Desalination in the Oil & Gas Industry

Webinar prepared for the
Young Leaders Program
of the
International Desalination Association

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Provide a general overview of desalination in the oil and gas industry:

- why it is used / needed
- what technologies are used
- some examples
Why Desalination is used in the O&G Industry

Desalination is used for the following reasons:

- to generate drinking water onshore and offshore
  - seawater desalination for drilling and production rigs
  - salt water aquifer desalination in the desert

- to improve oil recovery (waterflood)
  - sulfate removal

- to enhance oil recovery
  - steam flood and SAGD
  - polymer flood
  - low salinity waterflood

- to allow recycling of hydraulic fracture flow back
  - salt sensitive polymers

- to allow surface discharge
  - e.g. Coal Seam Gas (Coal Bed Methane) water disposal
MARS
Potable Water – Mars Tension Leg Platform

120 to 160 POB (people on board)

floating structure – 1,000 m deep water

anchored to sea bottom by “tension legs”

peak production:
200,000 BOPD
(8.4 million gallons of petrol / day)
140 MM scf

cost of platform:
~ 1.5 billion USD including initial wells

Ursa platform:
24,000 m³/day sulfate rejection plant
Desalination is used to generate drinking, wash, and cooking water for onshore and offshore oil & gas facilities:
  o seawater desalination for drilling and production rigs
  o salt water aquifer desalination in the desert

Relatively small units:
  ~ 100 L / person / day
  oil rig: 200 people
  ~ 20 m3/day desalination

Process Line-up:
  course filtration (25 micron)
  fine filtration (10 micron – SDI to approximately 3)
  2 passes Reverse Osmosis membranes
  calcium carbonate (remineralization)
  storage
Stages of Oil Recovery:

- primary recovery: 20 to 30 % of oil in place
- secondary recovery (waterflood): additional 10 to 30 %
- tertiary recovery (EOR): up to 90 + % of oil in place

One potential complication in an offshore waterflood using seawater is the precipitation of barium sulfate in the producer wells:

- seawater ~ 2,700 mg/L sulfate
- some reservoir water contains barium (up to 100 mg/L or more)
- barium sulfate is only soluble up to about 3 mg/L
Sulfate Rejection Technology

North Sea Oil Platforms – extensive waterflooding

Marathon South Brae
North Sea
high \( \text{Ba}^{+2} \) in reservoir water
high \( \text{SO}_4^{-2} \) in sea water
\( \text{BaSO}_4 \) plugging of wells
SRP solved this problem
Rapid technology uptake due to:

- strong need
- favorable economics
- fit-for-purpose technology
Reservoir Sourcing: $\text{SO}_4^{2-} + \text{SRB} = \text{H}_2\text{S}$

SRB: sulfate reducing bacteria
Compact technologies for filtration and deaeration of seawater:

➢ Membrane MF/UF filtration –
  • eliminates use/risk of cartridge filters
  • eliminates multimedia

➢ Compact Deoxygenation –
  • replaces tower
  • proven onshore

Ref: Water Standard, LLC
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World-Wide Oil Reserves

Oil sands:
20% surface
80% subsurface

Alberta – a major steam flood region due to heavy oil sands, most of which is deeper than 150 m.

“barrels” = billions of barrels
6.29 barrels = 1 m³
Daily consumption: 80 MMbbl

Source: Oil & Gas Journal, 2007
Reference: Alberta Oil Sands Strategy
Steam T for Various Steam Floods

Steam saturation T vs steam pressure
Oil viscosity (for a particular oil)
Oil flow rate through porous media vs steam P (T)

<table>
<thead>
<tr>
<th>Project</th>
<th>Oil API</th>
<th>Steam T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carmon Creek (AL)</td>
<td></td>
<td>351</td>
</tr>
<tr>
<td>Cold Lake (AL)</td>
<td>11</td>
<td>340</td>
</tr>
<tr>
<td>Various AL</td>
<td></td>
<td>320 to 330</td>
</tr>
<tr>
<td>Fire Bag (AL)</td>
<td>12</td>
<td>320</td>
</tr>
<tr>
<td>Kern River (CA)</td>
<td>9 to 16</td>
<td>310</td>
</tr>
<tr>
<td>Mukhaisna (Oman)</td>
<td>16</td>
<td>280</td>
</tr>
<tr>
<td>Amal (CA)</td>
<td>17 to 20</td>
<td>275</td>
</tr>
<tr>
<td>Belridge (CA)</td>
<td>14</td>
<td>270</td>
</tr>
<tr>
<td>QA (Oman)</td>
<td>16</td>
<td>250</td>
</tr>
</tbody>
</table>

Oil flow rate through porous media depends on:
- Oil viscosity

Determine:
- Number of wells, length, spacing
- Steam T (P)
- Steam / Oil Ratio (SOR)
- Project economics

Ref: Edmunds, JCPT (Dec 2001) PETSOC-01-12; various other
Conventional Steam generation Process: OTSG

- Heavy oil EOR:
  - High oil viscosity (high steam T)
  - High Steam to Oil Ratio
  - Difficult oil/water separation

- Scarce water resources
  - Prod Water Reuse: w/ 300 mg/L silica

- Once Through Steam Generator:
  - 20% blowdown (80% steam)
  - Feed TH < 0.5 mg/L as CaCO₃
  - Silica < 50 mg/L
  - TDS < 10,000 mg/L
  - Oil < 10 mg/L

- Brine Blowdown – Limited disposal options

Ref: aquateam

OTSG: Once Through Steam Gen
PWRU: Produced Water Re-Use
SOR: steam oil ratio (v/v)
TH: total hardness
ZLD: Zero Liquid Discharge
CSS: Cyclic Steam Stimulation
SAGD: Steam Assist Gravity Drainage
Traditional vs Mechanical Vapor Compression

Slide 17
Feed brine is heated to its boiling point by heat exchange with the effluent streams (concentrated brine and distillate).

It passes through a deaerator to remove CO2 and other dissolved gasses.

It enters the evaporator sump where it mixes with a circulating brine slurry.

The brine slurry is continuously circulated to the top of the vertical tube bundle from which it flows as a thin film down the inside of the tubes.

A mixture of vapor and concentrated brine are discharged from the bottom of the tubes. The vapor is sucked into the compressor. The brine enters the brine sump.

The pump serves a dual function. It lowers the pressure in the brine sump which promotes evaporation, and it compresses the vapor, which heats it (like a heat pump), and pushes it into the shell side of the tube bundle.

In the tube bundle, the vapor condenses and yields its heat to the falling film brine on the tube side (inside) of the bundle.
MVR – Operating Experience

- Vigorous flashing of brine in the brine sump is required to produce the required vapor flow rate. This vigorous flashing produces small brine drops which must be removed to avoid compressor fouling.

- Demisting filters or mats cause a pressure drop which lowers overall efficiency.

- Frothing or foaming from too high oil content, or poor pH control, also causes carryover. Typically requires anti-foam chemical injection.

- Soft and hard scales can be a problem. Soft scales (calcium and magnesium carbonate) are controlled by lowering the pH, and by adding anti-scalants. Hard scales such as calcium sulfate hemihydrate are controlled by maintaining the temperature below 250 F. Other hard scales such as the silicates are controlled by limiting the inlet concentration, using seeded-slurry systems, by limiting carryover, and by chemical addition.

- Multi-effect units are also used to control scale and increase energy efficiency. Multi-effect units expose the lowest concentration brine to the highest temperature.
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Next several slides will show how Mechanical Vapor Compression is having an impact on reuse of hydraulic fracturing flow back water
Hydraulic Fracture Operation

- Frac tanks/fluid storage
- Data van
- Chem truck
- Well head
- Blender
- Pump trucks
- Sand storage units
Recycle HF FB: Salt Sensitive Polymers Require Desalination

The flowback water is typically very saline (e.g. 195,000 mg/L TDS). Saline water has an adverse effect on the polymers used for fracturing. In order to recycle flowback water, it can be desalinated.

MVR is one option.
Modular Desalination for Hydraulic Fracture Flow Back

- Modular Mechanical Vapor Recompression

A modular unit is transported on three flat bed trucks; erected in 3 or 4 days; operated by 3 operators 24/7 for two or three months. Then it is packed onto the trucks and moved to another site.
Typical Queensland Desalination of CSG

- Associated Water Collection Pond
- Pre-Treatment
  - Micro-Filtration
  - Ion Exchange
  - Reverse Osmosis
- Brine Management Pond
  - Evaporation
  - Regulated Waste Facility
- Permeate Irrigation & Surface Disposal
- Solid Management Pond
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Questions?
Alberta Heavy Oil / Bituminous Sands – General Background:

“Bituminous sands (oil sands) contain naturally occurring mixtures of sand, clay, water, and a dense and extremely viscous form of petroleum technically referred to as bitumen.” Ref: Wikipedia.

World Heavy Oil/Bitumen reserves:
1,100 billion m³

Canadian bitumen reserves:
50 billion m³

roughly 20 % of Canadian HO/B reserves can be surface mined, the remainder must be extracted with steam

CA, Oman, Alberta: all three regions are "arid" from the standpoint of water availability.

Ref: http://environment.alberta.ca/01729.html
Water handling and steam generation is 50% of project cost
   o therefore Steam to Oil Ratio (SOR) is important to economics

Well cost is between 20% to 30% of project cost
   o many wells are required due to low productivity

Considerations in selecting the operating steam pressure (T):
   o higher pressure results in higher well productivity;
   o steam pressure does not significantly affect the ultimate recovery;
   o higher steam pressure results in higher water treating CAPEX and OPEX due to higher pressure rated system, and due to higher quality feed water requirement (silica and hardness removal);
   o higher steam pressure results in greater energy losses to surrounding rock which increases the operating cost.

High steam pressure justifies the use of mechanical vapor compression

Ref: N. Edmunds, JCPT (2001)
Mechanical Vapor Recompression (MVC or MVR)
Evaporation Technologies

**MVC**: Mechanical Vapor Compression  
aka **MVR**: Mechanical Vapor Recompression

**MED**: Multi – Effect Distillation

**RO**: Reverse Osmosis (not a thermal or mechanical process)

**MSF**: Multi – Stage Flash Distillation

**MED – TVC**: Multi – Effect Distillation with Thermal Vapor Compression  
aka **TCD**: Thermal Compression Distillation

**MED – MVC**: Multi – Effect Distillation with Mechanical Vapor Compression
Comparison of Steam Generating Options:

Falling Film Evaporation:

- Reduces mechanical and chemical treatment required to recycle the produced water
- Higher capital cost / lower operating and lower life cycle costs
- No softener sludge is generated (no addition of calcium hydroxide)
- Minimizes the overall volume of waste streams
- Increases OTSG / boiler feed water quality thus extending equip life
- Allows the use of package boilers instead of OTSG
- Higher steam pressure justifies the use of desalination