton
Total Full Liquid Weight	40	13	Ton
Footprint	33	33	m^3
Overall Volume	90	71	m^3

Table 6. VT vs MDA: Plant size and weight

Figure 5. 3D Model of Membrane deaeration system

Figure 6. 3D Model of Vacuum Tower system

two deaeration systems, also an analysis was made in terms of plant management and maintenance (**Table 7**). Regarding the chemicals, while the adoption of vacuum towers implies the ordinary use of chemicals such as biocides, antifoaming and oxygen scavenger, the adoption of membrane contactors implies only a periodical cleaning by the Cleaning in Place (CIP) skid. The lower chemicals' demand in membrane deaeration represents an important advantage since their supply is particularly critic in offshore installations.
On the other side, while the vacuum tower packing does not imply a frequent replacement, in fact the plastic random packing could even last all life, the membrane deaeration requires a replacement of the membranes.
The lower volume and the high modularity of the MDA allow an easier installation. On the contrary, in case of VT, a more complex assembly and interconnection between different platforms' desks is required. At last the heavier VT's impact on offshore structures imply more critical mechanical constrains as, for instance, to their own static action, waves motions has to be considered properly.

4.3 CAPEX and OPEX analysis

The economical comparison between membrane deaeration and vacuum tower based project was made in terms of both CAPEX (capital expenditure) and OPEX (operating expenditure).
For capex evaluation, different contributions were taken into account: the equipment, the instruments and the valves (**Table 8**). Equipment costs included the deaeration systems (the vacuum towers and the membrane contactors) plus the internals and packing and the skids for chemicals and/or cleaning. In addition, for capex evaluation, also the vacuum generating system (including the liquid ring vacuum pumps and the ejector) as well as Nitrogen generation and purification system (to reach a final Nitrogen purity equal to 99.99%) were considered.
Dual media filters pretreatment contribution (and all the other common equipment) was not included in capex evaluation since the pretreatment was common for the vacuum towers and membrane deaeration. Similarly, the cost of the two feeding pumps to the Dual Media filters, was not taken into account being a common contribution for MDA and VT.
The calculation of OPEX was made by considering the contribution of feeding power costs, the chemicals and consumables associated to both the processes (**Table 9**). For electrical feeding power costs, the adsorbed power of all the pumps (dosing pumps, booster pumps) and of the control panel unit was considered. Moreover the contribution of the chemicals was also included: for the VT process the biocide I, the biocide II, the antifoaming and the oxygen scavenger consumption were considered. In the case of membrane deaeration, only the contribution of the

chemicals for the periodical cleaning (CIP, cleaning in place) and periodical biocide addition were taken into account.
Finally, to complete the operative costs also the consumption of consumables was evaluated: random packing was considered for the vacuum towers while both membrane and cartridge filters replacement were considered for the membrane deaeration project.

Properties	MDA	VT
Chemicals (Antifoaming and Biocide)	CIP mainly for surface / raw water	Biocide I, biocide II, antifoaming and oxygen scavenger
Internals	Membrane Cartridge filters	Random Packing
Expected Service Life	Of the FRP vessel is higher than 10 years	Related to packing material
Installation	Easy Installation and Modularity	More Complex

Table 7. VT vs MDA: General characteristics

In terms of operative costs, the process based on the utilization of membrane deaeration is more expensive. In the costs analysis, the adsorbed power was not associated to any costs, since usually in platforms the electricity is produced in place. The higher adsorbed power of the vacuum deaerator project is due to the utilization of the booster pumps and of all the chemical dosing pumps which are not required in the MDA based project.
In addition, a lower annual chemical consumption of chemicals is required for the membrane deaeration than in the vacuum towers: in fact, while in the case of VT oxygen scavenger biocide I, biocide II and antifoaming should be dosed to the tower, in the case of membranes only a periodical cleaning (CIP) is required.
On the other side, regarding the consumables costs, the use of vacuum towers is cheaper since the plastic random packing has very long life while in the case of MDA project, membrane cartridge replacement after about 3 years and cartridge filters replacement 4 times per year should be provided.
As a conclusion of costs comparison between vacuum towers and membrane deaeration systems, a capex saving of 14% is obtained when membrane deaeration systems are used instead of vacuum towers. On the contrary, the utilization of the MDA instead of VTs implies 14% higher operative costs (OPEX) because of the high membranes replacement cost.

CAPEX	MEMBRANE DEAERATION (€)	% OF THE TOTAL CAPEX	VACUUM TOWERS (€)	% OF THE TOTAL CAPEX
EQUIPMENT	330000	67%	405000	71%
INSTRUMENTS	68000	14%	63000	11%
PIPING & VALVES	91000	19%	102000	18%
TOT(€)	489000		570000	

Table 8. Capex comparison between membrane deaeration and vacuum towers project

	MDA		VT	
	OPEX	% of the total OPEX	OPEX	% of the total OPEX
Adsorbed Power	200000 KWh/y	-	540000 KWh/y	-
Chemicals	6700€/year	9%	66000€/year	100%
Consumables	70000€/year	91%	0	0%
TOT	76700€		66000€	

Table 9. Opex comparison between membrane deaeration and vacuum towers project

5. Conclusions

Membrane deaeration represents a promising alternative to the conventional deaeration based on vacuum towers in the field of offshore seawater injection applications. A comparison between two equivalent systems with an equal capacity of 92.5 m^3/h, showed that MDA overperformed VT system in many aspects:

- In terms of processing performances: oxygen outlet concentration was lower than 10 ppb while in VT was about 50 ppm;
- From an economical point of view: 14% CAPEX savings and 14% OPEX loss;
- In terms of space and weight savings: 21% overall

volume savings and 63% weight savings;
- In terms of maintenance: Chemicals not required during operation (only periodical cleaning).

References:

1.Stephen Van Pelt & Holly Churman(1996). "Offshore Membrane Deaeration as Replacement for Vacuum Tower Deaeration – A Comparative Study". *Society of Petroleum Engineers*, 1-16.

2.Ulbricht, M., Schneider, J., Sengupta, A., Willis, S. (2014). "Enabling flexibility in process water deoxygenation with gas transfer membranes". *Proceeding of the 15thAachenerMembranKolloquium, 12-13 November 2014*, 1-5.

3.Reed, B.W. Semmens, M.J. & Cussler, E.L.: "Membrane Contactors". In R.D Nobel & S. & Stern (Eds), Membrane Separations Technology, Principles and Appications (1 ed., pp. 467-498). *Boulder, CO, USA: Elsevier Science B.V., 1995*.

4.Miller, B., Munoz, J. &Wiesler, F.: "Boiler Feedwater Degasification Using Membrane Contactors – New Methods for Optimized Performance". *International Water conference Proceedings. Pittsburgh: International Water Conference, 2005.*

5.Sengupta, A. & Pittman, R.,A.: "Application of Membrane contactors as Mass Transfer Devices". *In A.K. Pabby, S.H. Rizvi &Sastre (Eds.). Handbook of Membrane Separations (pp. 7-24). Boca Raton, FL, USA: CRC Press, 2009.*

6. Ulbricht, M., Schneider, J., Sengupta, A. &Kitteringham, B.: "Expanding application of hollow fiber membrane contactors", *13thAachenerMembranKolloquium (AMK) conference proceedings, Aachen, 2010.*

Authors

Artes Ingegneria S.p.A., Via Irno, 84084 Salerno (SA), Italy

Studio comparativo tra due diverse tecnologie per la rimozione dell'ossigeno dall'acqua di iniezione sulle piattaforme offshore: vacuum tower vs membrane deaeration

Lo studio realizzato da Artes Ingegneria, mira a fare un confronto completo tra le tecnologie "vacuum towers e membrane deaeration (MDA)" per la rimozione dell'ossigeno dall'acqua di iniezione sulle piattaforme offshore.
Il confronto esamina diversi aspetti:
- performance del trattamento di degasaggio
- configurazione della struttura/attrezzatura
- valutazione dei costi di investimento e operativi
- caratteristiche generali (footprint/impatto, peso, consumo di elementi chimici, trasporto ecc)

I risultati ottenuti mostrano che il degasaggio tramite membrane è preferibile in termini di minima concentrazione di ossigeno ottenuta, minor ingombro e ridotto investimento; operativamente comporta dei costi più elevati delle "concorrenti" vacuum towers.
Il degasasggio a membrane risulta quindi la scelta migliore quando si vuole raggiungere concentrazioni molto basse, meno di 10ppb, di ossigeno.

Serena De Maria

Graduated cum laude in Chemical Engeneering in 2011 at University of Salerno with a thesis in chemical plants design; she achieved PhD in Chemical Engineering. Since 2015 has been working in Artes Ingegneria as a R&D Engineer being currently involved in several projects in the field of water process treatments.

Ivan Saracino

Graduated cum laude in Chemical Engineering in 2002 at University of Salerno, in the same year started to work as project engineer at Artes Ingegneria SpA. Project manager from 2007, in 2012 he was nominated R&D Manager focusing on energy efficiency, water reuse and innovative processes.

Giulia Sporchia

Graduated in Environmental Engineering in 2011 at Politecnico di Milano. Since 2012 she has been working in Artes Ingegneria supporting the sales office as a process and engineering coordinator proposal, for technical and process issues.

Walter Tina

Graduated in Chemical Engineering in 1997 at University Federico II of Naples. In 1999 he started working as project engineer at Artes Ingegneria SpA. From 2003 he has been the Chief of the Technical Department.