

Technical Memorandum

Date: March 30, 2017
To: Sylvan Source
From: Michael DiFilippo
Subject: Equipment Cost Estimates for April 2017 Update to the Core Evaluation for Oilfield Softened Produced Water

Included is a generalized summary of equipment for each technology as well as installed costs which were included in the updated "Evaluation of Sylvan Source Evaporative Technology for Oilfield Produced Water Treatment" Technical Report. As requested, the RO equipment has more cost detail.

Oilfield Softened Produced Water

For all of the treatment alternatives, Floatation Units (oil removal), Walnut Shell Filters (further oil removal), SAC (and and/or WAC) Softeners, intermediate transfer pumps and hold tanks, regeneration equipment, Softwater Storage Tank, Process Feed Pumps (e.g. Sylvan Core), Product Water Tank, and Product Water Pumps were not included, since they are the same for all alternatives. Generalized equipment lists for evaporative treatment processes follow...

<u>Sylvan Core</u>		<u>Vapor Compressor Evaporator</u>	
SSI Cores	10	VCE Body & Sump	1
Brine Transfer Pumps	10	Recirculation Pump	1
Deaerator	1	Deaerator	1
Feedwater Heater	1	Compressor	1
Distillate Transfer Tank	1	Feedwater Heater	1
Feed Tank	1	Distillate Transfer Tank	1
Core System Feed Pumps	2	Feed Tank	1
Distillate Take-Away Pumps	2	VCE Feed Pumps	2
		Distillate Take-Away Pumps	2
		<u>MED System</u>	
		Evaporator Effects (falling film)	6
		Recirculation Pumps	6
		Deaerator	1
		Surface Condenser w/Steam Eject	1
		Cooling Tower	1
		Circulating Water Pumps	2
		Feedwater Heater	1
		Distillate Transfer Tank	1
		Feed Tank	1
		VCE Feed Pumps	2
		Distillate Take-Away Pumps	2

Budgetary equipment costs were provided by Sylvan Source for Core technology and GE Water for VCE and MED. The following costs are for a 1 MGD feed system.

	Produced Water System Cost - Oilfield		
	Eqpmt	Installed	Install Factor
SSI Core	\$8,300,000	\$17,700,000	2.1
MED	\$17,900,000	\$44,500,000	2.5
VCE	\$15,300,000	\$36,300,000	2.4

The RO system information is from a budgetary system quote prepared last year for an oil client and it replaces the data in the previous oilfield Core report. Of note, is that the ion exchange pre-softening provided for the evaporation systems is not part of upstream treatment for RO. Of concern is silica fouling of membranes, silica fouling of disposal wells (from RO reject) and boron in product water for beneficial reuse. Therefore, lime/MgO softening is provided and the RO system is operated at high pH. This treatment is currently in use in two oilfield projects (California and Utah). RO system components by treatment area follow...

RO Alternative Treatment Areas and Components

MultiFlo Softening System	1	MultiFlo Feed Pumps	2
Lime & MgO Silos	2	MultiFlo Sludge Pumps Pumps	2
Sludge Hold Tank	1	Lime & MgO Make-Down Tanks	2
Filter presses	2	Lime Recirc Pumps	2
Filtrate Tank	1	MgO Feed Pumps	2
		Filter press Feed Pumps	2
		Filtrate Transfer Pumps	2
Ceramic Membrane UF	2	Ceramic Membrane Feed Pumps	2
Ceramic Membrane CIP Tank	1	Ceramic Membrane Circ Pumps	2
Ceramem Building	1	Ceramic Membrane Backpulse Pumps	2
		Ceramic Membrane CEB Pumps	2
		Ceramic Membrane CIP Pumps	2
WAC IX	3	WAC Feed Pumps	2
WAC Feed Tank	1	WAC Acid Regen Pumps	2
HCl Tank	1	WAC Caustic Regen Pumps	2
NaOH Tank	1	WAC Dilution Water Pumps Pumps	2
Neutralization Tank	1	Neutralization Tank Acid Pumps	2
		Neutralization Tank Caustic Pumps	2
Cooling Tower (3 cells)	1	Cooling Tower Circ Pumps	2
RO Heat Exchanger	1		
1st Pass RO System Feed Tank	1	1st Pass RO System Feed Pumps	2
1st Pass RO System	1	1st Pass RO System Booster Pumps	2
2nd Pass RO System Feed Tank	1	2nd Pass RO System Feed Pumps	2
2nd Pass RO System	1	2nd Pass RO System Booster Pumps	2
RO CIP System	1	Anti-scalant Pumps	2
RO Building	1	Surfactant Pumps	2
Final pH Control System (CO2)	1		

The following costs are for a 1 MGD feed RO system. An additional 15% was included in the cost summary to cover uncertainties since the project is somewhat complex. It was not applied to the evaporative process cost summaries.

<u>Produced Water System Cost - Oilfield - RO System</u>		
Softening System		\$3,500,000
Ceramic UF System		\$2,100,000
WAC System		\$1,800,000
Cooling System		\$400,000
2-Pass RO System		<u>\$1,900,000</u>
Total Equipment		\$9,700,000
Install Factor	3.00	
Uncertainty	15%	
Installed Cost		\$33,500,000